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The Association Between Social Cohesion and Physical Activity in Communities Across Canada: A Multilevel Analysis

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Abstract

Background: In Canada, only 15% of adults meet physical activity guidelines for optimal health. Previous research has suggested that social cohesion may promote physical activity.

Objective: To assess the association between social cohesion and physical activity among adults aged 18 to 64 years in Canada.

Methods: Data from the 2009-2010, 2011-2012, and 2013-2014 cycles (N=245,150) of the Canadian Community Health Survey were used. Physical activity level was operationalized using average daily energy expenditure, social cohesion was determined by self-rated sense of belonging to the local community, and communities were represented by Canada's Forward Sortation Areas. Multilevel regression models were used to assess the association between social cohesion and physical activity.

Results: Both individual- and community-level social cohesion were positively associated with physical activity. Weight status modified the association between community-level social cohesion and physical activity.

Conclusion: Social cohesion may contribute to promoting physical activity among adults in Canada.

Keywords

physical activity, social cohesion, community, neighbourhood, obesity, multilevel modelling, Canadian Community Health Survey

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List of Abbreviations

BMI	Body Mass Index
BRFSS	Behavioural Risk Factor Surveillance System
CCHS	Canadian Community Health Survey
CDC	Centers for Disease Control and Prevention
CIHI	Canadian Institutes for Health Information
CMAR	Completely Missing at Random
CMHS	Canadian Health Measures Survey
CSEP	Canadian Society for Exercise Physiology
EE	Energy Expenditure
FSA	Forward Sortation Area
ICC	Intraclass Correlation Coefficient
IPAQ	International Physical Activity Questionnaire
MET	Metabolic Equivalent
MVPA	Moderate-to-Vigorous Physical Activity
RDC	Research Data Centre
SD	Standard Deviation
SES	Socioeconomic Status
LTPA	Leisure-Time Physical Activity
USA	United States of America
WHO	World Health Organization

Chapter 1

1 Introduction and Background

1.1 Introduction

Physical activity refers to the expenditure of energy to produce bodily movements using skeletal muscles.[1] This includes activities ranging from those that are light in nature (e.g., walking) to those that are vigorous and demanding such as muscle-strengthening exercises.[2] Physical activity is performed for numerous purposes, including leisure, transportation, work, and planned fitness-related exercise.[2] Regular engagement in physical activity is associated with myriad positive health impacts, including reductions in the risk of obesity, type 2 diabetes and certain cancers, as well as improvements in bone and muscle strength, mental health and overall longevity.[3] The public health importance of physical activity is clear when considering that physical inactivity has been estimated to cause 3.2 million deaths globally every year, representing the fourth leading risk factor for death worldwide.[2] In Canada, only 15% of adults meet physical activity guidelines set out by the World Health Organization (WHO) for optimal health.[4] Since physical activity is a potentially modifiable behaviour, its promotion holds promise for improving quality of life and reducing mortality, morbidity, and adverse health outcomes.

In promoting physical activity, there needs to be consideration for the idea that physical activity behaviour is affected by factors at multiple levels of the ecological model.[5] Physical activity behaviour is influenced by biological and psychosocial factors at the individual level, and a multitude of environmental factors in the community.[5] Social cohesion is a particularly interesting factor because of the increasing number of studies that investigated its influence on physical activity in recent years.[6-25] In theory, social cohesion may promote physical activity by strengthening social bonds between peers, increasing the number of opportunities to engage in physical activity, and reducing the prevalence of deterrents to physical activity such as neighbourhood crime.[26-29] Of the 20 identified studies that investigated the effect of social cohesion on physical activity, only 2 found social cohesion to provide no significant benefit with regards to physical activity behaviour.[8, 16] In previous research, social cohesion has been defined as an individual's

perception of the overall level of cohesion in his or her neighbourhood, as well as an individual's contributions to neighbourhood cohesion through social participation, engagement, and other activities that foster a sense of belonging.[14, 15, 17, 18, 20, 22-24] These two definitions have also been used to assess social cohesion at the group level, which typically involves the calculation of a mean score from aggregated individual responses within a defined geographical area.[6, 9, 10, 12, 13, 21] An individual's perceived level of neighbourhood social cohesion was found to be beneficial for physical activity behaviour in numerous studies[14, 17, 18, 20, 23] Similarly, an individual's connectedness to the local community was found to be associated with a higher odds of engaging in physical activity, while trust of neighbours and social participation were observed to be associated with a lower odds of being physically inactive.[15, 22, 24] As a group-level influence, neighbourhood social cohesion was found to be associated with an increased odds of being physically active, and a decreased odds of being physically inactive.[6, 9, 12, 13]

This thesis proposes that investigating social cohesion at both the individual- and community-levels concurrently is important, as one does not necessarily have to feel socially connected to the local community to reside in an area with an overall high level of social cohesion, and vice-versa. While a socially cohesive community may present more opportunities to engage in physical activity, the likelihood that an individual will take advantage of these opportunities may be affected by the extent to which he or she is socially connected within the community.[26-28] When considering that community-based public health initiatives targeting social cohesion and physical activity have been found to be well-accepted and cost-effective, it is clear that there would be benefit in furthering insight into the association between social cohesion and physical activity.[30, 31]

1.2 Thesis Overview

The primary objective of this study was to investigate the simultaneous effects of individual- and community-level social cohesion on physical activity while taking into account the effects of clustering by geographical location. The secondary objective was to determine if weight status modifies the association between social cohesion and physical activity.

The thesis begins with the provision of background information, which includes an overview of the concept of physical activity (Chapter 1.3), why physical activity is an important public health issue (Chapter 1.4), and how it can be measured (Chapter 1.5). This is followed by the literature review and conceptual framework section, which includes a summary of key physical activity influences (Chapter 2.1), a review of previous studies that investigated the relationship between social cohesion and physical activity (Chapter 2.2), an explanation of why social cohesion is important for physical activity and overall health (Chapter 2.3), and an overview of the conceptual framework that was used to inform the design of this study (Chapter 2.4). The next section describes the objectives (Chapter 3.1) and hypotheses (Chapter 3.2) of the study. This is followed by the methods section, which includes an overview of the data source (Chapter 4.1), how each concept was operationalized in the analysis (Chapter 4.2), an introduction to the statistical methods used (Chapter 4.3), the specific statistical model used for each objective (Chapter 4.4), and other statistical considerations (Chapter 4.5). In the next section, results are presented in the forms of descriptive statistics (Chapter 5.1) and findings from the multilevel models (Chapter 5.2). The final section discusses the findings and how they compare with the hypotheses and existing literature (Chapter 6.1), the implications of findings for health promotion (Chapter 6.2), strengths and limitations of the present study (Chapters 6.3 and 6.4, respectively), recommendations for future research (Chapter 6.5), and a summary of the conclusions drawn (Chapter 6.6).

1.3 Physical Activity

Any form of movement involving skeletal muscles that requires the expenditure of energy can be classified as physical activity.[1] Physical activity is distinct from exercise in that it includes a broader array of activities. Exercise is a form of physical activity that is planned and structured, and is often performed with the ultimate goal of improving or maintaining some aspect of physical fitness.[1] In addition to activities performed predominantly for health- and fitness-related purposes, physical activity also includes forms of energy expenditure that result as a by-product of activities performed during leisure, work, transportation, or household chores.[1]

1.3.1 Domains of Physical Activity

Leisure

Physical activity performed during leisure represents the most prevalent subtype of physical activity in published studies.[32] Leisure has been defined as "time when one is not working or occupied" and therefore any form of planned exercise would fall into the category of leisure physical activity.[33] Among adults, leisure-time physical activity (LTPA) has been associated with improvements in mental and physical health, as well as decreases in mortality risk that exhibit a dose-response relationship.[34, 35] Moreover, LTPA has been associated with anthropometric, metabolic, and blood lipid measures that are protective against cardiovascular diseases, while no such benefits were associated with occupational physical activity in the same population.[36]

Occupational

Physical activity may be performed as a product of occupation-related activities, but the overall impact of this form of physical activity on health is unclear. One study found that a high level of occupational physical activity was associated with a lower risk of having any chronic disease independent of LTPA, suggesting that occupational physical activity may be beneficial for health.[37] On the contrary, occupational physical activity has been associated with potential health risks, particularly in comparison to LTPA.[38-40] For example, LTPA was found to decrease the risk of absence from work due to long-term sickness, while occupational physical activity was found to increase this risk.[38] Similarly, a high level of occupational physical activity was associated with a higher systolic blood pressure, while a high level of LTPA was associated with having a lower systolic blood pressure.[39] Moreover, occupational physical activity has been positively associated with the incidence of myocardial infarction and all-cause mortality in men who did not report engaging in a high level of LTPA.[40] A possible explanation for the differences between the observed health impacts of LTPA and occupational physical activity stems from the finding that LTPA tends to be more prevalent among high socioeconomic status (SES) groups, while occupational physical activity is more prevalent in low SES groups.[32]

Transportation

Physical activity may occur as a result of active transportation, a method of travel that includes walking or cycling.[41] This includes the use of public transportation where an individual travels to and from transit actively.[42] A systematic review of 30 studies found that active transportation was associated with health benefits in the forms of increases in life expectancy and disability-adjusted life years, and decreases in health costs and the risk of mortality.[41] Additionally, increases in physical activity from active transportation were not found to displace LTPA, suggesting that the two forms of physical activity may be complementary and not come at the expense of one another.[42]

1.3.2 Physical Activity Intensity

Physical activity may be performed at varying levels of intensity determined by the energy required to perform the activity per unit of time.[43] The intensity of an activity can be expressed in terms of metabolic equivalents (METs), where the reference value of one MET is equivalent to the energy expended when sitting quietly.[44] Light activities require less than 3 METs, and include slow walking, cooking, and instrument-playing.[44] Moderate intensity tasks are those requiring 3 to 6 METs, and include activities such as brisk walking and light cycling.[44] Vigorous activities are those such as jogging, soccer, and basketball, which require more than 6 METs to perform.[44] Moderate- and vigorous-intensity activities are generally referred to as aerobic activities, which involve the sustained rhythmic movement of large muscles and contribute to improving cardiovascular fitness.[45] When physical activity intensity was taken into account, vigorous physical activity was associated with the greatest health benefits, followed by moderate intensity physical activity, then finally by light physical activity.[46] Similar findings were reported for physical and mental health functioning. Vigorously active adults tended to report better scores than moderately active adults, and moderately active adults tended to report better scores than their inactive counterparts.[34]

1.3.3 Physical Activity Guidelines

For optimal health, the WHO recommends that adults aged 18 to 64 years engage in at least 150 minutes of moderate-intensity aerobic physical activity, 75 minutes of vigorous-

intensity activity, or an equivalent combination of both moderate- and vigorous-intensity physical activity every week.[47] The WHO guidelines suggest that each session of activity should be sustained for at least 10 minutes, and that muscle-strengthening activities such as weightlifting, push-ups and sit-ups should be performed at least twice a week.[47, 48] These guidelines have been adopted by both the Centers for Disease Control and Prevention (CDC) in the United States of America (USA) and the Canadian Society for Exercise Physiology (CSEP) in Canada.[48, 49]

1.4 Physical Activity as a Public Health Issue

1.4.1 Physical Activity in Canada

The Canadian Health Measures Survey (CMHS), which collects objectively-measured physical activity data through the use of accelerometers, found that only 15% of adults meet WHO physical activity guidelines.[4] In light of the many known health benefits associated with physical activity and the numerous health risks associated with physical inactivity, it is unsurprising that physical inactivity represents a significant burden to the Canadian health care system, accounting for an estimated $6.8 billion in annual health care costs.[4, 50, 51] Among the long list of physical and psychological health benefits attributable to physical activity, the strongest evidence exists for reductions in the risk of cancer, and cardiovascular and heart diseases.[52] Considering that cancer and heart disease have been the leading causes of death in Canada since 2000, the potential for physical activity to improve health outcomes through primary prevention is clear.[53]

1.4.2 Benefits of Physical Activity

The myriad physical and mental health benefits of regular physical activity have been well-documented, and these include decreases in the risk of cardiovascular disease, diabetes, hypertension, osteoporosis, depression, and all-cause mortality.[50]

Physical Health

Although the WHO recommends that adults engage in at least 150 minutes of moderate-to-vigorous physical activity (MVPA) each week, there is evidence suggesting that

increases in physical activity can lead to significant benefits even if WHO recommendations are not met.[2, 54] A study of over 400,000 adults found that adults who engaged in just 15 minutes of MVPA per day, or approximately 90 minutes per week, saw a 14% lower risk of all-cause mortality and an increase in life expectancy of 3 years compared to inactive adults.[54] This finding remained consistent for both males and females across all age groups.[54] Moreover, each additional 15 minutes of daily MVPA was found to reduce the risk of all-cause mortality by another 4%, suggesting the potential existence of a dose-response relationship.[54] Similar findings have been reported specifically for LTPA in a study of over 600,000 adults in the USA.[35] Even those who engaged in less than the minimum weekly recommended amount of physical activity for Americans saw a 20% lower mortality risk than those who did not report engaging in any LTPA.[35] Additional increases in LTPA were associated with increasingly large reductions in mortality risk, implicating a dose-response relationship.[35] Furthermore, a study that investigated the association between physical activity and health status reported a similar dose-response relationship.[50]

Psychological Health

The potential population-level impact of physical activity has been implicated through its association with positive mental health outcomes. In particular, physical activity has been shown to exert stress-reducing properties through physiological mechanisms, with some evidence suggesting it may affect physiological responses to stress such as inflammatory markers and cortisol.[55, 56] The stress-reducing effects of physical activity are important because stress has been associated with adverse health outcomes and poorer disease prognoses.[56] An overwhelming amount of evidence has linked psychological stress to heart disease, the second leading cause of death in Canada.[53, 57] Additionally, stress-reduction has been cited as a potential path by which physical activity reduces the risk of heart disease.[56] From a psychological standpoint, stress has been associated with anxiety and depression, and a potential dose-response relationship was implicated through the finding that levels of depression and anxiety declined gradually with decreasing levels of stress.[58]

1.4.3 Physical Activity and Obesity

An analysis of evidence found that physical activity was consistently associated with the prevention of weight gain.[52] This finding is particularly important in Canada, where the proportion of the population categorized as obese has increased by three folds in the past three decades.[59] This trend is concerning because excess weight is associated with numerous adverse health outcomes including type 2 diabetes, cardiovascular diseases, and some cancers.[60] As with physical inactivity, overweight and obesity collectively represent a significant economic burden to healthcare systems across Canada.[60]

Obesity is the result of sustained positive energy balance, where energy intake exceeds energy expenditure.[61] Interventions targeting obesity may seek to reduce energy intake through diet, increase energy expenditure through physical activity, or aim to change both energy intake and energy expenditure simultaneously.[61] As one of the main determinants of weight gain, physical activity also represents an ideal factor to address because it is potentially modifiable.[62] Even in the absence of weight loss, physical activity is beneficial because of its numerous aforementioned health benefits. Although less than 1 in 6 Canadian adults engage in sufficient amounts of physical activity, there remains even more room for improvement among those carrying excess weight.[4] It was found that for both men and women, those who are overweight or obese spent less time in MVPA in comparison to their healthy weight counterparts.[4] Previous research suggested that this may be partially explained by barriers that overweight individuals tend to face. These include negative perceptions of one's physical appearance, embarrassment, and deficiencies in physical fitness.[63, 64]

1.4.4 Negative Effects of Physical Inactivity

Men and women who do not engage in recommended levels of physical activity are deemed to be physically inactive.[1] Physical inactivity has been associated with an increase in the risk of numerous adverse health outcomes.[65] On a global scale, physical inactivity has been estimated to be responsible for a sizeable proportion of the burden of several conditions, including 6% of coronary heart disease, 7% of type 2 diabetes, 10% of breast cancer, and 10% of colon cancer.[65] Furthermore, 9% of the 57 million premature

deaths in 2008 were deemed to be attributable to physical inactivity.[65] As a result, even small decreases in the prevalence of physical inactivity have been projected to prevent a large number of deaths annually.[65] For example, a 10% decrease in the prevalence of physical inactivity was estimated to reduce the number of deaths by over 500,000 in one year.[65] The negative mental health consequences of physical inactivity have also been reported to have substantial effects at the population level. Physical inactivity was found to significantly increase the risk of experiencing numerous common mental health conditions, and a reduction in physical inactivity as small as 10% has been projected to result in 167,000 fewer cases of common mental disorders in Canada in a single year.[66]

1.4.5 Physical Activity and Sedentary Behaviour

It has been suggested that sedentary behaviour is not simply the lack of physical activity, but rather is a separate entity referring to engagement in activities that are sedentary.[67] Sedentary activities refer to behaviours performed in a sitting or reclining position during waking hours requiring less than 1.5 METs.[67] As a reference, the average amount of energy required to stand still was found to be 1.59 METs.[68] Examples of sedentary activities include watching television, typing on the computer, and playing video games.[68] From a public health standpoint, sedentary behaviour represents a concern because it has been associated with an increased risk of numerous adverse health outcomes including diabetes, cardiovascular disease, and all-cause mortality.[69] A positive correlation was also observed between proportion of sedentary time and risk of developing metabolic syndrome, and this relationship was found to be independent of physical activity.[70] Also, physically active adults who engaged in more sedentary activities were just as likely to be overweight or obese as those who were less active but also spent less time being sedentary, reinforcing the proposition that the negative effects of sedentary behaviour may be independent of physical activity.[71] Although sedentary behaviour has been associated with health risks independent of physical activity, the promotion of physical activity should be stressed, because spending more time being physically active results in fewer opportunities to be sedentary.[70, 71] In light of the finding that adults tend to spend the majority of their leisure time being physically inactive or

sedentary, public health initiatives that promote LTPA have been recommended to combat sedentary behaviour.[72]

1.5 Measuring Physical Activity

Several methods exist for the measurement of physical activity, including self-reported measurement through questionnaires, interviews and surveys, objective measurement through instruments such as pedometers and accelerometers, and direct and indirect observation.[73]

1.5.1 Self-Reported Measures

Self-report strategies provide an indirect measure of physical activity, and often take on the form of a survey or questionnaire[74]. They are widely used in research because of associated benefits in terms of cost, acceptability and practicality.[74] Self-reported assessments are advantageous in that they can be developed to capture key elements of physical activity including frequency, duration, intensity, type, and location of an activity.[73] Survey and questionnaire measures are favourable because they are efficient in that they can be incorporated into existing surveys or questionnaires such as the Behavioural Risk Factor Surveillance System (BRFSS) in the USA that also assess other health behaviours at the population level.[75]

Along with the documented advantages, there are also several limitations associated with self-reported measures of physical activity. A systematic review of over 100 physical activity questionnaires found that very few questionnaires displayed promising results for both reliability and validity.[76] While a large number of questionnaires were found to be acceptable from a reliability standpoint, poor performance on measures of validity was a challenge.[76] Additionally, a study from 2012 found that the 34 newly developed questionnaires did not perform much better than 96 of their existing counterparts.[76] Sources of measurement error including recall bias and daily and seasonal variation in physical activity are thought to have a negative impact on the reliability and validity of self-reported assessments.[73]

1.5.2 Objective Measures

Objective measures of physical activity often refer to the measurement of physiological indicators using biological markers and the measurement of actual physical motion through the use of devices that monitor movement.[77] These methods are promising in that they can potentially remove some of the biases associated with self-reported measures, and therefore are thought to provide more accurate measures of energy expenditure.[77] A popular tool used to measure physical activity objectively is the accelerometer, an electronic motion sensor.[78] A review of evaluation studies found that measures of energy expenditure obtained from some accelerometers showed satisfactory correlation with energy expenditure derived using the doubly labelled water technique, the gold standard measurement method.[78]

Despite the benefits provided by objective measurement, there are also many factors that act as hindrances to their use in large scale studies.[77] Objective assessments are often expensive, time-consuming, and more intrusive than self-reported methods.[74] As a result, objective assessments of physical activity may not always be feasible to implement in research. For example, accelerometers may not be practical in some studies due to the high cost of purchasing the units and the additional time required to download and analyze the complex data.[79]

1.5.3 Comparing Self-Reported Measures to Objective Measures

The appropriateness of comparing self-reported and objectively-measured levels of physical activity is dependent on the extent to which the two measures align with one another. Findings from a systematic review of studies investigating the relationship between self-reported and objective measures of physical activity suggested that caution should be taken when making such comparisons.[77] Correlations between self-reported and objective measures of physical activity across studies were found to range from poor to moderate, and a lack of consistency was reported for the mean difference between the two types of measures.[77] Overall, self-reported physical activity levels were found to be higher than their objective counterparts; however, in some instances, they were found to be lower.[77] These findings suggest that it may be infeasible to correct for self-reported

measures of physical activity, and that limitations must be noted when comparing self-reported to objectively-measured levels of physical activity.[77]

1.5.4 Unit of Measurement

Several different units exist for the expression of measured levels of physical activity. These include the amount of time spent performing an activity, the total amount of work performed as a result of daily activities, and the average intensity of one's activities.[80] An investigation of all three of these measurement units found that physical activity explained more variance in predictor variables when expressed in terms of work than when expressed as time or mean intensity.[80] A noteworthy advantage to expressing physical activity in terms of work is that both time and intensity (energy expended per unit of time) are accounted for in a single numerical value.[80] Expressing physical activity as a single number in units of time requires a compromise, because activities of different intensities are treated as being equal.[80] A measure of physical activity in terms of mean intensity is limited in that it does not provide insight into the total amount of time spent performing particular activities or the total amount of energy expended.[80]

Chapter 2

2 Literature Review and Conceptual Framework

2.1 Physical Activity Influences

Previous research has suggested that the study of physical activity should be conducted through an ecological framework, where physical activity is seen as being affected by both intra- and extra-individual factors.[5] In this model, biological, psychosocial, and environmental factors all affect physical activity behaviour.[5] Individual factors refer to characteristics of a particular person, and may include sociodemographic attributes such as age, sex, and SES, as well as psychosocial factors such as self-efficacy.[81] Extra-individual or contextual factors act through the social context of an individual's daily life, and may include the influences of one's family, community or neighbourhood.[81] Investigating influences at multiple levels is particularly important for the understanding of physical activity behaviour, because physical activity is influenced by individual-level, social-environmental, and physical-environmental variables simultaneously.[82]

2.1.1 Individual-Level Factors

Sex

A review of the evidence on factors affecting physical activity suggested that among adults, males tended to be more physically active than females.[83] The trend is similar in Canada, where males are significantly more likely to be at least moderately active during leisure time in comparison to females.[84] Another study found that although there was no significant difference between men and women in terms of the overall quantity of physical activity reported, men were more likely to exercise vigorously compared to women.[85] Similarly, another study found that compared to females, males were more likely to engage in vigorous exercise or sports.[86]

Age

An inverse relationship has been observed between age and physical activity, suggesting that adults tend to become less physically active as they age.[83] This trend was also

observed in Canada, where the proportion of physically active men and women tend to decline with increasing age.[84]

Weight Status

Weight status may also affect engagement in physical activity, seeing that overweight adults are less likely to be physically active compared to their normal weight counterparts.[83] In Canada, there are data to suggest that those categorized as overweight or obese are less likely to be physically active than those categorized as being normal weight.[4]

Social Cohesion

Several indicators of social cohesion have been suggested to affect physical activity. Social support has been found to be positively correlated with the likelihood of engaging in physical activity, while the extent to which an individual is connected to the local community has been found to increase the odds of engaging in physical activity.[24, 83] Moreover, participation in formal associations within the community and having a more diverse social network have been associated with a lower likelihood of being physically inactive.[15]

Education

Education level has been suggested to influence physical activity, as adults with more formal education tend to be more likely to engage in physical activity.[83] An investigation of the relationship between education attainment and physical activity found that nearly all of the variance in physical activity observed across education levels could be explained by self-efficacy and social support.[87] This finding suggests that formal education may promote engagement in physical activity through increasing self-efficacy and social support.

Income

There is also evidence that income may be a key determinant of physical activity level. A study of residents from rural, urban, and suburban areas found that in each area type,

lower income residents were less likely to meet physical activity recommendations compared to their higher income counterparts.[88] This may be partially explained by the tendency for low income individuals to reside in low income neighbourhoods, which have been found to be lacking in parks and recreational facilities that encourage engagement in physical activity.[89]

Ethnicity and Immigrant Status

In Canada, physical activity participation has been found to vary by ethnicity.[90, 91] Compared to Caucasians, ethnic minorities were less likely to be physically active and less likely to participate in most forms of physical activity.[90, 91] Immigrant status was also found to contribute to the likelihood of one being physically active, as non-immigrants were overall more likely to be active than all immigrant groups.[90] Over the years, immigrants tend to become more similar to their non-immigrant counterparts with regards to physical activity behaviour, as immigrants who arrived in Canada at least 10 years ago were far much more likely to be physically active than recent immigrants.[90]

2.1.2 The Community

In public health, community refers to a group of people who are linked by social connections, common perspectives, or geographical locations or settings.[92] This has implications for public health practice, because it means a single positive change at the community level has the potential to affect a large number of individuals. For example, it has been suggested that regardless of one's individual-level characteristics, there are numerous tangible and intangible health-promoting factors associated with living in a healthy neighbourhood.[93]

Area of Residence

The geographical area in which an individual resides has been suggested to affect engagement in physical activity. A previous study of over 300,000 respondents found that those residing in more northern regions of England tended to engage in less physical activity than those in the South.[94] Moreover, residents of urban areas tended to report engaging in less physical activity in comparison to their counterparts from rural areas.[94]

A large-scale study from the USA also reported geographical variations in physical activity, although urban-rural differences were unclear.[95] In the South, residents from urban areas were found to be more physically active than those from rural areas, while the relationship was reversed in the West, and no consistent urban-rural differences were observed in the Midwest and Northeast.[95] It was suggested that geographical variations in physical activity may be a result of differences in access to recreational opportunities and socio-cultural factors.[94]

Physical Environment

Physical environmental characteristics found to be associated with engagement in physical activity include the walkability, safety, and aesthetic attractiveness of the built environment.[83] This suggests that individuals are more likely to be physically active when residing in a community that is safe, well-maintained, and designed to encourage travelling to nearby destinations by walking.[83] Another key environmental influence of physical activity was access to recreational facilities, which was positively associated with physical activity.[83] Access to recreational facilities may be one way in which some characteristics of SES are linked to physical activity. For example, income at the neighbourhood level has been positively correlated with access to physical activity resources, and thus income may have an indirect influence on physical activity.[89] This is supported by extensive research covering 19% of all census blocks in the USA that revealed an unequal geographical distribution in all major categories of physical activity resources.[89] Communities with a large proportion of visible minority groups and residents of low SES were found to be at the greatest disadvantage with regards to the distribution of recreational facilities such as parks, public facilities, and YMCAs.[89]

Social Environment

Several aspects of the social environment have been suggested to affect physical activity, many of which represent some aspect of social cohesion. Social cohesion has been defined as the result of "building shared values and communities of interpretation, reducing disparities in wealth and income, and generally enabling people to have a sense that they are engaged in a common enterprise, facing shared challenges, and that they are

members of the same community".[96] Numerous studies have found social cohesion at the neighbourhood level to be beneficial for physical activity behaviour. As a group-level influence, neighbourhood social cohesion was found to be associated with a significantly increased odds of being physically active or engaging in any physical activity, and a significantly decreased odds of being physically inactive.[6, 9, 12, 13] Moreover, several studies investigated perceived social cohesion in the neighbourhood and found that a higher level of perceived neighbourhood cohesion had a significant positive influence on physical activity.[14, 17, 18, 20, 23]

There are several hypotheses that may explain why neighbourhood social cohesion tends to be beneficial for physical activity behaviour. One proposition is that in socially cohesive neighbourhoods, community members may be more likely to create opportunities for physical activity through organizing activities such as sports leagues.[28] It has also been suggested that social cohesion may indirectly affect physical activity because a high level of social cohesion is associated with less crime, and low crime was found to be a key characteristic of neighbourhood environments associated with higher levels of physical activity.[26, 27]

2.1.3 Multilevel Influences

As previously discussed, the study of physical activity through the ecological framework involves consideration for both individual-level and community-level influences.[5] However, some factors have been suggested to act as an influence at both levels, having distinct effects depending on whether they are acting at the individual or community level.[97]

Income

An example of a multilevel influence is income. A higher income at the individual level has been shown to be associated with a greater likelihood of being physically active, while residing in a more affluent community has been linked with greater access to recreational facilities, ultimately leading to higher physical activity levels.[83, 88, 89] Conceptually, the influence of income at the individual level is distinct from the influence

of income at the community level, and the two influences of income may act in opposite directions. For example, in the case where an individual resides in a low income household located in a high SES community, the individual's low income status is expected to have a negative effect on his or her physical activity behaviour, while the benefits associated with residing in an affluent neighbourhood are expected to have a positive effect on his or her physical activity level.[83, 88, 89]

Social Cohesion

The present study proposes that social cohesion can also be viewed as a multilevel influence because one does not necessarily have to have a strong sense of connectedness or belongingness to the community to reside in an area with an overall high level of social cohesion, and vice-versa. An interesting proposition is the idea that the extent to which an individual is connected to, engaged in, or feels socially included the local community may affect the likelihood that he or she will benefit from residing in a socially cohesive community with abundant opportunities for physical activity. Thus, it would be beneficial to investigate social cohesion as a multilevel effect where its individual level counterpart refers to one's connectedness or belongingness to the local community.

2.2 Previous Studies on Social Cohesion and Physical Activity

In recent years, an increasing number of published studies have investigated the association between physical activity and indicators of social cohesion.

2.2.1 Search Strategy

The literature search was conducted in online databases in September 2015. PubMed (Medline) and Scopus were selected because of their breadth of coverage across disciplines in health and social sciences. Additional searches were performed in Google Scholar to retrieve articles that were not identified in PubMed or Scopus. The reference lists of retrieved articles were scanned to identify other potentially relevant articles. Details pertaining to the search strategy can be found in Figure 2.1.

Articles were initially selected based on a screening of their title and abstract. The full text of each selected article was reviewed to confirm its eligibility for the review. In total, 20 articles were determined to be eligible for the review, and a summary of each can be found in Appendix A. Data were summarized in terms of the study population and design, operationalization of social cohesion and physical activity, and main findings reporting on the association between social cohesion and physical activity.

Sources	**Inclusion Criteria**
▪PubMed	▪Investigated at least one measure of physical activity behaviour (e.g., physical activity status, engagement in physical activity) as a main outcome
▪Scopus	
▪Google Scholar	
▪References lists	▪Investigated at least one measure of social cohesion (e.g., social participation, interpersonal trust, community engagement) as an independent variable
Search Terms	▪Reported quantitative results
▪Physical Activity	▪Published in English
▪Social Cohesion	
▪Social Participation	
▪Social Engagement	**Exclusion Criteria**
▪Social Capital	▪Did not investigate at least one measure of physical activity behaviour as a main outcome
▪Trust	
▪Community	▪Did not investigate at least one measure of social cohesion as an independent variable
▪Neighbourhood	
	▪Did not report quantitative results
	▪Not published in English

Full PubMed search strategy: (social) AND (cohesion or engagement OR trust OR participation OR capital) AND (physical activity) AND (community OR neighbourhood)

Figure 2.1. Online search strategy for studies on social cohesion and physical activity

2.2.2 Study Population and Design

There was great variation in geographical setting across studies, as study locations included Australia, Brazil, Canada, China, Japan, New Zealand, the Netherlands, and the USA. One study did not specify the age range of the study population, while 9 studies were conducted in a general adult population, 4 studies included only older adults, and 6 studies included only adolescents. The majority of studies (17 out of 20) analyzed cross-sectional data where each study participant was assessed at one point in time, while 3 studies analyzed longitudinal data and included follow-up assessments. Twelve out of the

20 studies were multilevel in that they considered both individual-level influences as well as the contextual effects of the community or neighbourhood in which a respondent resides. Nine studies assessed social cohesion at the individual level, while 8 other studies assessed social cohesion as a group-level variable, and 3 studies included social cohesion in the analysis as both an individual- and group-level variable.

2.2.3 Operationalization of Social Cohesion

Although most studies investigating the effect of social cohesion on physical activity collected information on social cohesion using constructs related to sense of belonging to the local community, the variation in specific methods and constructs used in the assessment of social cohesion reinforce the abstract nature of social cohesion. Individual contributions to social cohesion and individual perceptions of neighbourhood cohesion were all informed by responses to survey items, and several involved asking the survey respondent to make selections from pre-determined responses on a rating scale.[7, 8, 11, 16, 24, 25] Multiple studies used surveys that included neighbourhood cohesion items from an existing 5-item scale.[7-10, 14, 20] Items in this scale asked respondents about several factors related to sense of belonging in the community, including the willingness of community members to help neighbours, whether the community is close-knit, and whether people in the neighbourhood are trustworthy, get along with one another, and share the same values.[26] To assess neighbourhood-level social cohesion, numerous studies aggregated data describing individual perceptions of neighbourhood level cohesion, resulting in cases where a socially cohesive neighbourhood would be defined as one in which a large proportion of residents perceive the neighbourhood as being cohesive.[7, 10-13, 16, 17, 21]

2.2.4 Operationalization of Physical Activity

Across studies investigating the effect of social cohesion on physical activity, much variation was seen in the operationalization of physical activity in terms of domain (e.g., leisure, transportation) and measurement scale (e.g., continuous, binary). Three studies investigated walking as the only measure of physical activity, though two of these studies included only older adults, and therefore it is understandable that only walking behaviour was assessed.[10, 17, 23] The majority of studies investigating the effect of social cohesion on

physical activity used self-reported data to assess physical activity, and many used some form of the popular International Physical Activity Questionnaire (IPAQ).[6-8, 11, 15, 16, 20] One study collected objective physical activity data through the use of accelerometers.[18] In the analysis, most studies (13 out of 20) treated physical activity as a binary outcome by either applying cut-off points to classify individuals as active or inactive, or by reporting physical activity as a "yes or no" outcome.[6-9, 11, 12, 15, 16, 19, 20, 22-24] The remaining 7 studies analyzed physical activity as a continuous outcome.

2.2.5 The Effect of Individual-Level Social Cohesion

Findings from previous research suggest that individual-level social cohesion could affect physical activity behaviour. A study of over 2,707 adults from 300 neighbourhoods across the city of Montreal in Canada investigated the effect of social participation (involvement in formal and informal groups or organizations in the local community) on physical activity status.[15] It was found that participants who reported no social participation were significantly more likely to be classified as physically inactive when compared to those who reported a high level of social participation.[15] Similarly, a study of 2,260 adults from 20 school districts in Japan investigated the effect of several measures of social capital (e.g., trust of neighbours, social participation), and found that individuals who reported a high level of trust had a significantly lower odds of being physically inactive compared to those who reported a low level of trust.[22] Another study analyzed survey data retrieved from 46,588 high school students across the state of California in the USA, and found that a higher self-rated sense of connectedness to the local community was associated with a higher odds of having participated in any form of physical activity the week the survey was administered.[24]

Several studies operationalized individual-level social cohesion as an individual's perception of the overall level of cohesion in his or her neighbourhood. A study of 2,783 older adults from 47 neighbourhoods in the city of Shanghai in China found that a higher level of perceived neighbourhood-level cohesion was associated with a greater odds of having engaged in LTPA.[11] Another study conducted among older adults included 4,317 participants from 82 census blocks across the city of Chicago in the USA, and found a

significant positive association between the perceived cohesiveness of the local neighbourhood and time spent walking.[17] Similar findings were observed in a third study that analyzed data from 41,545 respondents to the California Health Interview Survey (CHIS) and found a higher level of perceived social cohesion in the local neighbourhood to be associated with a greater likelihood of meeting recommended levels of walking.[23] One study of 1,347 African American adults from the city of Houston in the USA found that a higher level of perceived social cohesion was associated with a higher odds of being classified as physically active in women only.[20] Additionally, a longitudinal study of 143 Latino women from the city of San Diego in the USA performed assessments at baseline, at 3 months, and at 6 months, and found that perceived neighbourhood cohesion at 3 months was a significant predictor of engagement in LTPA at 6 months.[25] Furthermore, one study in the USA used accelerometers to collect objectively-measured physical activity data from 889 youth aged 10 to 15 years.[18] Parents' perception of the level of social cohesion in the local neighbourhood was found to be positively associated with engagement in MVPA during both weekdays and weekends.[18]

A study of 380 adults from 4 neighbourhoods in the city of Waterloo in Canada was particularly interesting because it concurrently investigated the effects of self-rated social cohesion and neighbourhood walkability on physical activity.[14] Overall, the high walkability and high social cohesion group reported spending significantly more time in recreational physical activity than all other groups.[14] However, the high social cohesion and low walkability group reported spending significantly more time in recreational physical activity than either the low social cohesion and high walkability group, or the low social cohesion and low walkability group.[14] These findings suggest that both perceived walkability and social cohesion may be independent contributors to recreational physical activity.

Two studies found no significant association between individual level social cohesion and physical activity. One of these studies included 4,108 female adults from across the state of Victoria in Australia, and found that although a higher level of social cohesion was initially associated with a higher odds of engaging in at least 150 minutes of weekly

LTPA, the association was no longer significant after controlling for age, urban-rural status, education, employment and marital status, number of children, and weight and smoking status.[8] The other study included 1,878 adults from 38 neighbourhoods in the city of Boston in the USA, and found no measure of social cohesion to be associated with physical activity status.[19]

2.2.6 The Effect of Community-Level Social Cohesion

When assessed as a community- or neighbourhood-level effect, social cohesion has repeatedly been suggested to have a positive influence on physical activity behaviour. A study of 582 older adults from 56 neighbourhoods in the city of Portland in the USA found a significant positive association between neighbourhood level social cohesion and frequency of walking.[10] A similar relationship was reported in a study of 6,101 adolescents from 262 Census Area Units across New Zealand. Specifically, social cohesion at the level of Census Area Units was found to be positively associated with the number of days in a week spent engaging in at least 1 hour of physical activity.[21] The potential benefits of residing in a socially cohesive community are reinforced by findings from a study of 3,597 adults from 149 census tracts across the city of Belo Horizonte in Brazil. Adults residing in a neighbourhood with a higher level of social cohesion were found to be significantly more likely to be classified as being physically active.[6] These results are supported by an analysis of longitudinal survey data from 57,092 adults across 320 neighbourhoods in the Netherlands finding that those who resided in a neighbourhood that saw an increase in social cohesion between 2006 and 2009 were significantly more likely to have engaged in at least one hour of physical activity per week.[12] Moreover, a study of 190 older adults from 8 neighbourhoods in the city of Denver in the USA suggested that the social environment may have a greater influence on physical activity behaviour than the physical environment. Physical activity engagement was found to be greatest in neighbourhoods that were deemed to be less walkable, but safer and more socially cohesive.[13] Finally, a study of 680 adolescents from 80 neighbourhoods in the city of Chicago in the USA found that compared to residing in less cohesive neighbourhood, residing in a neighbourhood with a high level of social

cohesion was associated with a decreased odds of being classified as inactive both at baseline and at the 2-year follow-up.[9]

Four studies that investigated social cohesion at the neighbourhood level reported finding no significant association between neighbourhood cohesion and physical activity. The first included 1,405 female adults from 45 neighbourhoods in the city of Melbourne in Australia, and assessed social cohesion as a separate construct from interpersonal trust. Although a higher level of interpersonal trust was associated with a higher odds of engaging in LTPA, no such association was found between social cohesion and LTPA.[7] This is in contrast to many other studies that assessed interpersonal trust as a component of social cohesion.[7-10, 14, 20] Thus, there should be consideration for the specific definition of social cohesion when interpreting the results from studies. The other 3 studies that found no significant association between neighbourhood-level social cohesion and physical activity included social cohesion in the analysis as both an individual- and group-level variable. Two of these studies initially found neighbourhood-level cohesion to be associated with physical activity, but reported a disappearance of the significant effect after controlling for individual-level social cohesion.[11, 17] The third study found that neither individual- or group-level social cohesion were associated with physical activity.[19]

2.2.7 Gaps in the Current Literature

A number of research gaps were revealed through reviewing the current literature on the association between social cohesion and physical activity. Although the current body of literature includes many studies that are multilevel in nature, only 3 studies investigated social cohesion as both an individual- and group-level effect. All 3 studies were limited in that they defined individual-level social cohesion as an individual's perception of social cohesion in his or her community, and therefore did not assess the extent to which an individual is socially connected or engaged in the local community. As a result, it remains unclear as to whether both an individual's extent of social cohesion in the community and social cohesion at the community level are associated with physical activity behaviour after controlling for one another. Additionally, 13 out of the 20

identified studies investigating the effect of social cohesion analyzed physical activity as a binary outcome, often dichotomizing continuous data to classify respondents as being active or inactive[6-9, 11, 12, 16, 19, 20, 22-24] Dichotomizing a continuous variable leads to the loss of information, and in the case of physical activity, much of the variation in data from questionnaires and motion sensors is ignored.[98, 99] The aforementioned research gaps would be addressed by a multilevel study that investigates social cohesion as a multilevel effect on physical activity, analyzes physical activity as a continuous outcome, and includes a large, representative population to produce generalizable findings. Ultimately, such a study would generate knowledge to inform public health practice aimed at increasing physical activity and overall health.

2.3 The Importance of Social Cohesion

For Physical Activity

There is substantial evidence indicating that increasing social cohesion within communities represents a promising strategy for promoting physical activity. A systematic review of public health initiatives designed to increase physical activity found the promotion of social support for physical activity in community settings to be effective.[100] This was reflected in another review of physical activity interventions that suggested increasing social support for physical activity within specific neighbourhoods was a promising strategy for increasing physical activity.[101] From a policy standpoint, targeting physical activity through interventions that build on social cohesion is practical because it often does not require a substantial monetary cost.[101] For example, the creation of physical activity support groups within communities has been found to be an effective, low-cost method of increasing walking.[102, 103] Past research has also found that both walking and social cohesion can be effectively promoted through community-based strategies such as social marketing.[30] An example of an intervention that can directly affect physical activity and social cohesion simultaneously is the provision of physical activity classes in the community.[101] These classes can be offered in existing facilities to minimize cost, and can be offered free of charge in socially disadvantaged areas where financial constraints may act as a barrier to physical activity.[101] Moreover, social support interventions and several other community-based interventions aimed at promoting

physical activity were deemed to be cost-effective public health strategies for preventing chronic disease.[31]

Population Health Impact

The potential population health impact of social cohesion has been implicated in previous research. For example, community integration has been positively correlated with the ability to recall disseminated health promotion messages, suggesting that increased social cohesion could provide benefits for future public health initiatives.[104] Also, social cohesion has particularly important implications for socioeconomically disadvantaged neighbourhoods because social cohesion and civic participation have been found to be important for health even after controlling for neighbourhood deprivation.[105] Similarly, another study found that social cohesion was associated with health benefits beyond what individual-level characteristics could explain.[106]

2.4 Conceptual Framework

2.4.1 Multilevel Structure

In public health research, it has been suggested that there needs to be consideration for the idea that a person's health and behaviour are influenced by both individual-level characteristics and the social context of which he or she is a part.[107, 108] For example, if data are collected from individual students across different schools, data from students within each school would be viewed as being in a nested structure.[109] Because of environmental similarities experienced by persons in the same school, greater correlation is expected among data from an individual school compared to data from different schools.[109] This is relevant to the present study because an individual may be more like others in the same neighbourhood than persons from other neighbourhoods because of social contextual effects.[108]

In this study, respondents were treated as being nested within communities defined by Forward Sortation Area (FSA) boundaries to account for the idea that individuals tend to be more similar to others from the same neighbourhood than to those from other

neighbourhoods. This results in a study sample with a multilevel structure composed of FSAs at the group level and individual respondents at the individual level.

2.4.2 Directed Acyclic Graph

In epidemiological research, a confounder is a variable that is associated with both the outcome and exposure of interest without being an intermediate step in the association between the exposure and outcome.[110] Causal graphs such as Directed Acyclic Graphs (DAGs) may be used to identify such variables that need to be controlled for to remove confounding from effect estimates.[111] A DAG illustrating the hypothesized relationship between social cohesion and physical activity is presented in Figure 2.2. Since the aim of the present study was to investigate associations rather than causal pathways, the intention was not to create a DAG that includes an exhaustive list of factors that influence physical activity behaviour. Rather, the DAG was used as an aid to identify key variables that, if controlled for, could result in a less biased estimation of the association between social cohesion and physical activity.

Confounders

Several of the aforementioned influences of physical activity including age, sex, education, income, and urban-rural status have also been suggested to be associated with measures of social cohesion. Age was included in the DAG because both physical activity and social connectedness have been suggested to vary across age groups.[112] Sex is a potential confounder because sex differences have been implicated for both physical activity behaviour and the creation of social networks.[113] Education was included because higher levels of education have been associated with benefits for both physical activity and social cohesion.[114] Income is another variable that has been suggested to affect both physical activity and social cohesion.[115] Also, area of residence and urban-rural status have been suggested to influence both physical activity and social cohesion.[14, 116]

Moderators

Weight status and ethnicity are absent from the DAG because they are hypothesized to be moderators in the association between social cohesion and physical activity. A moderator

is a variable that affects the strength or direction of an association between an independent variable and dependent variable.[117] It is recognized that those who are overweight or obese tend to be faced with psychological barriers related to body image and self-esteem that may deter them from engaging in physical activity.[63, 64] Thus, these deterrents could blunt the potential positive effect of social cohesion on physical activity and reduce the strength of the relationship between the two variables. Ethnicity is also hypothesized to be a moderator because findings from previous research suggest that correlates of physical activity, including social factors, have distinct effects for specific ethnic groups.[118] As a result, it is possible that differences in cultural norms and other factors that vary across ethnicities may affect the way in which social cohesion influences physical activity behaviour. It must be noted however that the investigation of ethnicity as a potential moderator was not an objective of this study, and therefore indicators of ethnicity were not included in the analyses.

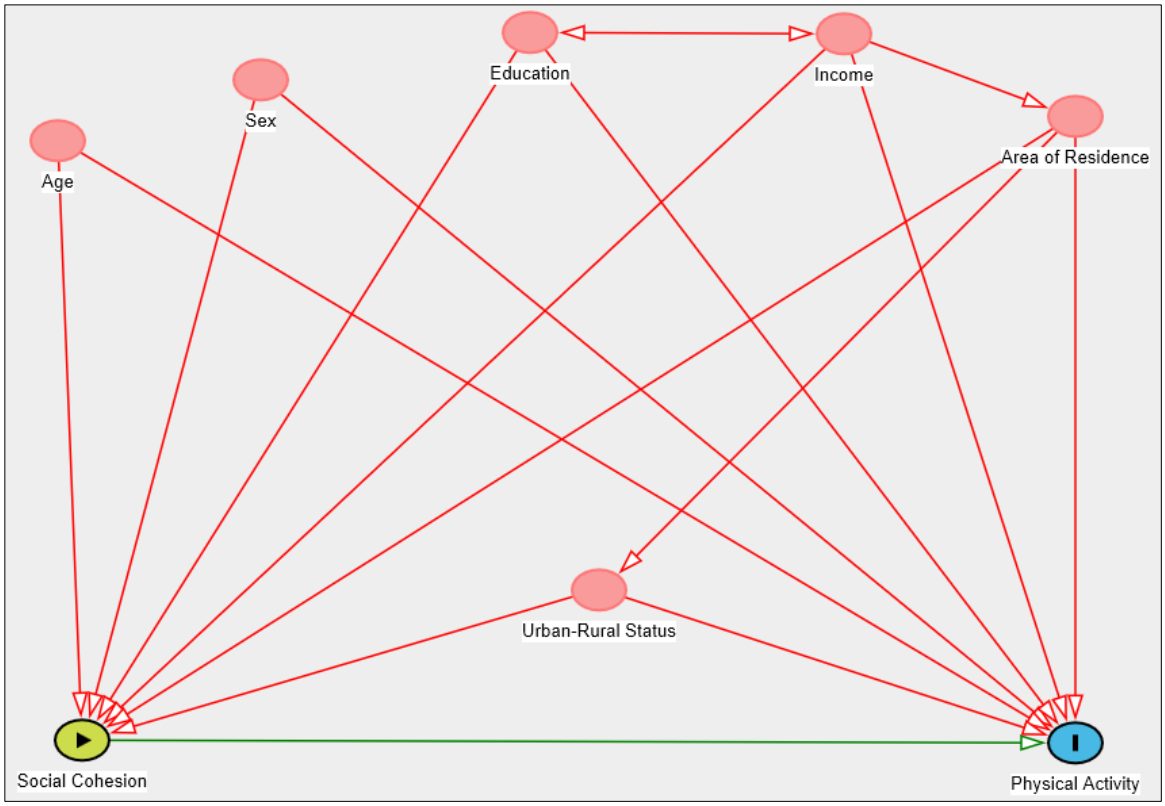


Figure 2.2 Directed Acyclic Graph illustrating the hypothesized relationship between social cohesion and physical activity

Chapter 3

3 Objectives and Hypotheses

3.1 Objectives

The primary purpose of this thesis is to investigate the association between social cohesion and physical activity. The secondary purpose is to determine if and how the association between social cohesion and physical activity differs depending on whether or not an individual is overweight. The study population consisted of adult respondents from the Canadian Community Health Survey (CCHS). The CCHS and the definition of "community" are described in further detail in the next chapter. The specific objectives of the analysis are outlined below.

Objective 1

The first objective was to assess the within- and between-community variation in physical activity among adults aged 18 to 64 years across communities in Canada. Specifically, there is interest in determining if a significant proportion of the variation in physical activity level can be attributed to geographically-defined communities.

Objective 2

The second objective was to investigate the relationship between social cohesion and physical activity, where social cohesion is assessed as both an individual- and community-level effect simultaneously. There is specific interest in assessing the effect after controlling for age, sex, household income, education and urban-rural status, as these variables are hypothesized to influence both social cohesion and physical activity.

Objective 3

The third and final objective was to assess potential differences in the effect of social cohesion on physical activity between normal weight and overweight individuals. Since those who are overweight tend to face unique barriers to physical activity, there is interest in determining if and how the association between social cohesion and physical activity differs depending on whether or not one is overweight.

3.2 Hypotheses

Objective 1

Based on the theory that individuals tend to be more similar to persons from the same neighbourhood than to persons from other neighbourhoods, it is hypothesized that there will be significant variation in the average level of physical activity across geographically-defined communities.

Objective 2

It is hypothesized that social cohesion at both the individual and community level has a significant positive influence on physical activity level after controlling for age, sex, household income, education and urban-rural status. Higher levels of both individual- and community-level social cohesion are expected to be associated with engagement in more physical activity.

Objective 3

To date, no known studies have investigated the difference in the relationship between social cohesion and physical activity between individuals who are overweight and those who are not. Based on existing research indicating that overweight individuals tend to face more barriers to physical activity and engage in less physical activity compared to their normal weight counterparts, it is hypothesized that both individual- and community-level social cohesion will have a more pronounced effect on physical activity among normal weight individuals.

Chapter 4

4 Methods

This chapter starts with an overview of the data used in the analysis (Section 4.1), including the data source and methods of data collection. Next, each construct included in the analysis is described in terms of how it was operationalized in the statistical models (Section 4.2). This is followed by a description of the multilevel modelling methods used (Section 4.3) and the specific analyses performed (Section 4.4). Finally, statistical considerations including the software used, the transformation of variables, sampling weights, and missing data are discussed (Section 4.5).

4.1 Data Source

To accomplish the previously outlined objectives, a secondary analysis was performed using data from the 2009-2010, 2011-2012, and 2013-2014 cycles of the CCHS. Three cycles of the CCHS were combined to increase sample size, ultimately decreasing the proportion of communities with very few (fewer than 5) respondents. These data files were accessed through the Statistics Canada Research Data Centre at Western University following the approval of an application submitted to Statistics Canada through the Research Data Centres (RDC) Program. The CCHS, a joint effort between the Canadian Institutes for Health Information (CIHI), Statistics Canada and Health Canada, is a cross-sectional survey that collects information related to determinants of health, health status, and health care utilization among Canadians.[119] Surveying took place on a biennial basis from 2001 to 2005, then occurred annually from 2007 onwards.[119] Despite the change in the data collection schedule, the sample of respondents selected across any 2 year period was maintained at 130,000.[119] Each of the CCHS data files used in the analysis included two years of data.

4.1.1 Content of the CCHS

The specific objectives of the CCHS are to a) support health surveillance programs by providing health data at the national, provincial and intra-provincial levels, b) provide a single data source for health research on small populations and rare characteristics, c)

timely release information easily accessible to a diverse community of users, and d) create a flexible survey instrument that includes a rapid response option to address emerging issues related to the health of the population.[119] The specific topics covered by questions in the CCHS are disease and health conditions, general health, health care services, lifestyle and social conditions, mental health and well-being, and the prevention and detection of disease.[119]

Three components comprise the contents of the CCHS, and these are the common content, the optional content, and the rapid response content.[119] Questions from the common content are presented to all respondents, and these questions collect a broad range of information including sociodemographic characteristics (e.g., age, sex, education, income), height and weight, health behaviours (e.g., smoking, fruit and vegetable consumption, physical activity), and health care utilization.[120] The optional content varies by province and territory, and may include topics such as illicit drug use, mental health status, and cancer screening.[120] The rapid response content comprises the shortest section of the CCHS, requiring an average time of two minutes to complete.[120] Questions from this section are presented to all respondents in a single collection period, and aim to provide organizations with national estimates of an emerging health-related topic.[120] The present analysis only includes data collected from questions that were asked of all respondents.

4.1.2 Sampling Design

The target population of the CCHS includes the entire population 12 years of age and older living in all provinces and territories in Canada.[119] A few specific populations are excluded from the survey, and these are individuals living on Aboriginal reserves or Crown lands, full-time members of the Canadian Armed Forces, institutionalized persons, and persons residing in certain remote areas.[120] The excluded populations represent approximately 2% of Canadians 12 years of age or older.[120]

For sampling purposes, each province was divided into multiple health regions and each territory was designated as an individual health region.[120] Three key steps were taken to

ensure that each health region and province would be considered equal in importance. First, each health region was required to collect data from a minimum of 500 respondents to achieve a reasonable level of data quality.[120] Next, the remainder of the available sample was allocated proportionally to population size by province.[120] Notably, the territories were excluded from the proportional allocation, and instead were allocated a fixed number of sample units each year.[120] Yukon and the Northwest Territories were each allocated 600, and Nunavut was allocated 350.[120] In the last precautionary step, provincial samples were allocated to health regions within the province proportionally to the square root of the population in each region.[120]

To obtain the sample of respondents, households were selected using three sampling frames.[120] In total, 49.5% of the sample was selected from an area frame containing a list of dwellings, 49.5% was selected from a list of telephone numbers, and the remaining 1% of households was selected from random digit dialing.[120] The sampling strategy was based on that designed for the Canadian Labour Force Survey, which employed a multistage cluster design using dwellings as the sampling unit.[120, 121] Samples of geographical regions containing multiple dwellings are selected in the first stage, individual dwellings are selected in the second stage, and individual respondents from the chosen dwellings are selected in the final stage.[121] Stratification by geographical and SES characteristics was incorporated into the sampling strategy to obtain a representative sample.[120] The list of telephone numbers was obtained from the Canada Phone Directory, an administrative database containing names, addresses and telephone numbers.[120] After each telephone number was linked to a postal code and its associated stratum, a pre-determined number of telephone numbers was selected from each stratum through simple random sampling.[120] Finally, random digit dialing was used to partially account for the under-coverage of the telephone list frame by allowing respondents with unlisted telephone numbers to potentially be selected.[120]

4.1.3 Study Population

For the purposes of fulfilling the objectives, all analyses were limited to adults aged 18 to 64 years. Older adults (65 years and older) were excluded due to concerns that their

ability to engage in physical activity may be limited by health conditions or deficiencies in physical fitness. Pregnant women were excluded because they lacked the Body Mass Index (BMI) variable in the CCHS. Respondents from any of the three territories (Yukon, the Northwest Territories and Nunavut) were excluded due to concerns that the selected definition of "community" may not be appropriate in these settings. The three territories were also excluded because their respondents were not included in the calculation of household income decile. This is described in further detail below.

4.2 Measures

The analysis was conducted to assess the association between social cohesion and physical activity among adults in Canada while controlling for age, sex, household income, education and urban-rural status. The following sections describe how each of these constructs was measured in the CCHS and how they were incorporated into statistical models in the analysis.

4.2.1 Physical Activity

Mean daily energy expenditure (EE) was selected as the indicator of physical activity level. This variable was provided in the CCHS in terms of kilocalories per kilogram of body weight. The frequency, duration, and intensity of all leisure physical activities were taken into account when estimating average daily EE. The MET value of each activity was multiplied by N (the number of times a respondent engaged in the activity in the past 12 months) and D (the average duration of the activity in hours), then divided by 365 to derive the value for mean daily EE.

Due to highly right-skewed distribution of the mean daily EE variable, the data were organized into deciles by sorting the data in ascending order and dividing the data into ten groups (from 1 to 10) with approximately the same number of respondents. The least active 10% of the sample would fall into decile 1 and the most active 10% of the population would fall into decile 10 in the measure of physical activity level. The proportion of respondents falling into each of the 10 deciles was not exactly 10% because

average daily EE is rounded to the nearest tenth in the CCHS, and respondents with the same value were not divided to create precisely equal deciles.

4.2.2 Social Cohesion

Social cohesion was assessed using a survey item asking respondents to rate their sense of belonging to the local community on a 4-point scale. In the CCHS, respondents were asked "How would you describe your sense of belonging to your local community? Would you say it is...?" and were given the response options "very strong (1)", "somewhat strong (2)", "somewhat weak (3)", or "very weak (4)". In the analysis, the responses were re-coded in ascending order (1 was coded as 4, 2 was coded as 3, 3 was coded as 2, and 4 was coded as 1) so that higher numeric values indicate a stronger sense of belonging.

In the analysis, social cohesion was treated as a continuous variable. In the multilevel models, the mean score for social cohesion in each community was calculated and used as the aggregate FSA-level variable for social cohesion. Resultantly, communities with a high level of social cohesion are those in which a large proportion of residents reported having a strong sense of belonging to the local community.

4.2.3 Age

Age was included in the model because of the implicated inverse relationship between age and physical activity level.[83, 84] In the CCHS, the age of a respondent was provided in years. To obtain the information, the respondent was asked what his or her age was in years.

In the analysis, age was operationalized both as the actual age of the respondent in years and as his or her corresponding age group. The age group variable was created using data from the continuous age variable in the CCHS. From 25 to 64, each age group comprised of 10 individual years (25 to 34, 35 to 44, 45 to 54, 55 to 64), while those under 25 were in a category that included respondents aged 18 to 24 years. The purpose of creating the age group variable was to produce descriptive statistics to examine the linearity of

changes in the two main variables of interest (social cohesion and physical activity level) with age. This provided insight into whether or not it was appropriate to treat age as a continuous variable in the model.

4.2.4 Sex

Sex was included in the model because it has been suggested that males tend to be more physically active than females.[83, 84] In the CCHS, sex was reported as a binary variable (male or female). The interviewer was asked to enter the sex of the respondent, and if necessary, ask the respondent if he or she is male or female. In the analysis, a value of 0 for the sex variable referred to males and a value of 1 referred to females.

4.2.5 Household Income

Income was included in the model because having a higher income has been associated with being more likely to meet physical activity recommendations.[88] Specifically, household income was selected because it accounts for the idea that an individual's living condition may be affected by sources of income from other members of his or her household. In the CCHS, household income was provided as both an absolute value and as an adjusted decile (one of ten categories, each with approximately the same number of residents for each province). To derive household income decile, the CCHS calculated the ratio of total household income to the low income cut-off value that corresponds to the household and community size. These ratios were organized in ascending order and divided into ten deciles ranging from 1 to 10.

Household income decile was selected for the analysis because it is adjusted for the respondent's household characteristics and community size. Notably, respondents from the three territories were excluded from the calculation of household income decile.

4.2.6 Education

Education level was included in the model because having more formal education has been associated with a greater likelihood of being physically active.[83] Education attainment was provided in the CCHS as a categorical variable indicating the highest

level of education a respondent completed. The respondent was asked to select from a list of descriptions that reflects the highest level of education he or she completed. The choices provided to respondents were “Grade 8 or lower”, “Grade 9 to 10”, “Grade 11 to 13”, “Secondary school”, “Some post-secondary”, “Trade certificate or diploma from a vocational school or apprenticeship training”, “Non-university certificate from a community college, University below bachelor’s level”, “Bachelor’s degree”, and “University degree or certificate above bachelor’s level”. In the analysis, education was coded in ascending order from 1 to 10 where a higher value indicates a higher level of education completed, and then treated as a continuous variable.

4.2.7 Weight Status

Body Mass Index, a function of weight (in kilograms) divided by height (in metres) squared, was used as the indicator of weight status.[122] In the CCHS, BMI was derived using respondents’ self-reported measures of height and weight. Notably, pregnant women were excluded from the calculation of BMI.

The WHO recognizes numerous categories and sub-categories of weight status based on BMI.[122] Individuals with a BMI below 18.50 are considered underweight, while those with a BMI between 18.50 and 24.99 are considered normal weight.[122] Individuals with a BMI of 25.00 to 29.99 are considered overweight, and those with a BMI of 30 or greater are considered obese.[122]

In the analysis, weight status was operationalized as a binary variable, with individuals with a BMI below 25 falling into the normal weight category, and those with a BMI of 25 or greater falling into the overweight category. Multiple categories of weight status were collapsed into 2 categories to maintain large sample sizes after the stratification of results by weight status. Stratified results could have implications for public health practice because those who are overweight may need to be treated differently, as they are at a greater risk of numerous adverse health outcomes, and also tend to face unique barriers to physical activity.

4.2.8 Urban-Rural Status

Urban-rural status was included in the model to account for potential urban-rural differences in physical activity level across Canada. Previous studies have observed urban-rural differences in physical activity level, although the observed trends have been inconsistent. In some regions, residents of urban areas were found to be more physically active, while residents of rural areas were found to be more physically active in other regions.[94, 95]

One of the items in the CCHS used a respondent's address information and Census classification criteria to determine whether he or she resides in a population centre or rural area. A population centre is defined as an area with at least 1,000 residents and a population density of 400 persons per square kilometre, and a rural area is defined as all places outside of population centres.[123] In the analysis, urban-rural status was coded as a binary variable where a value of 0 represents residence in a population centre, and a value of 1 represents residence in a rural area.

4.2.9 Community

From a public health perspective, community has been defined as a group of people who share social connections, common perspectives, or geographical locations or settings.[92] In the present study, community was defined as what is often referred to as a neighbourhood, a geographical unit in which the circumstances are shared by residents.[124] Using neighbourhoods with pre-determined geographical boundaries is common in public health research because it allows for the analysis of health data from secondary sources such as the CCHS that also include data pertaining to areas within these boundaries.[125] Moreover, this is relevant to the present study because several indicators of social cohesion among community members such as trust, social contact, and feelings of shared norms, tend to be geographically bound to neighbourhoods.[126] In selecting an operational definition for community in the analysis, the goal was to select a unit large enough to provide sufficient sample sizes, but not so large that there would be concerns of significant heterogeneity in characteristics such as income and education attainment.

Several potential definitions using CCHS data were considered, and these included Health Region, Census Subdivision, and Postal Code Region.

Health Region and Census Subdivision were both deemed to be inappropriate geographical units because of the large, heterogeneous populations included in each unit. For example, an entire city could be included in a single Health Region as exemplified by the inclusion of the entire city of London, Ontario in the Middlesex-London Health Region. This is problematic because it is known that there is much variation in key SES characteristics such as income between neighbourhoods in London, and therefore it would not be meaningful to define the entire city as one unit in the analysis.[127] Although Census Subdivisions represent smaller geographical areas than Health Regions, they often include entire municipalities, and thus were determined to be too large to represent communities in urban settings.[128] The next smallest unit in the CCHS was Postal Code Region, which was deemed too small to represent communities in urban settings where they often include only one street block.

In this analysis, an ideal definition of community would be larger than a postal code region but smaller than a census subdivision. As a result, it was decided that communities would be defined as FSAs, each of which includes a geographical area sharing the same first three postal code characters.[129] The FSAs were created because the CCHS data in its raw form did not include FSA as a variable. The last three letters from each postal code were dropped, and all respondents sharing the first three postal code characters were aggregated into a single "community". In the three territories, defining each FSA as a community would result in communities that are extremely large in terms of geographical area. Thus, respondents from Yukon, the Northwest Territories or Nunavut were excluded from the analysis because of concerns that such large areas may not be appropriate representations of a neighbourhood or community.

4.3 Multilevel Modelling

Multilevel modeling is a term that refers to regression methods used in observational and experimental studies where data are viewed as being in nested structures.[109, 130] This is

relevant to the present study, which proposes that an individual may be more like others in the same neighbourhood than persons from other neighbourhoods because of the shared physical and social environments.[108] If such within-group correlation is evident through the detection of significant variance at the group level, traditional multiple regression analysis at the individual level would be inappropriate because the assumption of independence is violated by the data.[109] Using geographical areas as the unit of analysis would not be a practical solution because it would not account for within-group variance at the individual level, is unable to separate individual- and area-level effects, and has been found to overestimate the magnitude of associations.[131] Multilevel modeling would be appropriate in these cases because it allows for a regression model to be applied to individual level outcomes while taking into account systematic variation across groups.[130] This is accomplished through the separation of variation at the individual level from variation at the group level, allowing for the concurrent investigation of individual- and group-level effects, as well as interactions between these effects.[109, 132] This in turn allows for the testing of multiple hypotheses simultaneously.

Equations for multilevel models can include intercepts and effects that are either fixed or random.[133] Fixed effects are consistent for all individuals in the sample, while random effects allow for variables to have varying effects on different individuals in the sample.[133] In multilevel models, the intercept is often treated as a random effect, because it allows means for variables to vary between group-level units.[133] This type of variation across group-level units often accounts for a large proportion of the non-independence seen at the individual level.[133] The model can also include a random slope to allow for the effect of the individual-level predictor to vary across groups, which is important in the context of this analysis because it allows for the effect of individual-level social cohesion to vary across communities.[134] The basic equation of a two-level "random intercept and random slope" multilevel model with continuous outcome data for individuals within a particular group-level unit is as follows.[134]

$$Y_{ij} = \beta_{0j} + \beta_{1j}X_{ij} + e_{ij}$$

Where

Y_{ij} = the outcome for respondent *i* in group *j*

β_{0j} = the average outcome for group *j*

X_{ij} = individual level predictor for respondent *i* in group *j*

β_{1j} = the slope/regression coefficient for X_{ij}

e_{ij} = the random error for the individual respondent *i*

and $\beta_{0j} = y_{00} + y_{01}W_j + \mu_{0j}$ and $\beta_{1j} = y_{10} + \mu_{1j}$

Where

y_{00} = the overall of the outcome across all individuals and groups

W_j = the group level predictor for group *j* and y_{01}

μ_{0j} = random error representing a unique effect for group *j*

y_{10} = the average effect of the individual level predictor

μ_{1j} = random error representing a unique effect for individual *i*

Without the μ_{1j} term, this would be referred to as a random intercept model where the effect of the individual level predictor is fixed.[134] The addition of the μ_{1j} and μ_{0j} terms results in a random intercept and random slope model by allowing the association between the individual level predictor X_{ij} and the outcome Y_{ij} to vary across groups.[134]

4.3.1 Intraclass Correlation

In multilevel research, intraclass correlation refers to the extent to which data within a cluster are correlated, and can be quantified using the intraclass correlation coefficient (ICC).[135] The ICC separates variance at the cluster level from variance at the individual level, then calculates the proportion of total variance that is attributable to variance at the cluster level.[135] The equation for ICC is as follows.[134]

$ICC = \sigma^2_{group} / (\sigma^2_{group} + \sigma^2_{error})$

Where

σ^2_{group} = variance attributable to cluster level units

σ^2_{error} = variance attributable to individual level units

Values for ICC can range from a minimum of 0 to a maximum of 1.[135] An ICC of 0 indicates no correlation between data within clusters, and suggests that none of the total variance is explained by cluster-level variance.[135] An ICC of 1 indicates that observations within individual clusters are all the same, suggesting that 100% of the total variance can be explained by cluster-level variance.[135] A previous study on lifestyle risk factors and health outcomes found that values for ICC tend to be smaller for large geographical areas such as district health authorities, larger for smaller areas such as postal code sectors, and the largest for very small units such as households.[136] These findings suggest that while a large, diverse group-level unit may produce findings that are more generalizable compared to a smaller and more homogeneous unit, the greater within-group diversity reduces the chance that group-level differences and effects will be detected.[136]

4.3.2 Centering

Centering is a broad term that refers the scaling of variables in a way that affects the interpretation of the intercept in regression equations.[137] Without centering, the intercept represents the estimated outcome when all independent variables in the model equal zero.[137] In the present study, there would be no realistic scenario where all independent variables in the model equal to zero, so the value of the intercept without centering would not be meaningful. In multilevel regression modelling, centering can occur either around the grand mean or the group mean.[137] When centering around the grand mean, the intercept represents the expected outcome when an individual is at the overall mean for all independent variables.[137] When centering around the group mean, the intercept represents the expected outcome when an individual is at the mean of his or her group for all independent variables.[137]

In this study, it was decided that centering on the group mean would be more meaningful because correlation is expected among respondents within a community. For values of social cohesion at the individual level, age, sex, household income, education and urban-

rural status, aggregate means were calculated within each community. For each independent variable, a new variable was created to represent its centered counterpart, operationally defined as the value of a variable for a respondent minus the mean for the same variable within his or her FSA. This produces an intercept that takes into account the influence of differences in explanatory variables across communities. In the final models, the only variable that remains un-centered is social cohesion at the community level. As a result, the expected physical activity level of an individual who is at the mean for all predictor variables in his or her FSA is represented by the intercept plus the effect of community-level social cohesion.

4.3.3 Minimum Sample Size

In multilevel modelling, there needs to be consideration for both the number of observations in each group as well as the total number of groups in the overall sample.[138] Although there have been many investigations of the minimum requirement for the size of groups and the total number of groups, universally-accepted guidelines do not exist.[138, 139] Previous research has suggested that in multilevel modelling, the total number of groups is more important than the number of individuals in each group. A simulation study investigated an extreme case of small sample sizes where some groups were singletons with a sample size of one individual. The study found that when a large number of groups (e.g., 500) were included, the proportion of singleton groups had a minimal effect on estimates of parameters in the model regardless of model complexity.[138] The accuracy of parameter estimates was only found to be significantly affected by the proportion of singleton groups when far fewer groups (e.g., 50) were included.[138] These findings are reminiscent of those from another study of sample sizes in multilevel modelling that varied the number of total groups and the number of samples within each group. This study investigated the effect of sample sizes as small as 30 at the group level, and 5 at the intra-group level.[139] Unbiased and accurate estimates of regression coefficients, variance, and standard errors resulted from all conditions except when the sample size at the group level was small.[139] When 50 or fewer groups were included, estimates of standard errors were found to be biased.[139]

In the present study, sample size concerns pertain primarily to the number of individuals in each group, as the sample size at the group level is very large and includes over 1,000 communities. The selection of a minimum group-level sample size requires a trade-off, because while having a larger minimum sample size could yield less biased results, it requires a compromise in the form of data loss. A previous multilevel study investigating the relationship between social cohesion and physical activity excluded all neighbourhoods with fewer than 10 respondents, and this decision resulted in the loss of nearly one third of the sample.[21] Considering that previous research suggested a minimum sample size of 5 in each group could be sufficient when at least 100 groups are included, and that the inclusion of some singleton groups may be acceptable when at least 500 groups are included, there would be an argument for including all communities to minimize the loss of data. However, including communities with a sample size of 1 would lead to the concern that community-level social cohesion may not be meaningful because only one respondent is taken into account. Resultantly, it was decided that only communities with a minimum of 5 respondents would be included in the analysis. This was deemed to be a pragmatic decision because it resulted in the loss of only 81 respondents, representing less than 0.04% of the final sample.

4.4 Statistical Analyses

4.4.1 Descriptive Statistics

Frequency distributions were calculated for physical activity, social cohesion, age, sex, household income, education level, urban-rural status, and physical activity status. Mean scores for physical activity level and social cohesion were calculated for each category of age group, sex, household income, education level, and urban-rural status. Also, mean scores for physical activity level were calculated for each category of social cohesion, and mean scores for social cohesion were calculated for each physical activity level.

4.4.2 Analyses for Objective 1

The first objective was to assess if there is significant variation in physical activity level across communities. This was accomplished through fitting a multilevel regression model

without independent variables. The model included physical activity level as the outcome variable and FSA as the class variable. The intercept was designated as a random effect in the model, and an ICC was calculated to estimate the proportion of variance in physical activity level that is accounted for by FSAs.

4.4.3 Analyses for Objective 2

The second objective was to assess the association between social cohesion and physical activity level. Age, sex, household income, education level and urban-rural status were included as covariates. A multilevel regression model including all the covariates was fitted to satisfy this objective. The model included individual- and community-level social cohesion as the independent variables, physical activity level as the dependent variable, and FSA as the class variable. Community-level social cohesion was represented by the average of all individual scores within a single FSA, and individual-level social cohesion was represented by a centered value relative to the mean in the respondent's FSA. Both the intercept and social cohesion at the individual level were designated as random effects, while social cohesion at the community level was defined as a fixed effect.

4.4.4 Analyses for Objective 3

The third objective was to assess if and how the relationship between social cohesion and physical activity differs depending on whether or not an individual is overweight. To test for this potential effect modification, two interaction terms were added to the model. The first was an interaction term between individual-level social cohesion and weight status, and the second was an interaction term between community-level social cohesion and weight status. To assess how the effect of social cohesion on physical activity differs depending on whether or not one is overweight, the sample was stratified by weight status. The intercept and social cohesion at the individual level were designated as random effects, while social cohesion at the community level was defined as a fixed effect. For the normal weight model, only data for respondents with a BMI of less than 25 were included, and in the overweight model, only data for respondents with a BMI of 25 or higher were included.

4.5 Other Statistical Considerations

4.5.1 Software

All statistical procedures, including descriptive statistics and multilevel regression models, were performed in SAS software version 9.3.[140] All multilevel models were estimated using the PROC MIXED procedure, with FSA as the class variable, the intercept and social cohesion at the individual level defined as random effects, and social cohesion at the community level defined as a fixed effect.

4.5.2 Transformations of Variables

Social Cohesion

Self-rated sense of belonging to the community, the variable used as the indicator of social cohesion, was provided in the CCHS as an ordinal variable. While the size of numbers is meaningful in sets of ordinal data (e.g., a rating of 3 is better than a rating 2), the difference between adjacent values may not be consistent.[141] In the context of the sense of belonging variable, this means that the difference between "very weak" and "somewhat weak" may not necessarily be the same as the difference between "very strong" and "somewhat strong". This is distinct from an interval variable such as energy expenditure, where the difference between the values 1 and 2 would be equivalent to the difference between the values 9 and 10.[141] It was previously suggested that parametric analyses should not be used for ordinal data because it would involve treating the data as being on an interval scale where the difference between adjacent whole numbers is consistent.[142] It was argued that such an assumption would be invalid because on a scale where 1, 2, 3, and 4 represent poor, fair, good, and excellent, respectively, reporting an average score of 2.5 would be inappropriate because it would be equivalent to reporting the average as being "fair and a half".[142] Resultantly, it was suggested that ordinal data should be analyzed as ranked data in nonparametric analyses.[142] This view was criticized in a recent paper that advocated for the use of analyses that treat ordinal data as being on an interval scale.[143] Although a key concern with treating ordinal data as interval data in regression and correlation analyses is that it may lead to incorrect answers due to

undesirable characteristics of the data distribution such as skewness and non-linearity, there is evidence supporting the robustness of such analyses against extreme violations of both assumptions of normality and the type of scale.[143, 144] To illustrate this point, several examples were provided using real patient data where the severity of a problem was rated on a scale of 0 to 10.[143] In the most skewed case, a new 4-point ordinal scale was created where 1 included only ratings of 0, 2 included ratings of 1 and 2, 3 included ratings of 4 and 5, and 4 included and ratings of 6, 7, 8, 9, and 10.[143] When the parametric Pearson correlation and the rank-based Spearman correlation were computed between responses at 2 different time points and compared, it was found that the Pearson correlation and its non-parametric (Spearman) equivalent were nearly identical, with the means of the two being within 0.004 of one another in all conditions.[143] As a result of this finding and tests on several other parametric analyses that found the parametric methods to be extremely robust to violations of assumptions, it was suggested that parametric statistics can be used with non-normally distributed Likert-type (ranked ordinal) data without the concern of arriving at the wrong conclusion.[143]

In the present study, social cohesion was treated as an interval variable in parametric analyses to allow for the possibility of calculating aggregate group means and analyzing data using multilevel regression models. The limitations of analyzing ordinal data as interval data was considered in the interpretation of results.

Physical Activity Level

Mean daily EE, the variable selected as the indicator of physical activity level, was found to be positively-skewed by high values. Although the mean was 2.256 kcal/kg/day, the median was 1.600 kcal/kg/day, indicating that 50% of all respondents had a value at or below 1.600. A recent Statistics Canada publication described a few decile estimation techniques that can be applied to highly positively-skewed population survey data to reduce bias and provide the data with reasonable statistical properties.[145] The simplest of these methods involved obtaining decile estimates from cumulative distributions.[145] In the present study, this method was used to create deciles for physical activity level, though it must be noted that the mean daily EE variable was rounded to the nearest tenth,

and that individuals with the same value were always placed in the same decile. As a result, each decile contained approximately 10% of the sample, but not exactly 10% of the sample.

4.5.3 Sensitivity Analysis

Although there is evidence to suggest that social cohesion can be analyzed as a continuous variable in this study, a sensitivity analysis was performed to determine if and how conclusions would have differed if social cohesion were treated as a binary variable instead. A social cohesion value of 1 was given to respondents who rated their sense of belonging to the local community as "very strong" or "somewhat strong", and a social cohesion value of 0 was given to respondents who rated their sense of belonging as "somewhat weak" or "very weak". Social cohesion at the community level was defined as the proportion of respondents from a single FSA with a value of 1 for social cohesion. As a result, a socially cohesive community would be defined as one in which a large proportion of residents feel that they belong to the local community, which is consistent with the definition of a socially cohesive community when social cohesion was treated as a continuous variable. All of the multilevel analyses were repeated with social cohesion treated as a binary variable instead of a continuous one.

4.5.4 Sampling Weights

All descriptive statistics and regression models were calculated using sampling weights provided in the CCHS. This was necessary to allow for estimates to be calculated from survey data that is representative of the population included in the CCHS.[120] In the CCHS, a survey weight is provided for each respondent, and this weight corresponds to the number of individuals the respondent represents in the covered population.[120] Weights were standardized for each cycle of the CCHS, and therefore the weight applied to each data point is dependent on the CCHS cycle from which it originated.

4.5.5 Missing Data

In the final sample, 21,126 respondents representing 9.1% of the total sample had missing data for an independent, dependent, or control variable. A common method for working

with missing data is complete case analysis, where respondents with missing data for any of the variables of interest are excluded from the analysis.[146] Although this method is advantageous in that it is simple to apply, its main drawback is that it assumes data are completely missing at random (CMAR), where the complete cases represent a random sample of the target population.[146, 147] In large-scale surveys, it is very unlikely that data are CMAR, seeing that data for variables such as income are often missing for a sizeable proportion of respondents.[148] Previous research has also implicated that respondents with missing data for income tend to be younger and less educated.[148] Thus, there was some concern that the use of complete case analysis in the present study may lead to biased estimates.

Data Imputation

When there are cases with missing data, single imputation refers to replacing the missing data with one plausible value, and multiple imputation refers to the replacement of missing data with multiple plausible values.[149] Of these two variants of data imputation, multiple imputation is more common, and is particular advantageous in that standard errors and p-values are generally valid because the distribution of possible values incorporates some degree of uncertainty associated with missing values.[149] This is in contrast to single imputation which treats values for missing data as if they are known.[149]

In the analysis, multiple imputation was used to replace missing values in the data set. Although there are no universally-accepted guidelines concerning the number of imputations that should be performed, it was previously suggested that it is dependent on the proportion of missing data.[150] When the proportion of missing data is high, the loss of power resulting from performing fewer imputations is much higher than when the proportion of missing data is low.[150] A simulation study found that when only 10% of data are missing, the loss of power attributed to performing 3 imputations instead of 100 imputations was less than 4%, but the loss of power increased to 13% when 30% of data were missing.[150] Since less than 10% of data in the present study are missing, it was decided that 10 imputations would be sufficient. When only 10% of data are missing, it was found that performing 10 imputations resulted in only a 1.4% loss in power

compared to performing 100 imputations.[150] For each multilevel model, the relevant statistical model was fitted to each of the 10 imputed data sets, and the results were pooled using the PROC MIANALYZE procedure in SAS to obtain effect estimates that take into account the range of estimates from all 10 imputations. Frequency tables were produced for each imputation to verify that the imputed data are plausible in that all intervals were appropriate and that the imputed data fell between the minimum and maximum values for each variable.

Chapter 5

5 Results

This chapter begins with a description of the characteristics of the sample in terms of age, sex, household income, education level, weight status, urban-rural status, weight status, and physical activity status. Next, the trends in physical activity level and social cohesion by demographic characteristics are described. Finally, results from the multilevel analyses are presented. These results include findings pertaining to the variation in physical activity level across communities, the influence of both individual- and community-level social cohesion on physical activity, and differences in the influence of social cohesion on physical activity between normal weight and overweight respondents.

5.1 Descriptive Statistics

5.1.1 Sample Characteristics

After combining the 2009-2010, 2011-2012, and 2013-2014 cycles of the CCHS, the total sample included 252,697 respondents from 1,610 communities. After excluding respondents younger than 18 or older than 64 years of age, pregnant women, and respondents from the three territories because of reasons previously discussed, 245,231 respondents and 1,601 communities remained in the sample. After communities with fewer than 5 respondents were excluded, 245,150 respondents from 1,570 communities remained in the final sample used for the analyses. Descriptive statistics for the overall sample can be found in Tables 5.1, 5.2, 5.3, 5.4 and 5.5, and the same statistics stratified by CCHS cycle can be found in Appendix C.

Table 5.1. Characteristics of the sample

	Percentage (%)
Sex	
Male	49.9
Female	50.1
Age Group	
18 to 24	14.2
25 to 34	20.2
35 to 44	21.1
45 to 54	22.8
55 to 64	21.8
Social Cohesion	
Very Weak	9.0
Somewhat Weak	28.2
Somewhat Strong	47.9
Very Strong	14.9
Activity Status	
Active	27.7
Moderately Active	25.4
Inactive	49.9
Weight Status	
Normal weight or underweight	50.5
Overweight or obese	49.5
Education Attainment	
Grade 8 or lower	2.5
Grade 9 to 10	4.1
Grade 11 to 13	3.3
Secondary school	19.0
Some post-secondary	7.2
Trade certificate or diploma	11.2
College diploma or certificate	23.0
University below Bachelor's level	3.7
Bachelor's degree	17.9
Above Bachelor's degree	8.0
Urban-Rural Status	
Urban	82.5
Rural	17.4

5.1.2 Physical Activity Level

Overall, the mean value for daily EE was 2.256 kcal/kg/day (SD = 2.563) and the median was 1.600. According to the classification used in the CCHS, almost half of the sample (46.9%) was inactive (< 1.5 kcal/kg/day), while 25.5% was moderately active (1.5 ≤ kcal/kg/day < 3), and 27.7% was considered active (≥ 3 kcal/kg/day).

Table 5.2. Summary of physical activity level deciles

	Proportion (%)	Mean Daily EE
Decile 1	12.0	0.025 (0.049)
Decile 2	8.9	0.299 (0.087)
Decile 3	10.8	0.647 (0.121)
Decile 4	8.0	1.005 (0.092)
Decile 5	11.5	1.387 (0.155)
Decile 6	8.9	1.897 (0.153)
Decile 7	11.0	2.470 (0.218)
Decile 8	9.3	3.221 (0.242)
Decile 9	9.6	4.304 (0.457)
Decile 10	10.0	7.618 (2.900)

Abbreviations: EE (energy expenditure in kcal/kg/day); SD (standard deviation)

Males tended to be more physically active than females, with an average physical activity level of 5.572 compared to 5.288 for females. Compared to those who are overweight or obese, normal weight individuals tended to be more physically active, with an average physical activity level of 5.620 compared to 5.239 for the overweight and obese group. Urban-rural differences were also observed, as respondents residing in rural areas tended to be slightly more physically active than their counterparts from urban locations (mean level of 5.416 vs. 5.486). Physical activity level appeared to decline with age, with the youngest age group seeing a mean physical activity level of 6.221 that gradually receded to 5.180 in the oldest age group. Physical activity level increased with both household income and education level. Those in the lowest household income decile were the least physically active (mean level of 4.764), while those in the highest income decile were the most physically active (mean level of 6.300). Similarly, respondents in the group with the lowest level of formal education attainment (Grade 8 or below) were the least physically active (mean physical activity level of 4.090), while the most educated group (above Bachelor's degree) was the most physically active (mean level of 5.876). This trend in physical activity was also observed for social cohesion, with those reporting the weakest sense of belonging to the community being the least physically active (mean level of 4.707) and those reporting the strongest sense of belonging being the most physically active (mean level of 5.743).

Table 5.3. Trends in physical activity level

	Mean (SD)
Overall	5.430 (3.160)
By Sex	
Male	5.572 (3.358)
Female	5.288 (2.978)
By Age Group	
18 to 24	6.221 (3.510)
25 to 34	5.563 (3.360)
35 to 44	5.265 (3.329)
45 to 54	5.211 (3.279)
55 to 64	5.180 (2.588)
By Weight Status	
Normal Weight or Underweight	5.620 (3.286)
Overweight or obese	5.239 (3.033)
By Household Income	
Decile 1	4.746 (3.428)
Decile 2	4.874 (3.358)
Decile 3	4.869 (3.369)
Decile 4	5.172 (3.181)
Decile 5	5.306 (3.145)
Decile 6	5.421 (3.011)
Decile 7	5.602 (3.086)
Decile 8	5.722 (2.995)
Decile 9	5.966 (2.895)
Decile 10	6.300 (2.803)
By Education Attainment	
Grade 8 or lower	4.090 (2.814)
Grade 9 to 10	4.307 (2.866)
Grade 11 to 13	5.002 (3.116)
Secondary school	5.316 (3.110)
Some post-secondary	5.617 (3.353)
Trade certificate or diploma	5.141 (2.976)
College diploma or certificate	5.544 (3.076)
University below Bachelor's level	5.712 (3.221)
Bachelor's degree	5.785 (3.278)
Above Bachelor's degree	5.876 (3.307)
Urban-Rural Status	
Urban	5.416 (3.364)
Rural	5.486 (2.494)

Abbreviations: SD (standard deviation)

5.1.3 Social Cohesion

Overall, the mean score for individual-level social cohesion across the sample was 2.687 (SD = 0.903). Almost half of the sample (47.9%) rated their sense of belonging to the local community as “somewhat strong” (3), while 28.2% provided a rating of “somewhat weak” (2), 14.9% provided a rating of “very strong” (4), and 9.0% felt that their sense of belonging to the local community was “very weak” (1). The mean score for community-level social cohesion across FSAs was 2.740 (SD = 0.166).

On average, the reported level of social cohesion was greater among females than males, although the difference was very small (mean of 2.699 vs. 2.676). Similarly, self-rated social cohesion was higher in the overweight group than in the normal weight group, but the difference was minor (mean of 2.700 vs. 2.676). Urban-rural differences were also observed, as respondents residing in rural areas tended to report a stronger sense of belonging than their urban counterparts (mean of 2.759 vs. 2.672). Contrary to the direction of the trend in physical activity level, social cohesion tended to increase with age. Respondents in the youngest age group reported the lowest scores (mean of 2.612), while those in the oldest age group reported the highest scores (mean of 2.773). Social cohesion also tended to increase with physical activity level and household income. The mean score for social cohesion was the lowest in the least physically active group at 2.518, and gradually rose to 2.825 in the most active group. Respondents in the poorest household income decile reported the lowest scores (mean of 2.578) and those in the wealthiest decile reporting the highest scores (mean of 2.754) for social cohesion. When looking across levels of formal education, no consistent pattern was seen in social cohesion.

Table 5.4. Trends in social cohesion

	Mean (SD)
By Sex	
Male	2.676 (0.950)
Female	2.699 (0.865)
By Age Group	
18 to 24	2.612 (0.963)
25 to 34	2.583 (0.950)
35 to 44	2.711 (0.940)
45 to 54	2.725 (0.955)
55 to 64	2.773 (0.777)
By Weight Status	
Normal Weight or Underweight	2.676 (0.927)
Overweight or obese	2.700 (0.884)
By Household Income	
Decile 1	2.587 (1.027)
Decile 2	2.662 (1.003)
Decile 3	2.674 (0.965)
Decile 4	2.688 (0.923)
Decile 5	2.680 (0.908)
Decile 6	2.692 (0.868)
Decile 7	2.690 (0.881)
Decile 8	2.699 (0.848)
Decile 9	2.727 (0.826)
Decile 10	2.754 (0.820)
By Education Attainment	
Grade 8 or lower	2.778 (0.900)
Grade 9 to 10	2.672 (0.899)
Grade 11 to 13	2.612 (0.878)
Secondary school	2.685 (0.882)
Some post-secondary	2.622 (0.937)
Trade certificate or diploma	2.654 (0.874)
College diploma or certificate	2.668 (0.884)
University below Bachelor's level	2.734 (0.923)
Bachelor's degree	2.722 (0.942)
Above Bachelor's degree	2.759 (0.955)
Urban-Rural Status	
Urban	2.672 (0.960)
Rural	2.759 (0.726)

Abbreviations: SD (standard deviation)

Table 5.5. Trends in physical activity level vs. social cohesion

	Mean (SD)
Physical Activity Level by Social Cohesion	
Very Weak	4.707 (3.375)
Somewhat Weak	5.208 (3.265)
Somewhat Strong	5.621 (3.068)
Very Strong	5.743 (3.043)
Social Cohesion by Physical Activity Level	
Decile 1	2.518 (1.031)
Decile 2	2.612 (0.913)
Decile 3	2.626 (0.912)
Decile 4	2.680 (0.891)
Decile 5	2.688 (0.877)
Decile 6	2.711 (0.874
Decile 7	2.737 (0.871)
Decile 8	2.745 (0.869)
Decile 9	2.764 (0.852)
Decile 10	2.825 (0.881)

Abbreviations: SD (standard deviation)

5.2 Multilevel Analyses

5.2.1 Variance in Physical Activity Level

Results from the multilevel models are presented in Tables 5.6 and 5.7. In the unadjusted null model (Model 1), there was evidence of correlation among observations within FSAs, suggesting that there is variation in physical activity level across geographically-defined communities. The variance within communities was 9.477, and the variance between communities was statistically significant at 0.401. These values correspond to an ICC of 0.041, indicating that communities explained 4.1% of the total variance in physical activity level. In the first fully-adjusted model (Model 2), declines were seen for both between- and within-community variance in physical activity level. The variance between communities declined by 8.2% to 0.368, while the variance within communities saw a 6.1% decline to 8.901. These reductions in variance following the addition of social cohesion and accompanying covariates suggest that these variables were able to explain some of the variance in physical activity level from the null model.

5.2.2 Association Between Social Cohesion and Physical Activity

Model 2 controlled for age, sex, household income, education and urban-rural status, and found that both individual- and community-level social cohesion were significantly associated with physical activity. Social cohesion at the community level was found to have a greater effect on physical activity than social cohesion at the individual level. Each unit increase in the score for social cohesion at the individual level was estimated to increase physical activity level by 0.357 deciles, while each unit increase in the score for social cohesion at the community level was estimated to increase physical activity level by 0.784 deciles. The intercept of the model was 3.310, indicating that the expected physical activity level of an individual at the mean for all predictor variables in his or her FSA is 3.310 plus the effect of community-level social cohesion. If the individual resides in a FSA with an average score for community-level social cohesion, his or her level of physical activity is estimated to be 5.46.

Model 3 included two interaction terms to test for potential interaction effects between social cohesion and weight status. A significant interaction was observed between community-level social cohesion and weight status ($p<0.001$), while the interaction term between individual-level social cohesion and weight status was found to be insignificant ($p=0.108$). Unsurprisingly, when comparing normal weight to overweight respondents, the effect of community-level social cohesion was found to be 81% stronger, while the effect of individual-level social cohesion was found to be approximately equal with a difference of less than 2%. Thus, there is evidence that weight status moderates the relationship between community-level social cohesion and physical activity, suggesting that the association between social cohesion at the community level and physical activity differs between normal weight and overweight respondents. This finding warrants the stratification of models by weight status.

Table 5.6. Results from the multilevel models – Overall sample

	Model 1	Model 2	Model 3
Variance Component			
Between community	**0.401**	**0.368**	**0.368**
Within community	**9.477**	**8.901**	**8.874**
ICC	**0.041**	**0.040**	**0.040**
Intercept	5.484	3.310	3.310
β Coefficients (95% CI)			
I_Cohesion		**0.357 (0.331, 0.382)**	**0.357 (0.331, 0.382)**
C_Cohesion		**0.784 (0.589, 0.978)**	**0.784 (0.590, 0.979)**
Age		**-0.028 (-0.028, -0.027)**	**-0.025 (-0.026, -0.025)**
Sex		**-0.252 (-0.274, -0.230)**	**-0.310 (-0.333, -0.288)**
Income		**0.125 (0.120, 0.130)**	**0.126 (0.122, 0.131)**
Education		**0.087 (0.082, 0.093)**	**0.086 (0.080, 0.091)**
Urban-Rural Status		-0.041 (-0.089, 0.007)	-0.045 (-0.093, 0.003)
Weight Status			**0.789 (0.406, 1.173)**
Weight Status*I_Cohesion			-0.023 (-0.051, 0.05)
Weight Status*C_Cohesion			**-0.410 (-0.552, -0.267)**

Notes: (1) Variance components and β coefficients significant at a p-value of 5% are bolded
Models: (1) Null model without independent variables; (2) Fully-adjusted model without interaction terms; (3) Fully-adjusted model with interaction terms
Abbreviations: ICC (intraclass correlation coefficient); CI (confidence interval) I_Cohesion (individual-level social cohesion); C_Cohesion (community-level social cohesion)

5.2.3 The Influence of Weight Status

Normal weight

Model 4 was limited to only normal weight individuals and included 116,215 respondents from 1,569 communities. After controlling for age, sex, household income, education and urban-rural status, social cohesion at both the individual level and community level were significantly associated with physical activity level in a positive manner. Community-level social cohesion was found to have a stronger positive effect on physical activity level, with each unit increase in its score estimated to increase physical activity level by 1.112 deciles. Comparatively, each unit increase in individual-level social cohesion was estimated to result in a 0.359 decile increase in physical activity level. The intercept of the model was 2.615, indicating that the expected physical activity level of an individual at the mean for all predictor variables in his or her FSA will be 2.615 plus the effect of community-level social cohesion. If the individual resides in a FSA with an average score for community-level cohesion, his or her level of physical activity is estimated to be 5.66.

Overweight

Model 5 was limited to only overweight individuals and included 128,935 respondents from 1,568 communities. After controlling for age, sex, household income, education and urban-rural status, social cohesion at both the individual level and community level were found to be significantly associated with physical activity level in a positive manner. Community-level social cohesion was found to have a stronger positive effect on physical activity level, with each unit increase in its score estimated to increase physical activity level be 0.613 deciles. Comparatively, each unit increase in social cohesion at the individual level was estimated to result in a 0.353 decile increase in physical activity level. The intercept of the model was 3.310, indicating that the expected physical activity level of an individual at the mean for all predictor variables in his or her FSA will be 3.604 plus the effect of community-level social cohesion. If the individual resides in a FSA with an average score for community-level cohesion, his or her level of physical activity is estimated to be 5.28.

Table 5.7. Results from the multilevel models – Stratified by weight status

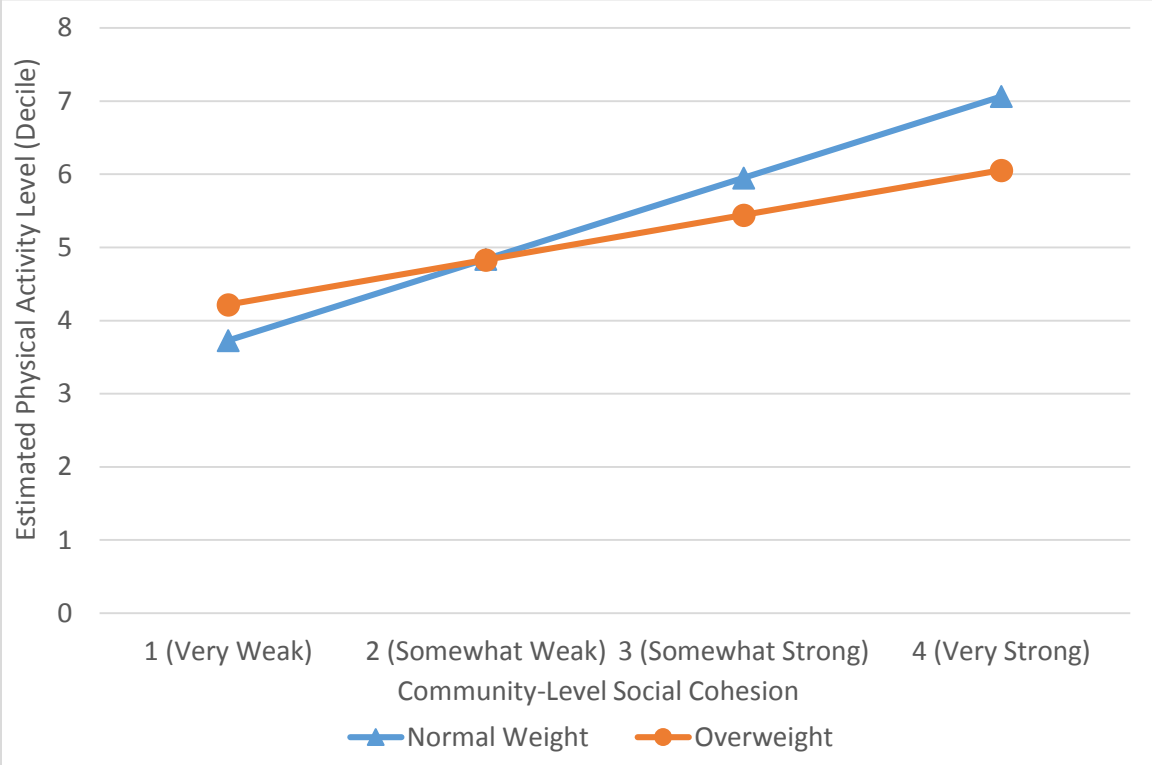
	Model 4	Model 5
Intercept	2.615	3.604
β Coefficients (95% CI)		
I_Cohesion	**0.359 (0.324, 0.394)**	**0.353 (0.319, 0.388)**
C_Cohesion	**1.112 (0.876, 1.347)**	**0.613 (0.393, 0.834)**
Age	**-0.021 (-0.023, -0.020)**	**-0.030 (-0.032, -0.029)**
Sex	**-0.210 (-0.244, -0.177)**	**-0.412 (-0.443, -0.381)**
Income	**0.130 (0.123, 0.136)**	**0.122 (0.115, 0.129)**
Education	**0.071 (0.062, 0.079)**	**0.097 (0.089, 0.105)**
Urban-Rural Status	**-0.097 (-0.172, -0.022)**	-0.009 (-0.071, 0.053)

Notes: (1) Variance components and β coefficients significant at a p-value of 5% are bolded
Models: (4) Fully-adjusted model with normal weight respondents only; (5) Fully-adjusted model with overweight respondents only
Abbreviations: CI (confidence interval) I_Cohesion (individual-level social cohesion); C_Cohesion (community-level social cohesion)

Weight Status as an Effect Modifier

The effect of weight status on the association between community-level social cohesion and physical activity is visually represented using a specific example in Figure 5.1.

Estimates are presented for two individuals who are at the mean for all predictor variables in their FSA. One line illustrates estimates for a normal weight individual, while the other line illustrates estimates for an overweight counterpart. As seen in Figure 5.1, community-level social cohesion is a much more influential predictor of physical activity in the normal weight individual. In an extreme case where everyone in the community rates their sense of belonging as "very weak", the normal weight individual is expected to be less physically active than the overweight counterpart. This gap narrows until community-level social cohesion reaches a value of 2, where the normal weight and overweight individuals are expected to be approximately equal with respect to physical activity level. When the value for community-level social cohesion is higher than 2, the normal weight individual is always expected to be more physically active, and the gap gradually widens with additional increases in community-level social cohesion.



Notes: Estimates based on a hypothetical scenario where two individuals (one normal weight and one overweight) are at the mean for all predictor variables in their Forward Sortation Area

Figure 5.1. Estimated effect of community level social cohesion on physical activity – By weight status

5.2.4 Results from the Sensitivity Analysis

Results from the sensitivity analysis with social cohesion treated as a binary variable can be found in Appendix D. With exception to an additional significant interaction, all findings remained unchanged when social cohesion was treated as a binary variable instead of a continuous one. The previously insignificant interaction between community level social cohesion and weight status became significant (from $p=0.108$ to $p=0.028$). Although this may seem to suggest a potential significant difference in the effect of individual-level social cohesion on physical activity between normal weight and overweight respondents, the difference in the magnitude of effect was very small (5% with social cohesion treated as binary and less than 2% with social cohesion treated as continuous). In contrast, the interaction between community level social cohesion and weight status was highly significant regardless of whether social cohesion was treated as a continuous or binary variable ($p<0.001$ for both), and the difference in the magnitude of effect was over 80% in both scenarios.

Chapter 6

6 Discussion

The primary goal of this study was to assess the association between social cohesion and physical activity. Contrary to previous studies that investigated social cohesion as a multilevel influence, the present study operationalized social cohesion as a respondent's sense of belonging to the local community instead of his or her perceived level of cohesion in the community. The study also investigated the potential role of weight status as an effect modifier in the association between social cohesion and physical activity.

6.1 Overview of Findings

Objective 1 – Variance in Physical Activity Level

Hypothesis 1 is supported by the significant variance in physical activity level between communities. This indicates that physical activity data from respondents within communities tend to be correlated, meaning that residents within a community tend to be more similar to persons from the same community than to those from other communities with regards to physical activity behaviour. It also suggests that there are significant differences in physical activity level across geographically-defined communities in Canada.

Objective 2 – The Association Between Social Cohesion and Physical Activity

Hypothesis 2 is supported by the significant positive association between physical activity and social cohesion at both the individual and community levels. These findings suggest that social cohesion at each level may be an independent contributor to the promotion of physical activity. Implicitly, one tends to be more physically active when he or she either has a strong sense of belonging to the community or resides in a community where a large proportion of residents report high scores for sense of belonging.

Objective 3 – Weight Status as an Effect Modifier

Hypothesis 3 is partially supported, as results from the multilevel model with interaction terms indicate a significant interaction effect between weight status and community-level

social cohesion, but not between weight status and individual-level social cohesion. This suggests that the association between physical activity and community-level social cohesion differs between normal weight and overweight respondents. Compared to overweight respondents, normal weight respondents saw a positive effect of community-level social cohesion that was much greater in magnitude. However, the effects of both individual- and community-level social cohesion were still significant among overweight respondents, suggesting that despite differences in the magnitude of effect, both measures of social cohesion may promote physical activity regardless of weight status.

6.1.1 Influence of Individual-Level Social Cohesion

The observation of a significant positive association between an individual's extent of cohesion in the local community and physical activity supports findings from previous research that suggested a higher level of social cohesion assessed at the individual level was associated with either an increased odds of engaging in physical activity or a decreased odds of being physically inactive.[15, 22, 24] The results suggest that individuals who report having a stronger sense of belonging to the community tend to be more physically active than those who report having a weaker sense of belonging. These implications are plausible considering that previous research found factors such as social participation, connectedness to the community, and trust of neighbours to be beneficial for physical activity.[15, 22, 24] It may be that these indicators of individual level cohesion are all linked, since those who are engaged in their community may also be more likely to trust their neighbours and feel that they belong to the community.

Several studies operationalized individual-level social cohesion as an individual's perception of social cohesion in his or her neighbourhood, and found it to be significantly associated with a greater odds of engaging in physical activity, being physically active, or engaging in more physical activity.[11, 14, 17, 18, 20, 23] These results are important because they suggest that regardless of the actual level of social cohesion in the neighbourhood, residents are more likely to be active simply because they perceive their neighbourhood to be socially cohesive.

6.1.2 Influence of Community-Level Social Cohesion

Results from the present study indicating a significant positive association between social cohesion at the community level and physical activity are consistent with findings from previous studies that reported such a relationship.[10, 21] These results are also supported by previous research suggesting that a higher level of neighbourhood social cohesion is associated with either a significantly increased odds of being physically active or a significantly decreased odds of being physically inactive.[6, 9, 12, 13]

There are theories that potentially explain why social cohesion at the community level may have a positive influence on physical activity. Social cohesion at the community level predominantly refers to the absence of social conflict and the presence of strong social bonds among residents.[29] A reduced level of social conflict is important because it contributes to a lower prevalence of crime, a neighbourhood characteristic consistently associated with greater engagement in physical activity.[26, 27] The strong social bonds aspect of neighbourhood cohesion is also key, because it may contribute to residents organizing community activities that present opportunities for engagement in physical activity.[28]

6.1.3 Social Cohesion as a Multilevel Influence

The present study is the first to investigate social cohesion at both the individual and community level where social cohesion refers to an individual's own contribution to social cohesion in the local community through his or her feelings of belongingness. Three previous studies investigated social cohesion as both an individual- and group-level effect, but defined social cohesion as an individual's perception of social cohesion in his or her neighbourhood. After all adjustments, two of these studies found that only social cohesion at the individual level had a positive influence on physical activity.[11, 17] The third study found that neither measure of social cohesion significantly associated with physical activity.[19] The current findings suggesting that both individual- and community-level cohesion are significantly associated with physical activity after controlling for the effects of one another indicates that both an individual's sense of cohesion in to the local community and the overall level of cohesion in the community

may promote engagement in physical activity. A possible explanation for this is that while a higher level of community-level cohesion may result in greater opportunities to engage in physical activity, having a strong sense of belonging to the community provides additional benefits because it increases the likelihood that an individual will take advantage of these opportunities.

6.1.4 Weight Status as an Effect Modifier

The findings pertaining to the influence of weight status represent a novel contribution to the literature because there are no known studies to date that have investigated the potential effect of weight status on the relationship between social cohesion and physical activity. It was interesting to see that community-level social cohesion was a much stronger predictor of physical activity among normal weight respondents in comparison to their overweight counterparts. This implies that while feeling connected to the local community benefits normal weight and overweight adults equally, normal weight respondents see greater benefits from residing in a socially cohesive community. This disparity may be partially explained by the tendency for overweight individuals to face unique psychological barriers to physical activity including those related to body image, self-esteem, shyness, and embarrassment.[63, 64] These deterrents could reduce the likelihood that overweight individuals will take advantage of opportunities to partake in physical activity in the community, mitigating the effect of community-level social cohesion on physical activity. That said, it was promising to see that both an individual's level of social cohesion in the community as well as the overall level of cohesion in the community still had a significant positive influence on physical activity in the overweight group, suggesting that overweight adults could still benefit from feeling that they belong to the local community or residing in a socially cohesive community.

6.2 Implications of Findings for Health Promotion

The numerous health benefits associated with engagement in physical activity and the vast array of adverse health outcomes associated with physical inactivity have been well-documented.[2, 3] In Canada, physical activity represents a public health concern because less than 1 in 6 adults meet physical activity guidelines for optimal health.[3] As a result, it

is clear that increasing engagement in physical activity could lead to improved health outcomes at the population level. Furthermore, even minor increases in physical activity are of interest, as increases in physical activity have been found to improve health outcomes in population-based studies regardless of whether or not guidelines are met.[35, 54]

The current findings have several implications for health promotion. They indicate that promoting social cohesion at both the individual and community levels may also promote engagement in physical activity. In communities where a smaller proportion of residents feel that they belong, physical activity among residents could potentially be increased by promoting social engagement and participation among community members. For example, it may be particularly beneficial for policy makers to target ethnically heterogeneous neighbourhoods, where levels of trust and social contact between neighbours tend to be lower.[151] In communities where the overall level of social cohesion is already high, further benefits for physical activity may be achieved by encouraging integration into the community among residents who do not already feel that they belong. Moreover, the potential benefits of increasing social cohesion have been suggested to extend beyond increasing engagement in physical activity in socially disadvantaged neighbourhoods, where social cohesion and civic participation have been found to be positively associated with self-reported health even after controlling for neighbourhood deprivation.[105]

Notably, there should be consideration for the observation that in the context of physical activity behaviour, normal weight adults tend to see greater benefits from increases in social cohesion than overweight adults. In light of this finding, efforts should be made to ensure that interventions promoting social cohesion reach all residents, especially those who are overweight. If social cohesion interventions are only benefiting normal weight individuals, existing disparities in physical activity behaviour and related health outcomes between normal weight and overweight individuals could widen.

Since physical activity interventions aiming to build on social cohesion are often inexpensive, there may be leftover funds for additional health promotion initiatives.[101] It

has been suggested that social cohesion interventions may result in even greater benefits when combined with other efforts to facilitate physical activity. One such example is increasing social cohesion while simultaneously increasing the walkability of the physical environment. Previous research found that residents from neighbourhoods with a high level of walkability and social connectedness engaged in significantly more physical activity than residents of neighbourhoods with only either a high level of walkability or a high level of social connectedness.[14] Furthermore, community integration has been associated with the ability to recall disseminated health promotion messages, and thus the promotion of social cohesion could potentially increase the efficacy of unrelated public health initiatives implemented in the future.[104]

6.3 Strengths

6.3.1 Size and Representativeness of the Sample

A prominent strength of this study is the size and representativeness of the sample. With over 200,000 respondents from more than 1500 communities, the sample is larger than that of any other known study investigating the association between social cohesion and physical activity. Moreover, the use of a national population-based survey in the form of the CCHS contributed to ensuring the study sample would be representative of the population from which the sample was drawn. The CCHS sampling frame included over 98% of the Canadian population 12 years of age or older, and thus the CCHS data can provide estimates that are representative of the entire Canadian adult population. Additionally, the CCHS used sampling weights to adjust for response rates and to ensure that the sample of respondents accurately reflects the overall population in Canada.

6.3.2 Definition of Social Cohesion

The definition of social cohesion distinguishes the present study from previous studies that investigated social cohesion as a multilevel influence on physical activity. Previous studies defined social cohesion as the respondent's perception of cohesion in the local neighbourhood. These studies provided a passive measure of social cohesion because the extent to which the respondent is socially integrated into the neighbourhood was not

assessed. At the group level, a socially cohesive community would be defined as one in which a large proportion of residents perceive the overall level of cohesion to be high. This is potentially problematic, as it would be difficult to identify outliers such as an individual who resides in a cohesive community but feels socially excluded, or an individual representing one of only a few residents who are socially integrated in an overall non-cohesive community. The individual who feels excluded from the cohesive community may still perceive the overall level of cohesion to be high, and the individual who is highly engaged in a non-cohesive community may acknowledge that the overall level of cohesion is low.

The present study defined social cohesion as a respondent's sense of belonging in his or her community. This is a strength because it represents a more active measure of social cohesion in that it provides insight into the social integration of specific respondents. At the group level, a socially cohesive community would be defined as one in which a large proportion of residents actually feel that they belong. As a result, the aforementioned outliers can be identified through low individual scores for sense of belonging in communities with a high mean score, or high individual scores for sense of belonging in communities with a low mean score.

6.3.3 Operationalization of Physical Activity

The current study differs from most previous studies in that physical activity was operationalized as a continuous outcome. In prior research, physical activity was predominantly operationalized as a binary outcome by either applying cut-off points to classify individuals as active or inactive, or by reporting engagement in physical activity as a "yes or no" outcome. To minimize the loss of variation in physical activity data associated with such dichotomization, physical activity was analyzed as a continuous variable. Furthermore, the aforementioned benefits of minor increases in physical activity suggest that even in cases where two individuals are both categorized as being "inactive", the slightly more active one is likely to be see better health outcomes than his or her less active counterpart. Thus, there is interest in distinguishing between respondents who are

truly inactive, and those who are slightly more active but would still be classified as being inactive by physical activity guidelines.

6.4 Limitations

6.4.1 Crude Measure of Social Cohesion

A noteworthy limitation of this study is the use of a crude measure of social cohesion that included only a single question asking respondents to rate their feeling of belongingness to the local community. This is in contrast to some previous studies that included scales with multiple questions to gain insight into indicators of social cohesion beyond just one's sense of belonging. Despite the limitation, many of the other aspects of social cohesion that were assessed in previous studies (e.g., social participation, social bonds within communities, trust of neighbours, sharing of values) can be reasonably thought to be related to sense of belonging.

6.4.2 Self-Reported Physical Activity Data

The self-reported nature of the data used to inform physical activity level implicates the introduction of bias and measurement error. However, the survey items pertaining to engagement in physical activity took into consideration the frequency, intensity, and duration of all leisure physical activities. Further, the use of self-reported physical activity data allows for the inclusion of a much larger sample than would be possible had objective measures (i.e., the use of accelerometers or other motion sensors) of physical activity been used.

6.4.3 Generalizability to Specific Population Subgroups

Although one of the strengths of this study was the use of a large, representative population of adults from across Canada, the exclusion of specific population subgroups from the analysis limits the generalizability of findings to particular populations. These subgroups included children and youth, older adults, pregnant women, and residents of Yukon, the Northwest Territories and Nunavut.

6.4.4 Temporality

Due to the cross-sectional nature of this study, conclusions cannot be drawn with regards to the direction of the relationship between physical activity level and social cohesion. Although this study could establish the existence of an association between physical activity level and social cohesion, it remains unclear as to whether physical activity tends to increase as a result of improvements in social cohesion, or whether social cohesion tends to increase as a result of increased engagement in physical activity. The former is plausible for reasons previously discussed, but the latter is also possible considering that engagement in physical activity may present opportunities to meet and socialize with others in the community.

6.5 Future Directions

Some key areas for future research have been identified. Qualitative research aiming to gain insight into the reasons why social cohesion may or may not be beneficial for promoting physical activity would be of interest. Further investigation into the pathways by which social cohesion may affect engagement in physical activity would be beneficial for public health initiatives aiming to increase physical activity. Also, it would be interesting for future research to investigate ethnicity as a potential effect modifier in the association between social cohesion and physical activity. Although ethnicity was hypothesized to be an effect modifier in the present study, the investigation of the potential effect of ethnicity on the relationship between social cohesion and physical activity was not an objective of this study. If significant differences in the association between social cohesion and physical activity are observed across ethnicities, there could be implications for the targeted promotion of social cohesion and physical activity. Finally, it is recommended that future research address the limitations of the current study by using a more comprehensive measure of social cohesion while also employing a longitudinal study design to gain insight into the direction of the association between social cohesion and physical activity.

6.6 Conclusions

The present study proposed that social cohesion should be assessed as a multilevel influence because it is possible for an individual to reside in a community with a high level of social cohesion without feeling socially included in the community, and vice-versa. Physical activity level was found to vary across geographically-defined communities throughout Canada. Results from the analysis suggest that both an individual's sense of cohesion in the local community and the contextual effect of the overall level of social cohesion in that community are positively associated with physical activity. Weight status was found to modify the association between community-level social cohesion and physical activity. Although the association between community-level social cohesion and physical activity was of a greater magnitude among normal weight adults, the effect was still significant in overweight adults. Future research should aim to address the limitations of the present study by using a more comprehensive measure of social cohesion and employing a longitudinal study design to gain insight into the direction of the relationship between social cohesion and physical activity.

References

1. World Health Organization. *Global Strategy on Diet, Physical Activity and Health – Physical Activity* (2015). Retrieved from http://www.who.int/dietphysicalactivity/pa/en/. Accessed December 2015.

2. World Health Organization. *Global recommendations on physical activity for health* (2010). Switzerland: WHO Press. Retrieved from http://www.ncbi.nlm.nih.gov/books/NBK305057/. Accessed December 2015.

3. Centers for Disease Control and Prevention. *Physical Activity and Health* (2014). Retreived from. https://www.cdc.gov/physicalactivity/basics/pa-health/. Accessed December 2015.

4. Colley RC, Garriguet D, Janssen I, Craig CL, Clarke J, Tremblay MS. Physical activity of Canadian adults: accelerometer results from the 2007 to 2009 Canadian Health Measures Survey. *Health Rep* 2011;22(1):7-14.

5. Spence JC, Lee RE. Toward a comprehensive model of physical activity. *Psychol Sport Exerc* 2003;4(1):7-24.

6. Andrade AC, Peixoto SV, Friche AA, Goston JL, Cesar CC, Xavier CC, et al. Social context of neighborhood and socioeconomic status on leisure-time physical activity in a Brazilian urban center: The BH Health Study. *Cad Saude Publica* 2015;31(Suppl 1):136-47.

7. Ball K, Cleland VJ, Timperio AF, Salmon J, Giles-Corti B, Crawford DA. Love thy neighbour? Associations of social capital and crime with physical activity amongst women. *Soc Sci Med* 2010;71(4):807-14.

8. Cleland V, Ball K, Hume C, Timperio A, King AC, Crawford D. Individual, social and environmental correlates of physical activity among women living in socioeconomically disadvantaged neighbourhoods. *Soc Sci Med* 2010;70(12):2011-8.

9. Cradock AL, Kawachi I, Colditz GA, Gortmaker SL, Buka SL. Neighborhood social cohesion and youth participation in physical activity in Chicago. *Soc Sci Med* 2009;68(3):427-35.

10. Fisher KJ, Li F, Michael Y, Cleveland M. Neighborhood-level influences on physical activity among older adults: a multilevel analysis. *J Aging Phys Act* 2004;12(1):45-63.

11. Gao J, Fu H, Li J, Jia Y. Association between social and built environments and leisure-time physical activity among Chinese older adults--a multilevel analysis. *BMC Public Health* 2015;15:1317.

12. Jongeneel-Grimen B, Droomers M, van Oers HA, Stronks K, Kunst AE. The relationship between physical activity and the living environment: a multi-level analyses focusing on changes over time in environmental factors. *Health Place* 2014;26:149-60.

13. King D. Neighborhood and individual factors in activity in older adults: results from the neighborhood and senior health study. *J Aging Phys Act* 2008;16(2):144-70.

14. Kaczynski AT, Glover TD. Talking the talk, walking the walk: examining the effect of neighbourhood walkability and social connectedness on physical activity. *J Public Health (Oxf)* 2012;34(3):382-9.

15. Legh-Jones H, Moore S. Network social capital, social participation, and physical inactivity in an urban adult population. *Soc Sci Med* 2012;74(9):1362-7.

16. Mackenbach JD, Lakerveld J, van Lenthe FJ, Kawachi I, McKee M, Rutter H, et al. Neighbourhood social capital: measurement issues and associations with health outcomes. *Obes Rev* 2016;17(Suppl 1):96-107.

17. Mendes de Leon CF, Cagney KA, Bienias JL, Barnes LL, Skarupski KA, Scherr PA, et al. Neighborhood social cohesion and disorder in relation to walking in community-dwelling older adults: a multilevel analysis. *J Aging Health* 2009;21(1):155-71.

18. Pabayo R, Belsky J, Gauvin L, Curtis S. Do area characteristics predict change in moderate-to-vigorous physical activity from ages 11 to 15 years? *Soc Sci Med* 2011;72(3):430-8.

19. Pabayo R, Molnar BE, Cradock A, Kawachi I. The relationship between neighborhood socioeconomic characteristics and physical inactivity among adolescents living in Boston, Massachusetts. *Am J Public Health* 2014;104(11):e142-9.

20. Strong LL, Reitzel LR, Wetter DW, McNeill LH. Associations of perceived neighborhood physical and social environments with physical activity and television viewing in African-American men and women. *Am J Health Promot* 2013;27(6):401-9.

21. Utter J, Denny S, Robinson E, Ameratunga S, Milfont TL. Social and physical contexts of schools and neighborhoods: associations with physical activity among young people in New Zealand. *Am J Public Health* 2011;101(9):1690-5.

22. Ueshima K, Fujiwara T, Takao S, Suzuki E, Iwase T, Doi H, et al. Does social capital promote physical activity? A population-based study in Japan. *PloS One* 2010;5(8):e12135.

23. Wen M, Kandula NR, Lauderdale DS. Walking for transportation or leisure: what difference does the neighborhood make? *J Gen Intern Med* 2007;22(12):1674-80.

24. Yang F, Tan KA, Cheng WJ. The effects of connectedness on health-promoting and health-compromising behaviors in adolescents: evidence from a statewide survey. *J Prim Prev* 2014;35(1):33-46.

25. Martinez SM, Arredondo EM, Roesch S. Physical activity promotion among churchgoing Latinas in San Diego, California: does neighborhood cohesion matter? *J Health Psychol* 2013;18(10):1319-29.

26. Sampson RJ, Raudenbush SW, Earls F. Neighborhoods and violent crime: a multilevel study of collective efficacy. *Science* 1997;277(5328):918-24.

27. Ferreira I, van der Horst K, Wendel-Vos W, Kremers S, van Lenthe FJ, Brug J. Environmental correlates of physical activity in youth - a review and update. *Obes Rev* 2007;8(2):129-54.

28. Cohen DA, Finch BK, Bower A, Sastry N. Collective efficacy and obesity: the potential influence of social factors on health. *Soc Sci Med* 2006;62(3):769-78.

29. Berkman LF, Kawachi I. *Social Epidemiology* (2000). New York: Oxford University Press.

30. Coulon SM, Wilson DK, Griffin S, St George SM, Alia KA, Trumpeter NN, et al. Formative process evaluation for implementing a social marketing intervention to increase walking among African Americans in the Positive Action for Today's Health trial. *Am J Public Health* 2012;102(12):2315-21.

31. Roux L, Pratt M, Tengs TO, Yore MM, Yanagawa TL, Van Den Bos J, et al. Cost effectiveness of community-based physical activity interventions. *Am J Prev Med* 2008;35(6):578-88.

32. Beenackers MA, Kamphuis CB, Giskes K, Brug J, Kunst AE, Burdorf A, et al. Socioeconomic inequalities in occupational, leisure-time, and transport related physical activity among European adults: a systematic review. *Int J Behav Nutr Phys Act* 2012;9:116.

33. Oxford Dictionaries. *Leisure* (2016). Retreived from http://www.oxforddictionaries.com/definition/english/leisure. Accessed December 2015.

34. Lahti J, Sabia S, Singh-Manoux A, Kivimaki M, Tatsuse T, Yamada M, et al. Leisure time physical activity and subsequent physical and mental health functioning among midlife Finnish, British and Japanese employees: a follow-up study in three occupational cohorts. *BMJ Open* 2016;6(1):e009788.

35. Arem H, Moore SC, Patel A, Hartge P, Berrington de Gonzalez A, Visvanathan K, et al. Leisure time physical activity and mortality: a detailed pooled analysis of the dose-response relationship. *JAMA Internal Medicine* 2015;175(6):959-67.

36. Sofi F, Capalbo A, Marcucci R, Gori AM, Fedi S, Macchi C, et al. Leisure time but not occupational physical activity significantly affects cardiovascular risk factors in an adult population. *Eur J Clin Invest* 2007;37(12):947-53.

37. Probert AW, Tremblay MS, Connor Gorber S. Desk potatoes: the importance of occupational physical activity on health. *Can J Public Health* 2008;99(4):311-8.

38. Holtermann A, Hansen JV, Burr H, Sogaard K, Sjogaard G. The health paradox of occupational and leisure-time physical activity. *Br J Sports Med* 2012;46(4):291-5.

39. Clays E, De Bacquer D, Van Herck K, De Backer G, Kittel F, Holtermann A. Occupational and leisure time physical activity in contrasting relation to ambulatory blood pressure. *BMC Public Health* 2012;12:1002.

40. Holtermann A, Marott JL, Gyntelberg F, Sogaard K, Suadicani P, Mortensen OS, et al. Occupational and leisure time physical activity: risk of all-cause mortality and myocardial infarction in the Copenhagen City Heart Study. A prospective cohort study. *BMJ Open* 2012;2(1):e000556.

41. Mueller N, Rojas-Rueda D, Cole-Hunter T, de Nazelle A, Dons E, Gerike R, et al. Health impact assessment of active transportation: A systematic review. *Prev Med* 2015;76:103-14.

42. Lachapelle U, Frank LD, Sallis JF, Saelens BE, Conway TL. Active Transportation by Transit-Dependent and Choice Riders and Potential Displacement of Leisure Physical Activity. *J Plann Educ* 2015; in press. Retrieved from http://jpe.sagepub.com/content/early/2015/11/16/0739456X15616253. Accessed December 2015.

43. Centers for Disease Control and Prevention. *Measuring Physical Activity Intensity* (2015). Retrieved from http://www.cdc.gov/physicalactivity/basics/measuring/. Accessed December 2015.

44. Harvard T. H. Chan School of Public Health. *Examples of Moderate and Vigorous Physical Activity* (2016). Retrieved from https://www.hsph.harvard.edu/obesity-prevention-source/moderate-and-vigorous-physical-activity/. Accessed January 2016.

45. Centers for Disease Control and Prevention. *Glossary of Terms* (2015). Retrieved from http://www.cdc.gov/physicalactivity/basics/glossary/index.htm. Accessed December 2015.

46. Lee IM, Paffenbarger RS, Jr. Associations of light, moderate, and vigorous intensity physical activity with longevity. The Harvard Alumni Health Study. *Am J Epidemiol* 2000;151(3):293-9.

47. World Health Organization. *Physical Activity and Adults* (2016). Retrieved from http://www.who.int/dietphysicalactivity/factsheet_adults/en/. Accessed January 2016

48. Centers for Disease Control and Prevention. *How much physical activity do adults need?* (2015). Retrieved from http://www.cdc.gov/physicalactivity/basics/adults/. Accessed December 2015.

49. Canadian Society for Exercise Physiology. Read the Guidelines (n.d.). Retrieved from http://www.csep.ca/en/guidelines/read-the-guidelines. Accessed December 2015.

50. Warburton DE, Nicol CW, Bredin SS. Health benefits of physical activity: the evidence. *CMAJ* 2006;174(6):801-9.

51. Janssen I. Health care costs of physical inactivity in Canadian adults. *Appl Physiol Nutr Metab* 2012;37(4):803-6.

52. Kruk J. Physical activity in the prevention of the most frequent chronic diseases: an analysis of the recent evidence. *Asian Pac J Cancer Prev* 2007;8(3):325-38.

53. Statistics Canada. *The 10 leading causes of death, 2011* (2014). Retrieved from http://www.statcan.gc.ca/pub/82-625-x/2014001/article/11896-eng.htm. Accessed December 2015.

54. Wen CP, Wai JP, Tsai MK, Yang YC, Cheng TY, Lee MC, et al. Minimum amount of physical activity for reduced mortality and extended life expectancy: a prospective cohort study. *Lancet* 2011;378(9798):1244-53.

55. Fleshner M. Physical activity and stress resistance: sympathetic nervous system adaptations prevent stress-induced immunosuppression. *Exerc Sport Sci Rev* 2005;33(3):120-6.

56. Hamer M. Psychosocial stress and cardiovascular disease risk: the role of physical activity. *Psychosom Med* 2012;74(9):896-903.

57. Dimsdale JE. Psychological Stress and Cardiovascular Disease. *J Am Coll Cardiol* 2008;51(13):1237-46.

58. Wijndaele K, Matton L, Duvigneaud N, Lefevre J, De Bourdeaudhuij I, Duquet W, et al. Association between leisure time physical activity and stress, social support and coping: A cluster-analytical approach. *Psychol Sport Exerc* 2007;8(4):425-40.

59. Twells LK, Gregory DM, Reddigan J, Midodzi WK. Current and predicted prevalence of obesity in Canada: a trend analysis. *CMAJ Open* 2014;2(1):E18-26.

60. Guh DP, Zhang W, Bansback N, Amarsi Z, Birmingham CL, Anis AH. The incidence of co-morbidities related to obesity and overweight: a systematic review and meta-analysis. *BMC Public Health* 2009;9:88.

61. Whitney EA, Rolfes SR, Hammond G, Piché L. *Understanding Nutrition (1st Canadian ed.)* (2013). Toronto: Nelson.

62. Craigie AM, Lake AA, Kelly SA, Adamson AJ, Mathers JC. Tracking of obesity-related behaviours from childhood to adulthood: A systematic review. *Maturitas* 2011;70(3):266-84.

63. Ball K, Crawford D, Owen N. Too fat to exercise? Obesity as a barrier to physical activity. *Aust N Z J Public Health* 2000;24(3):331-3.

64. Chang MW, Nitzke S, Guilford E, Adair CH, Hazard DL. Motivators and barriers to healthful eating and physical activity among low-income overweight and obese mothers. *J Am Diet Assoc* 2008;108(6):1023-8.

65. Lee IM, Shiroma EJ, Lobelo F, Puska P, Blair SN, Katzmarzyk PT. Effect of physical inactivity on major non-communicable diseases worldwide: an analysis of burden of disease and life expectancy. *Lancet* 2012;380(9838):219-29.

66. Meng X, D'Arcy C. The projected effect of increasing physical activity on reducing the prevalence of common mental disorders among Canadian men and women: a national population-based community study. *Prev Med* 2013;56(1):59-63.

67. Sedentary Behaviour Research N. Letter to the editor: standardized use of the terms "sedentary" and "sedentary behaviours". *Appl Physiol Nutr Metab* 2012;37(3):540-2.

68. Mansoubi M, Pearson N, Clemes SA, Biddle SJ, Bodicoat DH, Tolfrey K, et al. Energy expenditure during common sitting and standing tasks: examining the 1.5 MET definition of sedentary behaviour. *BMC Public Health* 2015;15:516.

69. Wilmot EG, Edwardson CL, Achana FA, Davies MJ, Gorely T, Gray LJ, et al. Sedentary time in adults and the association with diabetes, cardiovascular disease and death: systematic review and meta-analysis. *Diabetologia* 2012;55(11):2895-905.

70. Bankoski A, Harris TB, McClain JJ, Brychta RJ, Caserotti P, Chen KY, et al. Sedentary activity associated with metabolic syndrome independent of physical activity. *Diabetes Care* 2011;34(2):497-503.

71. Sugiyama T, Healy GN, Dunstan DW, Salmon J, Owen N. Joint associations of multiple leisure-time sedentary behaviours and physical activity with obesity in Australian adults. *Int J Behav Nutr Phys Act* 2008;5:35.

72. Macias R, Garrido-Munoz M, Tejero-Gonzalez CM, Lucia A, Lopez-Adan E, Rodriguez-Romo G. Prevalence of leisure-time sedentary behaviour and sociodemographic correlates: a cross-sectional study in Spanish adults. *BMC Public Health* 2014;14:972.

73. Bauman A, Phongsavan P, Schoeppe S, Owen N. Physical activity measurement-a primer for health promotion. *Promot Educ* 2006;13(2):92-103.

74. Dishman RK, Washburn RA, Schoeller DA. Measurement of Physical Activity. *Quest* 2001;53(3):295-309.

75. Centers for Disease Control and Prevention. *2013 Behavioural Risk Factor Surveillance System Questionnaire* (2012). Retrieved from http://www.cdc.gov/brfss/questionnaires/pdf-ques/2013%20brfss_english.pdf. Accessed June 2016.

76. Helmerhorst HJ, Brage S, Warren J, Besson H, Ekelund U. A systematic review of reliability and objective criterion-related validity of physical activity questionnaires. *Int J Behav Nutr Phys Act* 2012;9:103.

77. Prince SA, Adamo KB, Hamel ME, Hardt J, Connor Gorber S, Tremblay M. A comparison of direct versus self-report measures for assessing physical activity in adults: a systematic review. *Int J Behav Nutr Phys Act* 2008;5:56.

78. Plasqui G, Westerterp KR. Physical activity assessment with accelerometers: an evaluation against doubly labeled water. *Obesity (Silver Spring, Md)* 2007;15(10):2371-9.

79. Tudor-Locke CE, Myers AM. Challenges and opportunities for measuring physical activity in sedentary adults. *Sports Med* 2001;31(2):91-100.

80. Kerner MS, Kurrant AB. Leisure-Time Physical Activity: Operationally Defined as Time, Work, and Intensity. *Meas Phys Educ Exerc Sci* 2003;7(4):227-41.

81. McNeill LH, Stoddard A, Bennett GG, Wolin KY, Sorensen GG. Influence of individual and social contextual factors on changes in leisure-time physical activity in working-class populations: results of the Healthy Directions-Small Businesses Study. *Cancer Causes Control* 2012;23(9):1475-87.

82. Li F, Fisher KJ, Bauman A, Ory MG, Chodzko-Zajko W, Harmer P, et al. Neighborhood influences on physical activity in middle-aged and older adults: a multilevel perspective. *J Aging Phys Act* 2005;13(1):87-114.

83. Bauman AE, Reis RS, Sallis JF, Wells JC, Loos RJ, Martin BW. Correlates of physical activity: why are some people physically active and others not? *Lancet* 2012;380(9838):258-71.

84. Gilmour H. Physically active Canadians. *Health Rep* 2007;18(3):45-65.

85. Barnekow-Bergkvist M, Hedberg G, Janlert U, Jansson E. Physical activity pattern in men and women at the ages of 16 and 34 and development of physical activity from adolescence to adulthood. *Scand J Med Sci Sports* 1996;6(6):359-70.

86. Deaner RO, Geary DC, Puts DA, Ham SA, Kruger J, Fles E, et al. A sex difference in the predisposition for physical competition: males play sports much more than females even in the contemporary U.S. *PloS One* 2012;7(11):e49168.

87. Cerin E, Leslie E. How socio-economic status contributes to participation in leisure-time physical activity. *Soc Sci Med* 2008;66(12):2596-609.

88. Parks SE, Housemann RA, Brownson RC. Differential correlates of physical activity in urban and rural adults of various socioeconomic backgrounds in the United States. *J Epidemiol Community Health* 2003;57(1):29-35.

89. Popkin BM, Duffey K, Gordon-Larsen P. Environmental influences on food choice, physical activity and energy balance. *Physiol Behav* 2005;86(5):603-13.

90. Tremblay MS, Bryan SN, Perez CE, Ardern CI, Katzmarzyk PT. Physical activity and immigrant status: evidence from the Canadian Community Health Survey. *Can J Public Health* 2006;97(4):277-82.

91. Dogra S, Meisner BA, Ardern CI. Variation in mode of physical activity by ethnicity and time since immigration: a cross-sectional analysis. *Int J Behav Nutr Phys Act* 2010;7:75.

92. MacQueen KM, McLellan E, Metzger DS, Kegeles S, Strauss RP, Scotti R, et al. What is community? An evidence-based definition for participatory public health. *Am J Public Health* 2001;91(12):1929-38.

93. Diez Roux AV. Investigating neighborhood and area effects on health. *Am J Public Health* 2001;91(11):1783-9.

94. Rind E, Jones AP. The geography of recreational physical activity in England. *Health Place* 2011;17(1):157-65.

95. Martin SL, Kirkner GJ, Mayo K, Matthews CE, Durstine JL, Hebert JR. Urban, rural, and regional variations in physical activity.*J Rural Health* 2005;21(3):239 44.

96. Maxwell J. *Social Dimensions of Economic Growth* (1996). Retrieved from https://era.library.ualberta.ca/downloads/nc580q389. Accessed December 2015.

97. Kavanagh AM, Goller JL, King T, Jolley D, Crawford D, Turrell G. Urban area disadvantage and physical activity: a multilevel study in Melbourne, Australia. *J Epidemiol Community Health* 2005;59(11):934-40.

98. Streiner DL. Breaking up is hard to do: the heartbreak of dichotomizing continuous data. *Can J Psychiatry* 2002;47(3):262-6.

99. Lovasi GS, Underhill LJ, Jack D, Richards C, Weiss C, Rundle A. At Odds: Concerns Raised by Using Odds Ratios for Continuous or Common Dichotomous Outcomes in Research on Physical Activity and Obesity. *Open Epidemiol J* 2012;5:13-7.

100. Kahn EB, Ramsey LT, Brownson RC, Heath GW, Howze EH, Powell KE, et al. The effectiveness of interventions to increase physical activity. A systematic review. *Am J Prev Med* 2002;22(4 Suppl):73-107.

101. Heath GW, Parra DC, Sarmiento OL, Andersen LB, Owen N, Goenka S, et al. Evidence-based intervention in physical activity: lessons from around the world. *Lancet* 2012;380(9838):272-81.

102. Kriska AM, Bayles C, Cauley JA, LaPorte RE, Sandler RB, Pambianco G. A randomized exercise trial in older women: increased activity over two years and the factors associated with compliance. *Med Sci Sports Exerc* 1986;18(5):557-62.

103. Lombard DN, Lombard TN, Winett RA. Walking to meet health guidelines: the effect of prompting frequency and prompt structure. *Health Psychol* 1995;14(2):164-70.

104. Viswanath K, Randolph Steele W, Finnegan JR, Jr. Social capital and health: civic engagement, community size, and recall of health messages. *Am J Public Health* 2006;96(8):1456-61.

105. Poortinga W. Community resilience and health: the role of bonding, bridging, and linking aspects of social capital. *Health Place* 2012;18(2):286-95.

106. Chuang YC, Chuang KY, Yang TH. Social cohesion matters in health. *Int J Equity Health* 2013;12:87.

107. Diez-Roux AV. Multilevel analysis in public health research. *Annu Rev Public Health* 2000;21:171-92.

108. Brauer C, Mikkelsen S. The influence of individual and contextual psychosocial work factors on the perception of the indoor environment at work: a multilevel analysis. *Int Arch Occup Environ Health* 2010;83(6):639-51.

109. Peugh JL. A practical guide to multilevel modeling. *J Sch Psychol* 2010;48(1):85-112.

110. McNamee R. Confounding and confounders. *J Occup Env Med* 2003;60(3):227-34.

111. Greenland S, Pearl J, Robins JM. Causal diagrams for epidemiologic research. *Epidemiology* 1999;10(1):37-48.

112. Emlet CA, Moceri JT. The importance of social connectedness in building age-friendly communities. *J Aging Res* 2011;2012.

113. van Emmerik IH. Gender differences in the creation of different types of social capital: A multilevel study. *Soc Networks* 2006;28(1):24-37.

114. Green A, Preston J, Sabates R. Education, equality and social cohesion: a distributional approach. *Compare* 2003;33(4):453-70.

115. Cattell V. Poor people, poor places, and poor health: the mediating role of social networks and social capital. *Soc Sci Med* 2001;52(10):1501-16.

116. Turcotte M. *Social engagement and civic participation: Are rural and small town populations really at an advantage?* (2005). Ottawa: Statistics Canada. Retrieved from http://www.statcan.gc.ca/pub/21-006-x/21-006-x2005004-eng.pdf. Accessed May 2016.

117. Mackinnon DP. Integrating Mediators and Moderators in Research Design. *Res Soc Work Pract* 2011;21(6):675-81.

118. Lee SH, Im EO. Ethnic differences in exercise and leisure time physical activity among midlife women. *J Adv Nurs* 2010;66(4):814-27.

119. Statistics Canada. *Canadian Community Health Survey - Annual Component (CCHS)* (2015). Retrieved from http://www23.statcan.gc.ca/imdb/p2SV.pl?Function=getSurvey&SDDS=3226. Accessed December 2015.

120. Statistics Canada. *Canadian Community Health Survey (CCHS) – Annual component* (2011). Retrieved from: http://www23.statcan.gc.ca/imdb-bmdi/document/3226_D7_T9_V8-eng.htm. Accessed December 2015.

121. Statistics Canada. *Methodology of the Canadian Force Labour Survey* (2008). Ottawa: Statistics Canada. Retrieved from http://www5.statcan.gc.ca/access_acces/alternative_alternatif.action?l=eng&loc=/pub/71-526-x/71-526-x2007001-eng.pdf Accessed December 2015.

122. World Health Organization. *Overweight and Obesity* (2016). Retrieved from http://www.who.int/mediacentre/factsheets/fs311/en/. Accessed June 2016.

123. Statistics Canada. *Population Centre (POPCTR)* (2015). Retrieved from https://www12.statcan.gc.ca/census-recensement/2011/ref/dict/geo049a-eng.cfm. Accessed May 2016.

124. Chaskin RJ. Perspectives on neighborhood and community: a review of the literature *Social Serv Rev* 1997;71:521-7.

125. Weiss L, Ompad D, Galea S, Vlahov D. Defining neighborhood boundaries for urban health research. *Am J Prev Med* 2007;32(6 Suppl):S154-9.

126. Meer Tvd, Tolsma J. Ethnic diversity and its effects on social cohesion. *Annu Rev Sociol* 2014;40(1):459-78.

127. Social Research and Planning. *London's anti-poverty strategy: literature review* (2008). London: City of London, Canada. Retrieved from https://www.london.ca/About-London/community-statistics/social-issues/Documents/Poverty%20in%20London.pdf. Accessed December 2015.

128. Statistics Canada. *Census subdivision (CSD)* (2015). Retrieved from https://www12.statcan.gc.ca/census-recensement/2011/ref/dict/geo012-eng.cfm. Accessed December 2015.

129. Statistics Canada. *Forward sortation area* (2008). Retrieved from https://www12.statcan.gc.ca/census-recensement/2006/ref/notes/FSA-RTR-eng.cfm. Accessed December 2015.

130. Gelman A. Multilevel (Hierarchical) Modeling: What It Can and Cannot Do. *Technometrics* 2006;48(3):432-5.

131. Merlo J, Ostergren PO, Hagberg O, Lindstrom M, Lindgren A, Melander A, et al. Diastolic blood pressure and area of residence: multilevel versus ecological analysis of social inequity. *J Epidemiol Community Health* 2001;55(11):791-8.

132. Duncan C, Jones K, Moon G. Context, composition and heterogeneity: using multilevel models in health research. *Soc Sci Med* 1998;46(1):97-117.

133. Hayes AF. A Primer on Multilevel Modeling. *Hum Commun Res* 2006;32(4):385-410.

134. Bell BA, Ene M, Smiley W, Schoeneberger JA. *A multilevel model primer using SAS® PROC MIXED* (2013). Retrieved from http://support.sas.com/resources/papers/proceedings13/433-2013.pdf. Accessed December 2015.

135. Park S, Lake ET. Multilevel modeling of a clustered continuous outcome: nurses' work hours and burnout. *Nurs Res* 2005;54(6):406-13.

136. Gulliford MC, Ukoumunne OC, Chinn S. Components of variance and intraclass correlations for the design of community-based surveys and intervention studies: data from the Health Survey for England 1994. *Am J Epidemiol* 1999;149(9):876-83.

137. Paccagnella O. Centering or not centering in multilevel models? The role of the group mean and the assessment of group effects. *Eval Rev* 2006;30(1):66-85.

138. Bell BA, Mogran GB, Kromrey JD, Ferron JM. The impact of small cluster size on multilevel models: a Monte Carlo examination of two-level models with binary and continuous predictors. *JSM Proceedings, Survey Research Methods Section* 2010:4057-67. Retrieved from https://www.amstat.org/sections/srms/proceedings/y2010/Files/308112_60089.pdf. Accessed January 2016.

139. Maas CJ, Hox JJ. Sufficient sample sizes for multilevel modeling. *Methodology* 2005;1:86-92.

140. *SAS Software* [computer program]. Version 9.3. Cary, NC: SAS Institute Inc; 2011.

141. Briggs A, Coleman M. Research Methods In Educational Leadership And Management. London: Sage Publications; 2007.

142. Kuzon WM, Jr., Urbanchek MG, McCabe S. The seven deadly sins of statistical analysis. *Ann Plast Surg* 1996;37(3):265-72.

143. Norman G. Likert scales, levels of measurement and the "laws" of statistics. *Adv Health Sci Educ Theory Pract* 2010;15(5):625-32.

144. Havlicek LL, Peterson N, L. Robustness of the Pearson correlation against violation of assumption. *Percept Mot Skills* 1976;43:1319-34.

145. Kaputa SJ, Thompson KJ. Estimation and replicate variance estimation of deciles for complex survey data from positively skewed populations. *Surv Methodol* 2013;39(2):351-68.

146. Pigott TD. A review of methods for missing data. *Educ Res Eval* 2001;7(4):353-83.

147. Rubin DB. Inference and missing data. *Biometrika* 1976;63(3):581-92.

148. Kim S, Egerter S, Cubbin C, Takahashi ER, Braveman P. Potential implications of missing income data in population-based surveys: an example from a postpartum survey in California. *Public Health Rep* 2007;122(6):753-63.

149. Nakai M, Ke W. Review of the methods for handling missing data in longitudinal data analysis. *Int J Math Anal* 2011;5(1):1-13.

150. Graham JW, Olchowski AE, Gilreath TD. How many imputations are really needed? Some practical clarifications of multiple imputation theory. *Prev Sci* 2007;8(3):206-13.

151. van der Meer T, Tolsma J. Ethnic diversity and its effects on social cohesion. *Annu Rev Sociol* 2014;40:459-78.

Appendices

Appendix A. Summary of previous studies investigating the association between social cohesion and physical activity

Appendix B. List of variables from the Canadian Community Health Survey included in the analysis

Appendix C. Descriptive statistics by CCHS Cycle

Appendix D. Results from the sensitivity analysis

Appendix A: Summary of previous studies investigating the association between social cohesion and physical activity

Reference Data Source	Study Population Study Design	Measure of Social Cohesion	Measure of Physical Activity	Summary of Findings
Andrade et al., 2015 Belo Horizonte (BH) Health Study	3,597 adults from 149 census tracts in Belo Horizonte, Brazil 53.1% Female Cross-sectional Multilevel Study	<u>Neighbourhood Level</u> Social cohesion assessed by aggregating individual responses to a previously-developed scale	Leisure-time PA assessed using the long-form International Physical Activity Questionnaire (IPAQ)	Adults residing in neighborhoods with higher scores for social cohesion had a higher odds of being physically active (OR:1.43, 95% CI: 1.02 to 2.01)
Ball et al., 2010 Socioeconomic Status and Activity in Women (SESAW) Study	1,405 adults (aged 18 to 65 years) from 45 neighbourhoods in Melbourne, Australia 100% Female Cross-sectional Multilevel Study	<u>Neighbourhood level</u> Social capital (interpersonal trust, norms of reciprocity, social cohesion) assessed by aggregating individual responses to items on rating scales	Self-reported PA level assessed using the long-version of the International Physical Activity Questionnaire (IPAQ)	A higher level of interpersonal trust was associated with a greater odds of leisure-time physical activity (OR: 1.73, 95% CI: 1.01 to 1.98) Social cohesion was not significantly associated with physical activity
Cleland et al., 2010 Resilience for Eating and Activity Despite Inequality (READI) study	4,108 adults (aged 18 to 45 years) from low socioeconomic (SES) neighbourhoods in Victoria, Australia 100% Female Cross-sectional Study	<u>Individual level</u> Perceived neighbourhood social cohesion assessed using responses to 5 items on rating scales	Self-reported PA level assessed using the long-version of the International Physical Activity Questionnaire (IPAQ)	In the partially adjusted model, a higher level of social cohesion was associated with a greater odds of engaging in at least 150 mins of leisure-time physical activity weekly (OR: 1.07, 95% CI: 0.95 to 1.06) In the fully adjusted model, social cohesion was not associated with physical activity

Reference Data Source	Study Population Study Design	Measure of Social Cohesion	Measure of Physical Activity	Summary of Findings
Cradock et al., 2009 Project on Human Development in Chicago Neighborhoods (PHDCN)	680 adolescents (aged 11 to 15 years) from 80 neighbourhoods in Chicago, USA 49% Female Longitudinal Multilevel Study (assessments at baseline and at 2 years)	<u>Neighbourhood Level</u> Social cohesion assessed using a five-item survey	Participation in recreational activities assessed using self-report data obtained from primary caregivers	Living in neighborhoods with higher levels of social cohesion was associated with a decreased likelihood of being inactive in recreational programs when compared with living in less socially cohesive areas both at baseline and at 2-year follow-up (OR: 0.43, $p<0.001$)
Fisher et al., 2004	582 older adults (aged 65 years or older) from 56 neighbourhoods in Portland, USA 69% Female Cross-sectional Multilevel Study	<u>Neighbourhood Level</u> Social cohesion derived from aggregated individual-level data obtained from responses to survey questions	Neighbourhood walking activity (frequency) assessed using three survey questions	Social cohesion at the neighbourhood level was positively associated with walking ($\beta = 0.034$, $p < .05$)
Gao et al., 2015	2,783 older adults from 47 neighbourhoods in Shanghai, China 59% Female Cross-sectional Multilevel Study	<u>Individual Level</u> Perceived neighbourhood social cohesion assessed using 4-item module <u>Neighbourhood Level</u> Social cohesion derived from averaging individual scores within neighbourhoods	Leisure-time PA assessed using a Chinese version of the long-form International Physical Activity Questionnaire (IPAQ)	A higher level of individual level social cohesion was associated with a greater odds of engagement in leisure-time physical activity (OR = 1.31, 95% CI: 1.11 to 1.58) Social cohesion at the neighbourhood level was not significantly associated with engagement in leisure-time physical activity

Reference Data Source	Study Population Study Design	Measure of Social Cohesion	Measure of Physical Activity	Summary of Findings
Jongeneel-Grimen et al., 2014 Netherlands Housing Survey (2006 and 2009 cycles)	57,092 adults (aged 18 to 84 years) from 320 neighbourhoods in the Netherlands 53% Female (2006) 56% Female (2009) Longitudinal Multilevel Study	<u>Neighbourhood Level</u> Social cohesion derived from averaging individual responses to a survey item within each neighbourhood	Physical activity assessed using a single survey item asking about number of hours spent engaging in PA or sports	An increase in social cohesion at the neighbourhood level between 2006 and 2009 was associated with a greater odds of engaging in at least 1 hour of physical activity per week (OR: 1.12, 95% CI: 1.05 to 1.19)
King, 2008	190 older adults from 8 neighbourhoods in Denver, USA Cross-sectional Multilevel Study	<u>Neighbourhood Level</u> Social cohesion assessed by aggregating individual responses to a 5-item subscale of a questionnaire asking about perceived neighbourhood social cohesion	Activity engagement assessed using the 33-item questionnaire	Activity engagement was highest in neighborhoods with higher perceived safety and social cohesion ($p < .01$)
Kaczynski & Glover, 2012 Physical Activity in the Community Study	380 adults from 4 neighbourhoods in Waterloo, Canada 64% Female Cross-sectional Study	<u>Individual Level</u> Perceived social connectedness (SC) in the neighbourhood assessed using responses to a 5-item questionnaire	Time (minutes) spent in recreational and transport PA assessed using a 7-day log book	The high walkability/high SC group reported more recreational physical activity (mean: 130.6, SD: 46.2) than all other groups ($p<0.05$) The low walkability/high SC group reported significantly more recreational physical activity (mean: 108.7, SD: 46.2) than the high walkability/low SC group (mean: 55.3, SD: 23.1) and the low walkability/low SC group (mean: 59.2, SD: 26.8) ($p<0.05$)

Reference Data Source	Study Population Study Design	Measure of Social Cohesion	Measure of Physical Activity	Summary of Findings
Legh-Jones et al., 2012 Montreal Neighbourhood Networks and Healthy Aging Study (MoNNET-HA)	2,707 adults (aged 25 years or older) from 300 neighbourhoods in Montreal, Canada 65% Female Cross-sectional Study	<u>Individual Level</u> Network capital assessed using a position generator, and generalized trust and social participation assessed using survey questions	Self-reported PA level assessed using an adapted version of the International Physical Activity Questionnaire (IPAQ)	No social participation was associated with a significantly higher likelihood of being physically inactive compared to having a high level of social participation (OR: 1.64; 95% CIs: 1.06 to 2.54)
Mackenbach et al., 2016 Sustainable Prevention of Obesity Through Integrated Strategies (SPOTLIGHT) Project	5,900 from 60 neighbourhoods across 5 countries in Europe 56% Female Cross-sectional Multilevel Study	<u>Neighbourhood Level</u> Social cohesion derived from averaging individual scores on a 13-item scale	Leisure-time and transport-related PA assessed using the International Physical Activity Questionnaire (IPAQ)	A higher level of social cohesion was associated with a lower odds of engaging in over 25 mins of transport-related PA (OR: 0.73, 95% CI: 0.53; 0.99) Social cohesion was not associated with leisure-time physical activity
Martinez et al., 2012	143 Latino women (aged 18 to 65 years) from San Diego, California 100% Female Longitudinal Study (assessments at baseline, 3 months, and 6 months)	<u>Individual Level</u> Perceived neighbourhood social cohesion assessed using an existing 6-item scale	Leisure-time PA assessed using the Global Physical Activity Questionnaire (GPAQ)	Perceived neighbourhood cohesion at 3 months was found to predict leisure-time physical activity at 6 months ($\beta = 0.19$, $p < .05$)

Reference Data Source	Study Population Study Design	Measure of Social Cohesion	Measure of Physical Activity	Summary of Findings
Mendes de Leon et al., 2009 Chicago Neighborhood and Disability Study (CNDS)	4,317 older adults (aged 65 years or older) from 82 census block groups from Chicago, USA 61% Female Cross-sectional Multilevel Study	<u>Individual Level</u> Social cohesion assessed using a six survey questions assessing <u>Neighbourhood Level</u> Social cohesion assessed by aggregating individual measures of social cohesion	Participation in walking (in minutes) assessed using the 1985 Health Interview Survey	Initially, neighbourhood-level social cohesion was significantly associated with walking; no longer significant after adjusting for individual-level social cohesion Individual-level social cohesion was associated with walking after all adjustments ($\beta = 2.43$, $p<.001$)
Pabayo et al., 2011 National Institute of Child Health and Human Development Study of Early Child Care	889 youth (aged 10 to 15 years) from neighbourhoods across the USA 50% Female Longitudinal Multilevel Study	<u>Individual Level</u> Parents' perceived neighbourhood social cohesion assessed using survey items administered to parents	Moderate-to-vigorous PA (in mean minutes) derived from accelerometer data	Social cohesion was positively associated with weekday moderate-to-vigorous physical activity ($\beta = 2.0$, $p<0.01$) and weekend MVPA ($\beta = 3.1$, $p<0.01$) across time
Pabayo et al., 2014 Boston Youth Survey (BYS)	1,878 adolescents from 38 neighbourhoods in Boston, USA 56% Female Cross-sectional Multilevel Study	<u>Individual Level</u> Social cohesion assessed using responses to survey items in the BYS <u>Neighbourhood Level</u> Social cohesion assessed using responses to survey items in the Boston Neighbourhood Survey (previously administered to a different population)	Physical inactivity assessed using a single question asking the respondent about frequency of engaging in at least 20 minutes of moderate-to-vigorous PA	No measure of social cohesion was associated with physical inactivity

Reference Data Source	Study Population Study Design	Measure of Social Cohesion	Measure of Physical Activity	Summary of Findings
Strong et al., 2013 Creating a Higher Understanding of cancer Research and Community Health (CHURCH) Project	1,347 African American adults from Houston, USA 75% Female Cross-sectional Multilevel Study	<u>Individual Level</u> Perceived neighbourhood social cohesion assessed using responses to 5 survey items	PA assessed using the short-version of the International Physical Activity Questionnaire (IPAQ)	Social cohesion was associated with a greater odds of being physically active in women only (OR: 1.06, 95% CI: 1.02 to 1.11).
Utter et al., 2011 Youth'07 Survey	6,101 adolescents (aged 13 to 17 years) from 262 Census Area Units from across New Zealand 47% Female Cross-sectional Multilevel Study	<u>Neighbourhood Level</u> Community social cohesion derived from the aggregation of responses to 6 survey items	PA assessed using a single item asking about the number of days per week a respondent spent engaging in at least 1 hour of PA	Positive association between community social cohesion and number of days per week spent engaging in at least 1 hour of PA ($\beta = 0.081$, $p<0.025$)
Ueshima et al., 2010 The Okayama Social Capital Study	2,260 adults (aged 20 to 80 years) from 20 school districts in Okayama City, Japan 58% Female Cross-sectional study	<u>Individual Level</u> Social capital assessed using survey questions asking about trust of neighbours and social participation	Physical activity assessed using a single Likert item asking about frequency of participation in physical exercise	Compared to the low trust group, the high trust group had a lower odds of being physically inactive (OR: 0.58, 95% CI: 0.42 to 0.70)

Reference Data Source	Study Population Study Design	Measure of Social Cohesion	Measure of Physical Activity	Summary of Findings
Wen et al., 2007 California Health Interview Survey (CHIS)	41,545 adults from California, USA 56% Female Cross-sectional Study	<u>Individual Level</u> Perceived neighbourhood social cohesion assessed using responses to 5 survey items	Walking behaviour assessed using responses to survey items asking about frequency and duration of walking	A higher level of perceived social cohesion was associated with a greater likelihood of meeting recommended levels of walking (OR: 1.09, 95% CI: 1.04, to1.14)
Yang et al., 2014 2006-2007 High School Questionnaire of the California Healthy Kids Survey (CHKS)	46,588 secondary school students from California, USA Cross-sectional Multilevel Study	<u>Individual Level</u> Connectedness to the community assessed using responses to 9 items on a 4-point Likert scale	Physical activity assessed using a single question asking about the number of days the respondent exercised for more than 20 minutes	A higher level of connectedness to the community was associated with a higher odds of engagement in physical activity for Asian Americans ($\beta = 0.13$, $p = .035$) Pacific Islanders ($\beta = 0.28$, $p = .016$), and White Americans ($\beta = 0.41$, $p<.001$)

Appendix B: List of variables from the Canadian Community Health Survey included in the analysis

Construct	Cycle	Variable Name	Question / Source
Outcome			
Daily Energy Expenditure	2009-2010	PACDEE	Derived from variables asking about participation in specific leisure activities
	2011-2012	PACDEE	
	2013-2014	PACDEE	
Physical Activity Status	2009-2010	PACDPAI	Derived from Daily Energy Expenditure
	2011-2012	PACDPAI	
	2013-2014	PACDPAI	
Predictor			
Sense of Belonging	2009-2010	GEN_10	How would you describe your sense of belonging to your local community? Would you say it is...?
	2011-2012	GEN_10	
	2013-2014	GEN_10	
Moderator			
Weight Status	2009-2010	HWTGBMI	Derived from self-reported height and weight
	2011-2012	HWTGBMI	
	2013-2014	HWTGBMI	
Covariates			
Age	2009-2010	DHHGAGE	What is your age?
	2011-2012	DHHGAGE	
	2013-2014	DHHGAGE	
Sex	2009-2010	DHH_SEX	Completed by the interviewer. If necessary, ask: Is respondent male or female?
	2011-2012	DHH_SEX	
	2013-2014	DHH_SEX	
Household Income	2009-2010	INCDRCA	Derived Variable
	2011-2012	INCDRCA	
	2013-2014	INCDRCA	
Education Attainment	2009-2010	EDUDR04	Derived Variable
	2011-2012	EDUDR04	
	2013-2014	EDUDR04	
Geographical Variables			
Postal Code Region	2009-2010	GEODPC	Derived from respondents' address information
	2011-2012	GEODPC	
	2013-2014	GEODPC	
Urban-Rural Status	2009-2010	GEODUR2	Derived from Census geography
	2011-2012	GEODUR2	
	2013-2014	GEODUR2	

Appendix C: Descriptive statistics by CCHS cycle

Table C1. Sample characteristics – By CCHS cycle

	CCHS Cycle		
	2009-2010 Percentage(%)	2011-2012 Percentage (%)	2013-2014 Percentage (%)
Sex			
Male	50.0	49.9	49.9
Female	50.0	50.1	50.1
Age Group			
18 to 24	14.2	14.1	14.2
25 to 34	19.9	20.2	20.5
35 to 44	21.8	20.8	20.6
45 to 54	23.6	22.7	22.1
55 to 64	20.5	22.2	22.6
Social Cohesion			
Very Weak	9.6	8.9	8.3
Somewhat Weak	27.7	28.6	28.4
Somewhat Strong	47.5	47.7	48.5
Very Strong	15.1	14.8	14.7
Activity Status			
Active	26.7	27.7	28.6
Moderately Active	25.2	25.8	25.4
Inactive	48.1	46.5	46.0
Weight Status			
Normal weight or underweight	51.2	50.8	49.6
Overweight or obese	48.8	49.2	50.4
Education Attainment			
Grade 8 or lower	2.7	2.5	2.3
Grade 9 to 10	4.4	4.2	3.7
Grade 11 to 13	3.6	3.2	3.3
Secondary school	17.4	18.4	21.3
Some post-secondary	8.7	6.9	6.1
Trade certificate or diploma	12.3	11.8	9.6
College diploma or certificate	22.1	23.2	23.5
University below Bachelor's level	3.6	4.3	3.1
Bachelor's degree	17.4	17.4	18.9
Above Bachelor's degree	7.8	8.1	8.1
Urban-Rural Status			
Urban	82.7	82.4	82.5
Rural	17.2	17.6	17.4

Table C2. Trends in physical activity level – By CCHS cycle

	CCHS Cycle		
	2009-2010 Mean (SD)	2011-2012 Mean (SD)	2013-2014 Mean (SD)
By Sex			
Male	5.521 (3.282)	5.559 (3.345)	5.631 (3.411)
Female	5.175 (2.939)	5.330 (2.938)	5.354 (3.041)
By Age Group			
18 to 24	6.127 (3.451)	6.265 (3.443)	6.248 (3.579)
25 to 34	5.460 (3.199)	5.589 (3.341)	5.638 (3.519)
35 to 44	5.186 (3.242)	5.279 (3.318)	5.336 (3.417)
45 to 54	5.167 (3.226)	5.204 (3.221)	5.263 (3.387)
55 to 64	5.081 (2.586)	5.190 (2.580)	5.252 (2.586)
By Weight Status			
Normal Weight or Underweight	5.509 (3.235)	5.629 (3.251)	5.705 (3.317)
Overweight or obese	5.179 (2.976)	5.253 (3.006)	5.283 (3.113)
By Household Income			
Decile 1	4.537 (3.176)	4.837 (3.418)	4.832 (3.630)
Decile 2	4.734 (3.188)	4.888 (3.344)	4.968 (3.479)
Decile 3	4.846 (3.230)	4.906 (3.363)	4.859 (3.477)
Decile 4	5.091 (3.143)	5.193 (3.230)	5.208 (3.187)
Decile 5	5.170 (3.141)	5.334 (3.048)	5.403 (3.277)
Decile 6	5.397 (3.019)	5.376 (2.969)	5.473 (3.123)
Decile 7	5.559 (3.015)	5.630 (3.148)	5.580 (3.142)
Decile 8	5.657 (3.088)	5.656 (2.941)	5.831 (3.001)
Decile 9	5.902 (2.945)	5.942 (2.928)	6.024 (2.862)
Decile 10	6.199 (2.789)	6.308 (2.777)	6.344 (2.865)
By Education Attainment			
Grade 8 or lower	3.958 (2.680)	4.163 (2.831)	4.420 (2.934)
Grade 9 to 10	4.344 (2.798)	4.371 (2.910)	4.270 (2.907)
Grade 11 to 13	5.024 (3.122)	4.954 (3.101)	4.999 (3.111)
Secondary school	5.175 (3.088)	5.373 (3.028)	5.363 (3.183)
Some post-secondary	5.492 (3.218)	5.548 (3.438)	5.783 (3.423)
Trade certificate or diploma	5.141 (2.942)	5.131 (3.010)	5.183 (2.990)
College diploma or certificate	5.476 (3.025)	5.553 (3.053)	5.590 (3.146)
University below Bachelor's level	5.578 (3.242)	5.765 (3.231)	5.774 (3.174)
Bachelor's degree	5.735 (3.230)	5.796 (3.219)	5.814 (3.375)
Above Bachelor's degree	5.777 (3.265)	5.930 (3.259)	5.918 (3.385)
Urban-Rural Status			
Urban	5.340 (3.307)	5.436 (3.345)	5.472 (3.441)
Rural	5.386 (2.477)	5.484 (2.475)	5.587 (2.531)

Abbreviations: SD (standard deviation)

Table C3. Trends in social cohesion – By CCHS cycle

	CCHS Cycle		
	2009-2010 Mean (SD)	2011-2012 Mean (SD)	2013-2014 Mean (SD)
By Sex			
Male	2.674 (0.946)	2.667 (0.944)	2.687 (0.952)
Female	2.689 (0.871)	2.703 (0.859)	2.704 (0.863)
By Age Group			
18 to 24	2.602 (0.976)	2.617 (0.947)	2.615 (0.960)
25 to 34	2.584 (0.913)	2.571 (0.945)	2.593 (0.988)
35 to 44	2.704 (0.931)	2.717 (0.938)	2.710 (0.953)
45 to 54	2.712 (0.954)	2.725 (0.946)	2.738 (0.967)
55 to 64	2.771 (0.799)	2.761 (0.779)	2.786 (0.753)
By Weight Status			
Normal Weight or Underweight	2.666 (0.928)	2.678 (0.920)	2.682 (0.926)
Overweight or obese	2.697 (0.886)	2.691 (0.880)	2.709 (0.885)
By Household Income			
Decile 1	2.557 (0.991)	2.590 (1.007)	2.609 (1.072)
Decile 2	2.612 (0.956)	2.696 (1.004)	2.664 (1.029)
Decile 3	2.648 (0.941)	2.665 (0.972)	2.696 (0.981)
Decile 4	2.675 (0.946)	2.693 (0.916)	2.683 (0.915)
Decile 5	2.688 (0.930)	2.689 (0.890)	2.662 (0.914)
Decile 6	2.699 (0.883)	2.664 (0.861)	2.715 (0.884)
Decile 7	2.693 (0.876)	2.683 (0.904)	2.698 (0.876)
Decile 8	2.699 (0.886)	2.701 (0.853)	2.703 (0.822)
Decile 9	2.729 (0.852)	2.714 (0.835)	2.742 (0.808)
Decile 10	2.766 (0.823)	2.739 (0.818)	2.761 (0.827)
By Education Attainment			
Grade 8 or lower	2.715 (0.889)	2.749 (0.900)	2.837 (0.894)
Grade 9 to 10	2.659 (0.906)	2.682 (0.908)	2.674 (0.876)
Grade 11 to 13	2.613 (0.900)	2.661 (0.869)	2.587 (0.878)
Secondary school	2.677 (0.892)	2.679 (0.864)	2.694 (0.892)
Some post-secondary	2.666 (0.894)	2.588 (0.975)	2.620 (0.953)
Trade certificate or diploma	2.644 (0.878)	2.672 (0.892)	2.656 (0.849)
College diploma or certificate	2.665 (0.896)	2.659 (0.876)	2.685 (0.881)
University below Bachelor's level	2.735 (0.964)	2.726 (0.933)	2.755 (0.850)
Bachelor's degree	2.712 (0.929)	2.727 (0.926)	2.726 (0.971)
Above Bachelor's degree	2.751 (0.970)	2.761 (0.934)	2.761 (0.961)
Urban-Rural Status			
Urban	2.661 (0.961)	2.669 (0.954)	2.686 (0.965)
Rural	2.776 (0.728)	2.760 (0.730)	2.742 (0.720)

Abbreviations: SD (standard deviation)

Table C4. Trends in physical activity level vs. social cohesion – By CCHS cycle

	CCHS Cycle		
	2009-2010 Mean (SD)	2011-2012 Mean (SD)	2013-2014 Mean (SD)
Physical Activity Level by Social Cohesion			
Very Weak	4.608 (3.270)	4.713 (3.402)	4.794 (3.428)
Somewhat Weak	5.148 (3.211)	5.197 (3.243)	5.230 (3.310)
Somewhat Strong	5.532 (3.309)	5.611 (3.032)	5.680 (3.118)
Very Strong	5.608 (2.954)	5.822 (2.993)	5.777 (3.166)
Social Cohesion by Physical Activity Level			
Decile 1	2.515 (1.014)	2.501 (1.033)	2.540 (1.036)
Decile 2	2.611 (0.904)	2.592 (0.905)	2.632 (0.926)
Decile 3	2.621 (0.929)	2.623 (0.894)	2.633 (0.908)
Decile 4	2.689 (0.896)	2.674 (0.873)	2.673 (0.902)
Decile 5	2.674 (0.889)	2.691 (0.874)	2.698 (0.865)
Decile 6	2.704 (0.862)	2.712 (0.885)	2.718 (0.873)
Decile 7	2.727 (0.883)	2.761 (0.862)	2.723 (0.866)
Decile 8	2.772 (0.862)	2.735 (0.879)	2.729 (0.864)
Decile 9	2.764 (0.867)	2.755 (0.843)	2.775 (0.846)
Decile 10	2.798 (0.868)	2.828 (0.868)	2.845 (0.901)

Abbreviations: SD (standard deviation)

Appendix D: Results from the sensitivity analysis

Table D1. Results from the multilevel models with social cohesion treated as a binary variable – Overall sample

	Model 2A	Model 3A
Variance Component		
Between community	**0.365**	**0.365**
Within community	**8.921**	**8.894**
ICC	**0.039**	**0.049**
Intercept	4.505	4.504
β Coefficients (95% CI)		
I_Cohesion	**0.560 (0.517, 0.603)**	**0.558 (0.515, 0.601)**
C_Cohesion	**0.014 (0.011, 0.018)**	**0.014 (0.011, 0.018)**
Age	**-0.027 (-0.028, -0.027)**	**-0.025 (-0.026, -0.024)**
Sex	**-0.251 (-0.274, -0.229)**	**-0.310 (-0.333, -0.287)**
Income	**0.126 (0.121, 0.130)**	**0.127 (0.122, 0.132)**
Education	**0.088 (0.083, 0.094)**	**0.087 (0.081, 0.092)**
Urban-Rural Status	-0.039 (-0.088, 0.009)	-0.043 (-0.092, 0.005)
Weight Status		**0.208 (0.049, 0.367)**
Weight Status*I_Cohesion		**-0.055 (-0.104, -0.006)**
Weight Status*C_Cohesion		**-0.008 (-0.011, -0.006)**

Notes: (1) Variance components and β coefficients significant at a p-value of 5% are bolded
Models: (2A) Fully-adjusted model without interaction terms; (3A) Fully-adjusted model with interaction terms
Abbreviations: ICC (intraclass correlation coefficient); CI (confidence interval) I_Cohesion (individual-level social cohesion); C_Cohesion (community-level social cohesion)

Table D2. Results from the multilevel models with social cohesion treated as a binary variable – By weight status

	Model 4A	Model 5A
Intercept	4.340	4.543
Parameter Estimates		
I_Cohesion	**0.573 (0.514, 0.632)**	**0.544 (0.482, 0.605)**
C_Cohesion	**0.021 (0.016, 0.024)**	**0.011 (0.007, 0.015)**
Age	**-0.021 (-0.022, -0.020)**	**-0.030 (-0.031, -0.029)**
Sex	**-0.206 (-0.240, -0.173)**	**-0.412 (-0.443, -0.381)**
Income	**0.130 (0.123, 0.137)**	**0.123 (0.117, 0.130)**
Education	**0.072 (0.064, 0.080)**	**0.098 (0.091, 0.106)**
Urban-Rural Status	**-0.087 (-0.162, -0.012)**	-0.011 (-0.073, 0.051)

Notes: (1) Variance components and β coefficients significant at a p-value of 5% are bolded
Models: (4A) Fully-adjusted model with normal weight respondents only; (5A) Fully-adjusted model with overweight respondents only
Abbreviations: CI (confidence interval) I_Cohesion (individual-level social cohesion); C_Cohesion (community-level social cohesion)

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Poster Presentations
Yip C, Wilk P. The Effects of Individual- and Community-Level Social Cohesion on Physical Activity in Canada: A Multilevel Analysis. Top 100 Poster Presentation at London Health Research Day. (London, Ontario; March 2016).