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Neighbourhood walkability associated with initiation of, and adherence to, a pedometer-based physical activity intervention among inactive Canadian adults

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Neighbourhood walkability associated with initiation of, and adherence to,
a pedometer-based physical activity intervention among inactive Canadian adults

by

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A THESIS

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Abstract

Consistent evidence suggests that the built environment can influence physical activity. However, the extent to which the neighbourhood built environment constrains or amplifies the effectiveness of physical activity interventions is understudied. The aim of this thesis was to investigate the role of the neighbourhood built environment in constraining or facilitating the effectiveness of a 12-week internet-facilitated pedometer-based physical activity intervention (UWALK) among inactive adults. Specifically, this thesis examined the effects of the objectively-measured neighbourhood built environment (i.e., walkability estimated via Walk Score®) and the self-reported (perceived) neighbourhood built environment on adoption of, adherence to the UWALK intervention, and levels of pedometer-measured physical activity. A quasi-experiment was undertaken in Calgary between May 2016 and August 2017 which included 573 inactive adults. Self-reported walkability was positively associated with pedometer-measured physical activity. Walk Score® was not significantly associated with pedometer-measured physical activity. Neither objectively-measured walkability or perceived walkability were significantly associated with UWALK adoption or adherence outcomes. Strategies for targeting neighbourhood perceptions may improve the effectiveness of physical activity interventions.

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In loving memory of my dearest friend, Pietro Nespoli,
Maestro di vita e amico caro.
servo di Dio e del prossimo

(Teacher of life and dear friend
servant of God and others)

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Glossary

Adoption of physical activity is defined as the beginning of an exercise program or regular physical activity (Dunn, 1996).

Adherence to physical activity is defined as the percentage of total number of sessions attended, total duration (minutes) of physical activity participation, or percentage of data collected from self-report questionnaires (White, 2005).

Built environment is referred to physical structures of the environment that have been made or modified by people. This includes buildings, open spaces, footpaths, cycle lanes, parks, and trails (Sallis, 2012).

Effectiveness is broadly defined as a statistically significant increase in physical activity or physical fitness over a period of one to six months (Dunn, 1996).

Exercise is a planned, structured and repetitive form of physical activity that needs to be performed to improve or maintain physical fitness (Caspersen, 1985).

Moderate-intensity activity requires a moderate amount of effort that noticeably accelerated the heart rate (e.g., brisk walking, digging the garden, medium paced swimming and cycling) (www.csep/guidelines).

Neighbourhood is defined as the area within 15-minute walk (in any direction) from the participant's home (Saelens, 2003).

Objectively-measured built environment environmental data collected with different methods including neighbourhood audits, Geographic Information System, and measures of neighbourhood walkability (e.g., Walk Score®).

Pedometer is a wearable device that measures the number of steps an individual takes. Pedometers cannot assess for frequency, intensity, duration, mode or context of physical activity (Welk, 2002).

Physical activity is defined as any bodily movement produced by skeletal muscles that results in energy expenditure (Caspersen, 1985).

Self-reported measures of the built environment are collected through questionnaires, surveys, interviews to capture people's perception of the built environment.

Vigorous-intensity physical activity requires a large amount of effort that causes rapid breathing and substantial increase in heart rate (e.g., aerobics, fast swimming, running, heavy shoveling, carrying heavy loads) (www.csep/guidelines).

Walkability is a term used to describe how the built environment influences the ease, comfort, accessibility, and motivating attributes that facilitate walking (Cerin, Saelens, Sallis, & Frank, 2006).

Walk Score® is a publicly available objective walkability index and reflects the level of access to nearby walkable amenities (www.walkscore.com).

Abbreviations

Abbreviation	Definition
b	beta coefficient
BDI	Beck Depression Inventory
BMI	Body mass index
CDC	Center for Disease Control and Prevention
CI	Confidence Interval
DSM-V	Diagnostic and Statistical Manual of Mental Disorders
EMPA	Ecological model of physical activity
GDP	Gross Domestic Product
GSI	Geographical Information System
HW	High Walkable
IRR	Incidence Rate Ratio
LW	Low Walkable
MW	Medium Walkable
NEWS-A	Neighbourhood Environment Walkability Scale – Abbreviated
METs	Metabolic equivalents
PEI-FSP	The Prince Edward Island – First Step Program
%HRmax	Percentage of measured or estimated maximum heart rate
OR	Odds Ratio
RCTs	Randomized Controlled Trials
SD	Standard Deviation
VIF	Variance Inflation Factor

Chapter One: Introduction

1.1 Introduction

Physical activity is defined as any bodily movement produced by skeletal muscles that results in energy expenditure (1). In daily life everyone without serious illness or mobility restrictions, can perform physical activity in the form of sports, playing, working, active transportation, household chores and recreational activities.

Evidence shows that regular physical activity is associated with a reduced risk of cardiovascular disease, diabetes, certain cancers, depression, and overweight and obesity (2-6). Despite the known health benefits of physical activity, accelerometer results from the 2007 to 2009 Canadian Health Measures Survey (CHMS) (7) show that an estimated 15% of Canadian adults accumulated the recommended levels of physical activity (e.g., 150 minutes/week of moderate-vigorous activity) to achieve these health benefits. Conversely, self-reported data from the 2019 Alberta Survey on Physical activity (8) show that 64% of adults report meeting these recommendations. Despite the high percentage of adults reporting physical activity participation at the recommended levels, the overall levels of physical activity have not increased in the last decade (2009-2019). Consistent evidence suggests that the built environment can be supportive of physical activity. For example, living in a neighbourhood with high residential density and high quality pedestrian infrastructures is associated with walking (9, 10). Similarly, positive perceptions about nice aesthetics and safety of the neighbourhood are associated with higher step counts among adults (11). There is also consistent evidence that demonstrates the success of pedometer interventions at increasing walking (12-14). However, the extent to which the built environment influences the effectiveness of pedometer interventions, is understudied.

Understanding how the neighbourhood built environment can influence the adoption of and adherence to physical activity interventions is important considering that even small increases in physical activity can provide substantial health gains among inactive adults. It is estimated that even encouraging 10% of inactive adults to become more physically active could significantly reduce the risk of major chronic health conditions and positively impact population health (15).

1.2 Conceptual framework

The guiding framework for this thesis is the socioecological models (Appendix A). Physical activity research has focused on identifying broader determinants of health behaviour that account for the context within which the health behaviour takes place (i.e., context-specific behaviour). It has been suggested that considering the context for physical activity is likely to be important because people behave differently in different contexts (16). Thus, studies that examine the environmental correlates of physical activity should assess the behaviour that is more specific for a given environment (e.g., walking in the neighbourhood), as this might enhance the study's validity and its predictive capacity (16).

This approach is consistent with ecological models for health behaviour that emphasize the interaction between individuals and their social and physical environment (17, 18). A key strength of socioecological models is the focus on multiple levels of behavioural influence encompassing *intra*-individual (personal beliefs, attitudes and behaviours) and *extra*-individual levels (physical, social, cultural environment, and policy) that are interdependent, meaning that a change at one level may affect all the other levels. For example, removing a recreational park (extra-individual level) may discourage residents to be active or residents may have to

accommodate their intra-individual behaviour to the change at the extra-individual level (e.g., families and children might have to find a new place to play, walk, and socialize) (19).

Furthermore, ecological models consider that individuals adapt, change, and respond to resources available in their extra-individual environment. For example, changes to the neighbourhood where people live in has the potential to influence our behaviour and health (18). Residential relocation studies found that participants who moved to more walkable neighbourhood increased their levels of transportation walking (20, 21). Similarly, improvements in neighbourhood perception (more positive) of street connectivity and aesthetics were positively associated with changes in recreational walking (22, 23). Spence et al. (19) proposed a more comprehensive ecological model of physical activity (EMPA) that also includes biological processes, psychosocial factors, and physical ecology. Physical activity levels might be influenced by genetically determined aspects of physical fitness (body composition, flexibility, speed) (24) and by inherited physical activity behaviour (25). Also, psychological factors like perception of barriers, social support, self-efficacy, and physical activity enjoyment might play a role in physical activity participation among adults (26). Finally, physical ecology (e.g., heat, air pollution, cold) and seasonal variation might directly influence physical activity. A systematic review reported highest levels of physical activity in spring and summer and a decline in outdoor physical activity during adverse weather conditions (e.g., cold, or repeated and heavy rain) including extreme heat (27). In ecological models, individual and external influences are integrated in a single framework and individual's behaviours are understood to be influenced by many different sources. Thus, the ecological perspective moves away from the personal responsibility models that hold individuals solely responsible for their harmful behaviours and recognizes that many forces can shape each person's behaviour (18).

1.3 Thesis Overview

This thesis describes one phase of a two-phase study (quantitative and qualitative components) that evaluates an intervention designed to increase physical activity. Specifically, this thesis evaluates the role of the built environment in the adoption of, adherence to a pedometer intervention among inactive adults who resided in neighbourhoods that differed in their urban design. Eligible participants completed a survey during an initial telephone interview. The telephone survey captured sociodemographic characteristics, perceived walkability, and household address. Household address was used for mailing study materials and pedometers and for linking survey data with Walk Score® (an objective measure of walkability). Participants were asked to commit to the pedometer intervention program for 12 consecutive weeks (84 days) and to report their daily pedometer steps into the intervention website.

1.3.1 Thesis aim

The aim of this thesis was to examine the role of the neighbourhood built environment in influencing the effectiveness of a 12-week internet-delivered pedometer-based physical activity intervention (UWALK) among initially inactive adults. Specifically, this thesis estimated the extent to which the objectively-measured neighbourhood walkability (i.e., walkability estimated via Walk Score®) and the self-reported neighbourhood walkability (walkability estimated via the abbreviated Neighbourhood Environment Walkability Scale: NEWS-A) adjusted for sociodemographic characteristics, were associated with the adoption of, adherence to the “UWALK” program, and levels of pedometer-measured physical activity.

1.3.2 Research questions and hypotheses

This study addressed the following research questions (RQ):

RQ₁: Are objectively-measured and self-reported neighbourhood walkability associated with early adoption of UWALK measured as walking initiation within 6 days from the survey?

***Hypothesis 1a:** Controlling for sociodemographic variables, objectively-measured walkability will be positively associated with early adoption of UWALK.*

***Hypothesis 1b:** Controlling for sociodemographic variables, self-reported neighbourhood walkability will be positively associated with early adoption of UWALK.*

RQ₂: Are objectively-measured and self-reported neighbourhood walkability associated with UWALK adherence measured as count of days of steps entered up to 12 weeks following the adoption of the UWALK intervention?

***Hypothesis 2a:** Controlling for sociodemographic variables, the UWALK adherence will be longer for participants residing in neighbourhoods with higher objectively-measured walkability.*

***Hypothesis 2b:** Controlling for sociodemographic variables, the UWALK adherence will be longer for participants reporting higher perceived neighbourhood walkability.*

RQ₃: Are objectively-measured and self-reported neighbourhood walkability associated with adherence measured as count of days with $\geq 10,000$ steps over 12 weeks following the adoption of the UWALK intervention?

***Hypothesis 3a:** Controlling for sociodemographic variables, the count of days with $\geq 10,000$ steps will be higher for participants residing in neighbourhoods with higher objectively-measured walkability.*

***Hypothesis 3b:** Controlling for sociodemographic variables, the count of days with $\geq 10,000$ steps will be higher for participants reporting higher perceived neighbourhood walkability.*

RQ4: Are objectively-measured and self-reported neighbourhood walkability associated with pedometer-measured physical activity levels measured as average daily steps over 12 weeks following the adoption of the UWALK intervention?

***Hypothesis 4a:** Controlling for sociodemographic variables, the pedometer-measured physical activity levels will be higher for participants residing in neighbourhoods with higher objectively-measured walkability.*

***Hypothesis 4b:** Controlling for sociodemographic variables, the pedometer-measured physical activity levels will be higher for participants reporting higher perceived neighbourhood walkability.*

1.3.3 Ethics approval

The University of Calgary Conjoint Health Research Ethics Board approved the role of the built environment in determining the effectiveness of a pedometer-based physical activity intervention study (Ethics ID: REB15-2944). Verbal informed consent was obtained from each participant before the telephone survey.

1.3.4 Thesis structure

This thesis contains four chapters.

Chapter 1 *Introduction*: A brief overview to introduce the topic of this thesis which focused on neighbourhood built environment, pedometer intervention, and physical activity. This chapter

includes the conceptual framework adopted for this thesis, study aim, research questions and hypotheses.

Chapter 2 *Literature Review*: Details on the benefits of physical activity, facilitators and barriers for physical activity adoption and adherence, and effectiveness of physical activity interventions.

Chapter 3 *Effects of objectively-measured and self-reported neighbourhood walkability on adoption, adherence, and physical activity during an internet-delivered pedometer intervention*:

This chapter describes the role of objectively-measured and self-reported neighbourhood walkability on the effectiveness of a pedometer intervention among inactive adults.

Chapter 4 *Conclusion*: A summary of the results of chapter 3, which provides interpretations of the findings, discusses the strengths and limitations of the thesis, implications of these findings, and suggestions for future research.

Following Chapter 4 is the appendices. Appendices include: Socioecological Framework (Appendix A), Study information and consent form (Appendix B), UWALK and neighbourhood environment survey (Appendix C), Instructions for pedometer and UWALK registration (Appendix D), UWALK activity log (Appendix E), Certification of Institutional Ethics Review (Appendix F), Table 7. Pedometer-measured physical activity for the first and the last week of UWALK intervention (Appendix G).

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Chapter Two: Literature Review

2.1 Background

2.1.1 Physical activity and health: an overview

The benefits of physical activity on health are well documented. Regular physical activity is associated with physical and mental health benefits, and reduced risk of premature mortality (1-4). Furthermore, physical activity contributes to the primary and secondary prevention of at least 25 chronic diseases and medical conditions (e.g., cardiovascular disease, obesity, depression) (5, 6). There is also evidence of a positive relationship between levels of physical activity and health status (7). However, most substantial health improvements are observed in the least active people who initiate regular physical activity (7).

The Canadian Physical Activity Guidelines recommend adults who are 18-64 years old to engage in at least 150 minutes a week of moderate-intensity, or 75 minutes a week of vigorous-intensity aerobic activity, or an equivalent combination of moderate- or vigorous-intensity aerobic activity to accrue optimal health benefits (8). Moderate-intensity physical activity requires a moderate amount of effort that noticeably accelerates the heart rate (e.g., brisk walking, digging the garden, medium paced swimming and cycling) (8). Vigorous-intensity physical activity requires a large amount of effort that causes rapid breathing and a substantial increase in heart rate (e.g., aerobics, fast swimming, running, heavy shoveling, and carrying heavy loads) (8).

2.1.2 Measures of physical activity intensity

Intensity refers to the rate at which the activity is being performed or the magnitude of the effort required to perform an activity or exercise (e.g., how hard a person works to do the

activity) (9). The intensity of physical activity can be described as light, moderate, or vigorous (10). There are different ways to measure the intensity of physical activity which can be expressed in absolute or relative terms. The absolute intensity can be assessed by oxygen uptake per unit of time (mL/min or L/min) or by metabolic equivalents (METs) which are estimated as the rate of energy expenditure while sitting at rest. Intensity of physical activity can be expressed as multiples of resting energy expenditure. MET levels estimated for physical activities in healthy adults, as designated in the Compendium of Physical Activities, range from 0.9 (sleeping) to 18 METs (running at 10.9 mph – 17.54 kph). (11). Based on the Compendium coding, moderate-intensity physical activities are those between 3 – 6 METs (e.g., walking at a moderate or brisk pace of 3 to 4.5 mph – 4.8 to 7.2 kph, bicycling 5 to 9 mph – 8 to 14.5 kph, yoga, moderate housework). Vigorous-intensity physical activities are those with METs greater than 6 (e.g., running, bicycling more than 10 mph -16.1 kph, mountain climbing). Importantly, measures of absolute physical activity intensity do not take into account individual factors such as body weight, sex, and fitness level, or disabilities therefore an activity that is classified as moderate-intensity might be experienced as vigorous-intensity based on the individuals' characteristics (e.g., old vs young, fit vs less fit,) (11).

Relative physical activity intensity is determined based on the individual's effort required to perform an activity. For example, less fit individuals might require a higher level of effort than fitter people to perform the same activity. Relative physical activity intensity can be expressed as the percentage of measured or estimated maximum heart rate (%HRmax) which is $220 - \text{age}$ (10). Moderate-intensity physical activities are estimated to have a %HRmax between 64-76, and vigorous-intensity activities between 77-93. Intensity can also be expressed as an index of individual rate of effort (how hard the person feels he/she is exercising), defined as the rating of

perceived exertion measured with the 20 value Borg score (12), or by frequency of breathing (Talk Test). Physical activity intensity reflects a Borg score between 12-13 when moderate, and between 14-16 when vigorous. Fast breathing compatible with speaking full sentences might apply to moderate-intensity physical activities (e.g., walking briskly, vacuuming, mowing law). Breathing very hard, incompatible with carrying on a conversation comfortably might occur during vigorous-intensity physical activities (e.g., running, swimming laps, heavy gardening, like digging).

2.1.3 Moderate-to-vigorous-intensity physical activity and health benefits

Recent evidence has emphasized that clinically significant health benefits can be achieved from moderate-intensity physical activity, especially among those who are inactive. No minimal threshold of physical activity appears to exist for health benefits, but simply moving from an inactive state to any level of physical activity can lead to significant risk reduction of many chronic diseases (e.g., cardiovascular disease, stroke, hypertension, colon cancer, breast cancer, type 2 diabetes) (5). Since *the US Department of Health and Human* (13) laid the basis for the concept of “health-enhancing physical activity” in 1996, the focus for interventions and research on physical activity has moved away from vigorous-intensity physical activities to moderate-intensity physical activities, especially for physical activities that can be incorporated into daily living (e.g., walking). This shift has been informed by epidemiological evidence suggesting that health benefits similar to those from vigorous-intensity activities can be achieved with less intense or moderate-intensity physical activity (5).

2.1.3.1 Cardiovascular disease

According to findings from a prospective study, middle-aged men involved in moderate-intensity activities such as walking and gardening experienced a 60% reduction in risk of chronic heart disease compared to inactive men (14). Similarly, a prospective study with a cohort of middle-aged women showed that women who walked between 1 and 2.9 hours per week at a brisk pace (3.0 to 3.9 mph – 4.8 to 6.3 kph) reported a 30% lower risk of coronary events compared to women who walked infrequently (15). Furthermore, physical activity is valuable for the secondary prevention of cardiovascular disease. Contrary to previous recommendations that suggested rest and physical inactivity for patients following a heart attack, recent findings show that for both men and women, participation in regular physical activity reduces the risk of premature death after experiencing myocardial infarction (16) and an increased energy expenditure up to 1600 Kcal/week can halt the progression of heart disease (17).

2.1.3.2 Cancer

Engaging in moderate-intensity physical activities (e.g., occupational, household, and recreational activity) is associated with lower risk of breast and colon cancer. In a population-based case-control study of 1,233 incident breast cancer cases and 1,241 controls conducted in Alberta, Canada (18), women who undertook moderate-intensity household activities had a 31% breast cancer risk reduction compared to women engaged in moderated-intensity recreational activities, which was not associated with a risk decrease. Moderate-intensity activities were defined as those that were not exhausting, that increased the heart rate slightly, and that may have caused some light perspiration (18).

Two longitudinal studies that examined the association between physical activity and the risk of developing colon cancer in men (19) and in women (20) reported that at least 30 minutes of moderate-to-vigorous physical activity, including walking or climbing stairs, was associated with 50% reduction in the incidence of colon cancer in men, and a 30-40% reduction of developing colon cancer in women compared to their less active counterparts (21). Furthermore, one follow up study involving patients diagnosed with breast or colon cancer reported that participation in recreational physical activity was associated with a 26-40% risk reduction of death from cancer and reduced cancer recurrence among the most active patients compared to the least active (22).

2.1.3.3 Diabetes mellitus

Evidence shows that higher levels of physical activity are associated with lower risk of developing type 2 diabetes mellitus (23, 24). In particular for patients at risk of diabetes, vigorous-to-moderate-intensity physical activity at least once a week was associated with reduced risk of type 2 diabetes (23, 24). Furthermore, in patients with diabetes mellitus, walking 2 hours per week was associated with a 39–54% reduction in mortality from diabetes mellitus, and a 34–53% reduction in mortality related to cardiovascular disease (25).

2.1.3.4 Obesity and overweight

Overweight and obesity are defined as abnormal or excessive fat accumulation that presents a risk to health (26). Physical activity has been identified as an important lifestyle behaviour that can impact body weight and body composition. It can also influence the prevention and treatment of overweight and obesity (27). Evidence suggests that physical

activity needs to be at least moderate in intensity to influence body weight and levels of adiposity (27).

A prospective cohort study followed 34,079 middle-aged healthy women for 13 years to examine the physical activity needed to prevent weight gain. Findings report that women who, on average, engaged in one hour a day of moderate-to-vigorous physical activity were successful in maintaining a steady weight throughout the study (28). Cross-sectional results from the LOOK AHEAD trial show a negative relationship between moderate-to-vigorous physical activity and body mass index (BMI). Weekly moderate-to-vigorous physical activity accumulated in bouts of ≥ 10 minutes was lower at higher levels of body mass index (BMI) (29).

For the treatment of overweight and obesity, clinical guidelines (30) recommend a comprehensive approach including both dietary changes for reduced calories intake and increased physical activity. A randomized controlled trial including 120 sedentary, overweight middle-aged adults who did not change their usual diet reports that participants who were assigned to the high-intensity regimen lost abdominal fat, whereas those assigned to the low- and moderate-intensity exercise regimens had no change in abdominal fat (31). These findings suggest that engaging in moderate-intensity physical activity may be effective in helping individuals to lose weight if also a dietary restriction is added to the intervention. Without any change in diet, vigorous-intensity physical activity might be more effective with weight loss.

2.1.3.5 Depression and anxiety

The role of physical activity in the prevention and treatment of mental health diseases is well documented (32). Participation in physical activity is associated with improvement and management of mild-to-moderate mental health diseases, especially depression and anxiety (33).

The beneficial effects of physical activity have been also noted in clinically depressed populations. Whereas few studies have evaluated the effects of physical activity on anxiety disorders meeting the criteria of a diagnostic system (33).

Mild depression is characterized by a period of frequent episodes of unhappiness (34). It is relatively common and often not diagnosed (34). Clinical depression is determined against diagnostic criteria with tools such as the Beck Depression Inventory (BDI) (35) or the DSM-V (36). Symptoms of elevated anxiety are often grouped in two categories: 1) state anxiety; 2) trait anxiety. State anxiety refers to an acute, transient psychological response to an event or stimulus and can be considered situational in nature. Trait anxiety indicates a chronic, long term tendency to become anxious, such as may be seen with generalised anxiety disorder (33).

Moses et al. (37) compared the effects of two aerobic programs of differing intensity on mood and mental-well-being in 109 sedentary volunteers who were not previously diagnosed as being clinically depressed. Participants were randomly assigned to 1 of 4 conditions: high-intensity exercise, moderate-intensity exercise, attention-placebo or waiting list. After a 10-week study period, significant improvements in psychological responses were seen with the moderate-intensity exercise group but not with the high-intensity and attention-placebo group. Sime et al. (38) examined 19 moderately depressed adults over a 10-week vigorous exercise program and found a significant reduction in their BDI score compared to the pre-exercise placebo phase (high BDI scores indicate more severe depression). Martinsen et al. (39) investigated the effects of aerobic training on 23 adults diagnosed with clinical depression and significant reduction in BDI scores were noticed after 9 weeks of vigorous-intensity activity.

In summary, there is a strong evidence that physical activity is associated with a decreased risk of developing clinical depression. Vigorous-intensity physical activity, in particular aerobic and resistance exercise are effective in treating depression (34).

Several studies have investigated the effects of physical activity of differing intensity and duration on anxiety (33, 40). Summarized findings report an association between physical activity and reduced anxiety symptoms but no results suggest a causal effect between physical activity and reduced anxiety symptoms (33). Moreover, aerobic exercise (vigorous -intensity) programmes produce larger effect sizes than weight training/flexibility program, and regular physical activity compared to irregular or acute physical activity is more effective in reducing anxiety symptoms (33, 40). Goodwin (41) used data from the National Comorbidity Survey (USA) to determine the association between physical activity and mental disorders among adults not previously diagnosed with anxiety. Results show that participants who reported being regularly active had a reduced risk of being diagnosed with an anxiety disorder compared to their sedentary counterparts. De Moor et al. (42) examined whether exercise participation (with a minimum of 60 minutes weekly at 4 METs) was associated with anxiety, depression and personality in a large population-based in the Netherlands and found that individuals who reported engaging in 240 minutes a week of exercise reported less anxiety and neuroticism compared with non-exercisers.

Interestingly, program's length was found to be very important for improvement of anxiety symptoms among adults. Petruzzello et al. (43) conducted a meta-analysis of the anxiety-reducing effects of acute and chronic exercise and found that physical activity sessions need to exceed 21 minutes in order to achieve significant reduction in trait anxiety. Moreover, the most beneficial effect on anxiety appear to be reached after 40 minutes of physical activity.

2.2 Effectiveness of physical activity interventions

In recognition of the health benefits of regular physical activity, extensive research has focused on designing interventions that may increase physical activity. The effectiveness of these interventions has been measured in different ways including changes in physical activity behaviour (44) or achievement of desired outcomes (e.g., number of people who adopt the program, maintenance of program outcomes at the individual level) (45).

Two systematic reviews, one including evidence on interventions to improve physical activity behaviours (44) and one review of physical activity interventions across countries (46), report that the most effective interventions are those that target the behaviour change across multiple levels of influence (e.g., personal, social, environmental) and include intersectoral approaches that operate at various levels. (46). These interventions comprise informational approaches of community-wide and mass-media campaign, behavioural and social approaches, and policy and environmental approaches (44, 46).

2.2.1 Informational approaches

Informational approaches attempt to raise awareness on the benefits of physical activity, in order to change knowledge, attitudes and behaviour at a community level (44). Community-wide campaign and mass media campaign use diverse communication techniques, such as newspapers, radio, television, billboards, advertisement in transit outlets or in trailers in movie theater, and websites, singly or in combination, to provide information to populations at the community level (47). Mass media and community-wide campaigns require a large amount of resources (e.g., time, staff, volunteers, funding) (48) and one of their biggest challenges is to

create appropriate and persuasive messages that can lead to a change in knowledge, attitudes, and behaviour over time. Furthermore, messages are often delivered to large and heterogenous audiences and exposure to such messages is passive (49).

A Canadian example of an informational approach intervention is ParticipACTION (www.participaction.com), a social marketing and communication organization that for over 45 years has promoted awareness of the benefits of active living and developed supportive environments for physical activity. A recent cross-sectional study reports that approximately 20% of Canadians reported unprompted awareness of ParticipACTION and 82% reported prompted awareness. Canadians who were aware of this organization were more likely to have children, more education, higher income, and be inactive but with positive beliefs about physical activity. This study also examined whether awareness of ParticipACTION was associated with self-reported leisure-time physical activity and found a negative association. The campaign messages appeared to resonate better with inactive Canadians compared to active Canadians. These findings do not support the suggestion that people who are active are more attune to physical activity messaging. (50).

2.2.2 Behavioural and social approaches

Approaches that involve both behavioural and social domains help individuals to gain skills and attain behavioural changes that support the initiation and maintenance of physical activity into their daily routines. These programs are often delivered to people either in groups or by email, internet, mail, or telephone, or by all four means (44). The interventions are typically tailored to the participant's physical activity readiness to change, interests and preferences (51). They can use buddy systems, social support groups and behavioural contracts between the

participants and the program leaders as effective means to increase physical activity at the individual level (52). Interventions involving both behavioural and social changes require careful planning and coordination, well-trained staff members who can provide evidence-based information for the development, evaluation and implementation of the program, and sufficient resources to carry out the program as planned (44, 45).

In Canada the UWALK intervention is an example of community-wide, multi-sector online intervention targeting physical activity behaviour change (www.uwalk.ca). The UWALK major strategy is to encourage the use of physical activity monitoring devices to self-monitor daily physical activity (e.g., pedometers, electronic devices, smartphone applications). UWALK users can participate in the program as individuals, teams or communities, and engage in interactive challenges (e.g., climb North Twin Peak in 153 days) by virtually interact with UWALK members (45).

2.2.3 Policy and environmental approaches

Environmental and policy approaches are designed to provide environmental opportunities to develop a healthier lifestyle and ensure access to safe, attractive, and convenient places where people can be physically active (44). Interventions in this category are implemented and evaluated to positively impact the health of the entire population. Thus, these interventions are not directed to the individuals but to physical and organizational structures. Their goal is to increase physical activity at the population level by changing the social networks, the organizational norms and policies, the physical environment, and by facilitating the access to resources and facilities. These interventions can be expensive and lengthy and require skilled staff members (44).

For example, the Canadian initiative *#CycleON: Ontario's Cycling Strategy* (53) is a 20-years strategy (2013-2033) that was developed to encourage cycling in Ontario and improve safety for the cyclists who ride across the province. Their 2033 vision is to create a more bike-friendly Ontario by increasing understanding and awareness on the benefits of cycling, improving cycling infrastructure in communities, creating a safer cycling environment, and connecting cycling routes for more cycling tourism.

The availability of several effective physical activity interventions is encouraging; however, the acceptability and scalability to different populations should also be considered when designing and implementing interventions that aim to address physical inactivity on a large scale (54). Pedometer interventions appear to encompass many of those features that make an intervention successful (i.e., affordable, acceptable, effective), thus, there has been a growing interest in using pedometer interventions in both the clinical and research settings.

2.3 Pedometer-based physical activity interventions

A pedometer is a step counter device worn on the body that measures steps taken (55). Mechanical pedometers detect steps by using an horizontal spring-suspended lever arm which moves up and down as a result of a vertical acceleration of the hip (56). The modern electronic pedometers operate with Piezo technology. It is based on a micro-electromechanical system (MEMS) and have a 3-D sensor that captures all movements (i.e., antero-posterior, medio-lateral, and vertical). The system inside the pedometer then translates this information into steps (57). Pedometers are frequently used in research because they are relatively inexpensive, easily accessible, low-literacy friendly, and immediately understandable to users (56). The effects of

pedometer use on physical activity levels and health outcomes have been widely examined (58-61).

Bravata et al. (58) summarized the evidence on the association of pedometer use with physical activity and health outcomes among adults. Of the 26 studies included in the review, 8 were randomized control trials (RCTs) and 18 were observational studies. The mean intervention length was 18 weeks. In the RCTs, participants allocated to the intervention arm were asked to wear the pedometer and view their daily steps counts, while participants allocated to the control arm wore sealed pedometers with no access to their own steps counts. Results reported an increase in physical activity by 2,491 steps per day for the intervention group as compared to the control group. In observational studies pedometer users significantly increased their physical activity by 2,183 steps per day, as compared to their baseline. Health outcomes from all pedometer users in both RCTs and observational studies showed a decrease in body mass index (BMI) by 0.38 and a decrease in systolic blood pressure by 3.8 mm Hg. Also, results from the same meta-regression analysis reported that having a step goal such as 10,000 steps per day is an important predictor of increased physical activity.

Obtaining 10,000 steps is considered a reasonable and achievable goal of daily activity for healthy adults (62). According to the following cut points: 1) <5,000 steps/day= sedentary; 2) 5,000-7,499 steps/day= low active; 3) 7,500-9,999 steps/day=somewhat active; 4) $\geq 10,000$ 12,499 steps/day=active; 5) $\geq 12,500$ =highly active (62), individuals who accumulate between 8,000 and 11,000 steps/day are more likely to meet the physical activity guidelines and accrue optimal health benefits (62). According to the step-count translation for physical activity guidelines (63), walking for 30 minutes at a pace of 100 steps/minute (moderate-intensity physical activity) results in 3,000 steps accumulated per day (64), that when added to a

'sedentary' level of 5,000 steps/day produces a floor value of 8,000 steps/day. Adding extra 30 minutes, as recommended in some physical activity guidelines, produces a total value of 11,000 steps/day. Tudor-Locke et al. (62) conducted a review to consider "how many steps are enough?". Findings from this review show that several cross-sectional studies attempted to set up steps/day cut points relative to any health-related outcome. For example, McKercher et al. (65) reported that women who achieved $\geq 7,500$ steps/day had a 50% lower prevalence of depression than women taking $< 5,000$ steps/day. Dwyer et al. (66) show that simply adding 2,000 steps/day to the habitual 2,000 steps/day was associated with a waist circumference reduction of 2.8 cm in men, and 2.2 cm in women. Finally, Tudor-Locke et al. (67) used data collected in Australia, Canada, France, Sweden, and the USA to evaluate the optimal steps/day related to BMI-normal weight and overweight/obese. They suggested that the total number of steps/day related to a normal BMI in adults should range from 11,000 to 12,000 in men and from 8,000 to 12,000 in women.

The Australian "10,000 Steps Rockhampton" project (68) and the "10,000 Steps Ghent" project (69) are two examples of successful multi-strategy community-based interventions that used pedometers to increase physical activity around the theme of '10,000 steps/day - Every step counts'. Data from two years follow up survey collected in Rockhampton, a typical Queensland regional community, and in the matched regional Queensland town of Mackay, show a change in physical activity among the 1,281 participants who completed the survey. Specifically, in Rockhampton the percentage of women categorized as "active" increased by 5% (from 35.8% to 40.8%) compared with a decrease of 4.1% (from 47.1% to 43.1%) in Mackay. Among men, the percentage of men categorized as active decreased by 8.9% in Mackay (from 49.6% to 40.7%), compared with a change of -4.2% (from 49.0% to 44.8%) in Rockhampton (68, 70). Similar

results were found in a controlled pre–post design study, with data collected at baseline and 12-months later, comparing the intervention community of Ghent and the control community of Aalst (Belgium) (69). After one year, the intervention community reported a significant average increase of 896 steps/day while the control community showed a decrease of 135 steps/day. Additionally, the intervention community showed an 8% increase from baseline (42%) to follow up (50%) in the proportion of participants who reached the 10,000 steps/day goal. Positive effects of a pedometer-based physical activity intervention were also found in a Canadian pre-post quasi-experiment study (PEI-FSP) that evaluated pedometer-determined steps per day and changes in body mass index (BMI), waist girth, resting heart rate, and blood pressure in sedentary workers (71). The Prince Edward Island - PEI-First Step Program (PEI-FSP) was implemented in five workplaces with moderately–highly sedentary jobs. Physical activity (pedometer-determined steps per day) was compared before and after a 12-week intervention and participants were their own controls. Prior to the intervention, baseline ambulatory activity was measured using sealed pedometers that participants wore during waking hours for two workdays and one weekend day. Similarly, collection of anthropometric and health indicator data was completed at each workplace before the intervention. Steps per day increased from 7,029 at baseline to a plateau of 10,480 steps/day by 3.96 weeks of the intervention. Increased steps per day were associated with decreased heart rate and waist girth. However, increasing steps per day did not influence the magnitude of BMI decreases, which was related only to the baseline steps per day. Finally, a meta-analysis that examined the effects of pedometer interventions on weight loss show that those who participated in pedometer interventions reported an average weight loss of 1.27 kg from baseline with greater weight change being associated with interventions of

longer duration. The duration of the interventions ranged from 4 weeks to 1 year, with a median duration of 16 weeks (72).

Although, pedometer interventions appear to be effective at promoting health benefits and increasing overall levels of physical activity in adults, many factors can influence the physical activity participation during an intervention, including pedometer interventions. Thus, knowing and understanding the correlates of physical activity initiation and maintenance is important to best inform the planning and design of effective physical activity interventions (73).

2.4 Correlates of adoption and adherence of physical activity and walking: an overview

The adoption of, and adherence to physical activity, including walking, are associated with demographic, psychological, social and environmental factors (73). *Adoption* is defined as the beginning of an exercise program or regular physical activity (74). *Adherence* to physical activity is not consistently defined across intervention studies (75). Common definitions describe adherence as a percentage of total number of sessions attended, total duration (minutes) of physical activity participation, or percentage of data collected from self-report questionnaires. For example, most of the studies included in a systematic review of determinants of physical activity maintenance defined maintenance as practicing moderate-to-vigorous-intensity leisure physical activity at least 3-5 times per week for at least 150 minutes per week (76).

Key correlates of adoption and adherence have been categorized in groups (77) including: a) *demographic characteristics*: age, gender, ethnicity, socioeconomic status, education; b) *health-related and clinical factors*: chronic illness, poor health status; c) *psychological factors*: perception of barriers, enjoyment of physical activity, self-efficacy, self-

motivation, readiness to change physical activity behaviour, psychological health; d) *program-related factors*: physical activity frequency, intensity, duration; e) *Environmental factors*: built environment characteristics, weather.

2.4.1 Demographic characteristics

Studies show that physical activity decreases with advancing age, with larger decline in women than in men (78). However, sex differences in physical activity persist across all ages, with men showing greater levels of physical activity than women (79). Self-reported barriers to physical activity particularly relevant to women include lack of social support, lack of a partner, and number of children. Due to insufficient child care and lack of support from family and friends, women with young children at home are typically less active than women without children (80). Recommended levels of physical activity are often not achieved among ethnic minorities like Blacks, Hispanics, Asians and American Natives (81). For example, the 2008 CDC surveillance system data reported that 68% of Whites met the physical activity recommendation of 150 minutes of moderate-intensity activity per week, or 75 minutes of vigorous-intensity activity per week, compared to 57% of Hispanic and Black people (81). Important barriers to physical activity among minority groups include family needs, financial constraints, and for women in particular, family disapproval (82). Consistent evidence shows that lower social economic status, education or income are associated with lower levels of physical activity (83). For adults with lower education and lower income a limited understanding of the health benefits associated with physical activity and reduced access to physical activity facilities or self-care programs appear to be barriers for an active lifestyle (84). Among individuals with low socioeconomic status there are several reasons that might influence physical activity levels.

These include lack of financial resources to access physical activity facilities or to purchase home exercise equipment, financial constraints, lack of social support for a physically active lifestyle, lack of work flexibility, limited understanding of the health benefits of physical activity, and higher likelihood of living in a community with fewer recreational facilities or parks (85).

2.4.2 Health-related and clinical factors

Individuals with a chronic disease and overall poor levels of health are likely to become less physically active (86). Lack of physical activity can be an initiating factor of the chronic condition or the chronic condition can contribute to progressive low levels of physical activity that can lead to physical deconditioning (87). The incorporation of physical activity as part of the medical management plan for primary and secondary disease prevention can help to develop and maintain good health for the individuals at risk; for individuals with certain chronic disease (e.g., diabetes, cardiovascular disease), it can reverse the downward cycle and result in a potential life extension and quality of life improvement (88).

2.4.3 Psychological factors

A systematic review on physical activity adoption reports that self-efficacy, defined as confidence in personal abilities to be physically active on regular basis, was the main correlate of physical activity adoption in both men and women (74). Similarly, a systematic review and meta-analysis of factors impacting maintenance of physical activity (76) reported higher self-efficacy among maintainers compared to individuals who relapsed to physical inactivity (76). Furthermore, individuals who stay active tend to perceive fewer barriers to physical activity,

hold more positive attitudes, have higher levels of intention, and identify more positive consequences compared to those who stop physical activity (76). Finally, active and inactive individuals who believe they have control over their ability to perform physical activity and who expect health benefits from physical activity participation are more likely to engage in an exercise program (89).

2.4.4 Program-related factors

Aspects of the physical activity program, including frequency, intensity, duration, and location can influence the initiation and adherence of physical activity (77). For example, King et al. (90) compared the effectiveness of group-based programs with home-based programs in increasing levels of physical activity among sedentary adults. They found that home-based programs were more successful than group-based program at attracting adults who wanted to start being physically active. Furthermore, higher levels of participation in home-based programs were maintained for a longer period of time compared to the group-based programs. Participants reported that increased convenience and flexibility were important factors for the success of the home-based program (90). A longitudinal study including sedentary adults examined the adherence to walking 30 minutes a day at a frequency of 5-7 days per week (defined as high frequency) at an intensity of 45%–55% (moderate) of maximum heart rate vs. 3-5 days a week (moderate frequency) at an intensity of 65%–75% (high) (91). Results show that the prescription of high frequency of walking at a moderate-intensity produced better adherence to the exercise prescription compared to prescription of low frequency and high intensity exercise program (91). This finding aligns with the physical activity guidelines that recommend at least 30 minutes of moderate-to-vigorous-intensity physical activity at high frequency.

A 10-week intervention study compared the effects of short and long bouts of brisk walking in sedentary women (92). Participants were randomly assigned to either three 10-minute walks (short bouts) per day, one 30-minute walk per day (long bouts) or no training (control). Brisk walking was defined as walking at a speed between 1.6 and 1.8 mph – 2.6 and 2.9 kph. Short-bout walkers completed 128 sessions of the 150 prescribed. Long-bout walkers completed 44 sessions of the 50 prescribed. However, similar improvements in fitness were reported for short and long bout walkers. Considering the lack of time and competing priorities are the most reported barriers to physical activity adherence (79), short bouts of walking taken at intervals throughout the day might be an appealing and feasible goal more likely to result in higher levels of physical activity (93).

2.4.5 Socio-cultural factors

Having friends who regularly participate in physical activity (94), having social support from family members (e.g., spouse) or friends (95), and seeing other people engaging in physical activity (96) emerged as consistently important correlates of physical activity participation. In a cross-sectional study that examined the effects of social support from family and friends on maintenance of sufficient levels of physical activity for long term health benefits (definition of sufficient activity was based on physical activity and health guidelines; i.e., 150 min/week) (97) participants who reported low levels of social support from either family or friends were 23-55% more likely to be insufficiently active compared to those who reported high levels of social support (98). A multisite active counseling trial targeted inactive men and women from eight primary care settings in three clinical centers (California, Texas, Tennessee) to identify factors associated with success at achieving the Surgeon General's recommendation for physical activity

(99) (i.e., 150 min or more of moderate-to-vigorous physical activity per week at 24 months (100). Results show that participants who reported that they frequently saw people exercising in the neighbourhood were significantly more likely to be successful at achieving the recommendation at 24 months compared to those who reported that they did not frequently see people engaging in physical activity in the neighbourhood. The subgroup that reported not seeing people walking in the neighbourhood reported that the environment was not supportive of physical activity due to lack of safety, high levels of crime, presence of stray dogs, and few enjoyable sceneries (100).

2.4.6 Environmental factors

One aspect of the environment that is increasingly receiving research attention is the built environment, which refers to physical structures of the environment that have been made or modified by people (101). This includes buildings, open spaces, footpaths, cycle lanes, parks, and trails.

Evidence from systematic reviews shows that self-reported (perceived) and objectively measured characteristics of built environment have an influence on physical activity adoption and adherence (85, 95, 102-104). Objectively-measured characteristics positively associated with physical activity (including walking) include accessibility to places, population density, land-use mix, low crime rate (102), availability to physical activity facilities, proximity to destinations, and pedestrian infrastructure (105). For example, Sallis et al. (106) found that having pleasant scenery in the environment and living in a residential neighbourhood were positively associated with initiation of physical activity among older women. Negative associations were found for lack of crosswalks, and high volume traffic (107). Positive associations were also found between

self-reported environmental characteristics and physical activity (108, 109). These include perceived presence of sidewalks, footpaths, accessibility to local facilities (94), having more destinations within walking distance from home, living close to a park or pedestrian trails, feeling safe from traffic, living in a well-maintained neighbourhood (e.g., free from garbage, broken glass, litter) (110), having access to large open public spaces (109), nice aesthetics (108), residential density, land-use mix, street connectivity, safety from crime, and proximity to parks (111). Negative associations were found for high-speed cars, heavy traffic, lack of crosswalks and sidewalks (107).

Another environmental factor associated with adoption and adherence of physical activity is weather (112). Tucker et al. (113) conducted a systematic review on the effects of seasonality and weather on physical activity in eight different countries (Canada, USA, Australia, Cyprus, Scotland, The Netherlands, France and Guatemala) and found that levels of physical activity appeared to be higher in spring and summer. Decline in physical activity levels was associated with cold temperatures or extreme heat (temperatures were not reported). A Canadian cross-sectional study including adults found that in winter (January 1-March 31) 64% of Canadian adults were inactive as compared to 49% in summer (July 1- September 30). (114). A cross-sectional study conducted in Calgary, Canada (115) examined seasonal variations in different types of physical activity including walking for recreation (WR), walking for transportation (WT), moderate-intensity (MODPA) and vigorous-intensity physical activity (VIGPA). Overall, participants were more likely to report WR in summer, spring, and fall than in winter. Participation in WT was more likely in fall than winter. MODPA participation was more likely in summer than in winter, but significantly more likely for younger adults compared to older adults. Seasonal variations were not found in sufficient VIGPA overall. A longitudinal study

conducted in Canada (112) (Charlottetown, Prince Edward Island) including young adults (mean age 44 years) enrolled in a pedometer intervention found that small amount of rain (5 mm) decreased the steps/day by 5.2% and progressively by 8.3% with 14 mm from baseline. Increased steps/day were associated with increased temperatures, with a 2.9% increase for each 10° C increase in temperature. Occurrence of snowfall produced different changes in physical activity by gender and BMI. Males with a BMI between 20 and 35 kg/m² had a 21% increase in steps/day after 10 cm snowfall but heavier males (BMI >35 kg/m²) had no significant change in physical activity. Females with a BMI between 20 and 35 kg/m² had no change in steps/day and heavier women (BMI >35 kg/m²) experienced a significant decrease of approximately 10% (112).

Physical activity interventions should consider strategies to maintain regular physical activity in winter and when the weather is not supportive of outdoor physical activity.

2.5 Assessment of the built environment

Built environment characteristics can be measured using self-reported or objective measures (107, 116). Self-reported measures are collected through questionnaires, surveys, interviews that capture people's perception of the built environment. These tools have been developed to capture micro-scale features of the neighbourhood (e.g., safety, aesthetic, crime) and macro-scale features of the neighbourhood (e.g., perceived residential density, street connectivity, land use mix and accessibility to facilities).

In public health research, the Neighbourhood Environment Walkability Scale (NEWS) (117) is widely used to examine the relationship between the individual's perception of the neighbourhood design features and physical activity. This questionnaire assesses both social and

physical aspects inside the neighbourhood – defined as a 10-to-15-minute walk from home (117). It comprises 98 questions that cover eight subscales including residential density, land-use mix (diversity and access), street connectivity, walking/cycling trails, aesthetics, traffic safety, and crime safety (117). The NEWS has been validated in several countries, and multiple versions have been developed including an abbreviated version (NEWS-A) (118). The abbreviated version comprises 54 questions and covers the same eight subscales used in the long form questionnaire (118). Several studies have examined the reliability of the NEWS-A in adult samples. McCormack et al. (119) used a convenient sample (n=68) of Canadian adults to assess the test-retest reliability of self-reported neighborhood walkability and social support items. Although the subscales did not match the same as other studies that used NEWS-A, they found that NEWS-A had moderate test-retest reliability (.50 to .88) and low to acceptable Cronbach's alpha scores ($\alpha = 0.33$ pedestrian infrastructures to $\alpha = 0.77$ aesthetics). Similarly, Leslie et al. (120) assessed the NEWS-A reliability with a sample of Australian adults and reported that NEWS-A items had an acceptable test-retest reliability (.62 to .88). The NEWS or NEWS-A have also been adapted for other countries such as Nigeria (121), China (122), Poland (123), and Belgium (124) Moreover, a NEWS-North has been adapted and pilot tested in Ottawa for use in Canada and other countries with northern climates (125). The NEWS-North is a 70-items questionnaire including nine subscales assessing neighbourhood walkability: land use mix-access, street connectivity, walking facilities, winter walking, aesthetics, traffic safety, crime safety, residential density, land use mix-diversity. The NEWS-North has low to high internal consistency ($\alpha = .75$ safety from traffic and land use access to $\alpha = .60$ for pedestrian/bike comfort) and high test-retest reliability (.85 to .93) (125).

The objective measures of the built environment use different methods to collect

environmental data. Two common methods include neighbourhood audits, and Geographic Information System (e.g., Walk Score®). Briefly, neighbourhood audits involve a direct observation of the neighbourhood by the researcher using validated checklists (126). The Geographic Information System (GIS) is a system designed to capture, store, manipulate, analyze, manage, and present all types of geographical data (127). GIS-derived measures are obtained by combining information from publicly available data files (e.g., street data files) into easily understandable maps. The variables of interest (e.g., number of intersections) are calculated within predefined geographic areas (e.g., residential neighbourhoods) using appropriate software (e.g., ArcMap 10.1, ESRI, Redlands, CA). The GIS is a reliable method for the environment assessment (128). Walk Score® (www.walkscore.com) uses publicly available data to assign score to a location based on the distance to 13 categories of amenities. Each category is weighted, and points are assigned and summed to obtain a score between 0-100. A high Walk Score® is indicative of high walkability. Walk Score® is associated with other GIS assessments of the neighbourhood built environment walkability and has been associated with walking and physical activity (129, 130). The Walk Score® description of walkability has been defined based on the following score assignment: ‘Car-Dependent’ (Score: 0 to 24; Almost all errands require a car), ‘Car-Dependent’ (Score: 25 to 49; Most errands require a car), ‘Somewhat Walkable’ (Score: 50 to 69; Some errands can be accomplished on foot), ‘Very Walkable’ (Score: 70-89; Most errands can be accomplished on foot), and ‘Walker’s Paradise’ (Score: 90 to 100; Daily errands do not require a car) The Street Smart Walk Score® is the newest version of Walk Score® and includes measures of land use mix, population density, intersection density, road metrics, and walking routes to nearby amenities (www.walkscore.com/methodology.shtml).

2.6 Neighbourhood built environment and walking

2.6.1 Neighbourhood perceived built environment and walking

A positive perception of the built environment is associated with increased levels of physical activity and walking (108, 110, 131, 132). Findings from a meta-analysis (108) of the association between selected perceived environmental characteristics and physical activity indicate that the perceived presence of physical activity facilities, sidewalks, shops and services and perceiving traffic not to be a problem were positively associated with more walking (108). Booth et al. (94) examined the perceived environmental influences associated with physical activity in older adults. Physical environment characteristics were assessed by asking dichotomous (yes/no) questions on safety or difficulty of walking in the neighbourhood during the day, and about access to facilities (e.g., recreation centre, cycle paths, gym, park). Results show that perceiving footpaths as safe for walking was significantly associated with being sufficiently physically active to achieve health benefits. Giles-Corti et al. (109) conducted a cross-sectional study of adults stratified by socioeconomic status to examine the effects of objective and perceived access to neighbourhood facilities (i.e., presence of sidewalks, lit streets, parks, shops, public transport within walking distance from home) and recreational and transport walking. Geographic Information System (GIS) was used to objectively measure spatial access to recreational facilities. Perceptions of the environment were assessed using dichotomous questions on whether there were sidewalks in the neighbourhood, the street were lit, public transport stop stations, parks or shops were within walking distance from their home. Participants were more likely to walk for transport if they lived in an area with the highest access to attractive public open space and if they perceived that their neighbourhood had sidewalks, a shop within walking distance, and more traffic and busy roads. The likelihood of walking for

recreation was higher for participants residing in a neighbourhood with the highest access to the beach and those who perceived their neighbourhood as being attractive, safe and interesting, and that there was support for walking locally. A cross-sectional study involving areas selected among tracts in St. Louis MO (“low-walkable” city) and Savannah GA (“high-walkable” city) examined the associations between objective and perceived environment measures and transportation- and recreation-based walking. The physical and the social environment were assessed objectively through audits. Perceived neighbourhood measures were collected via telephone survey questions largely derived from a national assessment of the reliability of various questions and scales for measuring the physical and social environments (133). Results show that transportation walking was positively associated with objectively measured and perceived number of destinations and public transits, perceived access to bike lanes, and count of active people in the neighbourhood. Transportation walking was negatively associated with objective and perceived condition of the sidewalk (uneven) and perceived and objective neighbourhood aesthetics (presence of garbage, broken glass, litter, disorder). Only positive associations were found for recreational walking which included perceived access to recreational facilities and objective measures of attractive features (110). King et al. (134) collected data from a large-scale cross-sectional survey of physical activity in middle-aged women. For the environmental variables, participants were asked (yes/no) whether the following features were present in their neighbourhood: sidewalks, heavy traffic, hills, street light, unattended dogs, enjoyable scenery, frequent observation of people exercising, and high level of crime. They found that the neighbourhood characteristics of enjoyable scenery and friendly neighbourhood, presence of hills, and seeing others exercising in the neighbourhood were significantly associated with physical activity among middle-aged women. The same study reported that unattended dogs

was also positively associated with a physically active status. A Canadian cross-sectional study (135) explored gender differences in perceived environmental correlates of physical activity. Eight questions from the International Physical activity Prevalence Study Environmental Survey Module (136) were used to assess participants' perceptions of the neighbourhood. Results show that women compared to men were more likely to perceive their neighbourhood as unsafe for a night walk, and less likely to perceive easy access to physical activity facilities. Higher levels of leisure physical activity were associated with perceived access to physical activity and attractive neighbourhood for men, while for women increased levels of leisure physical activity were associated to access to physical activity places and seeing others being active. Finally, Sugiyama et al. (131) used data collected in 12 countries to examine the association between perceived neighbourhood characteristics and recreational walking, including frequency and duration of walking, in adults. The Neighborhood Environment Walkability Scale (NEWS) (117) or NEWS-Abbreviated (118) was used to collect perceptions of the environment. Perceived aesthetics, perceived safety from crime, and proximity to parks were positively related with recreational walking, while having few cul-de-sacs in the neighbourhood was negatively related. Participants who reported that the streets were well-connected, and the neighbourhood had a better aesthetic were more likely to walk frequently, and those perceiving higher residential density and mixed land use were more likely to walk longer.

The consistency of findings across 12 countries suggests that environmental interventions have the potential to be effective in increasing levels of physical activity and could apply to many countries.

2.6.2 Objectively-measured built environment and walking

Consistent evidence suggests that some measurable characteristics of the built environment are associated with physical activity and walking, including street or pedestrian connectivity, population density, land-use mix, proximity or density of destinations, aesthetics, personal and traffic (105).

A cross-sectional study that examined the association between residential density and street intersections with leisure-time and transport-related physical activity in the York Region (north of Toronto) found that residents living in a neighbourhood with the highest number of intersections were more likely to engage in walking or cycling for leisure, whereas higher residential density was associated with greater odds of engaging in walking or cycling for transportation (137). A longitudinal study reported that participants with many destinations near home (e.g., shops, restaurants, services, schools) and many street connections between residential and commercial districts were more likely to engage in more than 30 minutes of moderate-intensity physical activity per day (138). A study that undertook a secondary analysis of physical activity data linked to Geographical Information Systems (GIS) data found that the presence and mix of destinations (e.g., convenience store, bus stop, post box, shopping mall, and train station) within 400 m and 1500 m were positively associated with regular walking for transport. Residing within 400 m of a shopping mall was associated with participation in irregular but not regular walking for recreation. Whereas having a transit station located within 1500 m was positively associated with regular walking for recreation and having a beach within 1500 m was positively associated with irregular walking for recreation. This finding suggests that proximal-transport related destinations might encourage physical activity (139). A Canadian cross-sectional study examined different types of walking in relation to land-use mix. Results

report that the odds of walking for errands less than 1 hour per week were significantly increased when walking in residential land (e.g., all private and rental dwellings such as high rises, low rises, garden/town homes, and single detached homes) but significantly decreased in commercial land (e.g., businesses with retail sales and services and professional offices) (140). A large-scale observational study conducted in Australia found that attributes of neighbourhoods that include street connectivity and proximity to retail and commercial destinations were associated with residents' walking for transport, but not with walking for recreation. They also found that more walkable neighbourhoods were associated with more frequent weekly walking for transport, which suggests that in more walkable neighbourhood more shorter trips were required to reach destinations compared to less walkable neighbourhood (141). Associations between objectively-measured neighbourhood characteristics and physical activity were also observed when composite walkability indexes were used. For example, findings from a longitudinal study show that living in a high walkable neighbourhood increased the probability of moderate-intensity utilitarian walking by 4% and overall moderate-intensity utilitarian walking increased from 24% to 36% over the study period, with the highest increase (15%) for people living in the most walkable neighbourhoods (142).

Evidence to date suggests that objectively measured characteristics of the built environment are potentially important for supporting physical activity and walking. This evidence is useful to inform urban and transportation policy that focuses on improving neighbourhood walkability and creating healthy communities.

2.7 Neighbourhood built environment and physical activity in adults in Alberta

The association between the neighbourhood built environment and physical activity has also been examined specifically in Alberta. Several studies were derived from the EcoEUFORIA project (Economic Evaluation of using Urban Form to Increase Activity). The aim of EcoEUFORIA was to evaluate the cost-effectiveness of creating walkable neighbourhoods to support physical activity. McCormack et al. (143) investigated the association between objectively-measured neighbourhood walkability and local walking among adults. Three cluster-derived neighbourhood types (HW=high, MW=medium, LW=low walkable) were identified across all Calgary neighbourhoods. LW neighbourhoods on average had: 1) lower street connectivity, population density, sidewalk availability, mix of recreational destinations, available business destinations and bus stops, 2) slightly higher amount of open space, a greater mix of park types and more path/cycleway availability. MW neighbourhoods compared to LW on average had: 1) higher connectivity, sidewalk availability, mix of recreational destination and mix of park types; 2) more business destinations, bus stops; and 3) a lower mix of park types, and slightly less green space and path/cycleway availability. HW neighbourhoods compared to the other two types of neighbourhood on average had considerably higher: 1) connectivity, population densities, mix of recreational destinations, numbers of business destinations and bus stops and kilometers of paths/cycleways available, mix of park types, and path/cycleway availability; and 2) more business destinations and bus stops. Residents in MW and HW neighbourhoods were more likely than residents in LW neighbourhoods to engage in neighbourhood-based transportation walking. Residents in HW neighbourhood reported 30 min/week more on neighbourhood-based transportation walking than residents in MW and LW neighbourhoods. However, MW neighbourhood residents spent 14 min/week more on

recreational walking than LW neighbourhood residents. Jack et al. (144) found that residents of an objectively-measured high walkable neighbourhood perceived their neighbourhood to have greater access to services, street connectivity, pedestrian infrastructure, and utilitarian and recreation destination mix compared to residents of an objectively-measured low walkable neighbourhood. Moreover, residents of high walkable neighbourhoods were more likely to engage and spend more time per week in transportation walking. McCormack et al. (145) in a study with two random cross-sectional samples of adults in Calgary found that physical activity levels were higher for residents of HW neighbourhoods compared to residents in MW and LW neighbourhoods, with the exception of participants who were older than 60 years, overweight, or owned dogs. Toohey et al. (146) examined the association between dog-ownership, neighbourhood characteristics and walking among older adults (≥ 50 years old). They found that frequent dog walkers were more likely to achieve ≥ 90 min/week compared with non-frequent or non-dog walkers. Furthermore, participants living in a warped-grid neighbourhood had higher odds of achieving ≥ 150 min/week of recreational walking compared with those living in a grid neighbourhood (warped-grid = medium walkable; grid = high walkable). As part of the EcoEUFORIA project, research has been conducted in Calgary to define neighbourhood types and understand the relationships between urban form and physical activity (147). In Calgary three different street patterns (*grid*, *warped*, *curvilinear*) developed throughout urban development eras (148). The *grid block pattern* was the prevailing urban pattern since the city's establishment in 1883 until the Second World War. It includes many of the land uses of the city (e.g., residential, commercial, offices) with several corner stores. It offers high street connectivity and streets usually include treed boulevards and sidewalks on both sides. The *warped-grid block pattern* developed after the Second World War. This street pattern favours

crescents, cul-de-sacs and curved roads resulting in a less pedestrian connectivity compared to the grid pattern. It offers less treed boulevards and sidewalks are directly adjacent to the driving surface. Neighbourhoods with this street pattern are defined as residential area consisting primarily of single-family houses usually surrounding a centrally located elementary school. The *curvilinear pattern* is the newest street layout which typically consists of curvilinear streets with strip convenient stores and services, without sidewalks in one or both sides, with high-volume collector roads and limited pedestrian connectivity. McCormack et al. (149) in a study that was part of the Pathways to Health project examined the relationships between different types of physical activity (e.g., transportation and leisure physical activity) among three neighbourhood designs (grid, warped-grid, or curvilinear.) Physical activity was collected using the Past Year Physical Activity Questionnaire (PYT-PAQ), which captured frequency (count of months/year and days/week) and duration (minutes) of physical activity. Walkability of the 12 neighbourhoods included in the study (4 grid, 4 warped-grid, 4 curvilinear neighbourhoods) was estimated with Walk Score®. Participants from grid neighbourhoods were twice as likely to participate in transportation walking and cycling, and active transportation (any transportation walking or cycling). Furthermore, leisure cycling was more likely among participants residing in the grid neighbourhood than those residing in curvilinear neighbourhoods. While vigorous-intensity leisure physical activity was more likely among grid and warped-grid neighbourhood participants compared to curvilinear neighbourhood participants.

Qualitative and mixed methods studies have also reported similar results. Montemurro et al. (150) conducted a qualitative study in Edmonton to understand the residents' perceptions of neighbourhood walkability. Most of the participants described their neighbourhood as very or reasonably walkable, regardless of the objective neighbourhood walkability. Seasonal influence

(e.g., cold winters, limited sidewalk accessibility due to ice or snow), lack of sidewalk connectivity, and traffic-related safety were indicated as barriers to some type of walking or physical activity. Connectivity of the river valley trail system was reported as a facilitator of walking. Similarly, in a mixed methods study, Salvo et al. (151) showed that participants who reported the presence of greenery, nice aesthetics, safety, street connectivity, and opportunities to connect in their neighbourhood were motivated to participate in leisure walking and physical activity. The quantitative results of the study show that participants who moved from a low to higher walkable neighbourhood reported a slight increase in transportation walking, while those who moved from a high to a lower walkable neighbourhood on average reported little or no perceived change in their transportation walking after relocation.

2.9 The Impact of built environments on physical activity interventions

Despite a plethora of evidence on the relations between the built environment and physical activity few studies have investigated the neighbourhood built environment impacts on the effectiveness of physical activity interventions (105, 152). Physical activity interventions that take into account neighbourhood characteristics might also lead to more effective and long-term changes in physical activity.

For example, Merom et al. (153) conducted a 3-months randomized control trial and found that inactive adults who participated in a theoretically-based self-help walking program and used a pedometer were significantly more likely than controls to undertake regular walking even in low aesthetic neighbourhood. Kerr et al. (154) used data from two randomized control trials of web-based intervention for physical activity and diet behaviour change, one study involving overweight men, and the other study involving middle-aged overweight women (BMI

of at least 25 was considered overweight). Men in the intervention group living in a low walkable neighbourhood increased their daily walking by 29 minutes compared to baseline, while those living in a high walkable neighbourhood decreased their daily walking by 10 minutes. For women, the effects of objectively-measured walkability were not significant, but women who perceived their neighbourhood to be safer from traffic, and speed of traffic increased their walking by 22 min, and 17 minutes respectively. Gebel et al. (155) conducted a quasi-experiment with middle-aged adults to examine the different influence of a mass media campaign – Wheeling Walks - on people living in different neighbourhoods. Participants living in a high walkable neighbourhood who perceived presence of usable sidewalks increased their walking by 45 minutes, and by 87 minutes for inactive adults (i.e., those not meeting 150 min/week). Moreover, those in high walkable neighbourhoods were twice as likely to increase their walking by 60 minutes compared to those in low walkable neighbourhoods. Similarly, another quasi-experiment study with only women, reported that the objectively measured presence of indoor and outdoor recreational facilities was associated with 66% increase in adherence to a walking program (Women’s Walking Program) (156).

Conversely, Riley et al. (157) found that the effectiveness of a 12-week behavioural risk reduction intervention in a coronary heart disease high-risk sample was not influenced by Walk Score®. Similarly, Michael and Carlson (158) found that the physical activity supportiveness of the neighbourhood did not modify the effects of a neighbourhood-based walking intervention.

Physical activity interventions taking place in neighbourhoods may be beneficial for people residing in a high walkable neighbourhood, but not for those residing in a low walkable neighbourhood (159). If a physical activity intervention promotes physical activity among

residents in a high walkable neighbourhood but does not impact physical activity among residents in a low walkable neighbourhood, the intervention could indirectly contribute to health inequalities. A better understanding of the interrelations between physical activity interventions and built environmental opportunities is needed to develop more effective population and public health strategies for increasing physical activity.

2.10 Chapter 2 references

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Chapter 3: Effects of objectively-measured and self-reported neighbourhood walkability on adoption, adherence, and physical activity during an internet-delivered pedometer intervention.

3.1 Abstract

Background Accumulating evidence suggests that the built environment influences physical activity behaviours. The extent to which the built environment influences adoption for and adherence to interventions promoting physical activity is unclear. The aim of this study was to investigate whether the neighbourhood built environment constrains or facilitates physical activity following a 12-week internet-delivered pedometer-based physical activity intervention (UWALK).

Method The study was undertaken in Calgary (Canada) between May 2016 and August 2017. Inactive adult volunteers (n=573) completed a telephone survey capturing sociodemographic characteristics and perceived (self-reported) neighbourhood walkability. Following the survey, participants were mailed a pedometer and instructions for joining UWALK. Participants were asked to report their daily pedometer steps into the online program on a weekly basis for 12 weeks (84 days). Walk Score® was used as an objective measure of neighbourhood walkability. NEWS-A (Neighbourhood Environment Walkability Scale – Abbreviated) was used to capture the participants' perceptions of the neighbourhood. Regression models estimated covariate-adjusted associations of objective and self-reported walkability with the following outcomes: 1) UWALK adoption (early vs late activity initiation); 2) adherence to the intervention (count of days with steps and count of days with $\geq 10,000$ steps); 3) overall physical activity levels (pedometer steps, a measure of behaviour).

Results On average, participants undertook 8,565 (SD=3,030) steps per day, reported steps on 67 (SD=22.3) days, and achieved $\geq 10,000$ steps on 22 (SD=20.5) days. Adjusting for covariates,

one-unit increase in self-reported walkability was associated on average with 45.76 (95CI 14.91, 76.61) more daily pedometer steps. Walk Score® was not significantly associated with pedometer steps. Neither walkability measure was significantly associated with UWALK adoption or adherence outcomes.

Conclusion The neighbourhood built environment may support physical activity behaviour but not adoption of or adherence to physical activity interventions. Perceived walkability appears to be more important than objective walkability in contributing to intervention-enhanced physical activity. Strategies for targeting neighbourhood perceptions could improve the effectiveness of physical activity interventions.

3.2 Introduction

Regular walking can assist adults in achieving levels of physical activity recommended to obtain optimal health benefits (i.e., 150 minutes/week of moderate-intensity physical activity) (1). Walking is a no cost physical activity that has low impact and has a low risk of injury (2, 3), can be undertaken by most able-bodied adults, can be incorporated into daily living (e.g., active transportation) (4), and is the preferred activity for sedentary individuals initiating physical activity routines (5). Regular walking provides health benefits including increased physical fitness (6), cardiovascular disease risk prevention (7), weight loss (8), improved blood pressure management (9), and reduced depressive symptoms (10). Despite awareness of these health benefits, too few adults in North America (11, 12) and elsewhere (13) are accumulating enough physical activity (and walking) for optimal health.

Recognizing the importance of walking for health, several studies have investigated the impact of physical activity interventions, including pedometer-facilitated interventions, on walking (14-18). Adults enrolled in pedometer interventions experience an average increase of physical activity of 26.9% from baseline which translates to an average of 2,000 more steps per day (14, 19). Furthermore, participation in pedometer interventions is associated with an average increase of 30-60 minutes of walking per week (20). Pedometer interventions are effective at increasing physical activity in sedentary adults (21), with people with the lowest baseline steps per day reporting the greatest increases in physical activity (22).

Given the growing popularity of pedometers for promoting physical activity, several studies have investigated the factors contributing to the effectiveness of pedometer-facilitated interventions (14, 19, 20). To date, most of the success of pedometer interventions is attributed to strategies that increase awareness and motivation in users, and thus behaviour modification (e.g.,

self-monitoring strategies and goal settings). Although, it is rarely considered, the built environment may have an the impact on the success of physical activity interventions (23-25), including pedometer-facilitated interventions (26, 27). Considering the impact of the built environment on physical activity interventions is consistent with the socioecological model (28, 29), which posits that an individual's behaviour is the product of many interacting factors at multiple levels (e.g., intra-individual, inter-individual, physical environment, policy, culture).

Self-reported ("perceptions") (30-33) and objective (34-37) measures of the neighbourhood built environment, including individual features and composite measures (i.e., walkability scores) (38) are associated with physical activity. Neighbourhood features including street and sidewalk connectivity, residential density, proximity, mix of destinations and land uses, and pedestrian infrastructure are consistently associated with walking (39-45). Higher objectively-measured walkability (e.g., higher Walk Score®) are positively associated with physical activity (46-48) and walking (49, 50). Walk Score® appears to be more strongly associated with transportation versus leisure walking (51-53). Also perceived neighbourhood features, including presence of recreation facilities, sidewalks, shops and services and safety are associated with physical activity (30-33). Studies incorporating both self-reported and objective measures of the neighbourhood features often find stronger association between the former and walking (54-56), suggesting that examining both types of built environment measure is important.

Consistent evidence for the association between the neighbourhood built environment and walking, suggests that the neighbourhood built environment could also contribute to the effects of physical activity interventions (23-25), in particular pedometer interventions (26, 27). Although several qualitative studies found that the built environment may modify the effects of

pedometer interventions (57, 58), little quantitative evidence exists to support this hypothesis (26).

The aim of this study was to investigate whether the neighbourhood built environment constrains or facilitates physical activity following a 12-week internet-delivered pedometer-based physical activity intervention (UWALK) among adult Albertans. Specifically, we estimated the associations between objectively-measured walkability (Walk Score®) and self-reported walkability (Abbreviated Neighbourhood Environment Walkability Scale – NEWS-A) and: i) UWALK adoption; ii) UWALK adherence; and iii) pedometer-measured physical activity.

3.3 Methods

3.3.1 Study design and recruitment

We conducted a one-group longitudinal quasi-experiment during which initially inactive adults (≥ 18 years of age) were involved in a 12-week pedometer-based physical activity intervention (UWALK). Between May 2016 and August 2017, we recruited adult volunteers from 198 Calgary (Canada) neighbourhoods that belonged to a network of 147 community associations. We used community associations to advertise the call for study participants via their newsletters, websites, and social media (i.e., Facebook and Twitter). Advertisements with community associations were posted for 3 months. We tweeted recruitment details to members of the University of Calgary; City of Calgary; and Federation of Calgary Communities. Calls for study participation were also advertised in a free, widely distributed, local newspaper (Metro News). The call for participants listed the eligibility requirements for study participation and requested that interested adults email the research coordinator. The research coordinator telephoned participants to confirm their study eligibility, described the study, obtained informed

verbal consent (Appendix B), and where possible, administered a survey (Appendix C) or scheduled the survey at a different time. The survey captured sociodemographic, perceptions of the neighbourhood walkability, and health information. The University of Calgary Conjoint Research Ethics Board approved this study (REB15-2944) (Appendix F).

3.3.2 Study location

The study was conducted in Calgary, one of the major cities in Alberta, Canada. The average daily temperatures in Calgary range from 16.5 °C in July to −6.8 °C in December. Winters are cold and the air temperature can drop below −30 °C (59).

3.3.3 Study eligibility

Eligible participants included those who were at least 18 years of age, in the “contemplation” or “preparation” stages of physical activity behaviour change (60), not previously or currently enrolled in UWALK, reported no mobility issues preventing the proper use of a pedometer, and had internet access. To identify the stage of behaviour change, participants reported “true” or “false” to the following statements: 1) I currently do not participate in recreational or transportation-related physical activity; 2) I intend to participate in recreational or transportation-related physical activity in the next 3 months; 3) I am currently participating in recreational or transportation-related physical activity ≥ 3 days/week, and; 4) I have been participating in recreational or transportation-related physical activity ≥ 3 days/week for the past 6 months. Using a staging algorithm, contemplators responded true to statements 1 and 2 and preparers responded false to items 1 and 3 (61). Only one adult per household was eligible to participate. We directed non-eligible individuals to the UWALK website where they

could join UWALK without being monitored as part of this study. The sample included 573 adults.

3.3.4 UWALK intervention

UWALK is an online multi-strategy, multi-sector, theory-informed, community-wide approach intervention (www.uwalk.ca) to promote physical activity in Alberta, Canada (58). UWALK was modelled on other pedometer-based interventions (62, 63) that have been successful for increasing physical activity. The UWALK primary focus is on accumulation of daily steps and flights of stairs (10 steps/stairs are equivalent to 1 flight). UWALK participants are encouraged to use physical activity monitoring devices to self-monitor their physical activity (e.g., pedometers, electronic devices, smartphone applications). UWALK includes a website where participants record their pedometer steps and track their own progress. In addition, the UWALK intervention uses simple but established health promotion approaches for empowering individuals to walk as a mean of increasing their physical activity levels. For this study we used the existing UWALK promotional material and online infrastructure, and we provided the participants with a Piezo StepX pedometer. Upon completion of the survey, a study package was sent to the participant's residence. The package contained the pedometer, instructions on how to use and wear the pedometer, and instructions for the UWALK website (i.e., how to register and track physical activity) (Appendix D), a daily tracking sheet (Appendix E), and the UWALK promotional material.

3.4 Measures

3.4.1 UWALK intervention adoption and adherence

In relation to physical activity interventions, adoption has been defined as the beginning of an exercise program or regular physical activity (64). Conversely, the definition of physical activity adherence varies widely across studies (65). Studies have defined adherence as the percentage or total number of sessions attended, total duration (minutes) of physical activity participation, or percentage of data collected from self-report questionnaires (65). Despite these definitions, the measurement or operational definition of physical activity intervention adoption and adherence are inconsistent, and no gold-standard exists (66). Thus, in this study we used UWALK website engagement as a source of data for our adoption and adherence outcomes. We operationalized “early adopters” as participants who started walking within the first 6 days following completion of the survey and “late adopters” as those who started walking at least 7 days after the survey. We estimated level of adherence from the count of days the participant entered their daily steps in the UWALK website (at least 84 days = the total days of UWALK intervention), and the count of days with $\geq 10,000$ steps.

3.4.2 UWALK monitored pedometer steps (behaviour)

The Piezo StepX pedometer is a reliable and valid device (67). Written materials instructed participants to wear the pedometer on their hip and to wear the pedometer at all times except while sleeping, swimming, bathing, or engaging in contact sports. The instructions also requested participants to record their daily steps into the UWALK website for the entire 12 weeks (84 days). We provided participants with weekly step tracking sheets in case they were not able to enter their steps into the UWALK website daily. Based on previous studies (68), daily

steps less than 100 and above 50,000 were considered invalid and deleted. For each participant, we estimated mean daily steps for valid days only during the 12-week intervention. We also estimated the count of days that the participant achieved $\geq 10,000$ steps per day during the 12-week intervention. We used this cut-off because achieving 10,000 steps per day is associated with lower prevalence of depression (69), reduced waist circumference and BMI (70, 71), lower prevalence of adverse cardiometabolic risk factors (72), and an increased likelihood of achieving the recommended levels of physical activity (1).

3.4.3 Objectively-measured neighbourhood walkability

A Walk Score® was linked to each participant's household via their 6-digit postal code. Walk Score® is a publicly available objective walkability index and reflects the level of access to nearby walkable amenities. Specifically, Walk Score® estimates neighbourhood walkability based on proximity to 13 amenity categories (e.g., grocery stores, coffee shops, restaurants, bars, movie theatres, schools, parks, libraries, book stores, fitness centres, drug stores, hardware stores, clothing/music stores) (73). Walk Score® values range from 0 to 100 with low scores representing lower walkability and higher scores representing higher walkability. Walk Score® values less than 50 are labelled as car-dependent, while scores great than 90 are labelled as a Walker's paradise (74). Walk Score® is correlated with other comprehensive measures of walkability (75, 76) and is associated with walking and other physical activity (46-48, 75).

3.4.4 Self-reported neighbourhood walkability

We used the abbreviated Neighbourhood Environment Walkability Scale (NEWS-A) (77) to capture participants' perceptions of the supportiveness of their neighbourhood for physical

activity (neighbourhood defined as a 15-minute walk from home). The NEWS-A includes items that capture perceptions regarding neighbourhood residential density, connectivity, access to facilities and services, aesthetics, and safety. To ensure that the length of the telephone survey was manageable, only 24 out of 54 items from the original NEWS-A were included in our survey. All items captured responses on a 4-point scale (i.e., strongly disagree to strongly agree). We used an established algorithm for creating a composite walkability index (78, 79), whereby lower scores represent less perceived walkability, and higher scores represent higher perceived walkability. In our study, the lowest NEWS-A score was 38 and the highest was 96. The NEWS-A has acceptable reliability and validity (78), including among Canadian adults. The NEWS-A had acceptable internal consistency in the current sample (Cronbach's $\alpha=0.80$).

3.4.5 Sociodemographic characteristics and weather

During the survey, participants reported their age, sex, self-rated health (Poor, Fair, Good, Very Good, or Excellent), highest education achieved (High school diploma or less, College, vocation, or trade, University undergraduate, University postgraduate), gross household annual income (0 - \$39,000, \$40,000 - \$79,000, \geq \$ 80,000, Unknown), number of dependents \leq 18 years of age at home, dog ownership (owner, not a dog owner), and motor vehicle availability for personal use (Always/Sometimes, Never/Do not drive). We also collected daytime temperature and daily precipitation data (publicly available from Environment Canada for the Calgary international airport). These covariates were chosen because they have been associated with physical activity in past research (80, 81).

3.5 Statistical analysis

We summarized the data using means, standard deviations or frequencies. We compared sociodemographic and built environment characteristics of those who did with those who did not register in the UWALK intervention after the survey was completed using Pearson's chi-square (for categorical variables) and independent t-test (for continuous variables) to assess potential differences between groups. We estimated the associations of objective neighbourhood walkability (Walk Score®) and perceived neighbourhood walkability (NEWS-A) with UWALK adoption (binary logistic regression), days of adherence (negative binomial regression), days achieving $\geq 10,000$ steps (negative binomial regression), and physical activity in daily steps (linear regression). For the count of days with $\geq 10,000$ steps, we specified individual's total days as offset variable to model the count of days with $\geq 10,000$ steps (count over the total days of steps of each participant). We first fitted two separate models to estimate the effect of objective neighbourhood walkability and perceived neighbourhood walkability on each outcome of adoption, adherence, and physical activity. To assess collinearity between perceived and objective measures of walkability, we studied the Pearson correlation coefficient before model fitting and the variance inflating factor of the model including both independent variables. We adjusted regression models for all sociodemographic and weather variables. We kept all variables in the models, regardless of statistical significance, based on previous knowledge of associations. Therefore, we did not proceed with any reduction of the models. For all participants, we compared the first to the last reported week of average daily steps using a dependent sample t-test. Also, for participants who completed the UWALK intervention (12 weeks), we compared the first week with the last week of average daily steps using a dependent sample t-test (Appendix G). We planned to use the negative binomial regression if Poisson count

data were over dispersed (variance larger than the mean). From these models we obtained measures of association between walkability and outcomes: Odds Ratios (ORs; logistic regression); unstandardized beta coefficients (bs; linear regression); and incidence rate ratios (IRRs; negative binomial regression). Assumptions for all models were checked (e.g., linearity, independence, normality, homoscedasticity). We tested statistical significance with a significance level alpha set at 0.05 as cut-off and reported the 95 percent confidence intervals (95CI) for each measure of association. Stata version 13.0 (Stata Corp, TX) was used to conduct the analyses.

3.6 Results

3.6.1 Sample characteristics

Complete data were available for $n = 573$ participants, of whom $n = 466$ registered in UWALK ($n = 107$ did not register). Except for annual gross household income ($p = 0.02$), those who did and did not register in UWALK were not statistically significant different on all other characteristics (Table 1). Those who registered in UWALK were on average 49.15 years old (SD=14.40). Of these, 83% were women, 45% were in good health, 40% received university education, 32% had annual gross household income $\geq \$ 80,000$, had on average 0.71 child ≤ 18 years old at home (SD=1.07), 79% were not dog owners, and 91% had access to a motor vehicle. The mean (SD) Walk Score® and NEWS-A score among those registered was 44.66 (21.30), and 77.13 (8.90) respectively (Table 1). Walk Score® and NEWS-A score were correlated ($r = 0.17$, $p = 0.001$), low level of collinearity was present (VIF =1.00). The mean (SD) daily precipitation and daily temperature was 1.06 mm (0.72) and 3.62°C (8.50) respectively. The majority of the participants initiated UWALK between Sept 2016 (late summer) and May 2017 (mid spring).

Table 1. Estimates of sociodemographic and built environment characteristics for participants who completed the survey and registered in UWALK and participants who completed the survey and did not register in UWALK.

Characteristics	Category	Study participants (n=466) Mean (SD)	Did not register (n=107) Mean (SD)	<i>p</i> value
Age in years	==	49.15 (14.40)	50.11 (14.57)	0.53
Sex %	Female	83.05	77.57	0.18
Self-rated health %	Poor	3.86	8.41	0.07
	Fair	23.61	31.78	
	Good	44.85	37.38	
	Very good	23.82	17.76	
	Excellent	3.86	4.67	
Highest education completed %	High school diploma or less	15.02	17.76	0.92
	College, vocation, or trade	24.25	23.36	
	University undergraduate	40.13	38.32	
	University postgraduate	20.60	20.56	
Annual gross household income %	0 - \$39,000	13.09	16.82	0.02*
	\$40,000 - \$79,000	18.45	29.91	
	≥\$ 80,000	32.19	24.30	
	Unknown	36.27	28.97	
Number of dependents ≤18 years old	==	0.71 (1.07)	0.78 (1.16)	0.58
Dog owner %	Yes	21.03	16.82	0.33
	No	78.97	83.18	
Motor vehicle available for personal use %	Always/Sometimes	91.20	94.39	0.28
	Never/Do not drive	8.80	5.61	
Walk Score ®	==	44.66 (21.30)	44.28 (19.48)	0.87
NEWS-A ^a	==	77.13 (8.98)	75.98 (9.67)	0.24

Note: Independent t-test was used for continuous variables. Pearson Chi-square test was used for categorical variables.

^a The abbreviated Neighbourhood Environment Walkability Scale (NEWS-A).

*<.05; b: unstandardized.

3.6.2 Neighbourhood walkability and UWALK adoption

Approximately 40% of the participants (“early adopters”) entered step data in the UWALK website within 6 days of completing the telephone survey (Table 2). Adjusting for all covariates, neither Walk Score® nor the NEWS-A score was significantly associated with being an early adopter (Table 3). None of the covariates were significantly associated with UWALK adoption.

Table 2. Estimates of the response variables (n=466)

Response variables	Estimates
UWALK adoption 0-6 days % ^a	38.9
Days of steps entered in UWALK mean (SD)	67.2 (22.3)
Days with $\geq 10,000$ steps mean (SD) ^b	22.5 (20.5)
Pedometer daily steps mean (SD)	8565.3 (3030.8)

Note: UWALK is a 12 weeks intervention (=84 days).

^a Four missing data excluded from the analysis (n=462).

^b Twelve missing data excluded from the analysis (n=454).

Table 3. Logistic regression estimates (OR and 95CI) for the association between objectively-measured walkability (Walk Score®) and self-reported walkability (Neighbourhood Environment Walkability Scale – Abbreviated; NEWS-A) and UWALK adoption (n=462)^a.

	Walk Score® only OR (95CI)	NEWS-A only OR (95CI)	Walk Score® and NEWS-A OR (95CI)
Walk Score®	1.00 (0.99, 1.01)		1.00 (0.99, 1.01)
NEWS-A		0.98 (0.97, 1.01)	0.99 (0.96, 1.01)
Age in years	1.00 (0.99, 1.02)	1.00 (0.99, 1.02)	1.00 (0.99, 1.02)
Sex (<i>ref: Female</i>)	1.04 (0.62, 1.73)	1.05 (0.63, 1.76)	1.06 (0.63, 1.78)
Self-rated health (<i>ref: Poor</i>)			
Fair	0.94 (0.32, 2.81)	0.94 (0.32, 2.80)	0.93 (0.31, 2.78)
Good	1.16 (0.40, 3.34)	1.17 (0.41, 3.37)	1.16 (0.40, 3.36)
Very good	1.11 (0.37, 3.34)	1.17 (0.39, 3.52)	1.16 (0.39, 3.48)
Excellent	1.06 (0.25, 4.34)	1.10 (0.27, 4.50)	1.11 (0.27, 4.53)
Highest education completed (<i>ref: High school or less</i>)			
College, vocation, or trade	1.40 (0.73, 2.69)	1.40 (0.73, 2.70)	1.40 (0.73, 2.69)
University undergraduate	1.44 (0.78, 2.66)	1.44 (0.78, 2.67)	1.44 (0.78, 2.66)
University postgraduate	1.72 (0.87, 3.39)	1.74 (0.88, 3.43)	1.73 (0.87, 3.41)
Annual gross household income (<i>ref: 0 - \$39,000</i>)			
\$40,000 - \$79,000	0.78 (0.38, 1.60)	0.75 (0.37, 1.55)	0.76 (0.37, 1.56)
≥\$ 80,000	1.02 (0.52, 1.99)	1.02 (0.52, 1.97)	1.03 (0.53, 2.01)
Unknown	1.40 (0.74, 2.64)	1.34 (0.71, 2.53)	1.36 (0.72, 2.58)
Number of dependents ≤18 years old	1.06 (0.87, 1.28)	1.05 (0.87, 1.28)	1.05 (0.87, 1.28)
Dog owner (<i>ref: non-owner</i>)	0.91 (0.56, 1.48)	0.92 (0.57, 1.50)	0.93 (0.57, 1.51)
Motor vehicle available (<i>ref: Never/do not drive</i>)	0.96 (0.46, 2.02)	0.97 (0.46, 2.03)	0.99 (0.47, 2.08)
Daily mean temperature (Celsius) ^b	1.01 (0.99, 1.02)	1.00 (0.99, 1.02)	1.01 (0.99, 1.02)
Daily mean total precipitation (mm) ^c	1.00 (0.94, 1.06)	1.00 (0.94, 1.07)	1.00 (0.94, 1.07)

Note: UWALK adoption within 0-6 days from the baseline survey. Early adopters (n=180), Late adopters (n=282).

Odd Ratio (OR): Unstandardized; 95CI: 95 percent confidence interval; *p < .05; All models adjusted for all sociodemographic characteristics and weather.

^a Four missing data excluded from the analysis.

^b Mean temperature was based on the 12 weeks UWALK intervention for each participant.

^c Mean total precipitation refers to rain and snow.

3.6.3 Neighbourhood walkability and UWALK adherence

On average, participants entered steps in UWALK on 67.2 (SD=22.3) days out of the 84 days of the intervention (Table 2). Adjusting for all covariates, Walk Score® and the NEWS-A score were not significantly associated with count of days steps entered in UWALK (Table 4). Furthermore, none of the covariates were significantly associated with UWALK adherence.

On average, participants reported achieving $\geq 10,000$ steps on 22.5 (SD=20.5) days during the 84 days UWALK intervention (Table 2). Adjusting for all covariates, neither Walk Score® nor the NEWS-A score was significantly associated with count of days achieving $\geq 10,000$ steps (Table 5). In the fully-adjusted model, good and excellent self-rated health (compared to poor health; IRR = 1.9; 95CI 1.1, 3.2, $p = 0.02$, IRR = 2.1; 95CI 1.0, 4.2, $p = 0.04$), number of dependents ≤ 18 years old (IRR = 1.1; 95CI 1.0, 1.2, $p = 0.04$), access to a motor vehicle (IRR = 0.6; 95CI 0.4, 0.9, $p = 0.01$), and daily mean temperature (IRR = 1.0; 95CI 1.1, 1.0, $p = 0.01$) were associated with count of days achieving $\geq 10,000$ steps (Table 5).

Table 4. Negative Binomial regression estimates (IRR and 95CI) for the association between objectively-measured walkability (Walk Score®) and self-reported walkability (Neighbourhood Environment Walkability Scale – Abbreviated; NEWS-A) and count of days with steps entered in UWALK (n=466).

	Walk Score® only IRR (95CI)	NEWS-A only IRR (95CI)	Walk Score® and NEWS-A IRR (95CI)
Walk Score®	1.00 (0.99, 1.00)		1.00 (0.99, 1.00)
NEWS-A		1.00 (0.99, 1.00)	1.00 (0.99, 1.00)
Age in years	1.00 (0.99, 1.00)	1.00 (0.99, 1.00)	1.00 (0.99, 1.00)
Sex (<i>ref: Female</i>)	1.02 (0.91, 1.13)	1.02 (0.92, 1.14)	1.02 (0.92, 1.14)
Self-rated health (<i>ref: Poor</i>)			
Fair	1.09 (0.87, 1.36)	1.09 (0.87, 1.36)	1.09 (0.87, 1.36)
Good	1.22 (0.98, 1.51)	1.22 (0.90, 1.52)	1.22 (0.99, 1.52)
Very good	1.15 (0.93, 1.45)	1.17 (0.94, 1.47)	1.17 (0.94, 1.47)
Excellent	1.10 (0.82, 1.47)	1.12 (0.83, 1.49)	1.11 (0.83, 1.49)
Highest education completed (<i>ref: High school or less</i>)			
College, vocation, or trade	1.08 (0.94, 1.23)	1.08 (0.94, 1.23)	1.08 (0.94, 1.23)
University undergraduate	1.05 (0.93, 1.19)	1.05 (0.93, 1.19)	1.05 (0.93, 1.19)
University postgraduate	1.08 (0.94, 1.24)	1.08 (0.94, 1.24)	1.08 (0.94, 1.24)
Annual gross household income (<i>ref: 0 - \$39,000</i>)			
\$40,000 - \$79,000	0.94 (0.81, 1.08)	0.93 (0.80, 1.08)	0.93 (0.80, 1.08)
≥\$ 80,000	0.99 (0.86, 1.13)	0.99 (0.86, 1.14)	0.99 (0.86, 1.13)
Unknown	0.96 (0.84, 1.10)	0.96 (0.84, 1.09)	0.96 (0.84, 1.09)
Number of dependents ≤18 years old	1.02 (0.98, 1.06)	1.02 (0.98, 1.06)	1.02 (0.98, 1.06)
Dog owner (<i>ref: non-owner</i>)	0.92 (0.83, 1.02)	0.93 (0.84, 1.03)	0.93 (0.84, 1.03)
Motor vehicle available (<i>ref: Never/do not drive</i>)	0.87 (0.75, 1.05)	0.88 (0.75, 1.02)	0.88 (0.75, 1.02)
Daily mean temperature (Celsius) ^a	0.99 (0.99, 1.00)	1.00 (0.99, 1.00)	1.00 (0.99, 1.00)
Daily mean total precipitation (mm) ^b	1.00 (0.99, 1.02)	1.00 (0.99, 1.00)	1.00 (0.99, 1.00)

Incidence Rate Ratio (IRR): Unstandardized; 95CI: 95 percent confidence interval; *p < .05; All models adjusted for all sociodemographic characteristics and weather.

^a Mean temperature was based on the 12 weeks UWALK intervention for each participant.

^b Mean total precipitation refers to rain and snow.

Table 5. Negative binomial regression estimates (IRR and 95CI) for the association between objectively-measured walkability (Walk Score®) and self-reported walkability (Neighbourhood Environment Walkability Scale – Abbreviated; NEWS-A) and count of days with $\geq 10,000$ steps entered in UWALK (n=454)^a.

	Walk Score® only IRR (95CI)	NEWS-A only IRR (95CI)	Walk Score® and NEWS-A IRR (95CI)
Walk Score®	1.00 (0.99, 1.00)		1.00 (0.99, 1.00)
NEWS-A		1.01 (1.00, 1.02)	1.01 (1.00, 1.02)
Age in years	1.00 (1.00, 1.01)	1.00 (1.00, 1.01)	1.00 (1.00, 1.01)
Sex (<i>ref: Female</i>)	0.93 (0.71, 1.21)	0.92 (0.71, 1.19)	0.92 (0.71, 1.19)
Self-rated health (<i>ref: Poor</i>)			
Fair	1.32 (0.77, 2.24)	1.36 (0.80, 2.32)	1.37 (0.80, 2.32)
Good	1.89 (1.12, 3.17)*	1.90 (1.13, 3.19)*	1.90 (1.13, 3.19)*
Very good	1.56 (0.91, 2.68)	1.55 (0.90, 2.66)	1.55 (0.90, 2.66)
Excellent	2.16 (1.06, 4.39)*	2.08 (1.03, 4.22)*	2.09 (1.03, 4.23)*
Highest education completed (<i>ref: High school or less</i>)			
College, vocation, or trade	0.98 (0.70, 1.38)	0.98 (0.71, 1.37)	0.98 (0.70, 1.38)
University undergraduate	0.95 (0.70, 1.30)	0.96 (0.71, 1.31)	0.96 (0.71, 1.31)
University postgraduate	0.89 (0.62, 1.26)	0.88 (0.62, 1.26)	0.88 (0.62, 1.26)
Annual gross household income (<i>ref: 0 - \$39,000</i>)			
\$40,000 - \$79,000	0.70 (0.49, 1.01)	0.71 (0.50, 1.02)	0.71 (0.49, 1.03)
\geq \$ 80,000	1.06 (0.74, 1.51)	1.05 (0.74, 1.48)	1.05 (0.73, 1.49)
Unknown	1.02 (0.73, 1.43)	1.03 (0.74, 1.44)	1.04 (0.74, 1.44)
Number of dependents ≤ 18 years old	1.10 (1.00, 1.22)	1.11 (1.00, 1.23)*	1.11 (1.00, 1.23)*
Dog owner (<i>ref: non-owner</i>)	1.01 (0.79, 1.29)	1.01 (0.79, 1.29)	1.01 (0.79, 1.29)
Motor vehicle available (<i>ref: Never/do not drive</i>)	0.60 (0.41, 0.89)*	0.59 (0.41, 0.86)*	0.59 (0.41, 0.87)*
Daily mean temperature (Celsius) ^b	1.02 (1.01, 1.04)*	1.02 (1.01, 1.04)*	1.02 (1.01, 1.04)*
Daily mean total precipitation (mm) ^c	0.90 (0.71, 1.15)	0.90 (0.71, 1.13)	0.90 (0.71, 1.13)

Incidence Rate Ratio (IRR): Unstandardized; 95CI: 95 percent confidence interval; *p < .05; All models adjusted for all sociodemographic characteristics and weather.

^a Twelve missing data excluded from the analysis.

^b Mean temperature was based on the 12 weeks UWALK intervention for each participant.

^c Mean total precipitation refers to rain and snow.

3.6.4 Neighbourhood walkability and UWALK physical activity behaviour

On average, participants reported undertaking 8,565 (SD=3,030) steps per day during the UWALK intervention (Table 2). Adjusting for all covariates, NEWS-A score ($b = 45.8$; 95CI 14.9, 76.6, $p = 0.004$) but not Walk Score® ($b = 3.9$; 95CI -8.9, 16.9, $p = 0.5$) was associated with mean daily pedometer steps (Table 6). In the fully-adjusted model, excellent self-rated health (compared to poor health; $b = 2262.9$; 95CI 332.9, 4193.0, $p = 0.02$), number of dependents ≤ 18 years old ($b = 379.4$; 95CI 108.7, 650.1, $p = 0.01$), dog ownership ($b = 698.9$; 95CI 30.0, 1367.8, $p = 0.04$), access to a motor vehicle ($b = -1368.8$; 95CI -2393.3, -344.4, $p = 0.01$) and daily mean temperature ($b = 48.4$; 95CI 25.6, 71.2, $p = 0.001$) were associated with mean daily pedometer steps (Table 6). The differences between the average daily steps undertaken in the first and in the last week of the UWALK intervention were not statistically significant for those who completed ($t = -1.13$, $p = 0.26$), and did not complete ($t = 0.11$, $p = 0.92$) all 12 weeks of the UWALK intervention (Table 7- Appendix G).

Table 6. Linear regression estimates (b and 95CI) for the association between objectively-measured walkability (Walk Score®) and self-reported walkability (Neighbourhood Environment Walkability Scale – Abbreviated; NEWS-A) and pedometer-measured physical activity during UWALK (n=466).

	Walk Score® only b (95CI)	NEWS-A only b (95CI)	Walk Score® and NEWS-A b (95CI)
Walk Score®	6.87 (-6.05, 19.79)		3.98 (-8.98, 16.94)
NEWS-A		47.18 (16.71, 77.66)*	45.76 (14.91, 76.61)*
Age in years	2.23 (-18.63, 23.09)	3.04 (-17.61, 23.69)	2.78 (-17.91, 23.47)
Sex (<i>ref: Female</i>)	120.85 (-601.83, 843.52)	24.51 (-691.61, 740.62)	41.22 (-677.47, 759.93)
Self-rated health (<i>ref: Poor</i>)			
Fair	801.53 (-678.43, 2281.48)	860.45 (-605.91, 2326.81)	847.40 (-620.63, 2315.43)
Good	1369.85 (-65.34, 2805.03)	1364.55 (-57.40, 2786.50)	1354.58 (-68.77, 2777.92)
Very good	1230.29 (-265.36, 2725.93)	1134.59 (-347.73, 2616.92)	1110.53 (-374.93, 2595.99)
Excellent	2390.38 (446.16, 4334.61)*	2249.53 (321.37, 4177.69)*	2262.97 (332.93, 4193.01)*
Highest education completed (<i>ref: High school or less</i>)			
College, vocation, or trade	-501.82 (-1398.13, 394.48)	-484.97 (-1372.94, 403.00)	-492.08 (-1380.99, 396.83)
University undergraduate	-554.00 (-1389.00, 281.01)	-515.90 (-1342.81, 311.01)	-527.00 (-1355.29, 301.29)
University postgraduate	-440.02 (-1380.34, 500.30)	-423.29 (-1353.64, 507.05)	-439.63 (-1372.16, 492.90)
Annual gross household income (<i>ref: 0 - \$39,000</i>)			
\$40,000 - \$79,000	-704.75 (-1694.58, 285.08)	-640.66 (-1621.54, 340.22)	-623.58 (-1606.74, 359.57)
≥\$ 80,000	57.96 (-875.634, 991.56)	-10.01 (-929.03, 909.01)	23.57 (-902.592, 949.73)
Unknown	142.54 (-748.03, 1033.11)	208.43 (-670.87, 1087.73)	239.12 (-646.47, 1124.72)
Number of dependents ≤18 years old	370.86 (97.93, 643.79)*	376.13 (105.81, 646.45)*	379.44 (108.71, 650.18)*
Dog owner (<i>ref: non-owner</i>)	744.71 (70.98, 1418.44)*	689.40 (21.74, 1357.07)*	698.95 (30.09, 1367.82)*
Motor vehicle available (<i>ref: Never/do not drive</i>)	-1276.03 (-2307.1, -244.95)*	-1405.95 (-2422.53, -389.39)*	-1368.86 (-2393.32, -344.41)*
Daily mean temperature (Celsius) ^a	51.16 (28.28, 74.05)*	48.03 (25.31, 70.75)*	48.43 (25.66, 71.21)*
Daily mean total precipitation (mm) ^b	18.38 (-69.623, 106.39)	3.65 (-83.99, 91.28)	4.68 (-83.09, 92.44)
Intercept	7977.72 (5942.00, 10013.44)	4755.98 (1760.56, 7751.40)	4654.33 (1638.52, 7670.14)

Beta coefficient: Unstandardized; 95CI: 95 percent confidence interval; *p < .05; All models adjusted for all sociodemographic characteristics and weather.

^a Mean temperature was based on the 12 weeks UWALK intervention for each participant.

^b Mean total precipitation refers to rain and snow.

3.7 Discussion

Physical activity interventions, including those that promote walking (e.g., pedometer interventions) are effective for increasing physical activity levels in adults (14, 19). We examined the effects of the self-reported and objectively-measured neighbourhood built environment on physical activity following a 12-week internet-delivered pedometer-based physical activity intervention. Our findings show that one-unit increase in self-reported walkability was associated on average with 46 more daily pedometer steps. Conversely, the objectively measured neighbourhood walkability did not hinder or facilitate the walking behaviour among UWALK participants. The self-reported and objectively-measured neighbourhood walkability were not significantly associated with early adoption of, and adherence to the UWALK intervention.

Our finding of a positive association for the perceived walkability and no significant association for the objectively-measured walkability within models examining both measures of the built environment (perceived and objective) is consistent with other studies (82, 83). Perception of the built environment appears to be more strongly related to behaviour change than objectively-measured built environment characteristics (54, 84, 85). In a study conducted in Japan (82), adults who reported a positive perception of the neighbourhood were almost twice as likely to engage in leisure walking compared to those who reported a negative perception of the neighbourhood. The objective walkability was not associated with leisure walking. Similarly, among US adults, perceived walkability was associated with 12 more minutes of walking per week while Walk Score® did not produce any significant result (83). Studies (55, 84) that examined the concordance between similarly defined perceived and objective neighbourhood

characteristics revealed a low to moderate agreement between the two specific environment measures (objective and perceived). Similarly, in our study we found that NEWS-A and Walk Score® were weakly correlated which might suggest that these measures should not be used interchangeably (55) as they might capture different aspects of neighbourhood walkability and may influence walking behaviour in different ways (86, 87). In our study, the stronger contribution of the self-reported neighbourhood walkability compared to objectively-measured neighbourhood walkability might be related to the type of walking our participants chose to adopt during the 12 weeks intervention. Participants eligible for our study were adults in the “contemplation” or “preparation” stage of physical activity behaviour change who reported no participation in recreational or transportation-related physical activity in the six months prior the beginning of the study. Therefore, it is plausible that our participants were not practicing any habitual walking for transportation (walking to destinations like work, services and shops). As a result, leisure walking could have been the type of physical activity they consciously practiced during the 12 weeks intervention. This would be consistent with other studies that found that some perceived features (e.g., safety and aesthetics) are related to leisure walking (39, 88) while objective walkability is associated with transportation walking (89). Furthermore, we used Walk Score® to estimate the neighbourhood walkability. Although Walk Score® is a valid measure of accessibility to nearby amenities in urban neighbourhoods, one of its major limitations is that it does not account for built environment characteristics such as aesthetics, safety or presence of physical activity facilities, which are often perceived as important influences of leisure-time walking (90).

We found that living in a high walkable neighbourhood and having a positive perception of the neighbourhood were not associated with early adoption of the UWALK intervention. No other studies operationalized early adoption as our study. Studies that examined early adoption have referred to it as the initiation of a physical activity program or intervention immediately after the occurrence of a sudden illness or injury (e.g. spinal cord injury or venous thromboembolism (91, 92). Nevertheless, few studies have investigated the relationship between adoption of a physical activity intervention and neighbourhood environment characteristics (93, 94). Lee et al. (93) found that among African American and Hispanic or Latina women, traffic control devices and crossing aids contributed to physical activity adoption in the intervention group, while living in a neighbourhood with greater amenities was associated with higher likelihood of physical activity adoption among controls. Conversely, Sugiyama et al. (94) found that adoption of recreational walking was not significantly associated with objectively-measured and perceived attributes of green space. Lack of coherence among studies suggests that some characteristics of the neighbourhood built environment may be important resources to initiate a physical activity intervention, especially when these features support a specific type of physical activity (e.g., crossing aids and walking) (93). However, further investigation is needed to identify environmental characteristics that maximize the initiation of physical activity in different neighbourhood contexts. Furthermore, our findings suggest that the initiation of a physical activity intervention might require the interaction of the built environment with other factors involving the social and individual levels of influence (28, 29, 95). For example, the presence of a supporting family member or a friend might facilitate physical activity adoption within the neighbourhood (96, 97). Similarly, the success of physical activity adoption might be

influenced by the individual's motivation, self-efficacy and positive attitude toward physical activity (64, 98) which might also influence the perceptions of the neighbourhood (99, 100).

Living in a high walkable neighbourhood and having a positive perception of the neighbourhood did not appear to contribute to more days of walking or to a high number of days with $\geq 10,000$ steps among adults participating in the UWALK intervention. Our findings are inconsistent with other studies which reported positive associations between environmental factors and adherence to a physical activity intervention. Findings from a cross-sectional study (24) found that neighbourhood aesthetic and satisfaction with the ease and pleasantness of the neighbourhood was positively associated with more vigorous physical activity and with 30% more participants achieving the physical activity recommendations. Similarly, in a quasi-experimental study, the objectively-measured presence of public recreation centres and/or shopping malls (one or both) was associated with greatest adherence (percentage of prescribed walks completed) to a walking intervention among African American women (25). However, these studies only examined the self-reported or the objectively-measured built environment in relation to physical activity. On the contrary, Sugiyama et al. (94) examined both the self-reported and objective built environment and found that the perceived and the objective presence of more green space in the neighbourhood was associated with a higher likelihood of maintaining recreational walking over four years. In our study other environmental factors might have influenced the adherence to the UWALK intervention. Specifically, inclement weather or unfavorable outdoor conditions (e.g., ice on the ground) might have been perceived as a barrier to daily walking which resulted in less frequent walking or walks of shorter duration. The negative impact of weather on physical activity has been observed in other studies using pedometer-based interventions (101, 102) which reported lower counts of steps in winter

compared to other seasons. However, strategies can be adopted to increase adherence to a physical activity intervention. For example, Heesch et al. (103) describes how participants who were not achieving the recommended levels of physical activity, requested on how to cope with poor weather and how to obtain information on places where to walk in their community.

Our findings reported significant associations between several variables and pedometer-measured physical activity and adherence (count of days with $\geq 10,000$ steps). All associations were in the same direction as reported in other studies. Positive associations were found between pedometer physical activity and self-rated health (45), dog ownership (104), having children ≤ 18 years old (105), and daily mean temperature (106). A negative association was found between pedometer physical activity and access to a vehicle (107). Also, positive associations were found between count of days with $\geq 10,000$ steps and self-rated health (45), dog ownership (104), having children ≤ 18 years old (105), and daily mean temperature (106). A negative association was found between count of days with $\geq 10,000$ steps and access to a vehicle (107). These results suggest that the effects of the neighbourhood built environment on physical activity are more comprehensively explained when considering the influence of several factors (e.g., personal, social, and environmental). This is consistent with the socioecological model which posits that the individual's behaviour is the product of many interacting factors at multiple levels.

Our study has limitations. Our participants self-selected themselves into the study and the majority was middle aged, highly educated women with medium to high incomes.

Sociodemographic characteristics of volunteers might be different from those who do not volunteer for research studies (108). This might limit the generalizability of our findings.

Participants were asked to walk in their neighbourhood and report their steps in the UWALK website; however, tracking position devices were not used to monitor the location where our

participants walked. Participants might have walked outside their neighbourhood or accumulated their steps through activities inside their homes. In spite of these limitations related to the use of a natural environment for our study, the quasi-experimental design allowed us to address the research question with real-life responses. Moreover, it was a novel approach within the built environment and physical activity research area, which mainly uses cross-sectional studies. However, the quasi-experiment could have been stronger in determining a cause-and-effect relationship if the control group was included in the study design. Self-reported neighbourhood walkability data were collected prior to the intervention. Participants might have changed their perception over time or due to their participation in UWALK (109). Having self-reported neighbourhood walkability data collected at different points in time might have addressed our research question more accurately by observing the changes of physical activity levels as a function of the changes of built environment perceptions over time. Walk Score® was used to estimate the objectively-assessed walkability. Although Walk Score® does not capture all the attributes of the built environment, it is a publicly available website which is becoming widely used in health research. This might facilitate comparability of measurement across studies. In our database, data with less than 100 steps or more than 50,000 steps were considered invalid and deleted. Therefore, the count of days might have been underestimated and contribute the null results. Finally, we used daily steps count as a measure of physical activity. This measure has several valuable properties. It is an accurate and easily understood measure of physical activity. Step counts are easy to collect using pedometer or smart device, and they can be easily interpreted based on the established cut points for activity levels based on daily steps.

3.8 Conclusion

In summary, our study provides evidence about the intersect between individual-targeted (UWALK) and population-level (built environment) interventions and their influence on the behaviour of physical inactive adults. The neighbourhood built environment contributes to increased levels of physical activity, but not to the adoption and adherence of an internet-delivered pedometer-based physical activity intervention. Strategies targeting the individuals' perceptions of the neighbourhood (e.g., provide maps with walkable routes, suggest community events for physical activity participation) should be considered when designing physical activity interventions within different neighbourhood contexts.

3.9 Chapter 3 references

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Chapter Four: Conclusion

4.1 Summary of the findings

The purpose of this thesis was to contribute to the evidence on physical activity and built environment; in particular on how the neighbourhood built environment might influence the effectiveness of a physical activity intervention. In this thesis we examined the associations between the objective and self-reported neighbourhood walkability and the UWALK adoption, adherence, and levels of pedometer-based physical activity. Mechanisms and decision-making processes underlying our findings deserve some considerations.

4.1.1 Neighbourhood walkability and UWALK adoption

Physically inactive adults have the most to gain from increasing their physical activity levels, but they are often resistant to the adoption of physical activity (1, 2). We considered that the use of the neighbourhood and the involvement in a feasible and accessible physical activity, such as walking, had the potential to attract inactive adults to participate in a physical activity intervention. Self-reported and the objectively-measured neighbourhood walkability were not associated with UWALK early adoption in the fully adjusted model. Early adopters were operationalized as those who started walking within the first 6 days following completion of the survey and late adopters as those who started walking at least 7 days after the survey. We hypothesised that people residing in a high walkable neighbourhood with positive perceptions of their neighbourhood would be more likely to promptly start the intervention compared to those living in a low walkable neighbourhood and with negative perceptions of their neighbourhood. A plausible explanation to our null results is that the participants living in a more walkable neighbourhood may have not be aware of the available opportunities for physical activity

(presence of parks, sidewalks, access to amenities). As a result, the environmental advantage of living in a more walkable neighbourhood did not support a prompt initiation of UWALK (3, 4). In a qualitative study (5) that explored the decision-making processes underlying physical activity adoption, participants reported that unfamiliarity with their neighbourhood or insufficient information about the physical activity opportunities in the community represented important barriers to physical activity engagement as community members (5). Similarly, Lawton et al. (6) and Ollife et al. (7) highlighted that lack of knowledge about the geography of neighbourhood makes people more resistant to initiate any form of physical activity in the neighbourhood due to concerns related to personal safety. Knowing where to go for a walk can motivate inactive adults to explore the area around their home and access these places more frequently (4). To address this need, the inclusion of physical activity database in online interventions has been suggested as a way to promote adoption and maintenance of physical activity.

A limited number of studies investigated the factors influencing adoption of physical activity interventions in community samples and the majority of these studies focussed on psychological processes (8). Our study contributes in a novel way to the literature on physical activity intervention adoption as it focussed on the influence of the neighbourhood built environment. However, further evidence is needed to understand the environmental contribution for physical activity adoption to best inform the promotion of physical activity interventions.

4.1.2 Neighbourhood walkability and UWALK adherence

When considering UWALK adherence as count of days with steps, we found that, on average, participants reported 67 days of steps in UWALK out of 84 days intervention. Neither

self-reported nor objectively-measured neighbourhood walkability was associated with UWALK adherence. Adherers were operationalized as those who entered at least 84 days of walking into UWALK. Our findings appear to be inconsistent with other reports, which found that urban green spaces, gardens, flowers, and trees convey a sense of enjoyment that motivates people to be outside and be physically active, especially for walking in leisure-time (5). Furthermore, the availability of environmental cues, such as proximity to parks, well-maintained walking tracks, and exercise equipment appear to facilitate the formation of physical activity habits and motivate adults to engage in regular physical activity (9). Qualitative accounts of physically inactive adults may help explain the null results for the association between neighbourhood built environment and UWALK adherence. Arnautovska et al. (3) interviewed adults involved in a physical activity program and found that nearly all participants reported that competing priorities (e.g., work commitments, family needs, home chores) interfered with adherence to a physical activity intervention. In particular, unstructured physical activity programs (e.g., dedicating a block of time within a day for physical activity) pose unique decision-making challenges compared to structured programs (e.g., a set time for a structured program in a particular location) because participants need to determine when and where to engage in physical activity and self-motivate themselves to be regularly active (10). Although our participants were asked to report their daily pedometer counts, it is plausible that they overestimated their ability to walk every day for 12 weeks (due to competing priorities) and as result they might have set a more feasible goal (e.g., 3 days a week instead of every day) that could be sustained for the entire intervention. While this supposition requires further investigation, it echoes previously reported findings showing that setting individualized goals is a successful strategy to maintain physical activity in sedentary individuals, as they are more personally relevant, easy to adjust, and likely

to endure in the long-term (11). It is also been reported that intrinsic goals (e.g., opportunity for challenge, self-improvement) are instrumental for long-term commitment to a physical activity program, whereas extrinsic goals (e.g., satisfying others' recommendations) seem to be more important for the initiation of a physical activity intervention (12). Alternatively, it is also possible that our participants decided to adjust to more realistic goals to be able to commit to the research study (external goal). Larson et al. (13) and McCormack et al. (14) reported that participants who expressed a sense of responsibility for contributing to science developed strategies to facilitate their adherence to the intervention. To note, the two studies differed in their type of intervention, the former was a year-long structured exercise program in which inactive adults exercised three times per week in a private university fitness facility, whereas the latter was a 12-week pedometer-based physical activity intervention also involving inactive adults. Interestingly, for the structured exercise program it was reported that the strategies adopted to be more physically active during the intervention were discontinued upon completion of the intervention. Conversely, in the pedometer intervention, it appears that these strategies were progressively integrated in the participants' daily routine. This finding suggests that participants involved in unstructured interventions might take longer to fully adhere to a program, but the formation of habits for regular physical activity might be favoured in free-living interventions compared to structured interventions (15, 16). Further research is needed to gain a deeper understanding on what people should do in order to stay physically active even after the completion of an intervention.

In our study, adherence was also measured as count of days with $\geq 10,000$ steps. Our results show that on average participants reported achieving $\geq 10,000$ steps on 22.5 days during the 84 days of UWALK intervention. Objectively-measured and self-reported neighbourhood

walkability were not significantly associated with count of days with $\geq 10,000$ steps. The goal of 10,000 steps derives from a Japanese marketing campaign used to sell pedometers (17), however there is limited evidence-based information on how many daily steps are needed for health benefits in individuals who are not physically active (18). Our participants were recruited in our study because they were in a stage of contemplation or preparation for physical activity. It is therefore plausible that the 10,000 steps/day goal was an unattainable goal at least at the beginning of the UWALK intervention. Moreover, despite the UWALK promotional material and the website encouraged participants to set their default daily steps goal at 10,000 steps per day, we did not measure how effective this promotional message was on our participants, it is therefore possible that lack of active and meaningful messaging to the UWALK users might have limited their understanding on the benefits linked to the 10,000 steps goal (19). Despite we did not find significant results associated with the 10,000 steps goal, it is important to highlight that recent studies have investigated the health benefits associated with different cut points of daily steps (e.g., 5000, 7500 steps/day) and found that a lower amount of daily steps is associated with health benefits. For example, Lee et al. (18) examined the associations of number of steps per day and all-cause mortality in a cohort study including 18,289 U.S. women. Walking 4,400 steps per day was associated with a 41 % reduction in mortality rate compared with walking approximately 2,700 steps per day. Furthermore, steady declines in mortality rates were observed with more steps accrued up to approximately 7,500 steps per day, beyond which rates leveled. Dasgupta et al. (20) conducted a randomized trial to examine the effects of physician delivered step count prescriptions and monitoring on physical activity and health improvements in patients with type 2 diabetes or hypertension or both. The aim of the study was to achieve an increase of 3,000 steps/day from baseline to 1-year intervention, which is roughly equivalent to 30 minutes

of walking at moderate intensity. The physician-delivered step count prescription increased the daily step counts by approximately 1,200 steps from the baseline of 5,000 steps/day over 1 year. The 20% increase of daily steps was associated with improvements in haemoglobin A1c (0.38% reduction) and insulin resistance (0.96% reduction). Yates et al. (21) examined the relationship of daily step counts to cardiovascular events (i.e., cardiovascular death, nonfatal myocardial infarction, or nonfatal stroke) in a population at risk for type 2 diabetes and found that compared to baseline step count (5,892 steps/day) each 2,000-daily-step increment up to 10,000 steps was associated with a 10% lower cardiovascular event rate, and with 8% yearly reduction in cardiovascular event rate. These findings suggest that reaching 10,000 steps might be a difficult goal to attain in individuals with chronic diseases or health conditions, however it is encouraging that health benefits can be accrued with lower number of daily steps per day.

4.1.3 Neighbourhood walkability and UWALK physical activity behaviour

Participants reported undertaking on average 8,565 steps per day during the UWALK intervention. The steps count in our study is similar to the 2007-2009 Canadian Health Measures Survey (CHMS) which reports that Canadian men on average walk 9,500 steps per day, and women 8,400 steps per day (22). However, we collected steps using pedometers which are less accurate in steps counting than accelerometers, especially at low speed (23). Therefore, our results might be slightly underestimated compared to the national reports.

For the association between self-reported and objectively-measured neighbourhood walkability and pedometer-measured physical activity, we found that, on average, there were 45 more pedometer steps per day associated with the self-reported neighbourhood walkability, but no association was found with the objectively-measured neighbourhood walkability. Our

findings are consistent with other studies that only examined the effects of the perceptions of the built environment on physical activity interventions (24-27). Two quasi-experimental studies that assessed the effects of a community-based intervention on physical activity report evidence for a linear trend in increased walking levels among those living in environments that were perceived as having good access to destinations, sidewalks, places to rest, high connectivity, and a lot of other walkers using the neighbourhood infrastructures (24, 28). Similarly, an observational (29) and a prospective study (30) investigated the moderating effect of the built environment on physical activity and found that participants who reported safer neighbourhoods had greater increases in physical activity. Although these findings support the role of the perceived built environment on the effectiveness of physical activity intervention, it should be highlighted that only self-reported measures of neighbourhood characteristics were used in these studies.

Importantly, other studies that assessed the effects of both objective and self-reported environmental measures reported findings similar to ours. Perceptions of the built environment appear to be more strongly related to behaviour change than objectively measured built environment characteristics. For example, in a randomized 6-month neighborhood-based trial, Michael et al. (31) found that the objectively-measured neighbourhood walkability did not moderate the intervention effects, whereas the perception of neighbourhood problems was associated with an increase in levels of walking. Although this result appears counterintuitive, a plausible explanation was that regular walkers were more familiar with problems in the neighbourhood and thus more likely to report these problems. Conversely, infrequent walkers were more likely to report neighbourhood problems (e.g. stray dogs) as a barrier to their physical activity participation (29). Contrary to our expectations, the objectively measured neighbourhood walkability did not significantly influence the levels of physical activity among UWALK

participants. A positive linear association between perceived walkability and walking was observed regardless of the objective level of walkability of their residing neighbourhood. It is therefore possible that the positive perceptions of the neighbourhood walkability buffered the effects of an unsupportive environment (32). While this supposition requires further investigation, similar findings were reported elsewhere. For example, a prospective study explored the effects of the objectively-measured and self-reported neighbourhood built environment on walking time using data from two randomized controlled trials of one year, web-based physical activity intervention (33). One study included middle-aged, overweight women. The other study included middle-aged, overweight men. Women in the intervention group who perceived their neighbourhood to be safer from car traffic and who perceived the speed of traffic in the neighbourhood to be safe increased their walking time by 22 minutes and 17 minutes respectively from baseline to twelve months compared to the control group. Although no significant results were found for the objectively-measured walkability, women in the intervention group living in a low walkable neighbourhood reported the highest increase in walking time from baseline to 12 months compared to women in the intervention group living in a high walkable neighbourhood or women in the control group. Similarly, men in the intervention group living in objectively-measured low walkable neighbourhoods increased their walking time by 29 minutes from baseline to 12 months compared to those in the intervention group living in high walkable neighbourhoods who decreased the walking time by 10 minutes. This may mean that individuals who were living in a less walkable neighbourhood learned to overcome environmental barriers and increased their walking despite these challenges.

In summary, our findings show that perceptions of the walkability of the neighbourhood built environment influence the effectiveness of walking interventions. Online interventions, similar to UWALK might benefit from including interactive maps displaying walkable routes or places to go for physical activity or inform the participants about physical activity events happening in their neighbourhoods. These findings also suggest that urban design policies that aim to improve the aesthetic and safety of the neighbourhoods, as well as accessibility to places have the potential to improve the effectiveness of physical activity interventions and eventually impact the population health. Finally, our study provides evidence that is consistent with socioecological models that emphasize the interaction between individuals and their social and physical environment. The neighbourhoods where our participants walked appear to have positively influenced the levels of physical activity during the UWALK intervention.

4.2 Strengths and Limitations of the thesis

The strengths and limitations of the study were briefly described in chapters 3. Nevertheless, there are other considerations that should be highlighted to evaluate the internal and external validity of this thesis. The strengths of this thesis include the study design and the validity and reliability of the instruments for measurement. The limitations concern the volunteer bias, lack of control group, sample size, and unmeasured confounders.

4.2.1 Strengths

4.2.1.1 Study design

One of the primary strengths of this thesis is the incorporation of a quasi-experimental study design to evaluate the effectiveness of the UWALK intervention. This is a novel approach considering that the association between the built environment and physical activity has been

predominately examined within cross-sectional studies. Cross-sectional study designs provide a snapshot of the relationship between the exposure and the outcome, but causal relationships are difficult to derive within this study design (due to lack of temporal sequence between the exposure and the outcome). Based on Bradford-Hill criteria (34), temporality is one of the nine criteria proposed to determine a cause-and-effect relationship. Study designs, like RCTs or quasi-experiment fulfil this criterion better than observational study as the exposure precedes the outcome. Thus, to investigate the causal relationship between the neighbourhood built environment and the effectiveness of the UWALK intervention, a natural experiment (e.g., quasi-experiment) appeared to be more appropriate (35). Natural experiments are defined as studies that resemble true experiments but lack random assignment of participants to intervention groups. The researcher does not, and usually cannot, manipulate the intervention exposure or event (36). In our study, participants were not randomly allocated to neighbourhoods with different levels of walkability and an estimation of their neighbourhood walkability was conducted after their enrollment in the study. The exposure to the neighbourhood occurred before the participants were exposed to the UWALK intervention, therefore our study findings appear to provide a temporal evidence of the effects of the neighbourhood built environment on the effectiveness of the UWALK intervention. Moreover, this quasi-experimental study occurred in real-world conditions and therefore produces evidence that could best inform policy and decision-makers involved in the development and implementation of public health intervention and policy (37). The findings of this thesis can be used to inform policy changes for modification of neighbourhood environments so that they can be more supportive of physical activity and improve the effects of physical activity interventions.

4.2.1.2 Validity and reliability of the measures

An additional strength of this thesis is the use of valid and reliable instruments to measure physical activity, self-reported walkability, and the objectively-measured neighbourhood walkability. Measurement validity is defined as the extent to which an instrument measures what it purports to measure (38). Reliability refers to the consistency of a measure of a concept or a variable (38). The use of valid and reliable instruments reduces the likelihood of systematic and random errors that can threaten internal validity. In our study, levels of physical activity were measured with the Piezo StepMX pedometer. Its validity for measuring step count was examined with a convenient sample of 40 participants during a treadmill walking and running. Participants were wearing the StepMX pedometer and two other commercially available physical activity monitors (i.e., Yamax DigiWalker pedometer, Actical accelerometer). The mean measurement bias for the StepMX was lower compared to the other two devices. (39), which demonstrated that the StepMX pedometer is a valid tool that can be used to measure step counts. One source of error for a waist-worn pedometer, such as the StepMX, is slow walking speed which might result in an underestimation of the step counts. Most waist-worn pedometers are very accurate at speeds of 3.0 mph (80.4 m/min) or above. At lower speeds of 2.0 mph the accuracy is reduced to 75%, and at 1.0 mph they hardly capture any step. The StepMX has been validated also in older adults (mean age 81.5) with slow walking. Participants were asked to wear the StepMX, an accelerometer (ActiGraph GT3X+), and a mechanical pedometer (Yamax SW200) during a 100 m walk. A significantly lower percentage of error was reported for the SC-StepMX compared to the other devices (40). Another source of error with waist-worn pedometers might occur when the device is not properly positioned on the hips. To minimize this error type, we provided clear instructions to the participants about how to wear the pedometer.

The participants' perception of neighbourhood walkability was captured with the Neighbourhood Environment Walkability Scale – Abbreviated. The original NEWS was developed to assess neighbourhood environment characteristics hypothesized to be related to physical activity. The identification of the NEWS subscales was informed by evidence in the transportation and urban planning. Most of the NEWS subscales reported a test–retest reliability above .75, which is a high level of consistency (41). The validity of NEWS was evaluated with a multilevel confirmatory factor analysis which reported significant results for all the subscales included in the NEWS long version (42). The development and the validity of the short version NEWS-A was assessed in several cross-validation studies (43).

The objectively-measured neighbourhood walkability was estimated by linking the 6-digit postal codes captured from UWALK registrants to Walk Score®. The validity and reliability of Walk Score® have been assessed through geostatistical field validation studies that examined how Walk Score® corresponds with objective measures of the built environment. Three validation studies, one conducted in Rhode Island (44, 45), one including five highly urban regions of the United States (46, 47) and one conducted across three Canadian centres (48) reported that the Walk Score® metric provides a geographically valid assessment of walkability, which is comparable to more resource-intensive data collection methods.

4.2.2 Limitations

4.2.2.1 Volunteer bias

Our sample of adults self-selected themselves to participate in our study, introducing a possible volunteer bias. Volunteer bias can occur when the subjects who volunteer to participate in a research project are different in some ways from the general population. Volunteer bias is a type of systematic error due to a defect in study design that affects participation in the study (49). Our study was advertised through community newsletters, social media, and local newspapers. Individuals who were interested in our study contacted the study coordinator and eligible volunteers were included in the study. Those individuals who completed the telephone interview were included in the study. Participants were mainly middle-aged, Caucasian, tertiary-educated and middle-class women. Lack of ethnic and socio-economic diversity, and poor representation of men and different age groups, limits the generalizability of our findings. To note, findings from a systematic review that evaluated the sociodemographic characteristics of participants in physical activity intervention trials, show that individuals who participate in physical activity intervention studies are generally Caucasian, women, healthy but sedentary, middle-aged and tertiary-educated (50). These results emphasize the need for a better representation of the general population into physical intervention studies, but it also highlights that comparison between physical activity intervention studies might be easier due to similarity with the sample characteristics.

4.2.2.2 Lack of control group

Our study did not include a control group (i.e., participants who did not receive the UWALK intervention). However, the aim of this study was not to test the effect of UWALK.

Instead, we wanted to assess the impact of the built environment on the expected effects of the intervention (i.e., UWALK adoption, adherence, and pedometer-measured physical activity). According to our study design, participants all received the intervention and comparisons were made across levels of exposure (objectively-measured and self-reported neighbourhood walkability). We acknowledge that the lack of controls does not allow assessment of the effect of the exposure by receipt of intervention and possible effect modifications. Thus, associations may reflect both selection at the level of sampling (i.e., volunteer bias) and the effect of the exposure. Finally, since participants were not randomly assigned to a level of exposure, exposure groups may differ in ways that this type of design may not capture and the associations we found may be confounded.

4.2.2.3 Sample size

The final study sample size was $n=466$, after removing participants with incomplete covariate data. There were 10 covariates, some with multiple levels of responses (e.g., levels of education, household income). Our relatively small sample size might have reduced the power to detect associations actually present and increased the risk of Type II errors (failing to reject a null hypothesis that is false). A small sample size might also have contributed to wide 95% confidence intervals (CI) which indicate less precise results. Therefore, it is important to be careful before making any strong conclusions on the effects of self-reported and objectively-measured neighbourhood walkability on effectiveness of the UWALK intervention. Effective recruitment strategies to maximize the sample size should be considered in future studies.

4.2.2.4 Unmeasured confounding

The study of this thesis incorporated a quasi-experimental design which means that there was no random assignment to condition. A lack of random assignment results in a lack of control of pre-existing factors that could lead to unmeasured confounding. Confounding is defined as a distortion by a third variable in the estimated measure of the association between the exposure (e.g., neighbourhood built environment) and the outcome (e.g., pedometer-measured physical activity) (49). A confounder is an independent risk factor for the outcome of interest that is associated with the exposure and the outcome of interest, but it is not part of the causal pathway between the exposure and the outcome (49). There are two types of confounders: measured (i.e., can be adjusted for in analysis) and omitted or yet to be known (not accounted for in the study). A potential unmeasured confounder is knowledge and experience with online interventions. Participants who were unfamiliar with the UWALK website or found it difficult to navigate might have limited their use or entered the data irregularly or erroneously. Another potential unmeasured confounder is built environment modifications in the neighbourhoods selected in our study (e.g., sidewalks improvements, construction of pedestrian/cycling paths) Although we estimated the neighbourhood walkability using Walk Score®, we had no control over whether the Walk Score® website was frequently updated to account for the ongoing neighbourhood modifications in the city. Therefore, it is possible that some participants have encountered barriers due to constructions in their neighbourhood, while some other participants have benefited from recent changes supportive of walking.

4.3 Future directions

Future studies focusing on pedometer interventions within different neighbourhoods should consider the use of more sophisticated devices to collect data on physical activity (e.g., Fitbit). The advantages of these devices include immediate feedback on the individual's performance and constant motivational messages to achieve personal goals, which are identified as effective strategies for adherence to physical activity. Moreover, these devices can be directly synchronized to online interventions, like the UWALK program. This would minimize errors with data entry and facilitate the physical activity tracking through an instant update of the physical activity performance.

Studies with a focus on neighbourhood walking should consider incorporating GPS data to measure where physical activity is occurring during the pedometer intervention. This would allow researchers to identify the neighbourhoods where the participants walk, which can be the neighbourhood where they live, work or spend leisure time.

Future quasi-experiment study designs might consider the inclusion of a control group and pre-test and post-test design that can yield stronger causal inferences. Longer follow up periods might also be considered to evaluate long-term effects of the neighbourhood walkability on physical activity. Finally, perceptions of the neighbourhood built environment could be measured before and after the intervention to evaluate whether increased walking changes people's perceptions of their neighbourhood.

4.4 Implications

Our findings could be useful for improving the UWALK intervention. For example, neighbourhood context-specific strategies can be incorporated in the UWALK website to

promote more walking or to overcome environmental barriers. Also, step challenges, in particular for neighbourhoods with a high number of utilitarian destinations (train station, grocery store, public libraries) might be included to promote transportation walking.

Our study findings can also inform urban planners and designers involved in creating walkable communities. Neighbourhood modifications targeting features of the built environment related to perceptions should be considered.

The findings that participation in the UWALK intervention is effective in increasing walking could have an indirect impact on environmental pollution. If more people choose active transportation to reach locations close to home or adopt strategies to incorporate transportation walking in their daily routine, this might lead to a reduced use of motorized means of transportation and consequently reduced pollution.

Neighbourhood walking levels appeared to increase among Canadian adults who participated in a physical activity intervention. This might translate into an overall increase of physical activity at the population level which might result in a significant decrease of the incidence of major chronic health conditions and might positively impact the population health.

4.5 Chapter 4 references

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Appendices

Appendix A: Socioecological Framework

Appendix B: Study information and consent form

Appendix C: UWALK and neighbourhood environment survey

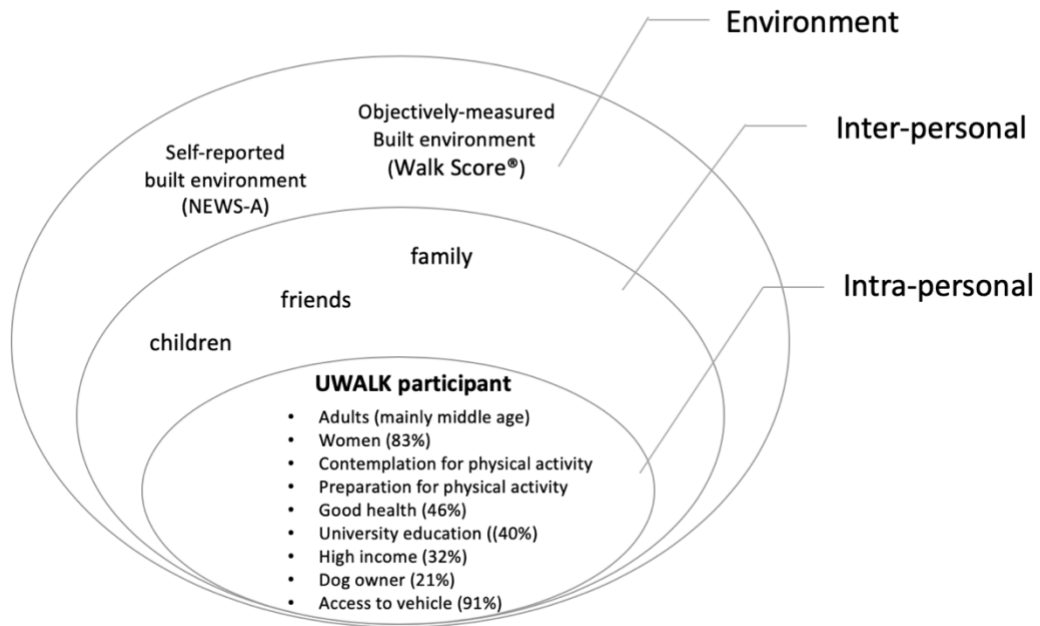
Appendix D: Instructions for pedometer and UWALK registration

Appendix E: UWALK activity log

Appendix F: Certification of Institutional Ethics Review

Appendix G: Table 7. Pedometer-measured physical activity for the first and the last week of UWALK intervention

Appendix A: Socioecological Framework



Socioecological framework adapted from Sallis et al. (2006).

Appendix B: Study information and consent form



Study Information and Consent Form

TITLE: Neighbourhood Environments and UWALK: The role of the built environment in determining the effectiveness of a pedometer-based physical activity intervention

SHORT TITLE: Neighbourhood Environment and UWALK Study

SPONSOR: Canadian Institutes of Health Research (CIHR)

INVESTIGATOR: Dr. Gavin McCormack (Principal Investigator)
Contact: 1-403-220-8193 or gmccorma@ucalgary.ca

This consent form is only part of the process of informed consent. It provides important information about what you will be asked to do during the study, the risks and benefits of the study, and about your rights as a research participant.

You have been selected for this study because you contacted our research team, met the eligibility criteria, indicated that you understood what your involvement in the study would mean, and provided your explicit verbal consent to participate. We greatly appreciate your willingness to take part in this study.

STUDY BACKGROUND

The neighbourhoods we live in can influence behaviour like physical activity, which can have an effect on our health and wellbeing. Neighbourhood features such as parks, stores, and sidewalks in walking distance from our homes can make a difference in the physical activity choices we make every day. This study will look at how neighbourhood characteristics affect initially inactive individuals' participation in a pedometer-based physical activity intervention - the Alberta 'UWALK' program. UWALK is a province-wide internet based program providing participants the ability for self-monitoring their physical activity progress. We are recruiting 2235 adults to take part in this study.

WHAT IS THE PURPOSE OF THE STUDY?

The overall purpose of the study is to understand the neighbourhood characteristics, which support or discourage physical activity among initially inactive adults enrolled in a pedometer-based physical activity intervention (UWALK). The information you and others provide will increase our knowledge about which neighbourhood characteristics affect inactive adults attempting to participate in physical activity. We also hope the findings from this study will provide information to neighbourhood planners and decision-makers about how to design neighbourhoods that can encourage and support everyone to become more physically active.

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WHAT WILL I HAVE TO DO?

STAGE 1

UWALK: Your study package includes a pedometer and instructions on how to register on the UWALK website. Pedometers count your steps. We would like you to enter your weekly pedometer counts into a diary on the UWALK website for 3-months.

SURVEYS: We will ask you to take part in three surveys; one by telephone and two that you will complete online. You will be asked to complete a telephone survey before you begin UWALK and then you will be asked to complete an online survey at 1-month and at 3-months after beginning UWALK.

The surveys will ask questions about your physical activity, neighbourhood, and socio-demographic characteristics such as sex, age, occupation, and education. It is important that all surveys be completed so that we get accurate and complete data for this study. Each survey will take you about 20 minutes to complete.

To help you remember when it's time to complete the surveys we will remind you by email and/or telephone call. The web-link to each online survey will be included in your reminder email. We ask that you complete the survey within two weeks of receiving the reminder email.

It is very important that all the information you provide is your own and not the opinion or views of other people. You do not need to answer questions that you do not want to answer or that make you feel uncomfortable.

STAGE 2

We will ask 30 participants to take part in a final telephone interview within two weeks of having completed their last online survey to share their experiences while involved in UWALK. The interview will take 30-45 minutes. These individuals will be selected from the participants who have agreed to participate in the study. You will be asked whether you would be willing to participate in this final interview during your initial survey. Participants can withdraw their consent to be interviewed at any time.

WHAT ARE THE BENEFITS AND WHAT ARE THE RISKS?

There may or may not be a direct benefit to you but the information you provide may help improve the health of Calgarians in general. Participating in this study should not harm you in any way and may even help improve your health. There is no risk of harm to you by wearing a pedometer. You will receive a pedometer to keep.

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DO I HAVE TO PARTICIPATE?

Your participation in this study is voluntary. If you decide to be part of the study, you can stop, for whatever reason, even after signing the consent form. If you decide to withdraw, there will be no consequences to you. In cases of withdrawal, any data you have provided will be retained unless you tell us otherwise. If you do not want to answer some of the questions you do not have to, and you can still be in the study. Your decision whether or not to be part of the study will not affect your continuing access to the UWALK website. Please keep in mind how very important your participation is in this study. We value your responses and contribution.

WILL I BE PAID FOR PARTICIPATING, OR DO I HAVE TO PAY FOR ANYTHING?

You will not be paid to participate but once you complete all three surveys you will receive a \$10.00 gift card and be entered into a draw for a chance to win a \$1000 Visa/MasterCard gift voucher. The participants who agree to take part and complete the end-of-study telephone interview will receive a \$25 gift card. The pedometer included in your study package is yours to keep. You will not be required to pay for anything.

WILL MY RECORDS BE KEPT PRIVATE?

Any information you provide is confidential. Hard copy personal information you provide will be kept separate from the questionnaires. Your information will be stored in a locked filing cabinet and in a locked office within the Cumming School of Medicine at the University of Calgary. Information you provide that is stored electronically will be password protected. Dr Gavin McCormack (Principal Investigator) only will have full access to the information you provide. Under the approval of the Conjoint Health Research Ethics Board and supervision of Dr. McCormack, graduate students and research staff may have restricted access to data collected for training purposes or for carrying out the study as planned.

Only grouped data will be summarized for any presentation or publication of results. You will be asked to provide your sex, age, education, occupation, and income information; however, the data you provide will be grouped with data from other participants who share similar characteristics. Grouping data ensures that your data remains anonymous when presenting the results.

The online surveys are hosted by "Survey Monkey" which is a web survey company located in the USA. All responses to the survey will be stored and accessed in the USA. This company is subject to US laws, in particular, to the US Patriot Act that allows authorities access to the records of internet service providers. If you choose to participate in the survey, you understand that your responses to the questions will be stored in the USA. The security and privacy policy for Survey Monkey can be viewed at <http://www.surveymonkey.com/>. **You will not be identifiable based on the responses you provide in the on-line questionnaires and information will not be shared with or disclosed to any third party.**

The data from the UWALK website will be stored on the secure, password protected servers located in Toronto, Canada. The security and privacy policy for the UWALK website can be viewed at <https://uwalk.ca/pages/terms/>.

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IF I SUFFER A RESEARCH-RELATED INJURY, WILL I BE COMPENSATED?

In the event that you suffer injury because of participating in this research, no compensation will be provided to you by the Canadian Institutes for Health Research, the University of Calgary, or the Researchers. You still have all your legal rights. Nothing said in this consent form alters your right to seek damages.

PROVIDING INFORMED CONSENT

Explicit Verbal Consent

A copy of the consent form was emailed to you by the Research Coordinator. You provided explicit verbal consent to take part in this study during your telephone call with our Research Coordinator. In providing consent you have agreed to wear a pedometer for three months, enter your weekly activity onto the UWALK website, and complete three surveys during a 4-month period. By providing the Research Coordinator your explicit verbal consent you are indicating that you understand to your satisfaction the information regarding your participation in this research project and you understand your rights and responsibilities as a research participant.

Your informed consent (explicit verbal consent and implied consent) in no way waives your legal rights nor releases the investigators, or involved institutions, from their legal and professional responsibilities. You are free to withdraw from the study at any time.

If you have any questions concerning your rights as a possible participant in this research, please contact the Chair, Conjoint Health Research Ethics Board, University of Calgary at 403-220-7990.

QUESTIONS

You are welcome to ask questions at any time before, during, or after your participation in this research. If you require more information about this study, please contact:

Rosemary Perry
Research Coordinator,
University of Calgary
403-210-7044
perryr@ucalgary.ca

or

Dr. Gavin McCormack
Principal Investigator,
University of Calgary
403-220-8193
gmcorma@ucalgary.ca

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UWALK AND NEIGHBOURHOOD ENVIRONMENT SURVEY	
1. WELCOME TO OUR SURVEY	
<p><i>The survey is about you, your physical activity and the neighbourhood you live in. The information collected will help us understand how neighbourhood design supports, encourages, or discourages physical activity. We value your opinion and contribution.</i></p> <p><i>By participating in this survey you are consenting to take part and to your responses being aggregated. In no way does this waive your legal rights nor release the investigators or involved institutions from their legal and professional responsibilities. You are free to withdraw from the study at any time.</i></p> <p><i>The University of Calgary is administering the survey, analyzing the data, and reporting the results with approval from the University of Calgary Conjoint Health Ethics Research Board. For any questions concerning your rights as a participant, please contact the Chair, Conjoint Health Research Ethics Board, at 403-220-7990. The study ID number is REB15-2944.</i></p> <p><i>Data will be analyzed anonymously by removing all personal identifiers (such as your name and contact information) during the data processing stage. Your answers are COMPLETELY CONFIDENTIAL.</i></p> <p><i>This survey should take you no more than 20 minutes to complete.</i></p>	

UWALK AND NEIGHBOURHOOD ENVIRONMENT SURVEY	
2. YOUR UNIQUE STUDY ID	
<p><i>Entering your unique study ID is required to continue the survey. It serves two purposes: provides an anonymous way for your survey data to be linked with your UWALK data and for your data to be analyzed anonymously. Your Unique Study ID was included in the study package we mailed to you.</i></p> <p>* Please enter your Unique Study ID.</p> <input type="text"/>	

UWALK AND NEIGHBOURHOOD ENVIRONMENT SURVEY	
3. ABOUT YOU	
* 3.1 Please enter your postal code.	

3.2 Is your dwelling...?

- Owned by you or a member of your household (even if it is still being paid for)
- Rented
- Other

3.3 Do you have a motor vehicle available for your own personal use?

- Yes, always
- Yes, sometimes
- Never
- Don't drive

3.4 Does your household own at least one dog?

- Yes
- No

3.5 In general, would you say your physical health is...?

- Poor
- Fair
- Good
- Very Good Excellent

* 3.6 In which year were you born?

Year of Birth (Drop down menu 1915 -1998)

* 3.6 Do you identify as...?

- Male
- Female

Another identity

Would you like to specify?

UWALK AND NEIGHBOURHOOD ENVIRONMENT SURVEY

4. ACCESS TO SERVICES IN MY NEIGHBOURHOOD

NOTE: For the purposes of this survey, your neighbourhood refers to the area within a 15-minute walk (in any direction) of your home.

4.1 Stores are within easy walking distance of my home (i.e., a 10-15 minute walk).

Strongly Disagree Somewhat Disagree Somewhat Agree Strongly Agree

4.2 There are many places to go within easy walking distance of my home.

Strongly Disagree Somewhat Disagree Somewhat Agree Strongly Agree

4.3 It is easy to walk to a transit stop (bus, train) from my home.

Strongly Disagree Somewhat Disagree Somewhat Agree Strongly Agree

4.4 The streets in my neighbourhood are hilly, making my neighbourhood difficult to walk in.

Strongly Disagree Somewhat Disagree Somewhat Agree Strongly Agree

4.5 There are major barriers to walking in my local area that make it hard to get from place to place (for example, highways, railway lines, rivers).

Strongly Disagree Somewhat Disagree Somewhat Agree Strongly Agree

UWALK AND NEIGHBOURHOOD ENVIRONMENT SURVEY

5. STREETS IN MY NEIGHBOURHOOD

5.1 The streets in my neighbourhood do not have many cul-de-sacs (dead-end streets).

Strongly Disagree Somewhat Disagree Somewhat Agree Strongly Agree

5.2 The distance between intersections in my neighbourhood is usually short (100 meters or less; the length of a football field or less).

Strongly Disagree Somewhat Disagree Somewhat Agree Strongly Agree

5.3 There are many alternative routes for getting from place to place in my neighbourhood. (I don't have to go the same way every time.)

Strongly Disagree Somewhat Disagree Somewhat Agree Strongly Agree

5.4 There are sidewalks on most of the streets in my neighbourhood.

Strongly Disagree Somewhat Disagree Somewhat Agree Strongly Agree

5.5 There are several **free or low cost** recreation facilities, such as parks, walking trails, bike paths, recreation centres, playgrounds, public swimming pools, etc. in my neighbourhood.

Strongly Disagree Somewhat Disagree Somewhat Agree Strongly Agree

UWALK AND NEIGHBOURHOOD ENVIRONMENT SURVEY

6. NEIGHBOURHOOD SAFETY

6.1 There is so much traffic along nearby streets that it makes it difficult or unpleasant to walk in my neighbourhood.

Strongly Disagree Somewhat Disagree Somewhat Agree Strongly Agree

6.2 The speed of traffic on most nearby streets is usually slow (50 km/h or less).

Strongly Disagree Somewhat Disagree Somewhat Agree Strongly Agree

6.3 Most drivers exceed the posted speed limits while driving in my neighbourhood.

Strongly Disagree Somewhat Disagree Somewhat Agree Strongly Agree

6.4 My neighbourhood streets are well lit at night.

Strongly Disagree Somewhat Disagree Somewhat Agree Strongly Agree

6.5 In my neighbourhood walkers on the street can be easily seen by people in their homes.

Strongly Disagree Somewhat Disagree Somewhat Agree Strongly Agree

6.6 There are crosswalks and pedestrian signals to help walkers cross busy streets in my neighbourhood.

Strongly Disagree Somewhat Disagree Somewhat Agree Strongly Agree

6.7 There is a high crime rate in my neighbourhood.

Strongly Disagree Somewhat Disagree Somewhat Agree Strongly Agree

6.8 The crime rate in my neighbourhood makes it unsafe to go on walks during the day.

Strongly Disagree Somewhat Disagree Somewhat Agree Strongly Agree

6.9 The crime rate in my neighbourhood makes it unsafe to go on walks at night.

Strongly Disagree Somewhat Disagree Somewhat Agree Strongly Agree

6.10 Unattended dogs in my neighbourhood make it unsafe to go walking.

Strongly Disagree Somewhat Disagree Somewhat Agree Strongly Agree

6.11 I see many people being physically active in my neighbourhood doing things like walking, jogging, cycling, or playing sports and active games.

Strongly Disagree Somewhat Disagree Somewhat Agree Strongly Agree

UWALK AND NEIGHBOURHOOD ENVIRONMENT SURVEY

7. NEIGHBOURHOOD SURROUNDINGS

7.1 There are trees along the streets in my neighbourhood.

Strongly Disagree Somewhat Disagree Somewhat Agree Strongly Agree

7.2 There are many interesting things to look at while walking in my neighbourhood.

Strongly Disagree Somewhat Disagree Somewhat Agree Strongly Agree

7.3 There are many attractive natural sights in my neighbourhood (such as landscaping, views).

Strongly Disagree Somewhat Disagree Somewhat Agree Strongly Agree

UWALK AND NEIGHBOURHOOD ENVIRONMENT SURVEY

8. FINAL QUESTIONS ABOUT YOU

8.1 Which category best describes your current marital status?

- Married
- Not married but living with a partner
- Single
- Separated
- Divorced
- Widowed
- Other Arrangement

8.2 How many dependents live at your home?

Number of dependents younger than 6 years of age:

Number of dependents 6 years to 18 years of age:

8.3 What level of education have you completed? [*Please select all that apply*]

- Some secondary (high) school or less (but not graduated)
- Secondary (high) school diploma or equivalency certificate
- Registered apprenticeship or trades certificate or diploma
- General or vocational college or other non-university certificate or diploma
- University certificate or diploma (below bachelor level)
- University degree, certificate or diploma (bachelor level)
- University certificate or diploma (professional degree eg., medicine, law, engineering)
- University certificate or diploma (above bachelor level)
- University degree (masters degree or doctorate)
- Other (please specify)

8.4 Which of the following best describes your current occupation?

- Homemaker
- Retired
- Student
- Unemployed
- Professional or para-professional
- Clerk, salesperson, personal service worker
- Manager administrator
- Tradesperson
- Labourer
- Plant or machine operator, driver
- Other (please specify)

8.5 What is your total gross household annual income (income before taxes, including all members of your household except roommates)?

(Drop down menu: Under 20,000; 20,000-39,999; 40,000-59,999; 60,000-79,999; 80,000-90,999; 100,000-119,999; 120,000-139,999; 140,000-159,999; 160,000-179,999; 180,000-199,999; 200,000 or more;)

THANK YOU FOR YOUR VALUABLE INPUT!

Appendix D: Instructions for pedometer and UWALK registration

NEIGHBOURHOOD ENVIRONMENT AND UWALK STUDY

Instructions for Pedometer and UWALK Registration

STEP 1

- **How to Set-up Your Pedometer**

Pedometers

Your study package includes a Piezo StepX pedometer purchased from StepCounts. If you are interested in viewing their website, here is the link: <https://www.stepscount.com/>

Page | 1



- The pedometer is easy to use. Just one button – **RESET**.
- Press & hold **reset button** for 2 seconds to clear your step total each day.

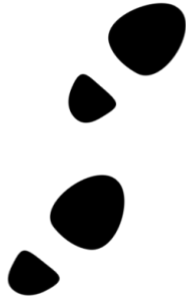
- To attach: slide one corner of clip onto waistband or belt and position it directly in line with your knee - same side as the hand you normally write with.
- **DO NOT FORCE CLIP ONTO THICK BELT. CLIP MAY BREAK.**
- Cover needs to be closed to accurately count your steps.
- You may attach the pedometer to the waistband of your undergarment, your shoe or bra strap if your clothing choice of the day does not have a waistband

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NEIGHBOURHOOD ENVIRONMENT AND UWALK STUDY

Instructions for Pedometer and UWALK Registration



Check Your Step Count

- Place your pedometer on your waist
- Open the cover and reset to zero
- Gently close the cover and take 20 steps
- If the StepX is not reading between 18 and 22:
 - Reset it to zero (hold the reset button down for 2 seconds) and gently close the cover
 - Take 20 steps (each time a foot strikes the floor is a step)
 - Stop. Check your number!
 - If still not reading between 18-22, try sliding it along your waist until the reading is correct.

Page | 2



Safety strap & Care of Pedometer

To prevent loss or damage, simply clip the StepStrap™ attached to your pedometer to a belt loop or pocket.

This will hopefully prevent it from dropping and getting damaged or lost (or falling in the toilet).

IMPORTANT: We are asking you to wear your pedometer all day - upon waking until you go to bed. Please do not wear swimming, bathing or showering.

P.S.

Your pedometer will not record when the cover is open, so keep the pedometer closed - unless of course you are checking your steps!

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NEIGHBOURHOOD ENVIRONMENT AND UWALK STUDY

Instructions for Pedometer and UWALK Registration

STEP 2

- [How to Register on UWALK](#)

UWALK

Page | 3

Step by Step Instructions:

1. To join our research community, The Neighbourhood Environment and UWALK Study, type this link: <https://uwalk.ca/user/invitation/?group=NEU>

IMPORTANT: If you register on the general UWALK website home page instead of the link above we will not be able to use your data for our study.

2. You will be taken to the page below. This information is necessary so that we know for certain which pedometer data is yours. Agree to the website's terms and agreements.

The screenshot shows a registration form for the 'ENVIRONMENT AND UWALK STUDY'. The form is titled 'Register With Your Email' and includes the following fields and sections:

- Registration Instructions:**
 - After creating an account, you will automatically be joined with this community.
 - If you are already a UWALK member, you will not be able to register again. Instead please **LOGIN** to the UWALK website and search for the community you are trying to join under the **FIND** page.
 - Changed your mind? [Create a standard UWALK account](#)
- Registration Fields:**
 - Email
 - First name
 - Last name
 - Postal code
 - Gender (dropdown menu)
 - Country
 - How did you hear about UWALK? (dropdown menu)
 - If you selected either: (text input)
 - Please confirm your date of birth
 - Date of Birth (MM-DD-YYYY) (calendar icon)
 - None (checkbox)
 - Password
 - Confirm Password
- Terms and Service Agreement:**
 - The data collected from the website will be used for Research Purposes, unless you indicate otherwise. This data is being collected to continually improve the website and for research purposes. After you have activated your account you will have the option to select not to have your data collected for Research Purposes. You will still be able to use the UWALK website regardless of your participation in the research component.
 - [Terms and Service agreement](#)
 - By registering below, you accept the terms and service agreement
 - I accept the terms

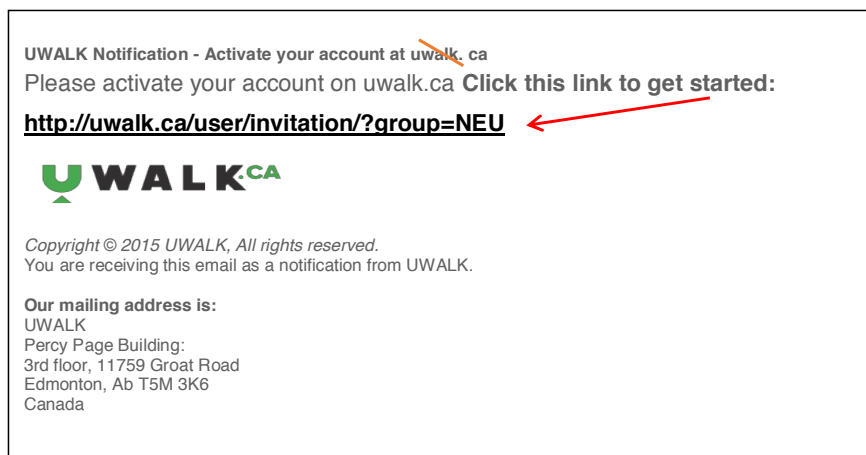
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NEIGHBOURHOOD ENVIRONMENT AND UWALK STUDY

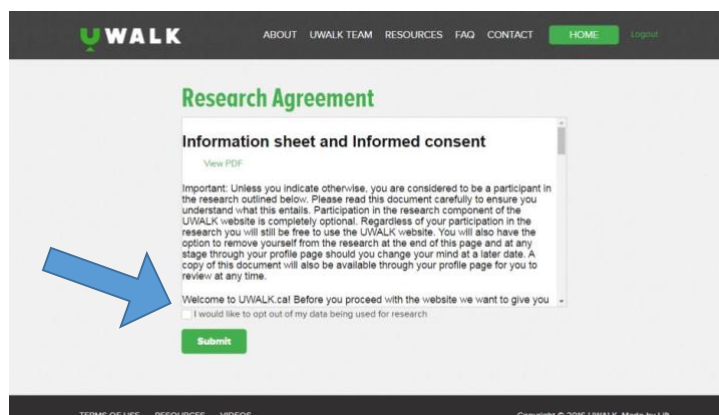
Instructions for Pedometer and UWALK Registration

- UWALK will send you a confirmation email to verify your email address and to complete your registration. Click the link provided in your email to activate your account-NOT uwalk.ca.



Page | 4

- You will be directed to a page asking your permission for **University of Alberta** researchers to use your data for research purposes. You can choose **I WOULD LIKE TO OPT OUT OF MY DATA BEING USED FOR RESEARCH. It is your choice to opt in or out.** If you choose to opt out it will not affect your involvement in the Neighbourhood Environment and UWALK study or the use of the website. Click Submit.



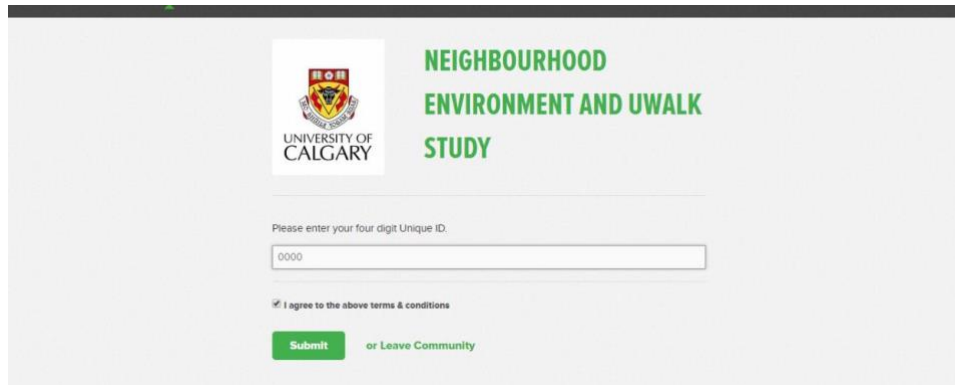
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NEIGHBOURHOOD ENVIRONMENT AND UWALK STUDY

Instructions for Pedometer and UWALK Registration

5. You are then directed to the Neighbourhood Environment and UWALK community page. Enter your Unique ID number, , then agree to the terms and conditions and click Submit.



UNIVERSITY OF CALGARY

NEIGHBOURHOOD ENVIRONMENT AND UWALK STUDY

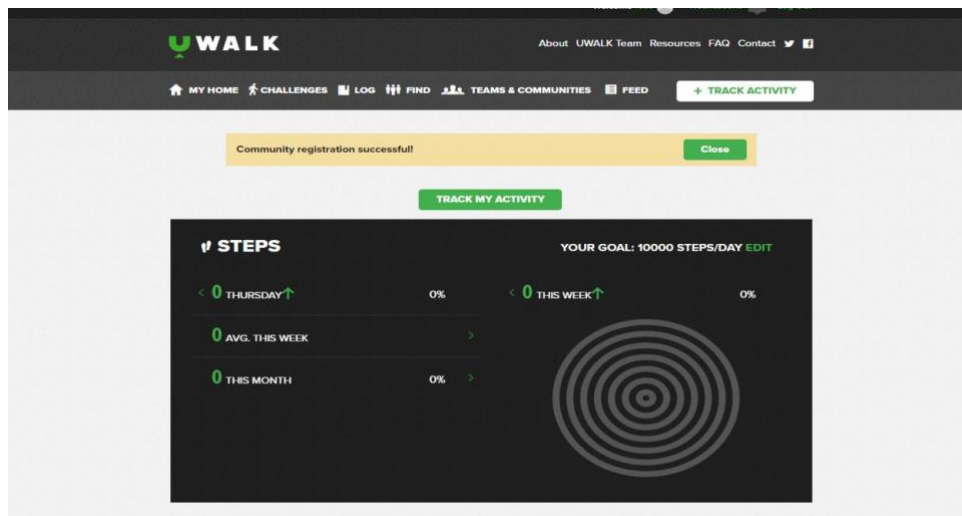
Please enter your four digit Unique ID.

I agree to the above terms & conditions

[Submit](#) or [Leave Community](#)

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6. You will be directed to the following page after registering. For a more detailed overview of how to use the website see WHAT TO DO AFTER YOU REGISTER.



Ethics ID: REB15-2944 This study has been approved by the University of Calgary Conjoint Health Research Ethics Board.
Study Title: Neighbourhood Environments and UWALK: The role of the built environment in determining the effectiveness of a pedometer-based physical activity intervention
PI: Dr. Gavin McCormack
Version#/date: V1 December 16, 2015



NEIGHBOURHOOD ENVIRONMENT AND UWALK STUDY

Instructions for Pedometer and UWALK Registration

1. **Remember:** enter your daily pedometer counts each week into the activity tracker connected to your profile on the UWALK website <https://uwalk.ca/user/login/>. It is very helpful when you enter your weekly steps accurately since this information will be an important part of our research study. Don't forget to click **SAVE** after you enter your steps. If you want to see who is in our study community, click on **Teams and Communities** and then **My Communities**.

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Questions? Problems registering on our UWALK Community site?

Contact Rosemary Perry
Phone: 403-210-7044
Email: perryr@ucalgary.ca .

If you have questions at any time during or after the study please feel free to contact:

Rosemary Perry
Research Coordinator
University of Calgary
403-210-7044
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OR

Dr. Gavin McCormack
Principal Investigator
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Appendix E: UWALK activity log



How to use: Record your daily activity below and calculate monthly totals

Steps: log your steps walked each day

Other: convert other activity to steps

Note: every 1 minute of moderate activity = 100 steps and

every 1 minute of vigorous activity = 200 steps

Total steps: add daily steps and steps from other activities to get your daily total

TOTAL: at the end of each week calculate your totals and overall total for the week!

Moderate e.g. mowing the lawn, brisk walking, digging in the garden, medium paced swimming and cycling.

Vigorous e.g. jogging, fast cycling, shovelling snow, aerobics and active sports such as football, squash and basketball.

	DAY	MONDAY	TUESDAY	WEDNESDAY	THURSDAY	FRIDAY	SATURDAY	SUNDAY	TOTAL
WEEK 1	STEPS								
	OTHER								
	TOTAL STEPS								
WEEK 2	STEPS								
	OTHER								
	TOTAL STEPS								
WEEK 3	STEPS								
	OTHER								
	TOTAL STEPS								
WEEK 4	STEPS								
	OTHER								
	TOTAL STEPS								
MONTHLY TOTAL									

To continue to track your activity visit UWALK.ca for access to free and fun resources and connect with friends, family and coworkers.

Join a team or group, set personal goals, or participate in a UWALK challenge! *Ethics ID: REB15-2944 This study has been approved by the University of Calgary Conjoint Health Research Ethics Board.*

Appendix G: Table 7. Pedometer-measured physical activity for the first and the last week of UWALK intervention.

Table 7. Dependent t-test estimates for the first and last week of UWALK intervention for participants who did not complete (n=250) and completed (n=216) the intervention.

Steps/duration	First week Steps/day Mean (SD)	Last week Steps/day Mean (SD)	<i>p</i> value
Completing <12 weeks	8290.91 (3170.02)	8268.46 (3971.69)	0.92
Completing 12 weeks	8634.47 (3971.69)	8896.69 (4060.16)	0.26

Note: For not-completers and completers, their first and last week of steps recorded in the UWALK website was used to estimate their daily steps.

*<.05