HEALTHY AGING IN THE NEIGHBORHOOD: EXAMINING THE RELATIONSHIP BETWEEN THE MICRO-SCALE BUILT ENVIRONMENT AND WALKING IN OLDER ADULTS

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ABSTRACT

Evidence suggests that neighborhood-built environments influence walking behavior in older adults. Most studies to date have examined how macro-scale features (connectivity, land-use mix, and population density) encourage walking in this population. Findings about neighborhood macro-scale features and walking, however, are not often practical to apply in existing neighborhood settings, as changing these features can require substantial reconfiguration of the neighborhood layout. Altering micro-scale features of neighborhoods (e.g., presence and quality of sidewalks, benches) may be a relatively cost-effective and efficient method of creating environments that are conducive to walking. This dissertation adopted an explanatory mixed methods approach to better understand the relationship between the micro-scale environment and walking.

The main findings of this dissertation are:

1. Reporting a research design and an integration strategy in mixed methods studies in the built environment and health field could help to strengthen our ability to gain new insights into the multidimensional nature of the relationship between the built environment and health.
2. Virtual-STEPS is a reliable tool for virtually assessing the micro-scale environment of neighborhoods. There was high reliability between virtual and field audits with Kappa and ICC statistics indicating that 50.0% of items had almost perfect agreement and 32.5% of items had substantial agreement. Inter-rater reliability was also high with 42.5% of items with almost perfect agreement and 27.5% of items with substantial agreement.
3. The micro-scale environment collectively promoted leisure walking in adults. The grand micro-scale score was associated with elevated odds of walking for leisure for

at least 150 minutes per week in adults from Montreal and Toronto, even after accounting for self-selection. Conversely, the association between micro-scale walkability and walking for utilitarian purposes was inconclusive.

4. The micro-scale environment promoted leisure walking in older adults. The grand micro-scale score was associated with greater odds of walking for leisure for at least 150 minutes per week. After stratifying for health conditions, the grand micro-scale score and the traffic calming total section score were only associated with walking for leisure in the sample with health conditions, further the aesthetics section score became significantly associated with walking for leisure in the sample of older adults with health conditions.
5. Semi-structured interviews conducted with older adults living in the suburbs of Montreal during the COVID-19 pandemic revealed that aesthetics, pedestrian infrastructure, proximity to shops/facilities, and building characteristics were perceived as walk-friendly, whereas traffic as well as unsafe intersections were perceived as barriers to walking. Older adults also reported avoiding crowded parks and crowded or narrow boardwalks, sidewalks, and walking paths due to difficulties with physical distancing.

Interventions to improve the micro-scale environment of neighborhoods could increase walking for leisure in older adults, a vulnerable population group, that may be particularly sensitive to the micro-scale features of their neighborhood environment.

RÉSUMÉ

Les écrits scientifiques suggèrent que les environnements bâtis du quartier influencent le comportement de marche des personnes âgées. La plupart des études à ce jour ont examiné comment les caractéristiques à macro-échelle encouragent la marche dans ce groupe populationnel. Cependant, les résultats sur les caractéristiques à macro-échelle du quartier et la marche sont souvent difficiles d'application dans les contextes existants du quartier, car la modification de ces caractéristiques peut nécessiter une reconfiguration substantielle du quartier. La modification des caractéristiques à micro-échelle (par exemple la présence et l'état des trottoirs, bancs) des quartiers peut être une méthode relativement rentable et efficace pour créer des environnements qui sont propice à la marche. Cette thèse a adopté un devis de méthodes mixtes explicatif pour mieux comprendre la relation entre l'environnement à micro-échelle et la marche. Les principaux résultats de cette thèse sont :

1. Le rapport d'un devis de recherche et d'une stratégie d'intégration dans des études de méthodes mixtes dans le domaine de l'environnement bâti et de la santé contribuait à renforcer notre capacité à acquérir de nouvelles connaissances sur la nature multidimensionnelle de la relation entre l'environnement bâti et la santé.
2. Virtual-STEPS est un outil fiable pour évaluer virtuellement l'environnement à micro-échelle des quartiers. Il y avait une grande fiabilité entre les audits virtuels et les audits effectués sur le terrain avec les statistiques Kappa et ICC, indiquant que 50,0% des items avaient un accord presque parfait et 32,5% des items montraient un accord substantiel. La fiabilité inter-juges était également élevée avec 42,5% des items présentant un accord presque parfait et 27,5% des items affichant un accord substantiel.
3. L'environnement à micro-échelle contribuait collectivement à la marche de loisirs chez les adultes. Le score cumulatif micro-échelle était associé à des chances élevées de marcher

pour les loisirs pendant au moins 150 minutes chez les adultes de Montréal et de Toronto, même après avoir tenu compte de l'auto-sélection. À l'inverse, l'association entre l'environnement à micro-échelle et la marche à des fins utilitaires n'était pas concluante.

4. L'environnement micro-échelle favorisait la marche de loisir chez les personnes âgées. Le score micro-échelle était associé à une plus grande probabilité de marcher pour les loisirs pendant au moins 150 minutes par semaine. Après stratification pour les conditions de santé, le score micro-échelle et le score total de la section d'apaisement de la circulation n'étaient associés qu'à la marche de loisir dans l'échantillon avec des problèmes de santé, plus encore, le score de la section esthétique devenait significativement associé à la marche pour les loisirs dans l'échantillon d'adultes âgés avec problèmes de santé.
5. Des entrevues semi-structurées menées auprès d'adultes âgés vivant en banlieue de Montréal pendant la pandémie COVID-19 ont révélé que l'esthétique, les infrastructures piétonnières, la proximité des commerces et les caractéristiques du bâtiment étaient perçues comme étant propices à la marche, tandis que la circulation ainsi que les intersections dangereuses étaient perçues comme des obstacles à la marche. Les personnes âgées ont également déclaré éviter les parcs bondés et les trottoirs et les sentiers de promenade bondés ou étroits en raison de difficultés à respecter la distanciation physique.

Les interventions visant à améliorer l'environnement à micro-échelle des quartiers pourraient accroître la marche à des fins de loisir chez les personnes âgées, un groupe de population vulnérable, qui peut être particulièrement sensible à l'environnement de leur quartier.

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ABBREVIATIONS

FSA: Forward Sortation Area

GSV: Google Street View

Virtual-STEPS: Virtual Systematic Tool for Evaluating Pedestrian Streetscapes

CONTRIBUTION OF AUTHORS

The objectives and research methods of my dissertation were developed with my supervisor, Dr. Nancy A. Ross, who provided me with guidance throughout the course of my research. Thesis committee members, Dr. Mylene Riva and Ahmed El-Geneidy also provided valuable feedback during the development phase of my dissertation.

I wrote the introduction, literature review, conclusion, and all other written components of my thesis. The dissertation consists of five manuscripts. The manuscripts have been published or will soon be submitted for publication in peer-reviewed journals. I am first author on all manuscripts included in this thesis. I wrote the manuscripts, performed all statistical or thematic analyses, and interpreted the results. I have described the contributions of my co-authors below.

Nancy A. Ross, PhD is a professor in the Department of Geography and an associate member of the department of Epidemiology and Biostatistics at McGill University. As my supervisor, Dr. Ross contributed to the conceptualization of all manuscripts and revised drafts of all manuscripts.

Ahmed El-Geneidy, PhD is a professor in the School of Urban planning. As a thesis committee member, Dr. El-Geneidy contributed to the conceptualization of manuscript 3. He also provided comments and edits for manuscript 3.

Pierre Pluye, PhD is a professor in the department of Family Medicine. As a co-author on the first manuscript, Dr. Pluye provided guidance on the mixed methods approaches that were addressed in manuscript 1. He also provided comments and edits for manuscript 1.

Kabisha Velauthapillai is a graduate from the undergraduate program of the McGill School of Environment. As an undergraduate research assistant and a co-author of manuscript 2, she contributed to the development of the Virtual-STEPS audit tool. She also provided comments for manuscript 2 and conducted many virtual audits with the Virtual-STEPS tool using Google Street View.

Grace O'Brien is a graduate from the undergraduate program of the McGill School of Environment. As an undergraduate research assistant and a co-author of manuscript 2, she contributed to the development of the Virtual-STEPS audit tool. She also conducted many virtual audits with this tool using Google Street View.

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1 CHAPTER ONE | INTRODUCTION AND RATIONALE

1.1 INTRODUCTION

Walking is a form of physical activity that could help older adults meet physical activity recommendations (Van Cauwenberg, Clarys, et al., 2012). A growing body of evidence suggests that built environments are important determinants of both leisure time walking (i.e., walking for pleasure) and utilitarian walking (i.e., walking for a purpose such as for shopping) (Cerin, Nathan, Van Cauwenberg, Barnett, & Barnett, 2017; Saelens & Handy, 2008a; Van Cauwenberg, Nathan, Barnett, Barnett, & Cerin, 2018). The majority of studies exploring the role of urban design for older adults' walking behavior have examined how 'macro-scale' components (density, land-use mix, and connectivity), structural features of the physical environment that characterize the 'walkability' (i.e., walking-friendliness) of a neighborhood, may be associated with walking for utilitarian purposes or for leisure (Barnes, Winters, Ste-Marie, McKay, & Ashe, 2016; Carlson et al., 2012; King et al., 2011; Shimura, Sugiyama, Winkler, & Owen, 2012; Thielman, Rosella, Copes, Lebenbaum, & Manson, 2015; Van Holle et al., 2014).

There is limited evidence on the influence of the micro-scale (i.e., street-level) built environment on walking in older adults. Micro-scale features of the built environment such as the condition of benches, sidewalks, trees, crossing signals, walking paths, cues of social disorganization or crime (e.g., graffiti) contribute to pedestrians' pleasure and comfort of walking (Cain et al., 2014; Sallis, Cain, et al., 2015). Gaining a better understanding of the role of the micro-scale environment for the mobility of older adults may be particularly important in this age group, as loss of functionality, and degenerative conditions may make older adults particularly sensitive to the constraints or supports existing in the environment (Shigematsu et al., 2009; Van

Cauwenberg, Van Holle, De Bourdeaudhuij, Van Dyck, & Deforche, 2016; Van Holle et al., 2014).

In this dissertation, the micro-scale environment was the focus of analyses using an explanatory mixed methods study design (Creswell & Plano Clark, 2011), a design that begins with a quantitative phase, that is used to inform the design of the qualitative data collection and analysis. This explanatory mixed methods dissertation tested the overarching hypothesis that the micro-scale environment promotes walking in older adults using virtual audits of pedestrian streetscapes, social surveys, and in-depth interviews.

The objectives of this dissertation are:

(1) **Explore and document best-practice approaches for mixed-methods studies on the built environment and health.** A review of research designs and integration strategies was conducted as a guide for how to apply mixed methods approaches to research on the built environment and health. Mixed methods studies from the built environment – health literature were also reviewed, to point to ways researchers can move forward methodologically in this field.

(2) **Create and validate a virtual auditing tool for the measurement of micro-scale features of the built environment that may influence walking behavior.** To achieve this objective, the Virtual-STEPS tool was created to measure the micro-scale environment using Google Street View. The tool has 40 items categorized into 6 domains (pedestrian infrastructure, traffic calming and streets, building characteristics, bicycling infrastructure, transit, and aesthetics). Reliability between virtual and field audits (n=40), as well as the inter-rater reliability (n=60) of the tool was assessed using percent agreement, Cohen's Kappa statistic, and the Intra-class Correlation Coefficient.

(3) **Evaluate the individual and collective influence of items from the Virtual-STEPS tool on walking outcomes (utilitarian walking and walking for leisure).** To achieve this objective, the micro-scale environment of 5% of street segments from 128 FSAs was virtually audited using the Virtual-STEPS tool. Individual and collective micro-scale environment scores were calculated for adults (N=1,403) that had participated in two waves of an internet survey and that were from FSAs in Montreal and Toronto stratified by high walking-friendly/high walking, high walking-friendly/low walking, low walking-friendly/high walking, and low walking friendly/low walking. A multilevel logistic regression analysis was used to model the relationship between features of the micro-scale environment and odds of walking for utilitarian purposes for at least 150 minutes per weeks and walking for leisure for at least 150 minutes per week. Models adjusted for demographic covariates (age, sex, number of cars in the household, dog ownership, city, health conditions, and neighborhood income), the Walkscore®, and residential self-selection.

(4) **Evaluate the individual and collective influence of items from the Virtual-STEPS tool on walking for leisure in older adults.** To achieve this objective, we selected the sample of older adults (N=605) from Montreal and Toronto FSAs that responded to the first wave of an internet survey. Multi-level logistic regression analyses examined the individual and collective influence of items from the Virtual-STEPS tool on walking for leisure for at least 150 minutes per week, while accounting for age, sex, education, dog ownership, health conditions, city, neighborhood income, and the Walkscore®. We also estimated this effect for older adults with and without health problems separately, to see if older adults with health issues were particularly sensitive to their micro-scale environment.

(5) **Explore how older adults' perceptions of their neighborhood environment influence their walking behavior.** To achieve this objective, older adults (n=23) were recruited from suburban areas in Montreal to participate in semi-structured interviews. Due to the Corona Virus Disease 2019 (COVID-19) pandemic, to avoid in-person contact with participants, participants were recruited over Facebook by posting flyers in community-oriented Facebook groups. Participants were asked questions on their physical activity, transport behavior, and the built environment. Participants were also asked how the COVID-19 pandemic might have affected their physical activity and how COVID-19 might have affected how they spend their time in their neighborhood. Interviews were recorded and transcribed by the interviewer. Thematic analysis was conducted on the transcripts using MAXQDA.

1.2 BACKGROUND

Population ageing is the main driver in the prominent increase in the prevalence of chronic diseases (Suzman, Beard, Boerma, & Chatterji, 2015). By 2030 approximately one in four Canadians will be over the age of 65 (Statistics Canada, 2014) and it's been claimed that Canada's health care system is underprepared for this rapidly aging population (Wister & Speechley, 2015). Physical activity contributes to the maintenance of independence and health related quality of life of older adults, and reduces risk of chronic disease and healthcare burden (Chodzko-Zajko, 2014). Despite the known health benefits of physical activity, 88% of older adults do not meet the Canadian physical activity guidelines of 150 minutes of moderate to vigorous physical activity per week (Statistics Canada, 2015) .

In high income countries, there has been a dramatic increase in the lifespan in the past three decades, with mortality decreasing in older age groups (Mathers, Stevens, Boerma, White, & Tobias, 2015). However, evidence suggests that rather than spending this period in good health, many older adults may be experiencing an extended period of morbidity (Beard et al., 2016). For example, the World Health Organization (WHO) suggests that although severe disability (requiring help for basic activities e.g., walking and eating) has slightly decreased, less severe disability has remained stable for older adults in the last 30 years (Beard et al., 2016; Chatterji, Byles, Cutler, Seeman, & Verdes, 2015). This extended period of morbidity emphasizes the importance of taking the necessary measures to increase the health-span of older adults (time that an individual is in good health), to ensure that older adults are able to remain functional during their old age (Mathers et al., 2015).

The World Report on Ageing and Health defines healthy aging as "the process of developing and maintaining the functional ability that enables wellbeing in older age" (World Health Organization, 2015, p. 28). It identifies four priorities that should be addressed to promote healthy ageing, one of them being the importance of growing old in physical and social age-friendly environments. This is because age-friendly environments act as a major determinant of the intrinsic capacity[1] of an individual by bolstering ability to maintain good health, encouraging capacity-enhancing behaviors (e.g., physical activity), providing services that promote capacities, and by promoting greater functioning in individuals with a particular level of capacity (Beard et al., 2016). A worldwide initiative to promote the development of environments that support healthy ageing is the World Health Organization Global Network of Age-friendly Cities and Communities, a network that fosters knowledge translation between cities that are striving to make their cities and communities age-friendly. Several Canadian cities are part of this network

[1] Intrinsic capacity is the combination of physical and mental capacities that an individual can make use of at any particular point in time.

including Montreal, Toronto, Saskatoon, and Calgary (World Health Organization, 2018).

There is increasing interest worldwide in developing initiatives to promote healthy aging. One method of bolstering and maintaining the intrinsic capacity of older adults is to design age-friendly cities that have built environments that support active ageing. A community that is age-friendly can lead to active-living by promoting pedestrian-oriented forms of transportation, and leisure physical activity. This physically active lifestyle can have many positive health benefits for older adults including: greater mobility, independence, the prevention of disability, a maintenance of the quality of life of older adults, and reduced risk of disease (World Health Organization, 2015). For example, evidence suggests that older adults living in neighborhoods with pedestrian friendly design (i.e., walkable neighborhoods) will have more favorable trajectories of mobility disability (Clarke, Ailshire, & Lantz, 2009), reduced incidence of type 2 diabetes (Auchincloss et al., 2009), lower weight (Li et al., 2009; Van Cauwenberg et al., 2016) and better mental health (Van Dyck, Teychenne, McNaughton, De Bourdeaudhuij, & Salmon, 2015).

The frailty that often accompanies aging implies that the mobility of the elderly is particularly sensitive to the constraints or supports existing in the environment (Shigematsu et al., 2009; Van Cauwenberg et al., 2016; Van Holle et al., 2014) and that disadvantageous built environments may impede older adults from maintaining their independence and an active lifestyle, undermining their ability to age in place (Balfour & Kaplan, 2002; Haselwandter et al., 2015). A number of researchers postulate that the influence of the neighborhood built environment on physical activity may differ according to life-stage and physical abilities (Haselwandter et al., 2015) . Physical activity decisions of older adults will often be less reliant on time constraints such as work-schedules, and transporting children (Barnes et al., 2016), and older adults may spend more time in their neighborhood environment (Perchoux, Chaix, Cummins, & Kestens, 2013). The unique relationship of older adults with their environment emphasizes the importance of investigating their mobility separate from that of younger adults.

1.3 RESEARCH RATIONALE

Many public health interventions adopt an individual centered approach to changing health behavior. However, relapse rates of interventions that focus on individual behavior are often high (Kwasnicka, Dombrowski, White, & Sniehotta, 2016). As a result, population level interventions are increasingly being proposed as an alternative to individual interventions. A population level approach to health interventions addresses the upstream determinants or root causes of a health behavior by addressing factors such as the environment or social norms (Frank, 1995; Government of Canada, 2013; Labonte, Polanyi, Muhajarine, Mcintosh, & Williams, 2005).

This thesis takes an approach grounded within the discipline of Health Geography to explore the contextual influence of built environments on physical activity. Creating environments that support physical activity is a population level approach with the potential to have widespread health benefits for the population. However, most research has focused on examining the macro-scale environment (e.g., density, street connectivity) of neighborhoods, elements of the neighborhood structure that are difficult to change. In contrast, changing the micro-scale environment could be a comparatively cost-effective method of changing the environment to support walking (i.e., installing benches or improving the quality of the sidewalk is less costly than reconstructing the street network to increase density)(Sallis, Cain, et al., 2015).

There is limited quantitative evidence on the relationship between the micro-scale environment and walking behavior in older adults (Cerin et al., 2017; Van Cauwenberg et al., 2018), and the studies present in the literature are often limited in geographic scope due to the resource intensive nature of the in-person auditing approach (Cain et al., 2014; Sallis, Cain, et al., 2015). There is a need for more quantitative studies that adopt a virtual auditing approach to measuring the micro-scale environment. Virtual audits are a cost-effective alternative to the in-person auditing approach, that are performed at a researcher's desk, often over Google Street View (www.google.com/maps) by navigating video stills of the street. Virtual audits do not require travel time, which reduces the travel and cost restraints associated with in-person audits. This can allow for a larger geographic scope of analysis (i.e., auditing large or distant areas), enhancing the generalizability of findings (Bader, Mooney, Bennett, & Rundle, 2017).

Most studies in this field are ecological studies that rely on objective measures of the environment to shed light on the relationship between the built environment and walking (Lee & Dean, 2018). There is limited qualitative evidence on how older adults' experiences of the micro-scale environment might influence their walking behavior (Lockett, Willis, & Edwards, 2005; Mitra, Siva, & Kehler, 2015; Moran et al., 2017; Van Cauwenberg, Van Holle, et al., 2012; Yoo & Kim, 2017). Qualitative studies can help researchers to understand the interplay between the built environment, walking, and an array of social, cultural, and political factors that might influence the relationship of interest (Steinmetz-Wood, Pluye, & Ross, 2019). Studies integrating experiences of places can also shed light on the effectiveness of potential interventions. These studies can help explain how the built environment influences walking, as well as why and where older adults walk, which provides an indication of whether older adults are actually walking in the available environment (Lee & Dean, 2018).

Within the context of an aging population, there is a need for policy amenable research to promote healthy aging. Mixed methods research uses multiple methods (quantitative and qualitative) that can help to bring to light the different dimensions of a phenomenon, giving it the potential to stimulate the methodological creativity needed to address complexity (Mertens et al., 2016). Researchers faced with understanding the complexity of urban systems on the health of populations have turned to mixed methods to gain a better understanding of the linkages that exist between humans and their environment, and to design interventions that can better account for these intricacies (Stathi et al., 2012; Van Cauwenberg et al., 2014; Van Cauwenberg et al., 2016; Zandieh, Martinez, Flacke, Jones, & Van Maarseveen, 2016).

Walking behavior is driven by individual factors (e.g., age, health, motivation, attitudes, and preferences) but the environment sets the conditions that make walking for leisure or utilitarian purposes feasible, pleasant, or safe. Ecological models suggest that interventions that account for individual characteristics, social environments, physical environments, and policies are needed to encourage population level changes in physical activity (Sallis et al., 2006). A mixed methods approach can inform interventions by helping researchers to gain a better understanding of the relationship between older adults and their built environment, and the complexities of the personal, social, and cultural mechanisms that might influence how older adults interact with this environment. Mixed methods studies could also be instrumental for understanding the relationship between the micro-scale environment and walking behavior, as the quantitative strand of a mixed methods study allows the identification of micro-scale determinants, while the qualitative strand allows the exploration of older adults' lived experiences of the micro-scale environment. Together these can provide a better understanding of the changes to the urban environment that will make the greatest difference for older adults' walking behavior and contribute to knowledge that could allow older adults to age well in their home neighborhoods.

1.4 DISSERTATION STRUCTURE

This thesis includes a collection of five manuscripts and is organized into eight chapters. In chapter 1, I introduce the reader to the thesis topic and present the dissertation research objectives. In chapter 2, I introduce my conceptual approach and review the literature on the relationship between the built environment and walking in older adults. In chapter 3, I present my first manuscript that presents best-practices for studies adopting the methodological approach adopted in my thesis – mixed methods. In chapter 4, I present the findings of my second manuscript that describes the creation and evaluation of the reliability of the Virtual-STEPS tool, a tool created to virtually evaluate neighborhood environments. In chapter 5, I present the findings of my third manuscript that tests the face validity of the Virtual-STEPS tool by evaluating the individual and collective influence of micro-scale features on walking outcomes (utilitarian and leisure walking) in a sample of adults. In chapter 6, I present the findings from my fourth manuscript, on the individual and collective influence of the micro-scale items from the Virtual-STEPS tool on walking outcomes (utilitarian and leisure walking) in older adults. In chapter 7, I present the findings from my fifth manuscript that explores older adults' perceptions of the built environment influences on walking. In chapter 8, I conclude by discussing the substantive knowledge, methodological, and policy contributions of my dissertation.

2 CHAPTER TWO | LITERATURE REVIEW

2.1 OVERVIEW

This chapter provides a review of the literature. The chapter begins by situating the thesis topic, the contribution of the micro-scale environment to the walking behavior of older adults, within the conceptual approach of interest. This is then followed by a summary of the studies that examined the influence of the built environment on physical activity. The review then focuses in on the studies that have examined the influence of the built environment on walking outcomes (utilitarian walking and walking for leisure). In terms of the built environment, the chapter first describes the literature that has examined the macro-scale environment (e.g., density, land-use mix, connectivity) of places and then moves on to describe the quantitative, qualitative, and mixed methods studies that have focused on the 'exposure' variable of interest, the micro-scale environment (e.g., sidewalks, nature areas, traffic calming features). The manuscripts are included in their original form in this dissertation, therefore there is some overlap between the literature that is discussed in this chapter and the material included in the manuscripts.

2.2 CONCEPTUAL APPROACH

This thesis takes an approach that is grounded within Health Geography, a sub-discipline of Human Geography, with a focus on the relationship between place and health (Collins & Evans, 2016). The approach is centered on the idea that researchers must step beyond the individual level approach to disease prevention towards an ecological approach that accounts for both upstream and downstream level influences on health (Meade, 2010). Health Geography considers the role of both compositional and contextual factors on human health, whereby compositional factors include individual characteristics (e.g., age, sex, education, genetics) and contextual factors are comprised of environments such as the social (e.g., collective efficacy of a neighborhood) or the physical environment (e.g., the built environment of a neighborhood) (Kawachi & Berkman, 2003).

With a focus on spatial variations in health and health determinants our neighborhood approach to analysis aims to better understand the influence of neighborhood-built environments on the health behavior of older adults. This is motivated by the idea that neighborhood features are inherently more modifiable than individual behaviors – the latter have been shown by the history of public health interventions to be notoriously difficult to change even under optimal circumstances (Dishman & Buckworth, 2007; Stamler, 1985).

The thesis approach is also guided by the population health framework. In Canada, the population health approach has been endorsed by many sectors of government including the federal, provincial, and territorial ministers of health. The Federal, Provincial, and Territorial Advisory Committee on Population Health (1999) defines the population approach as follows:

> As an approach, population health focuses on the interrelated conditions and factors that influence the health of populations over the life course, identifies systematic variations in their patterns of occurrence, and applies the resulting knowledge to develop and implement policies and actions to improve the health and well-being of those populations (p.7).

The Public Health Agency of Canada describes the population health framework as one that recognizes that the relationship between the determinants of health such as income, social status, social support, education, employment, the social environment, the physical environment, biology, gender, culture, and health services is complex and that these determinants interact to influence health status. This framework acknowledges the importance of accounting for exposures to risk factors across the life-course, and the importance of reducing health inequalities (Frank, 1995; Government of Canada, 2013; Labonte et al., 2005). It also recognizes the importance of investing in upstream determinants of health to address the root causes of health outcomes because changing these determinants has the potential to have the greatest impact on population health status.

This dissertation is also informed by socioecological models of physical activity. Socioecological models are interdisciplinary models that draw on perspectives from medicine, public health, and the behavioral, and social sciences. Socioecological models of health behavior are centered on the notion that health behaviors are influenced by multiple attributes of humans and their physical and social environments (Stokols, 1992). They are based on three key principles. The first is that there are multiple levels of influence on health behaviors (e.g., physical activity) and health status (Stokols, 1992; Sallis et al., 2008; Sallis et al., 2015). Levels will often include intrapersonal (e.g., biological and psychological), interpersonal (e.g., social and cultural), physical environment (objective and perceived), and policy levels (Sallis, Owen, & Fisher, 2008). The second is that multiple influences interact within and across levels (Sallis et al., 2008; Sallis et al., 2015). For example, an individual with a mobility disability may be less likely than an individual without a mobility disability to take regular walks in a walk-friendly environment. The third is that multi-level interventions will be the most successful in changing behavior and impacting health (Sallis, Owen, et al., 2015; Stokols, 1992). This means that interventions at one level should be accompanied by interventions at other levels. For example, media campaigns to promote physical activity should be coupled with improved access to recreational facilities.

Based on the Sallis et al. (2006) *Ecological Model of the Four Domains of Active Living*, a socioecological model of walking was created to visualize the multiple dimensions that influence walking behavior (Figure 2.1). The socioecological model has 5 levels: intrapersonal (e.g., sociodemographic characteristics), perceived environment (e.g., perceived safety), interpersonal (e.g., friends to walk with), behavior settings (e.g., the built environment), and the policy environment (e.g., zoning regulations). The micro-scale built environment (the independent variable of interest) is included within the behavior settings level under built environment and as is true for other socioecological models is believed to interact within and across the different levels.

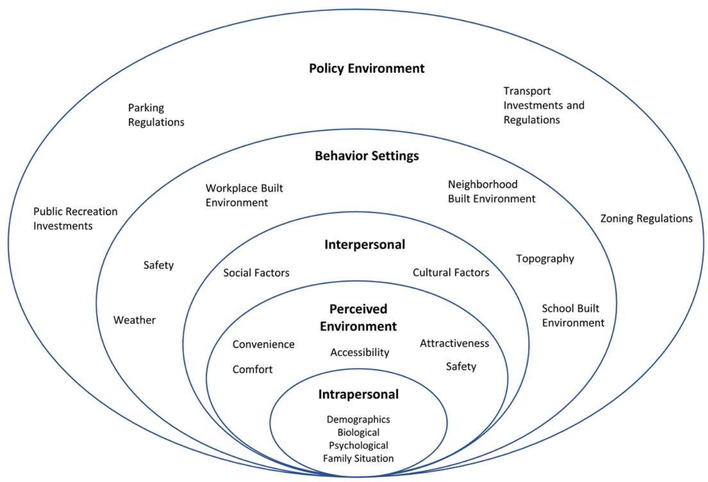

Figure 2.1: Socioecological model of walking (utilitarian/leisure) based on the Sallis et al. (2006) *Ecological Model of the Four Domains of Active Living*

2.3 THE BUILT ENVIRONMENT AND PHYSICAL ACTIVITY

Research suggests that an age-friendly neighborhood is a neighborhood that has environmental characteristics that support physical activity and health (Beard & Petitot, 2010; Clarke & Nieuwenhuijsen, 2009). Built environments have long been recognized as important for physical activity, and the vitality of neighborhoods. In 1961, Jane Jacobs argued that short blocks, a mix of land-uses, density, and buildings of different ages could help to encourage pedestrian activity. Decades later, Cevero and Kockelman (1997) developed a conceptual framework for understanding the influence of urban environments on transportation choices including active modes. The conceptual framework consists of the 3Ds: density, diversity, and design. The dimension of density encompasses the notion that compact neighborhoods decrease the average distance between origins and destinations, which can provide for more opportunities to walk or cycle to a destination. Density is often represented by the residential or population density of an area, which can be measured by taking the population of a unit and dividing it by the area of the unit. Diversity captures the notion of access to a diversity of land-uses within an area. Diversity is often represented by the land-use mix of an area, which can be measured using a variation of the Shannon entropy index[2]. Finally, design encompasses street design schemes that can make destinations more convenient and accessible. Design is often represented by the connectivity of an area, which can be measured by counting the number of four-way intersections or the number of dead ends and cul-de-sacs in an area. Design also encompasses site design, which can make destinations more convenient to reach (short setbacks, parking in the back), or provide amenities (e.g., sidewalks, trees, streetlights) to pedestrians or cyclists.

Since the development of this conceptual framework, many researchers have examined how 'walkable' (i.e., walk-friendly) environments, also known as 'neighborhood physical activity environments' (Hajna, Ross, Griffin, & Dasgupta, 2017) or 'active living environments' (Evenson, Sallis, Handy, Bell, & Brennan, 2012), encourage physical activity (Barnett, Barnett, Nathan, Van Cauwenberg, & Cerin, 2017; Cerin et al., 2017; Farkas et al., 2017; McCormack & Shiell, 2011; Van Cauwenberg et al., 2011; Van Cauwenberg et al., 2018). The walkability of neighborhoods is commonly measured using a composite index comprised of its macro-scale components[3]:

[2] The Shannon entropy index is an index with values that vary between 0 and 1, where 0 is a completely homogeneous area and 1 is a completely heterogeneous area, with respect to the land-uses of interest.
[3] Components of walkability that act to reduce the average distance that an individual will walk to get to a variety of destinations (e.g., connectivity, density of destinations)

population density, land-use mix, and connectivity (Carlson et al., 2012; Shimura et al., 2012; Van Holle et al., 2014). Social surveys (Cerin, Saelens, Sallis, & Frank, 2006) and neighborhood audits (Cain et al., 2014) have also allowed researchers to integrate detailed measures of micro-scale walkability[4] (i.e., pedestrian or cyclist amenities and site design) in their walkability metrics.

Many reviews of the literature suggest that there is strong evidence in support of a positive relationship between the built environment and physical activity (Barnett et al., 2017; Hajna et al., 2015; McCormack & Shiell, 2011; Saelens & Handy, 2008a; Van Cauwenberg et al., 2011). Evidence from a study consisting of a review of 13 reviews published between 2002 and 2006, and a review of 29 original studies published between 2005 and 2006 suggest that density, distance to non-residential destinations, and land-use mix were consistently associated with utilitarian walking (Saelens & Handy, 2008a). A systematic review and meta-analysis of the literature on Geographic Information Systems derived walkability and daily steps (measured using a pedometer or accelerometer) indicated that adults living in walkable neighborhoods accumulate 766 more steps per day (Hajna et al., 2015). A comparison study that used comparable built environment metrics across multiple countries also suggests that the built environment promotes physical activity (Sallis et al., 2016). In the study of 6,822 adults aged 18–66 years from 14 cities in ten countries on five continents, net residential density, intersection density, and public transport density were found to be associated with accelerometer assessed physical activity. Participants living in the most activity-friendly neighborhoods were significantly more physically active than those living in the least activity-friendly neighborhoods, with the authors observing a difference in physical activity ranging from 68 to 89 min/week (Sallis et al., 2016).

[4] Components of walkability that act on a pedestrian's pleasure or comfort when walking.

Systematic reviews of the literature in older adults also suggest that the built environment is positively associated with physical activity (Barnett et al., 2017; Cerin et al., 2017; Van Cauwenberg et al., 2011; Van Cauwenberg et al., 2018; Yen, Michael, & Perdue, 2009). A systematic review of the literature on the influence of neighborhoods on health and wellbeing in older adults examined six neighborhood exposures: neighborhood socioeconomic composition, racial composition, demographics, perceived resources and problems, the physical environment, and the social environment. They noted that most studies examined how physical environments contribute to physical activity, and that these studies suggest that neighborhood walkability was consistently positively associated with the walking behavior of older adults (Yen et al., 2009). A systematic review of the literature on the relationship between the built environment and physical activity reported that many studies have found that access to recreational facilities, and crime-related safety were positively associated with physical activity in older adults (Van Cauwenberg et al., 2011). Evidence from a systematic review and meta-analysis also suggests that built environments encourage physical activity in older adults. The authors found that ranked by strength of evidence, walkability, safety from crime, and access to destinations and services were important determinants of physical activity (Barnett et al., 2017).

2.4 MACRO-SCALE WALKABILITY AND WALKING IN OLDER ADULTS

Walking is a prime target for the implementation of public health interventions, as it is a safe, accessible (Hillsdon & Thorogood, 1996), popular form of physical activity in this age group (Lim & Taylor, 2005; Päivi, Mirja, & Terttu, 2010). Because walking is linked to many positive health benefits, promoting walking in older adults could be an important method of reducing the disproportionate demand for health care services that is projected for Canada's elderly population

(Wister & Speechley, 2015). Urban neighborhood built environments may also provide a promising target for public health interventions because more than 80% of Canadians live in cities (Statistics Canada, 2011).

Many researchers have inquired into the components of macro-scale walkability (connectivity, land-use mix, and the density of destinations or people) and how these might influence walking behavior (Procter-Gray et al., 2015; Sugiyama et al., 2015). Macro-scale walkability has been measured using composite indexes of the neighborhood layout such as the walkability index (Carlson et al., 2012; Frank et al., 2010; King et al., 2011; Shimura et al., 2012; Van Holle et al., 2014), the proprietary Walkscore® (Barnes et al., 2016; Thielman et al., 2015), or an active living index created using open data (Herrmann et al., 2019; Mah, Sanmartin, Riva, Dasgupta, & Ross, 2020).

Cross-sectional and longitudinal evidence suggests that macro-scale features of the built environment encourage utilitarian walking in older adults (Barnes et al., 2016; Carlson et al., 2012; King et al., 2011; Shimura et al., 2012; Thielman et al., 2015; Van Holle et al., 2014). Notably, a longitudinal study measured the change in neighborhood walkability over 4 years and its relation to declines in walking in mid-aged to older adults. Findings indicated that declines in utilitarian walking over the 4 year study period were significantly less in walkable neighborhoods (average of 1.1 minutes less per day in walkable neighborhoods versus an average of 6.7 for low walkable neighborhoods) (Shimura et al., 2012). A systematic review of the literature also supports these findings. Their results indicated that there was strong evidence of a positive association for residential density, walkability, and several measures of access to/availability of services/destinations and total walking for utilitarian purposes (Cerin et al., 2017) .

The cross-sectional evidence on associations between the macro-scale built environment and leisure walking is mixed, with many studies finding no significant association (Carlson et al., 2012; Procter-Gray et al., 2015; Van Holle et al., 2014). Most longitudinal studies examining the determinants of leisure walking concur with the cross-sectional evidence base (Hirsch, Diez Roux, Moore, Evenson, & Rodriguez, 2014; Hirsch, Moore, et al., 2014; Shimura et al., 2012), implying that other aspects of the physical or social environment may be more important for explaining walking for leisure in older adults (Van Holle et al., 2014). However, recent research reveals a relationship between walkability and leisure walking after controlling for population center size, a variable that has not been controlled for in previous studies on leisure walking in this population group. The longitudinal study of 11,200 Canadians, participating in the National Population Health Survey from 1994 to 2010 demonstrated that exposure to high walkable neighborhoods was associated with leisure walking for older adults living in medium (pop ≥100,000 and <500,000) or large (pop. ≥500,000) population centers (Wasfi, Steinmetz-Wood, & Kestens, 2017). Further, a systematic review and meta-analysis that synthesized the evidence on the built environment and walking for leisure in older adults concluded that there is some evidence that a relationship could exist between the walkability index, as well as land-use mix, and walking for leisure, although much stronger evidence exists for utilitarian walking (Van Cauwenberg et al., 2018).

2.5 MICRO-SCALE WALKABILITY AND WALKING IN OLDER ADULTS

2.5.1 Quantitative evidence

Another research focus is how micro-scale (i.e., street-level) built environment features may influence the walking behavior of older adults. In a systematic review of the literature, the authors concluded that there is some evidence that benches/sitting facilities, pedestrian friendly features, traffic volume, parks/open spaces/recreational destinations and lack of littering/vandalism/decay may encourage walking for utilitarian purposes in older adults. However, they emphasized that with the exception of pedestrian-friendly features, few studies have tested the effect of streetscape features on walking for transportation in this age-group implying that further research is needed (Cerin et al., 2017). In a large study of micro-scale elements of the built environment, consisting of a sample of 48,879 older adults from Belgium, Van Cauwenberg et al. (2012) reported that unexpectedly, perceived traffic safety, presence of public toilets, quality of sidewalks, and absence of noise and decay were negatively associated with utilitarian walking. Conversely, in another study using perceived measures of the environment, researchers found that aesthetically pleasing environments and traffic safety promoted walking for utilitarian purposes for at least 150 minutes per week (Inoue et al., 2011). Studies using a composite index of micro-scale walkability suggest that micro-scale features influence the utilitarian walking of older adults independently of the macro-scale walkability of a neighborhood. In the most comprehensive examination of micro-scale determinants of walking, Cain et al. (2014) used the Micro-scale Audit of Pedestrian Streetscapes (MAPS) direct observation instrument to assess the micro-scale environment along a quarter mile long road from the residence towards the nearest non-residential destination. Their results suggested that micro-scale elements of the built environment might explain differences in utilitarian walking rates in neighborhoods of a similar overall macro-scale walkability (Cain et al., 2014; Sallis, Cain, et al., 2015). Using the same sample of older adults, Sallis et al. (2015) found that improving neighborhoods with the least favorable micro-scale environment quintile to meet the standards of the highest quintile could result in a 250% increase in walking and biking for utilitarian purposes. The authors also observed a positive association between micro-scale features and walking for utilitarian purposes including: curb cut quality, intersection control, and building height setback (Sallis, Cain, et al., 2015).

A limited number of studies have examined the micro-scale determinants of leisure walking. Researchers using the MAPS direct observation instrument found that, after controlling for the macro-scale walkability of a neighborhood, there was no cumulative impact of micro-scale environmental features on leisure walking (Cain et al., 2014; Sallis, Cain, et al., 2015), although associations were observed for building aesthetics, absence of parking lots, building height setback, building height road width ratio, and wide one-way street design (Cain et al., 2014). Researchers using perceived measures of the micro-scale environment observed that no features of the micro-scale built environment were related to recreational walking including: perceived measures of walking/cycling facilities, aesthetics, pedestrian traffic safety, and safety from crime (Shigematsu et al., 2009). In contrast, several studies using perceived measures of the environment have demonstrated that aesthetically pleasing environments promote walking for recreation (Inoue et al., 2011; Troped et al., 2017). Results from an objective audit of pedestrian streetscapes revealed that many attributes of the micro-scale environment were positively related to walking for leisure including: building attractiveness, natural sights, absence of signs of crime/disorder, and absence of litter (Cerin et al., 2013). A recent study conducted objective audits of neighborhood environments using Google® Street View to audit the neighborhoods of 2,224 older adults. The study revealed that sidewalk characteristics, and the presence of gardens and flowers was associated with walking for leisure (Christman, Wilson-Genderson, Heid, & Pruchno, 2019). Finally, a systematic review and meta-analysis that synthesized the evidence on the objective and perceived built environment and leisure walking in older adults suggests that there is strong evidence linking a pleasant aesthetic environment to walking for leisure in older adults, with other features of the micro-scale environment to infrequently studied to draw firm conclusions (Van Cauwenberg et al., 2018).

2.5.2 Measuring the micro-scale environment

In quantitative studies, built environments can be measured subjectively using surveys aimed at identifying individual perceptions or "objectively" using administrative data or audits (observational method) (Brownson, Hoehner, Day, Forsyth, & Sallis, 2009). Most studies have used the traditional field auditing approach to measure micro-scale environments. This resource-intensive approach requires auditors to be physically present to conduct audits, which can lead to considerable time and cost restraints (Chudyk, Winters, Gorman, McKay, & Ashe, 2014; Lafontaine, Sawada, & Kristjansson, 2017). Technological advances have led to the development of virtual audits, efficient alternatives to observational field audits. These tend to be safe for auditors, require less time, are lower cost, and allow researchers to audit more study sites. It can also facilitate auditing of dispersed, large, or distant areas (Bader et al., 2017; Curtis, Curtis, Mapes, Szell, & Cinderich, 2013; Kelly, Wilson, Baker, Miller, & Schootman, 2013; Lafontaine et al., 2017) improving the geographic scope and generalizability of findings, since variations in the built environment of neighborhoods implies that associations may also vary (Bader et al., 2017). This method of data collection is also significantly more flexible compared to in-person auditing methods, as auditors can easily refer to street stills at a later point in time if they discover that the assessment of additional environmental features is warranted.

Most virtual audits have been performed using Google Street View™ (GSV) a web-service that has existed since 2007 (www.google.com/maps). This service was originally only available in American cities but has progressively expanded to provide video stills of streets from across the world (Griew et al., 2013). GSV can be accessed through Google Maps or Google Earth and provides a 360° horizontal and 290° vertical panoramic view of streets. This tool has allowed researchers to perform audits at their desk by virtually navigating streetscapes (Bader et al., 2017; Griew et al., 2013; Lafontaine et al., 2017).

Previous research has indicated high levels of agreement between virtual and in-person audits (Badland, Opit, Witten, Kearns, & Mavoa, 2010; Clarke, Ailshire, Melendez, Bader, & Morenoff, 2010; Griew et al., 2013; Kelly et al., 2013; Odgers, Caspi, Bates, Sampson, & Moffitt, 2012; Rundle, Bader, Richards, Neckerman, & Teitler, 2011). Research has also shown high agreement between Google Street View audits and assessments obtained from local residents (Chiang, Sullivan, & Larsen, 2017). Virtual audits can also provide a valid alternative to field audits for measuring micro-scale features (Zhu et al., 2017). Zhu et al. (2017) created an online version of the MAPS tool that would be compatible with GSV. The researchers audited designated routes in San Diego and Phoenix, and consistent with previous research, demonstrated a higher reliability for items that involve the verification of the presence of an item and lower reliability for items that are temporally variable or that require a subjective assessment (Zhu et al., 2017). This research is promising, as it suggests that virtual audit tools can reliably assess the micro-scale environment. However, many previous virtual auditing tools have not been specifically designed to measure the micro-scale environment. These tools are also often very lengthy (i.e., have many items), which means that even if street segments are evaluated virtually auditing can still be a very time-consuming process making it difficult to audit large geographic areas.

2.5.3 Qualitative evidence

A systematic review of qualitative studies found that micro-scale features are consistently mentioned in qualitative explorations of the micro-scale environment (Moran et al., 2014). Many qualitative studies emphasize the importance of pedestrian infrastructure (Lockett et al., 2005;

Mitra et al., 2015; Moran et al., 2017; Van Cauwenberg, Van Holle, et al., 2012; Yoo & Kim, 2017). One important perceived barrier to walking identified is sidewalk quality. For example, in a study of older Flemish adults, researchers conducted walk-along-interviews with older adults to and from a destination within a 15-minute walk from the participants' home. During the walk-along-interviews, almost all participants mentioned that sidewalk quality was a significant deterrent to walking. Uneven sidewalks, cracked tiles, and snow were other important barriers due to risks of falling (Van Cauwenberg, Van Holle, et al., 2012).

Qualitative studies have also found that traffic calming features are also perceived as positive elements of the environment that promote walking (Van Cauwenberg, Van Holle, et al., 2012). Features such as cross walks and traffic lights help older adults to feel safe, while they are crossing the street, and some older adults report following a longer route if it means that they can cross the street at an intersection with a cross walk or streetlight (Van Cauwenberg, Clarys, et al., 2012). Pedestrian timers that provide older adults with enough time to cross the street is another facilitator. For example, in Lockett et al. (2005), a photovoice study of older adults, an older women reported getting stuck on the traffic island in the middle of the street on her way to the mall because the traffic light would not provide her with enough time to finish crossing (Lockett et al., 2005).

Aesthetics is also perceived as an important enabler (Lee & Dean, 2018; Lockett et al., 2005; Mitra et al., 2015; Moran et al., 2014; Moran et al., 2017; Van Cauwenberg, Van Holle, et al., 2012; Yoo & Kim, 2017). In a study of frequent walkers (at least three days a week) conducted in Mississauga, Canada, proximity to parks and natural landscapes was an important contributor to walking. Aesthetic elements related to nature were the elements that were most frequently mentioned as enablers of walking (enjoyment of nature, nice scenery, fountains) and were thought to have positive effects on mental health (Mitra et al., 2015). Older adults have also reported preferring to walk in areas with aesthetically pleasing building architecture such as historic buildings, monuments, and older houses (Van Cauwenberg, Van Holle, et al., 2012). Older adults prefer places that facilitate strolling within the neighborhood with scenery that changes over the four seasons and that vary with respect to buildings, people, and products available in markets and shops (Yoo & Kim, 2017). Aesthetic elements can also act as barriers to walking. For example, older adults report that litter deters walking due to the smell, it attracts insects, it can act as a tripping hazard, and take up walking area on the sidewalk (Moran et al., 2017).

Seating can also help older adults to safely engage in physical activity. Many qualitative studies emphasize that older adults need resting areas with shelters, especially older adults with mobility impairments (Lockett et al., 2005; Mitra et al., 2015; Moran et al., 2014; Moran et al., 2017; Schmidt, Kerr, & Schipperijn, 2019; Yoo & Kim, 2017). For example, in Ottoni et al. (2016), a 64 year old women described how she planned her route according to the location of benches: "I have arthritis in my knees, so I try to walk where the walking is easy and there are benches to sit on… I like to walk where I can stop to rest if I have to." Benches should also have an accessible design and should be accessible during the winter (Moran et al., 2014). When benches are absent some older adults may use public seating in malls or community centers as resting places during their usual walk (Mitra et al., 2015).

A strength of qualitative studies is that they can help to shed light on the interaction between the environment and personal motivations for walking (Lee & Dean, 2018). A study of seniors in Toronto found that having positive experiences of the environment such as seeing trees, nature, and children playing can contribute to personal motivations for walking; whereas not being able to interact with the outside environment due to personal or environmental barriers discouraged older adults from being physical and put them at risk for isolation and depression. The study also emphasized how their objective measures obtained through field audits of the environment did not account for important social factors that influenced older adults' propensity to walk including: the number of people on the streets, the friendliness of locals, and levels of interactions that occur in public spaces. These factors are important because older adults wanted to walk, so as to participate in social life, and to experience a sense of community (Lee & Dean, 2018).

2.5.4 Mixed methods studies

Few studies exploring the influence of micro-scale features on the walking behavior of older adults have adopted a mixed methods approach. However, studies that have explored how these features contribute to older adults' walking behavior reveal insights that could help to better inform a policy response in favor of urban interventions to promote healthy aging. In Stathi et al. (2012) the authors used a mixed methods approach to explore barriers to older adults' physical activity. They conducted an explanatory mixed methods study, whereby they used a quantitative questionnaire to identify the perceived barriers to physical activity. These identified barriers were explored in depth in the qualitative semi-structured interviews. Older adults perceived that there were more barriers to their physical activity and walking behavior than what was included in the questionnaire and that these barriers were important contributors to older adults' decisions to be active in their neighborhood. Barriers identified in the semi-structured interview included: uneven sidewalks, slippery or uneven surfaces, poorly maintained gardens, and cleanliness. The semi-structured interviews also identified facilitators to neighborhood walking including micro-scale elements such as benches, and aesthetically pleasing environments.

In two mixed method studies by Van Cauwenberg et al. (2014; 2016), the authors attempted to gain a better understanding of how hypothetical environmental changes to the micro-scale environment might influence older adults' utilitarian walking. Older adults were asked to sort photographs in order of importance for utilitarian walking. Their analyses revealed that streets with even sidewalks, little traffic, and sidewalks that were clean had the greatest appeal for walking (Van Cauwenberg et al., 2014; Van Cauwenberg et al., 2016). In the interviews with participants, seniors also expressed a preference for streets with vegetation and pleasant aesthetic features. However they were mainly concerned with elements of the micro-scale environment that might increase their risk of falling and injury such as the presence of garbage on sidewalks or poor sidewalk upkeep (Van Cauwenberg et al., 2014).

3 **CHAPTER THREE |** MANUSCRIPT 1: THE PLANNING AND REPORTING OF MIXED METHODS STUDIES ON THE BUILT ENVIRONMENT AND HEALTH

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3.1 PREAMBLE

Mixed methods studies can allow researchers to identify environmental determinants in a population of interest and to better understand underlying contextual factors (e.g., social and cultural) that play an important role in built environment– health research. Many mixed methods studies in the built environment and health do not specify their methods, which could limit the quality of studies in this field. In this chapter, I addressed the first objective of the dissertation by *exploring and documenting best-practice approaches for mixed-methods studies on the built environment and health*. This manuscript provides an overview of mixed methods research designs and integration strategies. It also discusses recommendations for mixed methods research in the field of built environment – health research. We find that specifying a research design and an integration strategy has many advantages including: it can enhance the transparency of the study, enhance the reproducibility of the study, and provide guidance for researchers with little knowledge of mixed methods. Reporting a research design and an integration strategy in mixed methods studies could help to strengthen our ability to gain new insights into the multidimensional nature of the relationship between the built environment and health. This paper was published in *Preventive Medicine:*

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3.2 ABSTRACT

Researchers examining the influence of the built environment on health are increasingly using mixed methods approaches. The use of more than one type of methodology to address a single research question is compelling in this field because researchers investigating the impact of the built environment on health have been faced with proposing solutions to a complex societal problem involving interacting systems and social uncertainties. Mixed methods studies can help researchers to gain a better understanding of the relationships that exist between humans and their environment by drawing on qualitative and quantitative methods. Mixed methods studies could also be instrumental for providing effective policy solutions. This is because they allow researchers to identify built environment determinants of health in a population of interest and to understand the social and cultural factors that might influence the uptake of an intervention by this population. The objective of this paper is to assist those conducting research on the built environment and health who may have little background in mixed methods. We provide an overview of mixed methods research designs and provide concrete techniques for the integration of diverse methods. We also discuss the recommendations for mixed methods research in the field of built environment – health research, drawing on specific examples from published studies. Reporting a research design and an integration strategy in mixed methods studies could help to strengthen our ability to

gain new insights into the multidimensional nature of the relationship between the built environment and health.

3.3 INTRODUCTION

Researchers examining the effect of built environments on health are increasingly using a mixed methods approach (i.e., using quantitative and qualitative methods) in their research studies (Alexander, Alfonso, & Hansen, 2015; Brownson, Brennan, Evenson, & Leviton, 2012; Christensen, Mikkelsen, Nielsen, & Harder, 2011; Clark et al., 2010; Colabianchi et al., 2014; Dulin-Keita et al., 2015; Evenson et al., 2012; Guell, Panter, & Ogilvie, 2013; Heesch, Sahlqvist, & Garrard, 2012; Hennessy et al., 2010; Kipke et al., 2007; Lehning, 2012; Martínez-Andrés et al., 2012; Stathi et al., 2012; Walford, Samarasundera, Phillips, Hockey, & Foreman, 2011). Studies, for example, have employed questionnaires and semi-structured interviews to examine the relationship between the neighborhood environment and fruit and vegetable consumption (Park et al., 2011), or have employed GPS technologies and walking interviews (Zandieh et al., 2016) to examine how the environment influences physical activity.

Researchers investigating the impact of the built environment on health have been faced with proposing solutions to a complex societal problem involving interacting systems and social uncertainties (Rydin et al., 2012). Mixed methods research uses multiple methods (quantitative and qualitative) that can help to bring to light the different dimensions of a phenomenon, giving it the potential to stimulate the methodological creativity needed to address complexity (Mertens et al., 2016). This is because quantitative research is limited in understanding contextual factors and qualitative research may fail to identify important impactful features of the built environment that are not captured by participants perceptions of the environment.

Mixed methods research on the built environment can provide a better understanding of how features such as urban form (Zandieh et al., 2016), transportation (Northcutt Bohmert, 2016), access to healthy foods (Chrisinger, 2016), and green spaces (Honold, Lakes, Beyer, & van der Meer, 2016) are influencing health. Mixed methods studies could also be instrumental for providing effective policy solutions. This is because they allow researchers to identify built environment determinants of health in a population of interest and to understand the social and cultural factors that might influence the uptake of an intervention by this population. Many mixed methods studies in the built environment and health do not specify their methods, which could limit the transparency, reproducibility, and rigor of studies in this field. In this paper, we attempt to improve cross-disciplinary translation of knowledge between mixed methods studies on the built environment and health and those conducted by leading scholars in mixed methods research from other domains. Our paper provides researchers with a mixed methods roadmap to improve the rigor of studies, and knowledge of how to apply mixed methods approaches to research on the built environment and health. The main objective of this review paper is to lay out the foundations of key guiding practices and inform the planning and reporting of studies by providing an overview of mixed methods research designs and concrete integration strategies. We also perform an exploratory search of the literature to provide readers with a set of examples of self-identified mixed methods studies from the built environment and health literature that have adopted each of the research designs and integration strategies. We then discuss the recommendations for mixed methods research in the field of built environment – health research, drawing on specific examples from published studies in this field.

3.4 WHAT IS MIXED METHODS RESEARCH?

In mixed methods studies, researchers integrate quantitative and qualitative methodologies and methods, allowing researchers to tap into different aspects of a social phenomenon (Creswell & Clark, 2011). This research orientation should not be confused with multimethod studies, studies that use two or more research methods that both fall within the same research approach (quantitative or qualitative) (Tashakkori & Teddlie, 2003). The "paradigm war"[5] shaped the development of mixed methods research. The paradigm war was characterized by considerable debate on the compatibility of quantitative and qualitative methods, with some scholars arguing in favor of the "incompatibility thesis" (Lincoln & Guba, 1985; Smith & Heshusius, 1986). The incompatibility thesis posits that one should not include both quantitative and qualitative research in the same study, as they adopt different world views that are incompatible due to their conflicting epistemological and ontological stances (Lincoln & Guba, 1985; Smith & Heshusius, 1986). The incompatibility thesis has been largely refuted within the mixed methods literature with contemporary mixed methods researchers embracing world view and methodological pluralism (Teddlie & Tashakkori, 2012). The community has now moved beyond the idea that there is an "ownership" of methods by worldviews. As contended by Teddlie et al. (2012), "if researchers want to use QUAN or QUAL methods exclusively then this decision should be based on their research question, not some link between epistemology and methods" (p.780). Most contemporary mixed methods researchers now ascribe to a variety of philosophical orientations including pragmatism, critical realism, Campbell's postpositivism, Hacking's social constructionism, and critical theories (Campbell, 1978; Hacking & Hacking, 1999; Sayer, 2000; Teddlie & Tashakkori, 2012; Tyson, 2014; Waal, 2005). Creswell and Clark 2011 propose that a central premise of mixed

[5] Debate during the 1980's over the controversy of combining quantitative and qualitative methods due to the incompatibility of their paradigms.

methods research is that “the use of quantitative and qualitative approaches, in combination, provides a better understanding of research problems than either approach alone” (Creswell & Clark, 2011, p.5). For example, in Zandieh et al. (2016), their mixed methods design allowed them to both identify built environment determinants of walking and to gain an understanding of how participants perceptions of the environment might influence their walking behavior. They were able to point to evidence in support of neighborhood, safety, quietness, and aesthetics, as being important for walking levels because their qualitative and quantitative results converged for these three factors. Many other rationales for conducting mixed methods research have been identified including: to corroborate quantitative and qualitative data, to offset the weaknesses and maximize the strengths of quantitative and qualitative research approaches, to answer questions that require the use of both approaches (Bryman, 2006; Pluye & Hong, 2014), and to explain unexpected findings (Bryman, 2006; Doyle, Brady, & Byrne, 2009; Greene, Caracelli, & Graham, 1989). Mixed methods research can also yield rich sources of data producing a deeper understanding of participants’ experiences. This feature of mixed methods studies is particularly compelling because it reinforces the value of using mixed methods to understand complex social systems and inform policy (Stewart, Makwarimba, Barnfather, Letourneau, & Neufeld, 2008) – an attribute particularly well-suited for studies on the built environment and health.

There are many challenges associated with conducting mixed methods research. It can be difficult to find researchers that are comfortable with or are skilled in both quantitative and qualitative research methodologies (Teddlie & Tashakkori, 2012), and working with researchers with different backgrounds can potentially lead to tensions between team members subscribing to a diversity of worldviews and methodological orientations (Pluye & Hong, 2014). Researchers may also encounter difficulties when trying to design complementary quantitative and qualitative research questions (Stewart et al., 2008; Teddlie & Tashakkori, 2012), combining quantitative and qualitative sources of data, interpreting diverse sources of data, and interpreting divergent findings.

3.5 MIXED METHODS DESIGNS

3.5.1 Types of mixed methods designs

A mixed methods research design specifies the combination of quantitative and qualitative components and articulates when the integration of these components will occur (e.g., during the analysis or interpretation) (Creswell & Clark, 2011; Doyle et al., 2009). Authors should specify, define, and reference the mixed methods design that will be adopted in their study. Typically, these designs will be one of three main types: the convergent design, the explanatory design, and the exploratory design (Creswell & Clark, 2011) (Fig. 1).

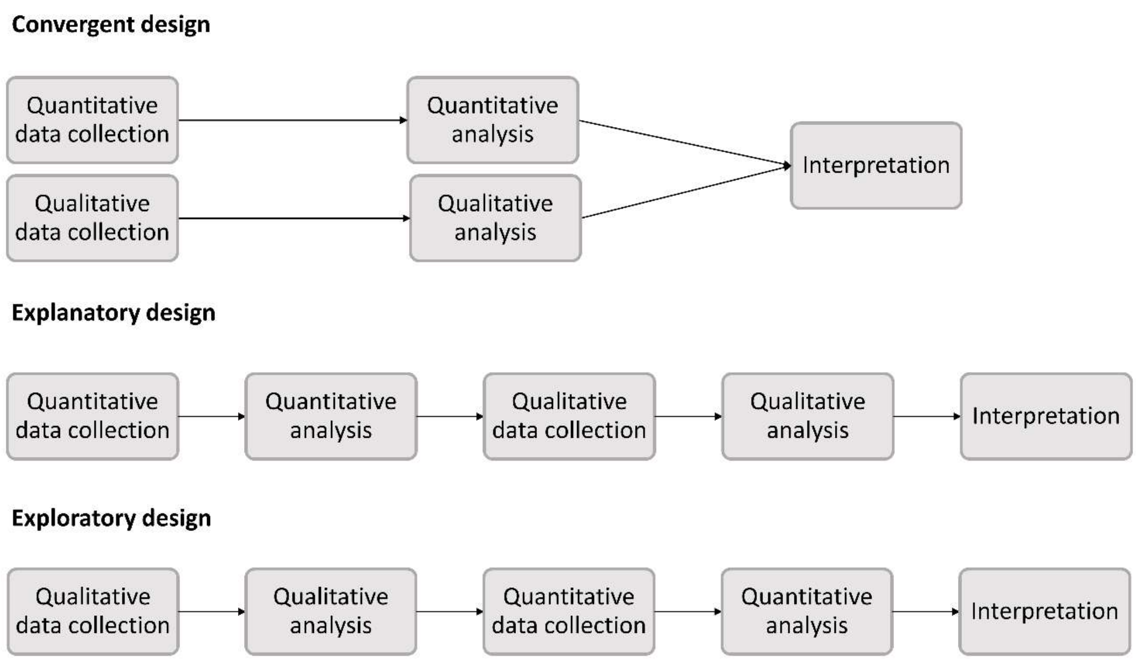

Figure 3.1: Diagram of the three main mixed methods designs.

3.5.2 Convergent design

In a convergent design, findings from a quantitative and qualitative strand are compared to develop a more comprehensive understanding of a phenomenon. In this design, the collection and analysis of quantitative and qualitative data will typically occur during a similar time frame. The collection and analysis of complementary data for the quantitative and qualitative strand are followed by integration of the sources of data during the results or interpretation stage (Creswell & Clark, 2011; Fetters, Curry, & Creswell, 2013). In the convergent design, the researcher is often seeking to compare complementary sources of quantitative and qualitative data, with the aim of identifying convergence/divergence in the results. For example, in their convergent mixed methods study, Zandieh et al. (2016) examined the relationship between potential neighborhood built environment features and walking levels using hierarchical linear regression modelling in their quantitative phase. These results were compared to participants' perceptions of the influence of the neighborhood environment on walking from the qualitative phase to identify converging/diverging findings.

3.5.3 Explanatory design

The sequential explanatory design begins with a quantitative phase – the researcher first collects and analyses the quantitative data. The findings from the first quantitative phase are then used to inform the design of the qualitative data collection and analysis. This type of study generally prioritizes the quantitative phase when addressing the study's research questions (Creswell & Clark, 2011) and aims to help explain the results of the quantitative phase by exploring participant viewpoints in greater detail (Ivankova, Creswell, & Stick, 2006). For example, Gichunge et al. (2016) used a sequential explanatory design to examine the availability and consumption of African vegetables among resettled refugees. Quantitative results revealed that individuals that were older, employed, gardened, and had a supermarket in their neighborhood, were more likely to have traditional vegetables in their home. A qualitative interview guide was subsequently developed to further explore and extend the quantitative findings.

3.5.4 Exploratory design

The exploratory design begins with the collection and analysis of qualitative data followed by the collection and analysis of quantitative data. The exploratory sequential design will generally prioritize the qualitative phase of the study when creating or addressing the study's research questions. The second quantitative phase is designed based on the findings of the first phase and will often aim to test or attempt to generalize the initial qualitative findings (Creswell & Clark, 2011). In Keddem et al. (2015), the authors used an exploratory design to examine how contextual neighborhood factors contribute to asthma control. They first used a semi-structured interviewing technique, to gain an understanding of the neighborhood characteristics that participants perceived as influencing their asthma control. The researchers then selected neighborhood characteristics based on the emerging themes of the qualitative analysis and tested the influence of these neighborhood characteristics on asthma control.

3.6 INTEGRATION

3.6.1 Types of integration strategies

Integration, the combination of quantitative and qualitative worldviews, and/or methods (e.g., integration at the design, data collection, or analysis stage of the research), is an integral part of mixed methods research. As noted by Creswell & Tashakkori: "Mixed methods research is simply more than reporting two distinct 'strands' of quantitative and qualitative research" (Creswell & Tashakkori, 2007, p.108). A mixed methods study should also mix or integrate findings. Integration can occur by comparing findings or through the connection of phases (Creswell & Plano Clark, 2007; Creswell & Clark, 2011). Connection usually occurs in sequential designs and comparison can occur in any type of design (Fetters et al., 2013). Integration strategies have been described in detail in previous work (Creswell & Clark, 2011; Fetters et al., 2013; O'Cathain, Murphy, & Nicholl, 2010; Pluye, Bengoechea, & Granikov, 2018; Pluye, Grad, Levine, & Nicolau, 2009). In this section, we describe the integration framework from Pluye et al. (2018) that outlines three distinct types of integration strategies: 1) the comparison of qualitative and quantitative results, 2) the connection of qualitative and quantitative phases, and 3) the assimilation of qualitative and quantitative data (Fig. 2). These strategies may be used in combination and are not hierarchical (i.e., comparison of results is not superior to phase connection).

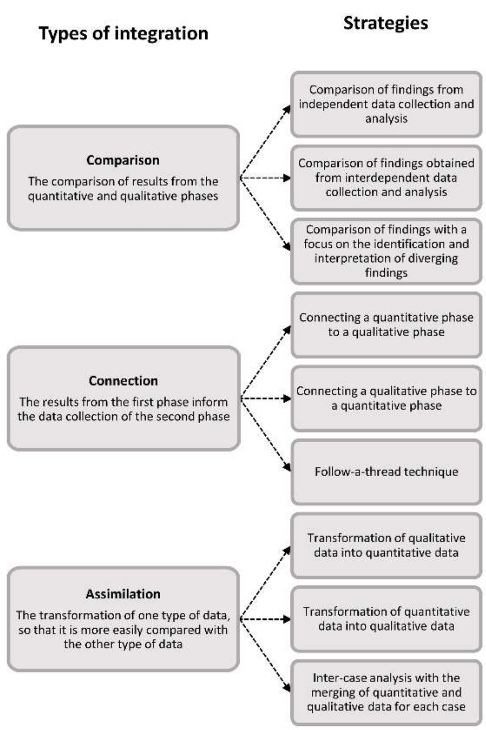

Figure 3.2: Diagram of comparison, connection, and assimilation mixed methods integration strategies.

3.6.2 Comparison of results

Researchers using the comparison strategy will compare the results from the quantitative and qualitative phases using a variety of approaches. Investigators may identify the findings in agreement or those that complement one another, but they may also identify findings that are discrepant, and point out where there are silences (a theme arises in one method and not the other) in the data (O'Cathain et al., 2010) to inform their interpretation of the findings. Often comparisons are presented by juxtaposing a list of findings from both strands on the same page or by placing the results in a table. For example, a category/theme joint display can be used to array the categories or continuous data (rows) from the quantitative analysis by themes (columns) from the qualitative analysis. A joint display can also be used to array the qualitative results and quantitative results (columns) by key themes (rows). A final method of comparing the results is to present the quantitative results followed by one or many quotes from the qualitative phase (or vice versa) in the results or discussion section, followed by a discussion of the convergence/divergence of these results (Creswell & Clark, 2011).

There are three different comparison integration strategies. The first comparison strategy is the *comparison of results from the quantitative and qualitative phases obtained from independent data collection and analysis*. For example, in Leedahl et al. (2014), the authors examined strategies for discharging nursing home residents with mental health issues to the community. The researchers collected quantitative data on the characteristics of individuals discharged from nursing homes and their transition patterns, and they complemented the results from this phase with qualitative findings on successful discharge strategies that were provided by nursing home staff. The second strategy is the *comparison of findings obtained from interdependent data collection and analysis (Creswell & Clark, 2011)*. In this strategy, the researcher will also compare the results using a comparison strategy, as was described above, except the researcher will also consider the *interdependency* of the data collection and analysis in their interpretation of the results. Interdependencies can be, for example, quantitative variables derived from qualitative themes or qualitative phase participants recruited from the sample of quantitative participants. For example, in DiSantis et al. (2016), the authors conducted a study on food shopping, where they first created a map using the location of participants routine destinations, and food stores located near routine destinations. In the semi-structured interviews, each participant was shown the map of their geospatial routine. The authors emphasized how showing the participants a map of their geospatial routine during the interviews revealed patterns in shopping practices that participants may not have noticed and subsequently discussed if the maps had not been present. The third strategy is derived from the first two strategies and consists of focusing the comparison of quantitative and qualitative results on the *identification and interpretation of diverging findings*. Divergence occurs when the findings from the two sources of data contradict one another. The divergence of quantitative and qualitative data can lead some researchers to discard or ignore findings preventing them from gaining unanticipated insights into the nature of the phenomena under study. Strategies for accounting for divergence include reconciliation and initiation. Reconciliation involves the researchers explaining why the divergence in findings is plausible within the context of the study and in some cases can lead researchers to re-analyze their data or to propose a new conceptual framework (Pluye et al., 2009). For example, in a study conducted by Crane et al. (2016) on the community impact of installing a new bicycle pathway, qualitative interviews revealed that community members that had never ridden a bicycle believed that only individuals living outside of the local neighborhood would use the bicycle pathway. However, in the quantitative phase, a survey revealed that most cyclists using the pathway were local residents. The authors made sense of this diverging finding by proposing that there may be a misperception among residents regarding who a cyclist is, since some residents perceived that cyclists are only those that dress in cycling apparel (Crane et al., 2016). The strategy of initiation typically implies that divergent findings provoke new research questions that lead to new data collection and analysis (Pluye et al., 2009). For example, in a study by Moffatt et al. (2006) the authors evaluated the effect of an intervention that delivered welfare rights advice to older adults on well-being and health. The quantitative analyses suggested that there was no difference in health and social outcomes between the intervention and control groups. However, views from the qualitative interviews suggested that the participants believed that the intervention had a positive effect on their well-being. To verify these findings, the researchers collected additional follow-up quantitative and qualitative data to confirm that the positive impacts of the intervention were experienced by more than just the smaller sub-sample of participants that had participated in the initial qualitative interviews.

3.6.3 Connection of phases

Integration by the connection of phases occurs when the results from the first phase inform the data collection of the second phase. This integration technique is usually applied in sequential mixed methods designs. The first connection strategy consists of *connecting a qualitative phase to a quantitative phase*. For example, in the exploratory design, the qualitative phase 1 results inform the phase 2 quantitative data collection and analysis. This strategy has several aims including: to test or generalize qualitative findings to a larger population, create an instrument, validate an instrument, develop a conceptual framework, or design an intervention. For example, In Ferrer et al. (2014), the authors used a connection strategy to assess how individual circumstances and neighborhood contexts influenced opportunities for diet and activity in individuals with obesity or diabetes. They conducted focus groups in a community sample of individuals. Emerging themes from the focus groups were used to develop a structured questionnaire that was administered to 300 respondents.

A second connection strategy consists of *connecting a quantitative phase to a qualitative phase*. For example, in the explanatory design, the quantitative phase one results inform the qualitative phase two data collection and analysis. The aim of this strategy is to validate an instrument or to have the qualitative findings explain the quantitative statistical analyses (e.g., to better understand the differences between groups or understand extreme cases). For example, in the Stathi et al. (2012) investigation of the personal, interpersonal, and environmental factors that influence older adults' physical activity in their neighborhood, the authors integrated by connecting a quantitative phase to a qualitative phase. The quantitative analyses identified findings requiring further clarifications (e.g., very high accelerometry-derived activity levels) that were then explored through careful probing during semi-structured interviews. The interviews also allowed participants to extend the author's findings by discussing the influence of barriers that were not included in the questionnaire. A final connection strategy is the *follow-a-thread technique* that is applied during the analysis stage of the research. In the follow-a- thread technique, the researchers will first conduct preliminary analyses for both phases and if they identify themes (from the qualitative strand) or statistical results (from the quantitative strand) that require further exploration they will follow these across to the other strand and conduct further analyses. A good example of the use of this strategy comes from the literature on occupational health. In Boot et al. (2016), the authors conducted an analysis of factors that are important for work participation in workers with health issues. The quantitative data from the first phase was used to inform the interview guide of the second qualitative phase consisting of semi-structured interviews and qualitative analyses. Based on the qualitative findings, the authors conducted further quantitative analyses as new potential predictors emerged.

3.6.4 Assimilation of data

There are multiple strategies for assimilation of data that all involve the transformation of one type of data, so that it is more easily compared with the other type of data (Creswell & Clark, 2011). One approach to assimilation is the *transformation of qualitative data into quantitative data*. For example, researchers can use quantitative content analysis to transform the qualitative results into numerical counts and variables and then compare this quantitative data to results obtained from the quantitative strand. A second assimilation strategy is the *transformation of quantitative data into qualitative data* by transforming statistical results into a narrative using interpretive analysis such as a thematic analysis. For example, in Reichwein et al. (2015), the authors conducted a study to identify the potential users of family planning interventions in Uganda and Vietnam. The authors created profiles of current user groups using service statistics from family planning services. These profiles were compared to profiles of potential users created from a health survey data analysis and literature review. A qualitative analysis was then performed to fill knowledge gaps regarding potential users.

The final assimilation strategy involves performing an *inter-case analysis with the merging of quantitative and qualitative data for each case*. This can be conducted with a sample or sub-sample of respondents with quantitative and qualitative data for each case. The data is summarized in a matrix with the rows representing the cases and the columns displaying the quantitative and qualitative data collected for each case. This allows researchers to examine the convergence or divergence in the data for each case and then to examine patterns emerging across all cases (O'Cathain et al., 2010; Pluye et al., 2013; Wendler, 2001). For example, in Pluye et al. (2013), the authors examined family physicians' use of an electronic knowledge resource. The quantitative data consisted of family physicians' responses to a questionnaire on their searches performed using the electronic resource and the qualitative data consisted of observations, log reports, archives, and interview data from a sub-sample of searches. They created clinical stories (i.e., vignettes) by merging the quantitative and qualitative data for each search, they then built a meta-matrix in excel with the vignettes as rows and the quantitative and qualitative data for each case as columns. The metamatrix facilitated a critical examination of the evidence available for each case (i.e., search performed by a physician).

3.7 WHY IS SPECIFYING A MIXED METHODS DESIGN IMPORTANT?

Scholars have argued that specifying a mixed methods design can help to convey methodological rigor and has the potential to provide guidance for researchers with little mixed methods experience (Bryman, 2006; Doyle et al., 2009). Methodological and epistemological disagreements have had the effect of many researchers only acquiring methodological experience in either quantitative or qualitative research with even fewer researchers acquiring training in mixed methods (Hesse-Biber, 2010). Specifying a mixed methods design when conducting a mixed methods study on the built environment and health can help readers to understand the justification for using a mixed methods approach and to understand how this approach will assist in answering the research question (Doyle et al., 2009). It can also help to provide a more detailed account of how the study was conducted. For example, in Alexander et al. (2015), the authors' described their concurrent (convergent) mixed methods design. They specified that their concurrent design involved separate data collection, data analysis, and interpretation of the quantitative and qualitative data, and that the data collection, analysis and interpretation of the quantitative and qualitative phases occurred concurrently. They also described how this design allowed for the collection of different but complementary data to be used to answer their research question. Providing such a detailed account of how the study was conducted enhances the reproducibility of the study. It can also help readers to understand and evaluate methodological rigor.

3.8 WHY IS SPECIFYING AN INTEGRATION PROCEDURE IMPORTANT?

There are many reasons why researchers may omit integration in their studies including methodological preferences, epistemological divisions, one set of data rearing more interesting results than the other, the tendency of journals to prioritize either quantitative or qualitative methodologies (Bryman, 2007), and little formal training in the planning and reporting of mixed methods (O'Cathain et al., 2010). What is apparent is that in studies on the built environment and health, integrating can make the conclusions and the process by which they were drawn more explicit for the reader. For example, in Zandieh et al. (2016), a study on the influence of the built environment on walking levels in older adults, the use of a joint display facilitated comparison of quantitative and qualitative findings. The summary table showed that, despite the authors finding perceived inequalities in built environment features, in their qualitative analysis, these inequalities were unlikely to influence older adults walking levels because these attributes were not significantly associated with walking levels in the quantitative phase. Another advantage of reporting an integration procedure is that studies that describe their mixed methods integration procedure enhance the reproducibility of the study. Integration is a step of the analysis process in mixed methods studies and describing an integration procedure ensures that the researcher is fully transparent about this process. Evaluation and comparison of research findings becomes difficult in the absence of a clear messaging about the integration of methods and can impede progress in knowledge creation.

Other writers have also emphasized the importance of integrating mixed methods findings (Creswell & Clark, 2011; Fetters & Freshwater, 2015; Johnson, Onwuegbuzie, & Turner, 2007; Pluye & Hong, 2014). An important aim of mixed methods research is to have mutually informative quantitative/qualitative strands to develop a more comprehensive understanding of a phenomena (Bryman, 2007; Creswell & Clark, 2011). A lack of integration can result in significant methodological deficiencies, since strands of a mixed methods study are unlikely to inform each other in a meaningful way if they are presented as parallel compartmentalized components. This is because the mixing of findings can offer insights that may not arise when analyzing strands with distinct quantitative and qualitative approaches (Bryman, 2007). Integration allows the two strands to complement, compare or expand on each other and will ideally facilitate drawing an overall conclusion. Therefore, many scholars argue that studies that do not integrate their findings are not mixed methods studies (Fetters & Freshwater, 2015; Johnson et al., 2007; Pluye & Hong, 2014) and that integration is one of the most critical steps of a trustworthy mixed methods study (Creswell & Plano Clark, 2007).

Table 3.1: Summary of the advantages of specifying a mixed methods design and integration strategy.

Research design	Integration strategies
Provides guidance for researchers with little knowledge of mixed methods research designs	Facilitates drawing conclusions
Assists readers in understanding the justification for adopting a mixed methods approach	Provides guidance for researchers with little knowledge of mixed methods integration strategies
Enhances the reproducibility of the study	Enhances the reproducibility of the study
Enhances the transparency of the research process	Enhances the transparency of the research process

3.9 DO RESEARCHERS CONDUCTING MIXED METHODS STUDIES ON THE BUILT ENVIRONMENT AND HEALTH SPECIFY THEIR DESIGN AND INTEGRATE THEIR FINDINGS?

Guiding frameworks outlining criteria to follow when reporting and appraising a mixed methods study include the Good Reporting of A Mixed Methods Study (GRAMMS) (O'Cathain, Murphy, & Nicholl, 2008) criteria and the Mixed Methods Appraisal Tool (MMAT) (Pace et al., 2012). These frameworks suggest that mixed methods studies should report their mixed methods design and integration strategy. We wanted to provide readers with a set of examples of self-identified mixed methods studies from the built environment and health literature that have adopted each of the research designs and integration strategies. We also wanted to gain a better understanding of the extent to which mixed methods studies on the built environment and health report a mixed methods design and an integration procedure. Therefore, we conducted an exploratory search on Scopus®, an abstract and citation database of peer-reviewed research. The studies identified by the search are provided in a table (Appendix A, Table 1A).[6] Our Scopus® search identified 267 articles, 50 articles were empirical mixed methods studies that explored the influence of the built environment on health and were written in English or French. 26% (13) of these studies specified their mixed methods design, 34% (17) of studies specified that they had integrated their quantitative and qualitative results[7] and 44% (22) of studies described an integration procedure[8] (Appendix A, Table 1A). Our exploratory search of the literature suggests that less than half of mixed methods studies report their research design and report integrating their

[6] We searched for empirical mixed methods studies published in 2011 to 2016 with the following query: ((TITLE-ABS-KEY(“mixed methods”) AND TITLEABS KEY(“built environment” OR “urban form” OR streetscape OR “physical environment” OR “community design” OR “urban planning” OR neighborhood)) AND DOCTYPE(ar) AND PUBYEAR>2010 AND PUBYEAR<2017). We only included studies that used at least one quantitative (e.g., close-ended interviews) and one qualitative method (e.g., focus groups or semi-structured interviews) and that examined the relationship between the built environment and a health outcome or health behavior (e.g., physical activity, or consumption of fruits and vegetables) and that were written in either English or French.

[7] Authors specified that they integrated (triangulated, combined) the quantitative and qualitative results.

[8] Authors described an integration procedure with or without mentioning that they integrated results.

findings, which could have a negative impact on the quality of the planning and reporting of mixed methods studies produced in this field.

3.10 CONCLUSION

The main objective of this paper was to assist researchers, with little background in mixed methods, with the planning and reporting of their studies by providing an overview of mixed methods research, mixed methods designs (i.e., the convergent, explanatory, and exploratory design), and concrete integration strategies (i.e., the comparison, connection and assimilation strategy). We identified many advantages associated with specifying a mixed methods design and integration. Specifying a mixed methods design can help readers to understand the justification for using a mixed methods approach and to understand how this approach will assist in answering the research questions. Studies that specified a mixed methods design and integration procedure are more transparent about the overall design and research procedure, which enhances the reproducibility of the study. Transparent research designs and procedures can facilitate evaluating and comparing research findings and can promote progress in knowledge creation. Integrating findings can also make the conclusions and the process by which they were drawn more explicit for the reader. Our exploratory search of the literature suggested that less than half of mixed methods studies report their research design and report integrating their findings, potentially impacting the quality of mixed methods studies produced in this domain. To strengthen our ability to gain new insights into the multidimensional nature of the systems governing the linkages between the built environment and health, this paper provided guidance for researchers to help improve the quality of the planning and reporting of their mixed methods studies.

4 **CHAPTER FOUR** | MANUSCRIPT 2: ASSESSING THE MICRO-SCALE ENVIRONMENT USING GOOGLE STREET VIEW®: THE VIRTUAL SYSTEMATIC TOOL FOR EVALUATING PEDESTRIAN STREETSCAPES (VIRTUAL-STEPS)

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4.1 PREAMBLE

As described in the literature review, most studies have measured micro-scale features of neighborhood walkability (e.g., benches, sidewalks, and cues of social disorganization or crime) using field audits. These audits can accrue significant time and travel costs limiting the number and geographic extent of audits. Most audit tools are also very lengthy causing additional accretions in cost and their complexity can limit the eventual use of the tools for modelling purposes. Technological advances have led to the development of virtual audits as alternatives to observational field audits, an alternative that eliminates travel time and is safer for auditors. The objective of my second manuscript was: to *create and validate a virtual auditing tool for the measurement of micro-scale features of the built environment that may influence walking behavior.* The auditing tool, Virtual-STEPS, is a concise tool with 40 items categorized into 6 domains (pedestrian infrastructure, traffic calming and streets, building characteristics, bicycling infrastructure, transit, and aesthetics). The reliability between virtual and field audits, as well as the inter-rater reliability of the tool using percent agreement was assessed using Cohen's Kappa statistic, and the Intra-class Correlation Coefficient. The results from this manuscript demonstrated that Virtual-STEPS is a reliable tool, with high reliability between virtual and field audits and high inter-rater reliability. The manuscript presented in this chapter was published in *BMC Public Health*:

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4.2 ABSTRACT

4.2.1 Background

Altering micro-scale features of neighborhood walkability (e.g., benches, sidewalks, and cues of social disorganization or crime) could be a relatively cost-effective method of creating environments that are conducive to active living. Traditionally, measuring the micro-scale environment has required researchers to perform observational audits. Technological advances have led to the development of virtual audits as alternatives to observational field audits with the enviable properties of cost-efficiency from elimination of travel time and increased safety for auditors. This study examined the reliability of the Virtual Systematic Tool for Evaluating Pedestrian Streetscapes (Virtual-STEPS), a Google Street View-based auditing tool specifically designed to remotely assess micro-scale characteristics of the built environment.

4.2.2 Methods

We created Virtual-STEPS, a tool with 40 items categorized into 6 domains (pedestrian infrastructure, traffic calming and streets, building characteristics, bicycling infrastructure, transit,

and aesthetics). Items were selected based on their past abilities to predict active living and on their feasibility for a virtual auditing tool. Two raters performed virtual and field audits of street segments in Montreal neighborhoods stratified by the Walkscore that was used to determine the 'walking-friendliness' of a neighborhood. The reliability between virtual and field audits (n = 40), as well as inter-rater reliability (n = 60) were assessed using percent agreement, Cohen's Kappa statistic, and the Intra-class Correlation Coefficient.

4.2.3 Results

Virtual audits and field audits (excluding travel time) took similar amounts of time to perform (9.8 versus 8.2 min). Percentage agreement between virtual and field audits, and for inter-rater agreement was 80% or more for the majority of items included in the Virtual-STEPS tool. There was high reliability between virtual and field audits with Kappa and ICC statistics indicating that 20 out of 40 (50.0%) items had almost perfect agreement and 13 (32.5%) items had substantial agreement. Inter-rater reliability was also high with 17 items (42.5%) with almost perfect agreement and 11 (27.5%) items with substantial agreement.

4.2.4 Conclusions

Virtual-STEPS is a reliable tool. Tools that measure the micro-scale environment are important because changing this environment could be a relatively cost-effective method of creating environments that are conducive to active living.

4.3 BACKGROUND

Evidence suggests that neighborhood built environments can support active living (Sallis et al., 2016) and improve health outcomes (Creatore et al., 2016; Wasfi, Dasgupta, Orpana, & Ross, 2016). Most studies have examined how macroscale elements of neighborhood walkability (connectivity, land-use mix, population density) contribute to active living and health. These findings can sometimes be difficult to implement in existing neighborhood settings. The street grid of North American cities is incredibly enduring and difficult to change (Barrington-Leigh & Millard-Ball, 2015) and changing macro-scale features can require substantial reconfiguration of the neighborhood layout.

Altering micro-scale features of neighborhood walkability (e.g., the presence and condition of benches, sidewalks, trees, crossing signals, walking paths, and cues of social disorganization or crime) is a relatively cost-effective and efficient method of creating environments that are conducive to active living (Cain et al., 2014). Evidence suggests that micro-scale elements of the built environment can account for differences in walking behavior in neighborhoods with a similar macro-scale walkability and that changes to the micro-scale walkability of a place could potentially lead to substantial increases in walking behavior (Sallis, Cain, et al., 2015). The evidence base on the contribution of micro-scale elements of the built environment to walking behavior is limited likely owing to the resource intensity of the traditional field-auditing approach. This approach requires auditors to be physically present to conduct audits, which can lead to considerable time and cost restraints even for very small-scale local studies (Chudyk et al., 2014; Lafontaine et al., 2017). Technological advances have led to the development of virtual audits, efficient alternatives to observational field audits, that are safe for auditors require less time and financial resources, allow researchers to audit more study sites, and to use historical images to examine changes in built environments over time. They can also facilitate the auditing of dispersed, large, or distant areas (Bader et al., 2017; Curtis et al., 2013; Kelly et al., 2013; Lafontaine et al., 2017) improving the geographic scope and generalizability of findings, since variations in the built environment of neighborhoods implies that associations may also vary (Bader et al., 2017). This method of data collection is also more flexible compared to in-person auditing methods, as auditors can easily refer to street stills at a later point in time if they discover that the assessment of additional environmental features is warranted.

Research has demonstrated that virtual audits can provide a valid alternative to field audits for measuring micro-scale features (Zhu et al., 2017). Zhu et al. 2017 created an online version of the Microscale Audit of Pedestrian Streetscapes tool, a well-known field auditing tool developed by Millstein et al. 2013, that was modified to render it compatible with virtual auditing (Zhu et al., 2017). The researchers audited designated routes in San Diego and Phoenix, and consistent with previous research, demonstrated a higher reliability for items that involve the verification of the presence of an item and lower reliability for items that are temporally variable or that require a subjective assessment (Zhu et al., 2017). This research is promising because it suggests that virtual audit tools can reliably assess the micro-scale environment. Most published virtual audits have been performed with Google Street View (GSV), a web-service that has existed since 2007 (www.google.com/maps). Google, an American-based, international private technology company, best known for its internet search engine, continues to support broad non-commercial access to their mapping products for research and creative purposes (https://www.google.com/permissions/geoguidelines.html). GSV was originally only available in U. S cities but has progressively expanded to provide video stills of streets from across the world (Griew et al., 2013). GSV can be accessed through Google Maps or Google Earth and provides a 360° horizontal and 290° vertical panoramic view of the streets. This tool has allowed researchers to perform audits at their desk by virtually "navigating" streetscapes.

Previous research has indicated high levels of agreement between virtual and field audits (Badland et al., 2010; Clarke et al., 2010; Griew et al., 2013; Kelly et al., 2013; Odgers et al., 2012;

Rundle et al., 2011) and has shown high agreement between GSV audits and assessments obtained from local residents (Chiang et al., 2017). Many previous virtual auditing tools have not been specifically designed to measure the micro-scale environment meaning that they aren't designed to minimize the limitations associated with virtually auditing this environment. These tools are also often very lengthy (i.e., have many items), which means that even if street segments are evaluated virtually and travel time is eliminated, auditing is still a very time-consuming process and not practical for the assessment of large geographic areas.

4.4 OBJECTIVE

The objective of this study was to examine the reliability of the Virtual Systematic Tool for Evaluating Pedestrian Streetscapes (Virtual-STEPS), an auditing tool specifically designed to remotely evaluate micro-scale characteristics of the built environment. To achieve this aim, we examined the agreement between virtual and field audits and the inter-rater agreement for the Virtual-STEPS tool.

4.5 METHODS

In November 2017, 2,200 adults in Montreal and Toronto were recruited as part of a study to examine the impact of the walkability of neighborhoods on active living. Participants were recruited from 136 (68 from Montreal/68 from Toronto) forward sortation areas (FSA) (first three digits of the postal code). On average, there are 8000 households within an FSA (Statistics Canada, 2009). One of the aims of the study was to develop an auditing tool that could potentially be applied at a national level to identify the micro-scale environmental features that support walking in Canadian cities.

4.5.1 Virtual Systematic Tool for Evaluating Pedestrian Streetscapes (Virtual-STEPS)

The Virtual Systematic Tool for Evaluating Pedestrian Streetscapes (Virtual-STEPS) is an observational audit tool that uses GSV to assess micro-scale features of neighborhood environments that might support active living. Two research assistants conducted a comprehensive literature review and identified 40 micro-scale elements of neighborhood environments that might support active living. The publications that influenced the creation of each item are included in Table 4.1. These items were categorized as follows: pedestrian infrastructure (e.g., sidewalks), traffic calming and streets (e.g., stop signs), building characteristics (e.g., length of building setback), bicycling infrastructure (e.g., bicycling lanes), transit (e.g., bus stops), and aesthetics/disorder (e.g., graffiti). The tool emphasized the inclusion of micro-scale features that have been found to contribute to active living in previous studies but are not usually readily available as Geographic Information System (GIS) layers in administrative databases, and those features that are feasible to measure using GSV (e.g., time provided to cross the street by a pedestrian signal might support walking but can't be assessed in GSV).

Table 4.1: The 40 Virtual-STEPS tool items and their categories grouped into six domains.

Items	Categories	Publications
Pedestrian infrastructure		
Presence of a sidewalk	Present-one side/Present-both sides/No	(Day, Boarnet, Alfonzo, & Forsyth, 2006; Hoehner, Ramirez, Elliott, Handy, & Brownson, 2005; Michael et al., 2009; Millstein et al., 2013; Pikora et al., 2002; Sallis, Cain, et al., 2015)
Sidewalk continuity	Yes/No	(Hoehner, Ivy, Ramirez, Handy, & Brownson, 2007; Michael et al., 2009; Millstein et al., 2013)
Sidewalk buffer	Yes/No	(Day et al., 2006; Griew et al., 2013; Hoehner et al., 2007; King, 2008; Michael et al., 2009; Millstein et al., 2013; Pikora et al., 2002; Sallis, Cain, et al., 2015)
Sidewalk quality	Good quality/Bad quality	(Clifton, Smith, & Rodriguez, 2007; Day et al., 2006; Griew et al., 2013; Hoehner et al., 2007; Hoehner et al., 2005; King, 2008; Michael et al., 2009; Millstein et al., 2013; Pikora et al.,

		2002; Porter et al., 2018; Sallis, Cain, et al., 2015)
Pedestrian signal/timer	Yes/No	(Day et al., 2006; Hoehner et al., 2007; King, 2008; Michael et al., 2009; Millstein et al., 2013; Pikora et al., 2002)
Pedestrian crossing sign	Yes/No	(Clifton et al., 2007; Day et al., 2006; Michael et al., 2009; Porter et al., 2018)
Cross walk markings	Yes/No	(Day et al., 2006; Hoehner et al., 2007; King, 2008; Michael et al., 2009; Millstein et al., 2013)
Benches	Yes/No	(Clifton et al., 2007; Day et al., 2006; Ewing, Handy, Brownson, Clemente, & Winston, 2006; Hoehner et al., 2007; Hoehner et al., 2005; King, 2008; Saelens et al., 2006; Sallis, Cain, et al., 2015)
Streetlights	None/Some/Many	(Bader et al., 2015; Badland et al., 2010; Clifton et al., 2007; Day et al., 2006; Griew et al., 2013; Hoehner et al., 2007; Hoehner et al., 2005; King, 2008; Michael et al., 2009; Millstein et al., 2013)
Curb cuts	Yes/No	(Clifton et al., 2007; Day et al., 2006; Griew et al., 2013; Hoehner et al., 2007; Hoehner et al., 2005; King, 2008; Michael et al., 2009; Millstein et al., 2013; Pikora et al., 2002; Sallis, Cain, et al., 2015)
Curb cut quality	Good quality/Bad quality	
Tactile paving	Yes/No	(Griew et al., 2013; Michael et al., 2009; Millington et al., 2009)
Traffic calming and streets		
Traffic lights	Yes/No	(Bader et al., 2015; Clifton et al., 2007; Day et al., 2006; Hoehner et al., 2007; Michael et al., 2009; Millstein et al., 2013; Pikora et al., 2002; Porter et al., 2018)
Traffic island	Yes/No	(Bader et al., 2015; Clifton et al., 2007; Day et al., 2006; King, 2008; Porter et al., 2018)
Stop lines	Yes/No	
Stops signs	Yes/No	(Day et al., 2006; Hoehner et al., 2007; Michael et al., 2009; Millstein et al., 2013; Porter et al., 2018)
Curb extension	Yes/No	(Clifton et al., 2007; Day et al., 2006; Michael et al., 2009; Millstein et al., 2013; Pikora et al., 2002; Porter et al., 2018)
Speed bump	Yes/No	(Clifton et al., 2007; Day et al., 2006; Michael et al., 2009; Pikora et al., 2002; Porter et al., 2018)
Bollards	Yes/No	(Saelens et al., 2006)
Number of traffic lanes	Continuous	(Badland et al., 2010; Clifton et al., 2007; Hoehner et al., 2007; Hoehner et al., 2005; King, 2008; Michael et al., 2009; Millstein et al., 2013; Pikora et al., 2002; Porter et al., 2018)
Number of parking lanes	Continuous	(Badland et al., 2010; Hoehner et al., 2007; King, 2008; Michael et al., 2009; Pikora et al., 2002; Porter et al., 2018)
Driveways	None/Some/Many	(Badland et al., 2010; Clifton et al., 2007; Day et al., 2006; Millstein et al., 2013)
Building characteristics		

Building height	N/A/1-2 stories/3-5 stories/6+ stories	(Clifton et al., 2007; Day et al., 2006; Ewing et al., 2006; Millstein et al., 2013; Sallis, Cain, et al., 2015)
Building setback	N/A/ 0m/0-3m/3-10m/>10m	(Bader et al., 2015; Burton, Mitchell, & Stride, 2011; Clifton et al., 2007; Millstein et al., 2013; Sallis, Cain, et al., 2015)
Building design variation	N/A /None/Some/A lot	(Boarnet, Forsyth, Day, & Oakes, 2011; Burton et al., 2011; Clifton et al., 2007; Day et al., 2006; Ewing et al., 2006; King, 2008; Millstein et al., 2013; Pikora et al., 2002; Sallis, Cain, et al., 2015)
Transit		
Presence of transit	Yes/No	(Day et al., 2006; Hoehner et al., 2007; Hoehner et al., 2005; King, 2008; Michael et al., 2009; Millstein et al., 2013; Porter et al., 2018; Sallis, Cain, et al., 2015)
Type of transit	Bus/Metro/Train	(Millington et al., 2009)
Transit facilities	None/Bench or shelter/both	(Clifton et al., 2007; Millstein et al., 2013)
Bicycling infrastructure		
Bike lanes	Yes/No	(Bader et al., 2015; Day et al., 2006; Hoehner et al., 2005; Michael et al., 2009; Millstein et al., 2013; Porter et al., 2018)
Bike buffer	Yes/No	
Bike facilities	Yes/No	(Badland et al., 2010; Pikora et al., 2002; Porter et al., 2018)
Aesthetics/disorder		
Trees	None/Few/Some/Many	(Badland et al., 2010; Day et al., 2006; Griew et al., 2013; Hoehner et al., 2007; Hoehner et al., 2005; King, 2008; Michael et al., 2009; Millstein et al., 2013; Pikora et al., 2002; Rodgers et al., 2018)
Shade	<30% of the street /≥30% of the street	(Clifton et al., 2007; Day et al., 2006; King, 2008; Porter et al., 2018; Saelens et al., 2006)
Nature areas	Yes/No	(Clifton et al., 2007; Day et al., 2006; Ewing et al., 2006; Rodgers et al., 2018)
Landscaping	None/Some/ A lot	(King, 2008; Millstein et al., 2013; Saelens et al., 2006)
Landscape maintenance	Yes/No	(King, 2008; Michael et al., 2009; Millington et al., 2009; Millstein et al., 2013; Pikora et al., 2002; Rodgers et al., 2018; Saelens et al., 2006; Sallis, Cain, et al., 2015)
Presence of litter	None/Some/ A lot	(Day et al., 2006; Hoehner et al., 2007; Hoehner et al., 2005; King, 2008; Michael et al., 2009; Millstein et al., 2013; Pikora et al., 2002; Porter et al., 2018)
Graffiti	None/Some/ A lot	(Bader et al., 2015; Badland et al., 2010; Day et al., 2006; Griew et al., 2013; Hoehner et al., 2007; Hoehner et al., 2005; King, 2008; Michael et al., 2009; Millstein et al., 2013; Pikora et al., 2002; Porter et al., 2018)
Broken/boarded windows	Yes/No	(Barrington-Leigh & Millard-Ball, 2015; Hoehner et al., 2005; King, 2008; Millstein et al., 2013)
Attractive segment	Unattractive/Neutral/Attractive	(Badland et al., 2010; Clifton et al., 2007; Day et al., 2006; Pikora et al., 2002)

4.5.2 Street selection

The auditing of street segments occurred between June and September 2017, using street segments from the two largest cities in Canada - Toronto and Montreal. We tested the reliability of the tool using Montreal street segments for practical locational reasons. Street segments are sections of a street that are located between two neighboring intersections or an intersection and a cul-de-sac (Figure. 4.1). We randomly selected street segments from within Montreal forward sortation areas (first three digits of the postal code) based on known levels of neighborhood walkability. The walkability of forward sortation areas was measured by taking the average of the Walk Scores® associated with the 6-digit postal codes located within each forward sortation area. The Walk Score® is an index that determines the walkability of a location based on the distance between that location and different types of amenities (http://www.walkscore.com/methodology.shtml). Walk Score has been validated against other measures of walkability in previous studies (Carr, Dunsiger, & Marcus, 2010, 2011).

To test the agreement between virtual and field audits, virtual audits and field audits were conducted by one rater for 40 street segments (10 high walkability (Walkscore®:70–89) /20 medium walkability (Walkscore®: 50–69) /10 low walkability (WalkscoreW: 0–49)). When testing the agreement between virtual and field audits, the virtual audits of street segments from one rater were compared to the field audits of the same street segments conducted by the same rater (i.e., virtual audit of a street segment conducted by rater 1 was compared to the field audit of the same segment conducted by rater 1). To test inter-rater reliability, 60 of the same street segments were virtually evaluated by both raters (20 high walkability/20 medium walkability/20 low walkability). We stratified by walkability to ensure that there would be enough variability in the built environment in our sample of streets and to decrease the likelihood that we would have high percent agreement but low Kappa statistics due to low frequencies of features in the environment.

Figure 4.1: Randomly selected streets and randomly selected audit start points within a forward sortation area.

4.5.3 Audit procedure

The two raters (KV and GO), that had contributed to the literature review and development of the Virtual-STEPS audit tool, conducted virtual and field audits of selected street segments. Raters travelled in person to street segments and conducted field audits independently. They also conducted virtual audits independently on separate computers. Field audits were conducted by walking down the street segment and auditing one intersection and both sides of the street. The start points (intersection) for the audits were selected randomly using Geographic Information Systems. The same auditing procedures were conducted for the virtual audits of street segments. To locate segments, we used QGIS, along with the go2streetview plugin (© 2014 Enrico Ferreguti). Auditors remotely audited the street segments using the most recent images available on GSV. For the virtual audits, raters also noted the year of the GSV images and whether their view was obstructed, or the image was distorted. The audit process unfolded as follows: (1) The attribute table was opened and the segment was selected using ‘zoom to feature’; (2) Once the segment appeared in the QGIS map the go2streetview plugin was used to find the appropriate intersection in GSV; (3) The intersection and the segment were audited with results input into a Microsoft Access database. The auditing process involved an assessment of features belonging to both sides of the segment, as well as the given intersection. The items assessed at intersections were crossing aids, curb cuts, curb tactile paving, curb quality, and certain traffic calming devices (e.g., traffic lights, stop lines, stop signs, and traffic islands). Transit stops, benches, and bike facilities were assessed along the segment and at the intersection. Examples of ratings are included in Fig. 4.2. It was important to ensure that it would be feasible to apply our auditing method across large geographic areas. To achieve this goal, we audited the first 300m of each street segment. Previous studies have eliminated streets over 300m from the dataset to ensure consistency (Griew et al., 2013). We chose to include all segments over 300 m, but for segments over this length to only audit the first 300m of the segment and the street segment was given the rating derived from the first 300 m. This approach allowed for the retention of longer streets in the database that might be important contributors to the overall micro-scale environment of a neighborhood. We also compared audits conducted on the first 300m of streets segments to audits conducted with the entire street segment for 32 randomly selected streets over 300m with an average length of 592.82 (SD:519.4). This comparison yielded an average percent agreement of 98% (see Appendix B, Table 1B).

Pedestrian Infrastructure

Image 1: Sidewalk continuity (Yes/**No**): The sidewalk is not continuous throughout the entire segment. Image capture Jun 2015 © 2017 Google

Image 2: Curb cut quality (Good quality/**Bad quality**): This curb cut is of bad quality. Image capture Aug 2016 © 2017 Google

Image 3: Sidewalk buffer (**Yes**/No): A sidewalk buffer is present. Image capture Aug 2017 © 2018 Google

Traffic Calming

Image 4: Stop sign (**Yes**/No): A stop sign is present at the intersection. Image capture Aug 2015 © 2018 Google

Image 5: Curb extension (**Yes**/No): A curb extension is present at the intersection. Image capture Aug 2017 © 2018 Google

Image 6: Bollards (**Yes**/No): Bollards are present. Image capture Aug 2015 © 2018 Google

Bicycling Infrastructure

Image 7: Bicycle lane (**Yes**/No): A bicycle lane is present. Image capture Aug 2017 © 2018 Google

Image 8: Bicycle buffer (**Yes**/No): A bicycle buffer is present. Image capture Jul 2017 © 2018 Google

Image 9: Bicycle facilities (bike share and bike racks) (**Yes**/No): A bicycle rack is present. Image capture Aug 2017 © 2018 Google

Aesthetics

Image 10: Graffiti (None/Some/**A lot**): Large amounts of graffiti present. Image capture Aug 2016 © 2017 Google

Image 11: Broken/boarded windows (**Yes**/No): Broken windows are present. Image capture Aug 2011 © 2017 Google

Image 12: Visible nature areas (e.g., lakes, rivers, parks) (**Yes**/No): A park is present. Image capture Aug 2016 © 2017 Google

Figure 4.2: Examples of ratings for Virtual-STEPS items. Image captures from Google Street View (www.google.com/maps).

4.6 ANALYSIS

The reliability between GSV and field audits and the inter-rater reliability of observed audit characteristics was calculated using Cohen's Kappa coefficient (Cohen, 1960). The Kappa coefficient accounts for agreement that would be expected to occur by chance (a value of 1 corresponds to perfect agreement and 0 corresponds to agreement that likely occurred by chance) (Landis & Koch, 1977). Weighted Kappa was used for ordinal variables. Cohen's Kappa coefficients have been classified into: < 0.20 (poor agreement), 0.21–0.40 (fair agreement), 0.41–0.60 (moderate agreement), 0.61–0.80 (substantial agreement), 0.81–1.00 (almost perfect agreement) (Landis & Koch, 1977). Percent agreement was also reported due to the Cohen's Kappa coefficient's sensitivity to prevalence, which can lead to high absolute agreement but low Kappa (Feinstein & Cicchetti, 1990). The Intraclass Correlation Coefficient (ICC) was used for continuous variables and the same classification system was also used to interpret ICC values (Millstein et al., 2013; Shrout, 1998). Analyses were performed using R.

4.7 RESULTS

Forty street segments were evaluated for agreement between virtual and field audits. One street segment was removed due to image obstructions. Sixty street segments were evaluated for inter-rater reliability. One street segment was removed due to image obstructions. Virtual audits took, on average 9.8 (range:19) minutes per street segment, while field audits took approximately 8.2 (range:16) minutes plus travel time.

4.7.1 Agreement between virtual and field audits

Absolute agreement was high with 32 of 40 (80.0%) items having an absolute agreement above 80%. The average absolute agreement was above 80% for pedestrian infrastructure (92.5%), traffic calming and streets (92.8%), transit (99.1%), bicycling infrastructure (94.0%), building characteristics (81.1%), and aesthetics/disorder (80.4%). Kappa and ICC statistics indicated that 20 of 40 (50.0%) items had almost perfect agreement (Kappa or ICC > 0.80), 13 (32.5%) items had substantial agreement (Kappa or ICC 0.61–0.80), 6 (15.0%) items had moderate agreement (Kappa or ICC 0.41–0.60), 1 (2.5%) item had fair agreement (Kappa or ICC 0.21–0.40), and that no items had poor agreement.

4.7.2 Inter-rater reliability

Absolute agreement was high with 30 of 40 items (75%) with an absolute agreement above 80%. The average absolute agreement was above 80% for pedestrian infrastructure (93.5%), traffic calming and streets (91.0%), transit (98.3%), bicycling infrastructure (97.2%), building characteristics (82.4%), and was slightly lower for aesthetics/disorder (76.6%). Kappa and ICC statistics indicated that 17 items (42.5%) had almost perfect agreement (Kappa or ICC > 0.80), 11 (27.5%) items had substantial agreement (Kappa or ICC 0.61–0.80), 6 (15.0%) items had moderate agreement (Kappa or ICC 0.41–0.60), 2 (5.0%) items had fair agreement (Kappa or ICC 0.21–0.40), and 1 (2.5%) item had poor agreement (Kappa or ICC < 0.21). The item "shade" (i.e., "Is 30% of the street sheltered from the sun") is included in Table 4.2 but will be removed from the tool due to an inter-rater reliability with both a poor percent agreement and low Kappa. For 3 items a Kappa coefficient couldn't be calculated (broken/boarded windows, sidewalk buffer, and bollards) due to a low frequency (n = 0) in the streets selected for inter-rater reliability (See Appendix B, Table 2B).

Table 4.2: Results for inter-rater reliability and reliability between GSV and in-field audits using percent agreement and the Kappa statistic.

	GSV with field		Inter-rater	
Item	**Percent agreement**	**Kappa or ICC**	**Percent agreement**	**Kappa or ICC**
Pedestrian infrastructure				
Presence of Sidewalks	100	1.00	96.6	0.97
Sidewalk Continuity	94.9	0.87	94.9	0.90
Sidewalk Buffer	100	1.00	100	N/A
Sidewalk Quality	82.1	0.63	91.5	0.81
Pedestrian Sign/Timer	100	1.00	100	1.00
Pedestrian Crossing Sign	92.3	0.63	94.9	0.38
Cross Walk Markings	92.3	0.85	96.6	0.91
Benches	89.7	0.73	94.9	0.74
Streetlights	69.2	0.51	78.0	0.69
Curb Cuts	97.4	0.93	91.5	0.83
Curb Cut Quality	94.9	0.64	93.2	0.31
Tactile Paving	97.4	0.93	89.8	0.79
Traffic calming and streets				
Traffic Lights	100	1.00	100	1.00
Traffic Island	97.4	0.84	94.9	0.80
Stop Lines	89.7	0.77	91.5	0.82
Stops Signs	97.4	0.98	96.6	0.91
Curb Extension	97.4	0.65	98.3	0.79
Speed Bump	97.4	0.66	98.3	0.66
Bollards	97.4	0.84	98.3	N/A
Number of traffic lanes	87.2	0.84	81.4	0.70
Number of parking lanes	76.9	0.82	66.1	0.64
Driveways	87.2	0.85	84.7	0.76
Building characteristics				
Building Height	89.4	0.88	94.9	0.91
Building Setback	87.2	0.88	82.8	0.83
Building Design Variation	66.7	0.47	69.5	0.47
Transit				
Presence of Transit	100	1.00	98.3	0.91
Type of Transit	97.4	0.92	98.3	0.93
Transit Facilities	100	1.00	98.3	0.97
Bicycling infrastructure				
Bike Lanes	92.3	0.75	98.3	0.91
Bike Buffer	100	1.00	100	1.00
Bike facilities	89.7	0.71	93.2	0.63
Aesthetics				

Presence of Trees	76.9	0.70	61	0.55
Shade	79.5	0.55	49.2	0.16
Nature Areas	82.1	0.62	84.7	0.69
Landscaping	79.5	0.56	86.4	0.42
Landscape Maintenance	94.9	0.72	86.4	0.42
Presence of Litter	71.8	0.47	71.2	0.54
Graffiti	84.6	0.69	94.9	0.88
Broken/boarded Windows	87.2	0.39	98.3	N/A
Attractive Segment	66.7	0.58	57.6	0.44

4.8 DISCUSSION

The Virtual- STEPS tool can provide a reliable measure of micro-scale characteristics that may support active living. Absolute agreement between virtual and field audits and inter-rater agreement was 80% or more for most items included in the Virtual-STEPS tool. Most items also had high to moderate levels of agreement according to Cohen's Kappa coefficients. Congruent with previous research (Chudyk et al., 2014; Griew et al., 2013; Zhu et al., 2017), the tool demonstrated higher reliability between virtual and field audits and inter-rater reliability for items that involve the verification of the presence/absence of large items (e.g., presence of traffic calming features, transit facilities, bike lanes, and bike buffers). This may be due to the fact that these items can be easily spotted by car and car-based cameras are used to capture GSV images (Lafontaine et al., 2017). The tool had lower reliability for items that require a subjective evaluation of a neighborhood characteristic (Chudyk et al., 2014; Griew et al., 2013; Vanwolleghem, Van Dyck, Ducheyne, De Bourdeaudhuij, & Cardon, 2014; Zhu et al., 2017) such as those that assess the condition of features (e.g., curb cut quality, landscape maintenance), variations in the environment (e.g., building design variation), or the aesthetics of the neighborhood (e.g., graffiti, litter, presence of landscaping, attractiveness of the segment). The temporal variability of certain aesthetic elements such as graffiti and litter could also explain the lower reliability observed between virtual audits and field audits for these items.

We chose to design a tool to specifically measure features of the micro-scale environment that may support active living, given the potential for these features to be reasonably modified within the scale of budgets of local governments. Transforming the micro-scale environment could have a meaningful impact on the active living potential of places (Cain et al., 2014; Sallis, Cain, et al., 2015; Van Cauwenberg et al., 2016; Van Holle et al., 2014). For example, Sallis et al. 2015, showed that an increase from the lowest quintile of micro-scale walkability to the highest quintile might lead to an almost 250% increase in walking for transportation in younger and older adults. Microscale features of the built environment that are unfavorable to active living may also actually offset the benefits of macro-scale walkability for vulnerable populations such as the elderly and the physically impaired (Cain et al., 2014; Thornton et al., 2016) contributing to the disproportionately high burden of poor urban design born by these population groups (Dannenberg et al., 2003).

4.8.1 Strengths and limitations

A lack of certain features in the environment can result in low Cohen's Kappa values but high percent agreement (Chudyk et al., 2014). We attempted to minimize this issue by including neighborhoods varying in neighborhood walkability (low/medium/high) in our assessment. Items with high percent agreement but for which a Kappa could not be calculated (e.g., bollards, broken/boarded windows) were retained in the tool because although the items did not occur frequently for the specific street segments selected, we still considered them to be important contributors to the walkability of neighborhoods. The item that asked the auditor to assess whether 30% or more of the segment was shaded from the sun had poor reliability that could not be explained by a low frequency in the selected street segments. This item was removed from the tool because although the benefit of including the item in the tool could be substantial, especially as heat events in cities are anticipated to rise, the inter-rater reliability was poor suggesting that raters had considerable difficulty agreeing on whether 30% of a street segment was shaded.

Virtual audits do not incorporate sensory inputs such as noise levels, soundscape, and scent (Lafontaine et al., 2017) that may contribute, to a pedestrians experience of a streetscape. GSV images may also change unpredictably. A previous study showed that this was common when virtually crossing intersections (Curtis et al., 2013) leading to temporal inconsistencies in the year or season of the images used for audits (Lafontaine et al., 2017). The auditors identified several shortcomings to the use of GSV. Compared to field audits, it was difficult to evaluate finer details of streetscapes such as condition (e.g., quality of sidewalks and curb cuts) and maintenance (e.g., landscape maintenance). Further, although GSV does provide a good "street view" it does not always provide an accurate "pedestrian view". GSV provides a view that is a bit higher than the typical pedestrian view with the images recorded from a car-mounted camera. The use of virtual audits with GSV therefore may result, for example, in the inclusion of features that will not necessarily influence the pedestrian experience such as including features on the other side of a large fence in microscale assessments when these features may not be visible by pedestrians.

Our results concur with the sentiments of Griew et al. 2013 who expressed that the advantages of virtual audits greatly outweigh their limitations. GSV allowed auditors to comfortably and safely audit features that were more difficult or dangerous to audit in person such as the presence of broken/boarded windows. Another item that auditors had difficulty auditing in person was setback length. In contrast, in virtual audits, auditors could easily approximate average setback length using the measurement tool in Google Satellite. Virtual-STEPS takes less than 10 min to complete and contains 40 reliable items that cover a variety of concepts that have been demonstrated to influence walking in past research. The items are also highly reliable between raters and reliably reflect field audits. The virtual audits took slightly longer than in-field audits (excluding travel time) to conduct on average because auditors had to virtually 'walk' down the street more than once using different camera angles to assess different items. Despite a slightly longer average auditing time, virtual audits were still much less expensive and time-consuming to conduct compared to field audits because field audits require significant amounts of travel time.

Our study differentiates itself from previous studies that have evaluated the micro-scale environment remotely such as that of Zhu et al. 2017 by creating a tool that is specifically designed to measure the micro-scale environment of large geographic areas. The tool responds to a need for auditing instruments that can efficiently be used for widespread surveillance. Existing auditing tools have an average of 92.2 items per tool (Burton et al., 2011; Clifton et al., 2007; Cunningham, Michael, Farquhar, & Lapidus, 2005; Day et al., 2006; Griew et al., 2013; Hoehner et al., 2007; Millstein et al., 2013; Pikora et al., 2002; Sallis, Cain, et al., 2015) making it difficult to apply them for surveillance purposes. The Virtual- STEPS tool is user-friendly with only 40 items. We also included lengthy segments in our audits to ensure that all types of segments would be included in our sample, but only audited the first 300m of each segment to maximize the tools potential for surveillance purposes. Our findings suggest that the tool has the potential to be used to assess the environments of large geographic areas and to be linked to large national scale administrative databases for epidemiological studies. This could enable the exploration of the variations in pedestrian streetscapes existing across cities and countries, subsequently allowing us to disentangle their contributions to active living across a diverse set of contexts. GSV Time-Machine could also allow the application of this auditing tool across images from multiple years allowing longitudinal examinations of changes in micro-scale environments that might be associated with health-related behavior changes. Machine learning techniques have been used with GSV to evaluate several characteristics of urban environments including pedestrian counts (Yin, Cheng, Wang, & Shao, 2015), visual enclosure (Yin & Wang, 2016), the construction and maintenance quality of building facades, and the continuity of the street wall (Liu, Silva, Wu, & Wang, 2017). The Virtual-STEPS tool was specifically designed for use with GSV giving it the potential to be used alongside and in validation of machine learning techniques for the automated extraction of built environment features for large scale surveillance.

4.9 CONCLUSION

Our findings suggest that the Virtual-STEPS tool is a reliable tool for assessing the micro-scale environment of neighborhoods, potentially important contributors to active living and health. This tool can help researchers and public health practitioners to identify the routine microscale elements of the built environment that encourage active living. Elements that can be modified at relatively low cost to promote the mobility of the entire population, but could be especially valuable for the mobility of vulnerable populations such as the elderly and the physically impaired; populations that disproportionately bear the burden associated with sub-optimal urban design.

5 CHAPTER FIVE | MANUSCRIPT 3: MOVING TO POLICY-AMENABLE OPTIONS FOR BUILT ENVIRONMENT RESEARCH: THE ROLE OF MICRO-SCALE NEIGHBORHOOD FEATURES IN PROMOTING WALKING

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5.1 PREAMBLE

Chapter 4 presented the results of the study that tested the reliability of the Virtual-STEPS tool (Manuscript 2), that demonstrated high reliability between virtual and field audits and high inter-rater reliability. Few studies have examined the collective influence of the micro-scale environment on walking outcomes and no previous studies have accounted for residential self-selection when examining the collective influence of the micro-scale environment on walking. Therefore, in chapter 5, we first tested the association between items in the Virtual-STEPS tool and walking outcomes in a sample of adults participating in a cross-sectional internet survey that had provided information on self-selection, before proceeding to examine the effect of these items on walking in our subpopulation of interest, in chapter 6. Our analyses, in chapter 5, addressed the third objective of this dissertation by *evaluating the individual and collective influence of items from the Virtual-STEPS tool on walking outcomes (utilitarian walking and walking for leisure).* In this study, we demonstrated that the environmental determinants of utilitarian and leisure walking differ. The micro-scale walkability of neighborhood environments collectively promoted leisure walking but not utilitarian walking, conversely the macro-scale walkability of neighborhoods supported utilitarian walking and not leisure walking. Associations remained significant even after accounting for self-selection. The manuscript presented in this chapter was published in *Health and Place*:

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5.2 ABSTRACT

5.2.1 Background

Altering micro-scale features of neighborhoods (e.g., the presence and condition of benches, sidewalks, trees, crossing signals, walking paths) could be a relatively cost-effective method of creating environments that are conducive to physical activity. The Virtual Systematic Tool for Evaluating Pedestrian Streetscapes (Virtual-STEPS) was created to virtually audit the microscale environment of cities using Google Street View (GSV). The objective of this study was to evaluate the collective influence of items from the Virtual-STEPS tool on walking outcomes (utilitarian walking and walking for leisure), while accounting for self-selection of walkers into walking-friendly neighborhoods.

5.2.2 Methods

Adults (N = 1403) were recruited from Montreal and Toronto from neighborhoods stratified by their level of macro-scale walking-friendliness and walking rates. The micro-scale environment of 5% of street segments from the selected neighborhoods was audited using the Virtual-STEPS tool and a micro-scale environment score was assigned. The scores were then

linked to each respondent from the survey. A multilevel logistic regression analysis was used to model the relationship between the micro-scale environment score and odds of both utilitarian walking (i.e., walking for purpose such as to go shopping or go to work or school) and walking for leisure for at least 150 min per week, while accounting for environmental and demographic covariates as well as self-selection.

5.2.3 Results

Micro-scale neighborhood features were associated with elevated odds of walking for leisure (OR: 1.14, CI: 1.04–1.25). The association between micro-scale neighborhood features and walking for utilitarian purposes was, however, inconclusive (OR: 1.01, CI: 0.90–1.13). On the other hand, macro-scale walk-friendliness was associated with elevated odds of walking for utilitarian purposes (OR: 2.01, CI:1.42–2.84) and the association between macro-scale features and leisure walking was inconclusive (OR: 1.02, CI: 0.78–1.34).

5.2.4 Conclusions

Our results imply that micro-scale features of neighborhoods collectively promote leisure walking but not necessarily utilitarian walking, even after accounting for self-selection. In contrast, macro-scale features may collectively promote utilitarian walking, but not leisure walking. Micro scale features of neighborhoods fall within the budget of local jurisdictions and our results suggest that jurisdictions that improve micro-scale features may expect increased leisure walking in populations.

5.3 INTRODUCTION

The economic burden of physical inactivity worldwide is 67.5 billion (INT$) in healthcare costs and productivity losses and it contributes to 13.4 million disability-adjusted life years

(DALYs) (Ding et al., 2016). Socioecological models of physical activity posit that health behaviors are influenced by multiple attributes of humans and their social and physical environments including the built environment of individual's neighborhoods (Sallis, Owen, et al., 2015). There is strong evidence in support of a positive association between the built environment and physical activity (Barnett et al., 2017; Hajna et al., 2015; McCormack & Shiell, 2011; Saelens & Handy, 2008a; Van Cauwenberg et al., 2011) and that changing the environment may be the most cost-effective population level approach to increase physical activity levels (Laine et al., 2014).

The majority of studies examining the contribution of the built environment to walking behavior have examined the 'macro-scale walkability' components (residential density or density of destinations, land-use mix, and connectivity) of a neighborhood that may be associated with walking for utilitarian purposes or for leisure (Barnes et al., 2016; Carlson et al., 2012; Herrmann et al., 2019; King et al., 2011; Sallis et al., 2016; Shimura et al., 2012; Steinmetz-Wood & Kestens, 2015; Thielman et al., 2015; Van Holle et al., 2014; Wasfi et al., 2017). Micro-scale features of neighborhoods are features that tend to be measured at a smaller spatial scale. Few studies have examined how these micro-scale (i.e., street-level) built environment determinants such as the condition of benches, sidewalks, trees, crossing signals, and walking paths contribute to walking behavior (Boarnet et al., 2011; Cain et al., 2014; Cerin et al., 2013; Christman et al., 2019; Sallis, Cain, et al., 2015; Shigematsu et al., 2009). Micro-scale features of the environment tend to be more readily modifiable (i.e., they do not require a complete restructuring of the neighborhood layout) which can facilitate a quick application of findings to existing neighborhood settings (Cain et al., 2014).

Studies have reported that features such as traffic calming measures (Boarnet et al., 2011), safety from crime (Van Cauwenberg, Clarys, et al., 2012), building height setback, trees (Cain et al., 2014), the presence of sidewalks (Boarnet et al., 2011; Cain et al., 2014), and sidewalk obstructions may be associated with walking for utilitarian purposes (Cain et al., 2014). There may also be features of the micro-scale environment that encourage walking for leisure, including: building aesthetics (Cain et al., 2014; Cerin et al., 2013), natural sights, absence of signs of disorder, absence of litter (Cerin et al., 2013), building height setback (Cain et al., 2014), building height road width ratio, building aesthetic design, wide one-way street design (Cain et al., 2014), and having many gardens/flowers in the neighborhood during the growing season (Christman et al., 2019). Some studies, however, found associations between features of the micro-scale built environment and walking for leisure were null or in the opposite direction to what was hypothesized (Boarnet et al., 2011; Cain et al., 2014).

The evidence base on the micro-scale environment's contribution to walking is still limited, with only two studies specifically assessing the collective influence of these features on walking outcomes (Cain et al., 2014; Sallis, Cain, et al., 2015). These two studies used a dependent variable that combined walking and biking trips together even though their micro-scale determinants may differ, and no studies have examined the influence of 'residential self-selection'. Residential self-selection can be described as individuals choosing their residence based on their preferences and lifestyle (Boone-Heinonen, Gordon-Larsen, Guilkey, Jacobs Jr, & Popkin, 2011; Cao, Mokhtarian, & Handy, 2009; Handy, Cao, & Mokhtarian, 2005; Heinen, Mackett, van Wee, Ogilvie, & Panter, 2018; Lamb et al., 2020; Van Dyck, Cardon, Deforche, Owen, & De Bourdeaudhuij, 2011). For example, neighborhood residents may choose to move into a neighborhood that is walkable to help them to maintain an already active lifestyle (Van Dyck et al., 2011). Studies that do not control for self-selection cannot easily disentangle individual motivations for walking from walking that is supported by neighborhood characteristics.

In this paper, we used the Virtual-STEPS tool, a virtual auditing tool that responds to a need for auditing instruments that could be used for widespread surveillance of urban environments (Steinmetz-Wood, Velauthapillai, O'Brien, & Ross, 2019), to conduct a detailed audit of the micro-scale walkability of neighborhoods with Google Street View ™ (GSV). We then evaluated the collective influence of items from the Virtual-STEPS tool on two different self-reported walking outcomes (utilitarian walking and leisure walking) while accounting for self-selection.

5.4 METHODS

5.4.1 Sample

In the fall of 2017, adults residing in neighborhoods in Montreal and Toronto (n = 2192) were recruited to participate in an internet survey. The survey was administered by Leger Marketing which had a panel of 400,000 members in 2017, with an average response rate of 20%, of which 40% of respondents resided in Ontario and 25% resided in Quebec. Participants 18 years of age and older in the greater Montreal and Toronto areas were recruited for the cross-sectional study from 128 forward sortation areas (FSA) (first three digits of the postal code). On average, there are 8000 households within an FSA (Statistics Canada, 2009). The average area of the 128 FSAs was 36.10 km^2(SD: 86.97) with a median of 8.81 km^2. The average population of the FSAs was 25,252 (SD: 17,139.22) with a median of 21,725. To ensure that there was a diversity in physical activity levels and the macro-scale environmental features of participants' neighborhoods, walking to work trips from the Montreal Origin destination survey (Origine-Destination, 2013), the Transportation Tomorrow Survey (Data Management Group, 2011), and geographic information system (GIS) methods were used to stratify neighborhoods in the Montreal and Toronto area by high walking-friendly/high walking, high walking-friendly/low walking, low walking-friendly/high walking and low walking friendly/low walking. The walking friendliness of forward sortation areas was measured by taking the average of the Walk Scores® associated with the postal codes located within each forward sortation area. The Walk Score® is an index that determines the walking-friendliness of a location based on the distance between that location and different types of amenities. It also measures walk-friendliness by incorporating measures of population density, block length, and intersection density. (http://www.walkscore.com/methodology.shtml).Walk Score has been validated against other macro-scale indices in previous studies (Carr et al., 2010, 2011). Postal codes from within each stratum were sampled and then participants were contacted with an aim of recruiting approximately 275 respondents from within each stratum. To account for self-selection, in the summer of 2018, a second wave was conducted where respondents were asked questions about the reasons that they moved into their neighborhood. There were more participants from Toronto that dropped out of the study after the first wave. 52% of the respondents from wave 1 living in Toronto participated in the second wave versus 76% of the respondents from wave 1 living in Montreal. Additional descriptive statistics for both survey waves are available in Table 1. 1403 respondents participated in the second wave of the survey. Our analysis was conducted using the 1342 participants that did not move to a new FSA between wave 1 and wave 2.

5.4.2 Utilitarian walking and leisure walking

Survey items queried walking behavior including three questions about walking for utilitarian purposes. These included questions about the type of transport respondents typically use to get to work, school, or leisure destinations (e.g., shopping, eating out, run errands). The utilitarian walking questions were based off questions that have been used in several transport surveys (Langlois, van Lierop, Wasfi, & El-Geneidy, 2015; Langlois, Wasfi, Ross, & El-Geneidy, 2016). Respondents were also asked if they walk for leisure (walk for fun or for exercise) such as if they walk their dog or if they walk for leisure or exercise outdoors (walking questions are included in Appendix C, Questions 2C-4C). Respondents were asked to record the number of days per week that they walked, as well as the number of minutes per day. The number of minutes per day was multiplied by the days per week to get the number of minutes per week. Minutes of utilitarian walking was dichotomized into: <150 min per week and ≥150 min per week. Minutes of leisure walking was dichotomized into: <150 min per week and ≥150 min per week. This threshold was chosen to be in line with physical activity guidelines for Canadians, which recommends 150 min or more of physical activity per week for improved health (Tremblay et al., 2011). Sensitivity analyses were performed with a 1-hour threshold or a threshold indicating if respondents had engaged in none versus any walking and gave results consistent with those presented in this analysis.

5.4.3 Covariates

Survey items gathered information on respondents' sociodemographic characteristics including age, sex, number of cars in the household, dog ownership, city, and if respondents had physical or mental health issues that could prevent them from being physically active. Age was centered. Education was categorized as follows: below a bachelor's degree, bachelor's degree, and above a bachelor's degree. Neighborhood income was obtained using the FSA median household income from the 2016 Canadian census. To account for macro-scale walking friendliness, we used the z-scores for the total sample of the average Walk Scores® of the FSAs. To measure self-selection, we used an adapted version of a question from the Neighborhood Quality of Life Study that asks respondents to rate the importance of a list of reasons for moving into their neighborhood (Sallis et al., 2009). A micro-scale residential self-selection variable was created by taking the average ratings from a five point Likert scale question of the following reasons participants provided about their motivations for moving into their neighborhood: ease of walking, presence of nature (e.g., trees, water), attractiveness of the neighborhood (e.g., landscaping, upkeep), pedestrian infrastructure (e.g., sidewalks, curb cuts, pedestrian crossing signs, cross walk markings), traffic calming infrastructure (e.g., traffic lights, stop signs, curb extensions, speed bumps, bollards), and characteristics of the buildings (e.g., building height, building design) (Appendix C, Question 1C).

5.4.4 Micro-scale environment

The Virtual Systematic Tool for Evaluating Pedestrian Streetscapes (Virtual-STEPS) was created to measure the microscale environment of cities using Google® Streetview. The reliability of the tool was tested by measuring the inter-rater reliability and the reliability between virtual and in-person field audits (Steinmetz-Wood, Velauthapillai, et al., 2019). A random sample of street segments (5%) was selected from each of the 129 FSAs located in the Greater Montreal and the Greater Toronto Areas. Each segment had an equal probability of selection except for highways, as they were removed from the street network selection file. Micro-scale walkability was assessed by virtually "walking" down street segments using GSV and auditing the first intersection and both sides of the street. Street segments consisted of sections of a street located between two intersections or an intersection and a cul-de-sac. The start points (intersection) for the audit was selected randomly using a geographic information system (ArcGIS). 3,450 segments were audited in total with an average 26.74 (SD: 17.14) segments audited per FSA. A detailed description of how each item was assessed is available in the Virtual-STEPS manual at https://nancyrossresearchgroup.ca/virtual-steps/. Scores were computed by summing the proportion of segments that had a characteristic for each item category multiplied by its weight. Weighting was based on the presence of the item on the segment. For example, the presence of sidewalks on both sides of the street = 1, on one side of the street = 0.5, or absence of sidewalks = 0. Items were organized into sections and a total score out of ten was computed for four sections: pedestrian infrastructure (e.g., sidewalks), traffic calming (e.g., stop signs), building characteristics (e.g., building height), and aesthetics/disorder (e.g., graffiti). Each item in the subscale had an equal weight. The scores for items such as graffiti, litter, and building setback were inversed when calculating the grand scores, as a high score on these items would not indicate a more favorable micro-scale environment. Cronbach's alpha of these sections was 0.93, 0.72, 0.66, and 0.76, respectively. Cronbach's alpha measures the internal consistency of items in a scale and is a function of the number of items, as well as the correlation between items (Tavakol & Dennick, 2011). The value of 0.66 for building characteristics was considered acceptable given the small number of variables in the building scale. A grand score was then computed by adding all the section scores, with a higher score (score approaching 40) indicating a favorable micro-scale environment and this score was then standardized as a Z-score. A detailed description of the computation of each score is included in Appendix C, Table 1C. The neighborhood micro-scale environment scores were then linked to each respondent from the internet survey using the first three digits of their postal code.

5.5 ANALYSIS

Several variables had missing values including education (n = 8), health problems that affect physical activity (n = 69), dog owner (n = 5), and residential self-selection (n = 47). Before running the models we performed multiple imputation (Enders, 2010) using five imputations. The data was assumed to be missing at random (MAR). Sex, age, education, neighborhood income, health problems that affect physical activity, number of cars, and city were used as predictors in the predictor matrix for the imputation. A multilevel (i.e., people nested within FSAs) logistic regression analysis was used to model the relationship between micro-scale walkability and odds of walking for utilitarian purposes (0: walked <150 min per week; 1: walked ≥ 150 min per week) and walking for leisure (0: walked <150 min per week; 1: walked ≥ 150 min per week). An unadjusted model, a model adjusting for demographic and environmental covariates and a fully adjusted model (adjusted for covariates and residential self-selection) was produced for both walking outcomes. The relationship with walking for each individual item in the tool controlling for covariates and self-selection was also tested and the results were included in Appendix C, Tables 4-5C. We also ran a multilevel logistic regression model controlling for covariates and self-selection with mutual adjustment for the four section scores (aesthetics, building characteristics, pedestrian infrastructure, and traffic calming). Analyses were performed using R statistical software.

5.6 RESULTS

Participants who dropped out of the survey after wave 1 were on average younger (45.07 (SD:16.92) versus 53.37 (SD:16.80)), had more cars (1.45 (SD:1.03) versus 1.35 (SD:0.98)), had a higher micro-scale score (18.57 (SD:2.12) versus 18.30 (SD:2.26)), and a higher Walkscore (56.52 (SD: 23.98) versus 53.11 (SD: 24.97)). Participants who dropped out had a greater percentage of females (54.75% versus 51.10%), a greater percentage of participants without health problems (53.61% versus 52.53%), a greater percentage of participants with a bachelor's degree

(30.16% versus 25.87%), a greater percentage of participants with a degree above the bachelor's level (17.49% versus 16.32%), a greater percentage of participants with dogs (25.48% versus 21.24%), a lower percentage of participants that walked for leisure (30.5% versus 31.29%), and a higher percentage of participants that walked for utilitarian purposes (23.32% versus 21.67%) (see Appendix C, Table 2C). 1403 individuals participated in both waves of the survey, 1342 of these participants did not move into a new FSA between wave 1 and wave 2. The average number of participants living within an FSA was 10.65 (SD:6.87), with a range of 1–34. In the sample of participants that did not move between wave 1 and wave 2, the average age was 53.80 (SD:16.57), the average number of cars owned by members of the household was 1.35 (0.98), the average micro-scale score was 18.31 (SD:2.25), the average Walkscore was 53.12 (SD: 24.94), the average self-selection score was 3.83 (SD:0.81). Most of the participants were female (50.67%), did not have a health condition that affected physical activity (51.71%), did not have a bachelor's degree (57%), did not own a dog (78.91%), did not walk for utilitarian purposes for at least 150 min (77.94%) and did not walk for leisure for at least 150 min (66.47%) (Table 5.1). Additional descriptive statistics by neighborhood type are available in Appendix C, Table 3C.

Table 5.1: Sociodemographic and neighborhood characteristics for the sample of participants from the greater Montreal and Toronto areas.

	Wave 1		**Wave 2**		**Wave 2 (No movers) [a]**	
	N	**% or mean (SD)**	**N**	**% or mean (SD)**	**N**	**% or mean (SD)**
Age	2192	50.38 (17.31)	1403	53.37 (16.80)	1342	53.80(16.57)
Sex						
Female	1149	52.42	717	51.1	680	50.67
Male	1041	47.49	686	48.9	662	49.33
Cars	2192	1.39 (1.00)	1403	1.35 (0.98)	1342	1.35(0.98)
Health Conditions						
Health condition affects physical activity	898	40.97	593	42.27	579	43.14
No health conditions that affect physical activity	1160	52.92	737	52.53	694	51.71
Education						
Above a bachelor's degree	367	16.74	229	16.32	226	16.84

Bachelor's degree	601	27.42	363	25.87	343	25.56
Below a bachelor's degree	1,206	55.02	802	57.16	765	57.00
Dog ownership						
Yes	495	22.58	298	21.24	278	20.72
No	1689	77.05	1101	78.47	1059	78.91
Micro-scale score	2192	18.40 (2.21)	1403	18.30 (2.26)	1342	18.31 (2.25)
Walkscore	2192	54.33 (24.66)	1403	53.11 (24.97)	1342	53.12 (24.94)
Self-selection score	NA	NA	1403	3.82 (0.81)	1295	3.83 (0.81)
Neighborhood median household income[b]	2192	76831 (22443.29)	1403	74959 (22150.01)	1342	75114(22177.51)
≥150 minutes per week of utilitarian walking						
Yes	488	22.26	304	21.67	292	21.76
No	1682	76.73	1095	78.05	1046	77.94
≥150 minutes per week of leisure walking						
Yes	683	31.16	439	31.29	432	32.19
No	1484	67.7	941	67.07	892	66.47
Neighborhood strata						
Montreal						
High walking/High Walkscore	275	12.55	200	14.26	185	13.79
High walking/Low Walkscore	278	12.68	213	15.18	200	14.90
Low walking/High Walkscore	274	12.5	197	14.04	190	14.16
Low walking/Low Walkscore	278	12.68	216	15.4	206	15.35
Toronto						
High walking/High Walkscore	277	12.63	152	10.83	148	11.03
High walking/Low Walkscore	272	12.41	153	10.91	149	11.10
Low walking/High Walkscore	280	12.77	153	10.91	148	11.03
Low walking/Low Walkscore	258	11.77	119	8.48	116	8.64

a: Sample excluding individuals that moved to a new forward sortation area between wave 1 and wave 2.
b: FSA Median household income from the 2016 Canadian census

5.6.1 Walking for leisure

In the unadjusted model, the grand micro-scale score was positively associated with walking for leisure (OR: 1.11, CI: 1.06–1.17). The association remained after adjusting for covariates (OR: 1.14, CI: 1.04–1.26) and after adjusting for self-selection (OR: 1.14, CI: 1.04–1.25) (Figure 1). In the model adjusting for covariates, the association between the Walkscore and walking for leisure was inconclusive (OR: 1.04, CI: 0.80–1.35) and remained so after adjusting for self-selection (OR: 1.02, CI: 0.78–1.34). In the model adjusting for covariates, age (OR: 1.03, CI: 1.02–1.04), and having a dog (OR: 3.31, CI: 2.46–4.45) were both associated with greater odds of leisure walking, whereas having a health problem that affects physical activity (OR: 0.59, CI: 0.45–0.76) was associated with lower odds of leisure walking – findings that remained statistically significant across the models. In the fully adjusted model, self-selection (OR: 1.35, CI: 1.15–1.59) was associated with walking for leisure (Table 5.2). In the models examining the association between the individual micro-scale items and walking for leisure. The streetlights score was associated with lower odds of walking for leisure after adjusting for covariates and self-selection (OR: 0.84, CI: 0.71–0.99). The building height score was associated with higher odds of walking for leisure after adjusting for covariates (OR: 1.29, CI:1.07–1.56) and after adjusting for self-selection (OR: 1.29, CI: 1.07–1.56). The presence of litter score was associated with lower odds of walking for leisure after adjusting for covariates (OR: 0.79, CI: 0.67–0.93) and after adjusting for covariates and self-selection (OR: 0.78, CI: 0.66–0.92). The attractive segment score was associated with higher odds of walking for leisure after adjusting for covariates (OR: 1.20, CI: 1.02–1.40) and after adjusting for self-selection (OR: 1.21, CI: 1.03–1.41). The aesthetics section score was also associated with higher odds of walking for leisure after adjusting for covariates (OR: 1.22, CI: 1.03–1.46) and after adjusting for self-selection (OR: 1.23, CI: 1.03–1.47) (See Appendix C, Table 4C). In the model with mutual adjustment for the four section scores, the aesthetics section score (OR: 1.27, CI:

1.06–1.53) and the building characteristics section score (OR: 1.27, CI:1.03–1.56) were associated with higher odds of walking for leisure. The association between the pedestrian infrastructure score (OR: 1.03, CI: 0.83–1.29), as well as the traffic calming score (OR: 1.07, CI: 0.93–1.23), and walking for leisure were inconclusive (Figure 5.2).

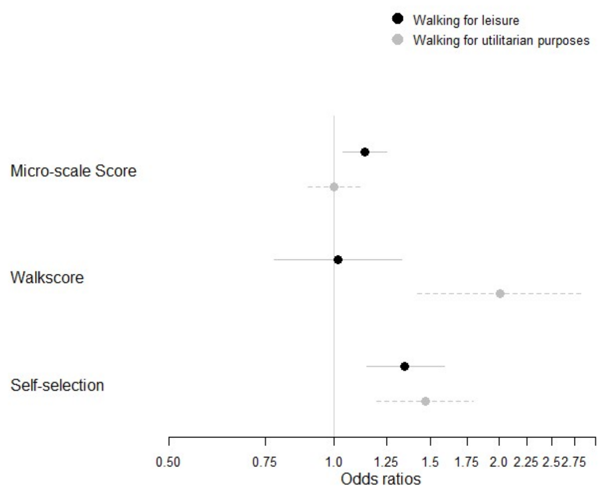

Figure 5.1: Odds ratios for the association between the micro-scale score, Walkscore, self-selection and the walking outcomes.

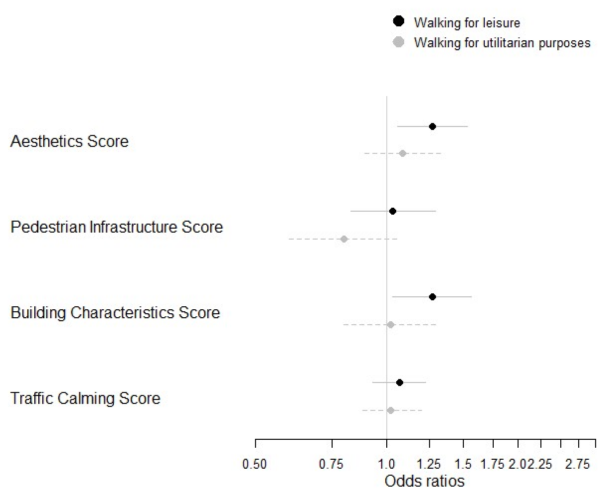

Figure 5.2:Odds ratios for the association between the aesthetics score, pedestrian infrastructure score, building characteristics score, traffic calming score, and the walking outcomes.

5.6.2 Walking for utilitarian purposes

In the unadjusted model, the grand micro-scale score was associated with walking for utilitarian purposes (OR: 1.42, CI:1.32–1.54). After adjusting for covariates, the association between the grand micro-scale score and walking for utilitarian purposes (OR:1.01, CI:0.91–1.14) was inconclusive and remained so in the fully adjusted analyses which accounted for self-selection (OR: 1.01, CI: 0.90–1.13) (Figure 5.1). In the model adjusting for covariates, the Walkscore (OR: 1.97, CI: 1.40–2.78) was associated with increased odds of walking for utilitarian purposes and remained so after adjusting for self-selection (OR: 2.01, CI:1.42–2.84). Number of cars in the household (OR: 0.65, CI: 0.53–0.79) was associated with lower odds of walking for utilitarian purposes – a finding that remained statistically significant across the models. Self-selecting into a walk friendly neighborhood (OR: 1.47, CI: 1.20–1.80) was also significantly associated with walking for utilitarian purposes. In the models examining the association between the individual micro-scale items and walking for utilitarian purposes. The number of traffic lanes score was associated with lower odds of walking for utilitarian purposes after adjusting for covariates (OR: 0.86, CI:0.74–0.99), but was inconclusive after adjusting for self-selection (OR: 0.87, CI:0.75–1.00). The presence of litter score was associated with lower odds of walking for utilitarian purposes after adjusting for covariates (OR: 0.79, CI: 0.65–0.97) and after adjusting for covariates and self-selection (OR: 0.79, CI: 0.65–0.97) (See Appendix C, Table 5C). In the model with mutual adjustment for the four section scores, the association between the aesthetics section score (OR: 1.09, CI: 0.89–1.34), the building characteristics section score (OR: 1.02, CI: 0.80–1.29), the pedestrian infrastructure score (OR: 0.80, CI:0.60–1.06), the traffic calming section score (OR:1.02, CI:0.88–1.20), and walking for utilitarian purposes was inconclusive (Figure 5.2).

Table 5.2: Univariate, partially adjusted, and fully adjusted models for the relationship between micro-scale walkability and walking outcomes in the total sample.

	≥150 minutes per week of walking for leisure (n=1,324)			≥150 minutes per week of walking for utilitarian purposes (n=1,338)		
	Model A	**Model B**	**Model C**	**Model A**	**Model B**	**Model C**
	OR (CI)	**OR (CI)**	**OR(CI)**	**OR (CI)**	**OR (CI)**	**OR(CI)**
Micro-scale walkability score	1.11 (1.06-1.17) *	1.14 (1.04-1.26) *	1.14 (1.04-1.25) *	1.42 (1.32-1.54) *	1.01 (0.91-1.14)	1.01 (0.90-1.13)
Walkscore		1.04(0.80-1.35)	1.02 (0.78-1.34)		1.97 (1.40-2.78) *	2.01 (1.42-2.84) *
Age		1.03 (1.02-1.04) *	1.02 (1.02-1.03) *		1.00 (0.99-1.01)	1.00 (0.99-1.01)
Sex						
Female		1.01(0.79-1.29)	0.95 (0.74-1.22)		0.82 (0.61-1.10)	0.76 (0.57-1.02)
Number of cars					0.65 (0.53-0.79) *	0.66 (0.54-0.80) *
Health problems						
Health problems affects physical activity		0.59 (0.45-0.76) *	0.58 (0.45-0.75) *		0.76 (0.56-1.03)	0.75 (0.55-1.02)
Education						
Bachelor's degree		1.16 (0.87-1.56)	1.18 (0.87-1.59)		1.36 (0.97-1.93)	1.40 (0.99-1.98)
Above a bachelor's		1.14 (0.81-1.62)	1.13 (0.80-1.60)		1.34 (0.91-1.98)	1.33 (0.90-1.97)
Neighborhood income		0.94 (0.785-1.13)	0.94 (0.78-1.13)		0.92 (0.73-1.16)	0.92 (0.73-1.15)
Dog ownership						
Dog owner		3.307 (2.46-4.45) *	3.37 (2.49-4.54) *			
Self-selection			1.35 (1.15-1.59) *			1.47 (1.20-1.80) *

A and D: Unadjusted model.
B: Adjusted for covariates: age, gender, education, having a dog, Walkscore, city, neighborhood income, and health issues.
C: Adjusted for covariates from B and self-selection.
E: Adjusted for covariates: age, gender, education, number of cars in the household, Walkscore, city, neighborhood income, and health issues.
F: Adjusted for covariates from E and self-selection.
*$p < 0.05$.

5.7 DISCUSSION

This study explored the value of incorporating street-level or what we call 'micro-scale' features of built environments into analyses of the walking-friendliness of neighborhoods. Our results suggest that the micro-scale environment is associated with leisure walking but the findings for utilitarian walking were inconclusive. Conversely, the macro-scale environment was associated with utilitarian walking but not conclusively with leisure walking. These results imply that the built environmental determinants of leisure and utilitarian walking may differ. Micro-scale walkability, the combined effect of street-scale elements that act on a pedestrian's pleasure or comfort when walking, may be more strongly supportive of leisure walking than utilitarian walking. In contrast, macro-scale walkability, the combined effect of elements that act to reduce the average distance that an individual will walk to get to a variety of destinations (e.g., density of destinations), appear to support utilitarian walking. Our results with mutual adjustment for the four section scores suggest aesthetics and favorable building characteristics encourage walking for leisure, with the aesthetics of a neighborhood having a slightly stronger association with walking for leisure. This suggests that investments in the micro-scale environment could focus on building characteristics and aesthetics to have the greatest impact on walking for leisure. In the building characteristics section, building height was associated with a higher odds of walking for leisure, whereas in the aesthetics section the attractive segment score was associated with higher odds of walking for leisure and the litter score was associated with lower odds of walking for leisure.

These findings contrast with those of a previous study that found that a summary micro-scale score was associated with active transport (walking/biking trips) and that associations between the micro-scale environment and leisure walking or leisure physical activity were non-significant or in the opposite direction (Cain et al., 2014). This contrast could be explained by differences in context (Canadian versus the United States), in study design (e.g., controlling for self-selection), the independent variable (e.g., different micro-scale items included in their tool) or in the dependent variables (e.g., our study did not combine walking and biking trips).

Previous studies have not incorporated measures of self-selection into their analyses of the micro-scale environment (Cain et al., 2014; Cerin et al., 2013; Christman et al., 2019; Sallis, Cain, et al., 2015; Shigematsu et al., 2009; Van Cauwenberg, Clarys, et al., 2012). Accounting for self-selection can improve our confidence in the accuracy of the estimate of the effect and help to strengthen the case in favor of a causal relationship (Heinen et al., 2018). Self-selection was associated with higher odds of walking for leisure and utilitarian walking, which is consistent with previous studies (Cao et al., 2009; Handy et al., 2005; Norman et al., 2013; Schoner & Cao, 2014). This suggests that individuals may self-select into neighborhoods with a favorable micro-scale walkability because it is conducive to walking. However, our results suggest that the micro-scale environment was an important determinant of leisure walking even after adjusting for the influence of self-selection. This supports the hypothesis that greater leisure walking in areas with a favorable micro-scale walkability results from the favorable environment and not only from residential sorting by preference for walking. Although longitudinal and natural experiments are needed to draw stronger conclusions on the relationship between the micro-scale environment and walking, these findings do strengthen the case for investments in the micro-scale environment of neighborhoods as a means for increasing physical activity.

5.7.1 Strengths and limitations

This study has many strengths. The modifiable nature of the built environment features that were studied implies that results could feasibly be applied to neighborhood settings. The tool that was used to assess the environment was specifically designed to remotely assess micro-scale features of the environment. The influence of the micro-scale environment was monitored using several walking outcomes (utilitarian walking and leisure walking) and a large sample of streets from many geographic regions (128 FSAs). Virtual audits are efficient alternatives to field audits.

The use of GSV for conducting virtual audits in this study allowed us to maximize coverage of neighborhoods with 5% of street segments sampled from each FSA. We also tested an efficient tool with 39 items (Steinmetz-Wood, Velauthapillai, et al., 2019). Many audit tools can be lengthy to use for surveillance purposes, with an average of 92.2 items per tool (Burton et al., 2011; Clifton et al., 2007; Cunningham et al., 2005; Day et al., 2006; Griew et al., 2013; Hoehner et al., 2007; Millstein et al., 2013; Pikora et al., 2002; Sallis, Cain, et al., 2015). Although, other recent concise virtual auditing tools have been developed (Mooney et al., 2020; Plascak et al., 2020).

Some limitations of the study are worth noting. There are temporal inconsistencies in the year and season of images used for audits, due to GSV image dates changing unpredictably (Lafontaine et al., 2017). GSV audits may include features that do not influence the pedestrian experience because GSV provides a view of the street that is higher than the typical pedestrian view (Steinmetz-Wood, Velauthapillai, et al., 2019). Image quality can also affect an auditor's ability to assess fine details of streetscapes (e. g., quality of sidewalks and curb cuts). Internet surveys also have disadvantages. As we expected given that we recruited approximately 25% of our sample from high walking/high walkability neighborhoods, our walking rates were high. However, social surveys will often attract healthier respondents (selection bias) (Pietilä, Rantakallio, & Läärä, 1995; Søgaard, Selmer, Bjertness, & Thelle, 2004) and social desirability or recall difficulties could lead to the under or over reporting of walking behavior. This study did not account for social or cultural factors that may influence the relationship between the neighborhood environment and walking. Future studies might consider performing mixed methods studies to better understand the multifaceted interactions occurring between the built environment and social, as well as cultural factors that might also influence this relationship (Steinmetz-Wood, Pluye, et al., 2019). It is possible that individuals living in areas with a favorable micro-scale environment could over-report walking for leisure. As is true for most studies that sample neighborhoods, it is possible that respondents engaged in leisure walking outside of their neighborhoods or on street segments that were not sampled. Our survey questions did not account for the intensity of the leisure walking performed. It is possible that a favorable micro-scale environment could encourage walking to occur at a slower pace. For example, individuals might stop to sit/chat on benches. Past studies exploring the influence of the macro-scale environment on walking have combined accelerometers with GPS monitoring to allow for a more precise estimate of the intensity of walking and exactly how much walking is occurring in and outside of the neighborhood (Hajna et al., 2016). Future studies could use these techniques to examine the influence of the micro-scale environment on walking.

5.8 CONCLUSION

Our results suggest that the environmental determinants of leisure and utilitarian walking differ, whereas macro-scale walkability supports utilitarian walking, micro-scale walkability is associated with leisure walking. The micro-scale environment was associated with leisure walking even after controlling for self-selection. To our knowledge, our study was the first to account for self-selection when examining the influence of the micro-scale walkability of neighborhoods on walking outcomes. The results emphasize the need to modify both the micro and the macro scale features of neighborhoods to achieve increases in leisure and utilitarian walking. Interventions that modify the micro-scale features of streets have the potential to promote leisure walking, an inexpensive and readily accessible form of physical activity, and improve health status in the population.

6 **CHAPTER SIX |** MANUSCRIPT 4: THE AGE-FRIENDLY STREETSCAPE: CONTRIBUTION OF MICRO-SCALE WALKABILITY TO LEISURE WALKING IN OLDER ADULTS

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6.1 PREAMBLE

As described in the literature review, older adults are a sub-population that may be especially sensitive to the facilitators and barriers to physical activity present in their neighborhood environment. The modifiable nature of micro-scale features makes them feasible targets for interventions aiming to improve the age-friendliness of neighborhoods. In this study, I present the results from an analysis that addressed the fourth objective of this dissertation, *to evaluate the individual and collective influence of items from the Virtual-STEPS tool on walking for leisure in older adults.* The study provides evidence that micro-scale features of the environment individually and collectively promote walking for leisure in older adults. Items from the traffic calming section, and aesthetics sections of the Virtual-STEPS tool were associated with walking for leisure. Stratifying the results by health conditions revealed that older adults with health conditions may be particularly sensitive to the micro-scale environment of neighborhoods. The analysis focused on walking for leisure, as leisure walking was a much more popular form of walking in the sample (see Table 1D, Appendix D). However, I also modelled the association between the Virtual-STEPS items and utilitarian walking in older adults and included these results in appendices (Table 2D, Appendix D).

6.2 ABSTRACT

6.2.1 Background

Few studies have examined the effect of micro-scale features of the environment (i.e., street-level) built environment determinants such as the condition of benches, sidewalks, trees, crossing signals, walking paths, or cues of social disorganization or crime (e.g., graffiti) on the walking behavior of older adults, a population who might be particularly sensitive to small scale features of the environment. In this study, we evaluated the association between micro-scale features of the built environment and walking for leisure in older adults.

6.2.2 Methods

Older adults from Montreal and Toronto (N=605) participated in an internet survey. The micro-scale environment of participants neighborhoods was audited using the Virtual-STEPS audit tool. The association between items from the Virtual-STEPS tool and walking for leisure was modelled using multilevel logistic regression analysis (≥150 minutes per week versus <150 minutes per week). We then stratified the sample by health condition and performed multilevel logistic regressions using both samples.

6.2.3 Results

The total number of lanes (OR:0.82, CI:0.67-1.00), and having many residential and high-volume driveways (OR:0.78, CI:0.64-0.97) in the neighborhood was associated with lower odds of walking for leisure, whereas the traffic calming total section score (OR:1.33, CI:1.08-1.63), the presence of nature areas (OR:1.23, CI:1.02-1.48), the attractive segment score (OR:1.36, CI:1.08-1.73), and the grand micro-scale score (OR:1.39, CI:1.01-1.91) were associated with greater odds of walking for leisure. After stratifying by health conditions, the traffic calming total section score

(OR:1.38, CI:1.00-1.92) and the grand micro-scale score (OR:1.92, CI:1.14-3.23) were only associated with walking for leisure in the sample with health conditions. The aesthetics total section score (OR:1.71, CI:1.12-2.61) was only associated with walking for leisure in the sample of older adults with health conditions.

6.2.4 Conclusions

Older adults with health conditions may be particularly sensitive to the micro-scale environment of their neighborhood. Considering the modifiable nature of these features, adapting the micro-scale environment could be a feasible and cost-effective method of making neighborhoods more inclusive and accessible spaces for older adults with health impairments.

6.3 INTRODUCTION

Rising life expectancy in high-income countries and reduced mortality at younger ages in low-income countries, coupled with falling fertility rates globally has led to rapid aging of the global population (Beard et al., 2016). The population over 60 years old is expected to nearly double between 2015 and 2050, from 12% to 22%, and by 2020 the population older than 60 will outnumber children below 5 years of age. In 2015, there were 125 million people that were 80 years old and older, in 2050 this will be 434 million people (World Health Organization, 2015a). Concomitantly, 54% of the world's population lives in urban areas, and by 2050 this is expected to reach 66 % (United Nations, 2014).

The combination of an aging population with growing urbanization has led to an increased interest in the role of urban environments in healthy ageing (Beard & Petitot, 2010). Research suggests that population aging will be a significant burden on healthcare and social systems (Colombier, 2018; Wister & Speechley, 2015). However, if older adults are able to maintain good health and are living in environments that allow them to remain involved in society, this could help to negate the assumption of the broader research community that older adults will necessarily be largely dependent on society (Beard & Petitot, 2010). Most older adults would prefer to age in place (Clarke & Nieuwenhuijsen, 2009; Kerr, Rosenberg, & Frank, 2012; Rosenbloom, 2001). In Canada, 90% of older adults are not living in an old age home, with 66% of older adults living in a private house (Fédération Canadienne des Municipalités, 2015).

It is especially important that neighborhoods be age-friendly because as older adults age, they may spend more of their time in their residential neighborhood (Perchoux et al., 2013). Declines in physical function (Clarke & Nieuwenhuijsen, 2009; Loh et al., 2019), cognitive function (Clarke & Nieuwenhuijsen, 2009), social networks (Glass & Balfour, 2003), and the loss of a driver's license (Dickerson et al., 2017; Liddle, Turpin, Carlson, & McKenna, 2008) may also make older adults especially vulnerable to the facilitators or barriers present in their neighborhood.

One of the evolving research agendas in the field has been on how neighborhood-built environments influence the active aging and health of older adults. Many of these studies have focused on whether the collective influence of macro-scale features of the built environment such as connectivity (i.e., number of intersections), land-use mix, and density (i.e., population density or density of destinations) encourage walking behavior (Barnes et al., 2016; Carlson et al., 2012; Kikuchi et al., 2018; King et al., 2011; Sallis et al., 2016; Shimura et al., 2012; Thielman et al., 2015; Van Holle et al., 2014; Yang, Xu, Rodriguez, Michael, & Zhang, 2018). A more recent research focus is on micro-scale (i.e., street-level) built environment determinants such as the condition of benches, sidewalks, trees, crossing signals, walking paths, or cues of social disorganization or crime (e.g., graffiti) and how they contribute to walking behavior (Cain et al., 2014; Cerin et al., 2013; Sallis, Cain, et al., 2015; Shigematsu et al., 2009). Micro-scale features of neighborhoods tend to be measured at a smaller spatial scale (Steinmetz-Wood et al., 2020) and often affect a pedestrian's pleasure or comfort while walking in a neighborhood (Cain et al., 2014; Sallis, Cain, et al., 2015) and may act as important facilitators or barriers to older adults' mobility. They are also inherently more modifiable than macro-scale features, that often require a complete restructuring of the neighborhood layout to change (Cain et al., 2014).

Most previous studies have used self-reported measures (Shigematsu et al., 2009; Van Cauwenberg, Clarys, et al., 2012) or field audits (Cain et al., 2014; Cerin et al., 2013; Hawkesworth et al., 2018; Sallis, Cain, et al., 2015) to collect data on the micro-scale environment of neighborhoods. New technology has allowed for virtual audits of neighborhood environments, an efficient, less expensive, and safer alternative to field audits (Badland et al., 2010). Virtual audits have also been found to be just as accurate as field audits for most auditing items, with studies finding high reliability between virtual and field audits (Badland et al., 2010; Clarke et al., 2010; Griew et al., 2013; Kelly et al., 2013; Odgers et al., 2012; Rundle et al., 2011). Most virtual audits have been performed using Google Street View ™ (GSV), a web-service that can be accessed through Google Maps or Google Earth and provides 360° horizontal and 290° vertical panoramic images of the streets (www.google.com/maps). This allows the researcher to audit at their desks by virtually walking along the street (Griew et al., 2013).

In the analyses that follow, we use the Virtual-STEPS tool, a virtual audit tool created to evaluate the micro-scale environment using GSV (Steinmetz-Wood, Velauthapillai, et al., 2019). We then link the audits to a sample of older adults, to test the hypothesis that micro-scale features of the built environment are associated with walking for leisure. Having a health condition can prevent older adults from being physically active and older adults with health conditions may be particularly sensitive to their built environments (Clarke, Ailshire, Bader, Morenoff, & House, 2008; Eisenberg, Vanderbom, & Vasudevan, 2017). Therefore, we also examined if the effect of the micro-scale environment on walking for leisure varied according to health condition.

6.4 METHODS

6.4.1 Sample

Adults residing in neighborhoods in Montreal and Toronto (n=2,192) were recruited to participate in an internet survey. Participants in Montreal and Toronto were recruited from 128 forward sortation areas (FSA) (first three digits of the postal code). On average, there are 8,000 households within an FSA (Statistics Canada, 2009). To ensure that there was a diversity in physical activity levels and the macro-scale environmental features of participants' neighborhoods, walking to work trips from the Origin destination survey as well as the Transportation Tomorrow Survey, and geographic information system (GIS) methods were used to stratify neighborhoods in the Montreal and Toronto area by high walking-friendly/high walking, high walking-friendly/low walking, low walking-friendly/high walking and low walking friendly/low walking. The walking friendliness of forward sortation areas was measured by taking the average of the Walk Scores® associated with the postal codes located within each forward sortation area. The Walk Score® is an index that determines the walking-friendliness of a location based on the distance between that location and different types of amenities. It also measures walk-friendliness by incorporating measures of population density, block length, and intersection density. (http://www.walkscore.com/methodology.shtml). Walk Score has been validated against other macro-scale indices in previous studies (Carr et al., 2010, 2011).The average area of the 128 FSAs was 36.62 km^2 (SD: 87.55) with a median of 8.98 km^2. The average population of the FSAs was 25,252 (SD: 17,139.22) with a median of 21,725. Postal codes from within each stratum were sampled and then participants were contacted with the objective of recruiting 275 respondents from within each stratum. Additional descriptive information on the forward sortation areas and the survey has been discussed elsewhere (Steinmetz-Wood et al., 2020). We performed our analyses using the 605 older adult (≥65 years old) that participated in the survey.

6.4.2 Walking for leisure

Respondents were asked if they walk for leisure (walking for fun or for exercise) such as if they walk their dog or if they walk for leisure or exercise outdoors. Respondents were asked to record the number of days a week that they walked, as well as the number of minutes per day. The number of minutes per day was multiplied by the days per week to get the number of minutes per week. A binary walking variable was created (<150 minutes per week/≥150 minutes per week). The 150 minute per week threshold was chosen to be in line with physical activity guidelines (Tremblay et al., 2011).

6.4.3 Covariates

Participants were asked questions regarding their sociodemographic characteristics including age, sex, education, dog ownership, city, and if they had physical or mental health conditions that could prevent them from being physically active. Neighborhood income was obtained using the FSA Median household income from the 2016 Canadian census. Age was centered. Education was categorized into three categories: high school or less, CEGEP\ trade school\ diploma below the bachelor's level, and bachelor's degree and above. Neighborhood income was converted to a Z-score. To account for macro-scale walkability, we used the Z-scores of the average Walk Scores® of the FSAs that were used to stratify neighborhoods in Montreal and Toronto by walking/walk-friendliness.

6.4.4 Micro-scale environment

We used the Virtual Systematic Tool for Evaluating Pedestrian Streetscapes (Virtual-STEPS) to virtually assess the microscale environment of selected FSAs using Google Street View. The Virtual-STEPS tool includes the following sections: pedestrian infrastructure (e.g., sidewalks), traffic calming (e.g., stop signs), building characteristics (e.g., building height), and aesthetics/disorder (e.g., graffiti). The creation and validation of the tool has been described elsewhere (Steinmetz-Wood et al., 2020; Steinmetz-Wood, Velauthapillai, et al., 2019). The tool manual and computation of scores is available online (https://nancyrossresearchgroup.ca/).

A random sample of street segments (5%) was selected from each of the 128 FSAs located in Montreal and Toronto, Canada. Field audits were conducted by remotely walking down street segments using GSV and auditing the first intersection and both sides of the street. Street segments consisted of sections of a street located between two intersections or an intersection and a cul-de-sac. The start points (intersection) for the audits was selected randomly using geographic information systems. 3,450 segments were audited in total with an average 26.74 (SD: 17.14) segments audited per FSA.

Once the audits were complete, scores were computed for each of the items by summing the proportion of segments that had a characteristic for each item category multiplied by its weight. Weighting was based on the presence of the item on the segment. For example, the presence of sidewalks on both sides of the street=1, on one side of the street=0.5, or absence of sidewalks=0. A total score out of ten was computed for the four sections: pedestrian infrastructure (e.g., sidewalks), traffic calming (e.g., stop signs), building characteristics (e.g., building height), and aesthetics/disorder (e.g., trees). Each item in the subscale had an equal weight. The scores for items such as graffiti, litter, and building setback were inversed when calculating the grand scores, as a high score on these items would not indicate a more favorable micro-scale environment. Cronbach's alpha of the sections was 0.93, 0.72, 0.66, and 0.76, respectively. Cronbach's alpha measures the internal consistency of items in a scale and is a function of the number of items, as well as the correlation between items (Tavakol & Dennick, 2011). The value of 0.66 for building characteristics was considered acceptable given the small number of variables in the building scale. A grand score was then computed by adding all the section scores, with a higher score (score approaching 40) indicating a favorable micro-scale environment and this score was then standardized as a Z-score. The scores were then linked to each respondent from the survey.

6.5 ANALYSIS

Several variables had missing values including education (n=6), and health conditions that affect physical activity (n=25) and walking for leisure (n=13). Before running the models we performed multiple imputation (Enders, 2010) using five imputations. The data was assumed to be missing at random (MAR). We imputed values for education and health conditions that affect physical activity. Sex, age, education, neighborhood income, dog ownership, health conditions that affect physical activity, and city were used as predictors in the predictor matrix for the imputation. Multilevel (i.e., people nested within forward sortation areas) logistic regression models examined the relationship between items from the Virtual-STEPS tool and odds of walking for leisure (0: <150 minutes per week, 1: ≥150 minutes per week). Models controlled for: age, sex, education, dog ownership, physical or mental health conditions, city, neighborhood income, and the Walkscore. We then stratified the sample by health conditions and ran multilevel logistic regression models controlling for covariates.

6.6 RESULTS

6.6.1 Descriptive statistics

The average age of the sample was 71.15 (SD: 4.80) (Table 6.1). Most participants were male (59.17 %), did not own a dog (85.12%), did not have health conditions that affect their physical activity (48.93%), had a bachelor's degree or above (37.19%), did not walk for leisure for ≥150 minutes per week (64.13%). The average neighborhood income was 77,446.51 (SD: 20,556.74). The average micro-scale score was 18.54 (SD: 2.27) and the average Walkscore was 44.78 (SD: 23.56). Participants without health conditions lived in neighborhoods with an average micro-scale score of 18.47 (SD: 2.27) and an average Walkscore of 45.46 (23.85), whereas participants with health conditions lived in neighborhoods with an average micro-scale score of 18.60 (SD: 2.23) and an average Walkscore of 43.89 (SD: 23.29).

Table 6.1: Descriptive statistics for the sample of older adults from Montreal and Toronto.

	Full sample (n=605)		**Sample without health conditions (n=296)**		**Sample with health conditions (n=284)**	
	N	**Average (SD) or %**	**N**	**Average (SD) or %**	**N**	**Average (SD) or %**
Age	605	71.15 (4.80)	296	70.70 (4.47)	284	71.58 (5.05)
Sex						
Male	358	59.17	191	64.53	151	53.17
Female	247	40.83	105	35.47	133	46.83
Dog owner						
Yes	90	14.88	37	12.50	50	17.61
No	515	85.12	259	87.50	234	82.39
Education						
Highschool diploma or below	151	25.96	61	20.61	82	28.87
CEGEP or trade school	223	36.86	117	39.53	95	33.45
Bachelor's degree and above	225	37.19	116	39.19	103	36.27
Neighborhood income	605	77446.51 (20556.74)	296	78071.54(20950.78)	284	77307.24 (20115.24)
Walkscore	563	44.78 (23.56)	296	45.46 (23.85)	284	43.89 (23.29)
Walked for leisure ≥150 minutes per week						
Yes	204	33.72	126	42.57	68	23.94
No	388	64.13	164	55.41	211	74..30
Health conditions that affect physical activity						
Yes	284	46.94				

No	296	48.93

6.6.2 Full Sample

In the traffic calming section, the total number of lanes (OR: 0.82, CI: 0.67-1.00, p<0.05) and the residential or high-volume driveways score (OR: 0.78, CI: 0.64-0.97) was associated with lower odds and the traffic calming total section score (OR: 1.33, CI: 1.08-1.63) was associated with greater odds of walking for leisure for at least 150 minutes per week. In the aesthetics section, the presence of nature areas score (OR: 1.23, CI:1.02-1.48), and the attractive segment score (OR: 1.36, CI: 1.08-1.73) was associated with greater odds of walking for leisure for at least 150 minutes per week. The grand micro-scale score (OR: 1.39, CI: 1.01-1.91) was associated with greater odds of walking for leisure for at least 150 minutes per week.

Table 6.2: Multilevel logistic regression models of the relationship between micro-scale characteristics of participants neighborhoods and walking for leisure for at least 150 minutes per week.

	Model A (n=592): Full sample			Model B (n=290): Sample without health condition			Model C (n=279): Sample with health conditions		
	Walking for leisure			Walking for leisure			Walking for leisure		
	OR	CI		OR	CI		OR	CI	
Item		Lower limit	Upper limit		Lower limit	Upper limit		Lower limit	Upper limit
Pedestrian Infrastructure									
Presence of Sidewalks Score	0.94	0.67	1.31	0.79	0.52	1.20	1.19	0.73	1.94
Sidewalk Buffer Score	0.88	0.65	1.19	0.71	0.46	1.09	1.06	0.65	1.74
Sidewalk Maintenance Score	1.01	0.75	1.36	0.84	0.57	1.23	1.26	0.81	1.94
Pedestrian Crossing Infrastructure Score	1.11	0.87	1.41	1.14	0.83	1.57	1.02	0.67	1.55
Benches Score	1.14	0.87	1.50	1.20	0.85	1.71	1.12	0.71	1.77
Streetlights Score	0.94	0.72	1.23	0.86	0.63	1.19	1.09	0.74	1.61
Curb Cuts Presence Score	0.90	0.65	1.25	0.78	0.52	1.16	1.14	0.70	1.86
Curb Cut Quality Score	1.13	0.92	1.40	1.11	0.83	1.50	1.25	0.90	1.75
Tactile Paving Score	0.90	0.68	1.19	0.77	0.54	1.09	1.11	0.74	1.68
Pedestrian Infrastructure Score Total	0.97	0.68	1.38	0.83	0.54	1.28	1.22	0.73	2.07
Traffic Calming									
Number of Types of Traffic Calming Devices Score									
3+	1.06	0.87	1.30	0.95	0.72	1.25	1.18	0.86	1.60
Number of Traffic Lanes									
3+	0.92	0.75	1.14	1.08	0.81	1.43	0.68	0.46	1.01
Total Number of Lanes Score									

4+	0.82*	0.67	1.00	0.85	0.65	1.10	0.76	0.55	1.07
Driveways Score	0.78*	0.64	0.97	0.67*	0.50	0.89	0.92	0.67	1.28
Traffic Calming Score Total	1.33*	1.08	1.63	1.31	0.98	1.75	1.38*	1.00	1.92
Building Characteristics									
Building Height Score	1.12	0.84	1.49	1.25	0.87	1.83	0.99	0.62	1.59
Building Setback Score	0.93	0.69	1.26	0.83	0.55	1.24	1.12	0.71	1.77
Building Design Variation Score	0.91	0.75	1.10	0.85	0.66	1.10	1.08	0.79	1.49
Building Characteristics Score Total	1.03	0.76	1.40	1.14	0.76	1.73	0.99	0.63	1.57
Aesthetics									
Presence of Trees Score	1.04	0.86	1.26	0.86	0.66	1.11	1.33	0.98	1.80
Nature Areas Score	1.23*	1.02	1.48	1.24	0.97	1.59	1.26	0.93	1.72
Landscaping Score	1.06	0.84	1.35	0.97	0.71	1.33	1.27	0.85	1.89
Landscape Maintenance Score	1.06	0.88	1.26	0.92	0.73	1.17	1.38	0.98	1.94
Presence of Litter Score	0.91	0.71	1.18	1.03	0.74	1.43	0.68	0.45	1.04
Graffiti Score	1.06	0.80	1.40	1.00	0.69	1.45	1.23	0.80	1.88
Social Disorder Score	1.03	0.76	1.39	1.08	0.73	1.60	0.88	0.54	1.45
Attractive Segment Score	1.36*	1.08	1.73	1.22	0.89	1.65	1.74*	1.16	2.60
Aesthetics Score Total	1.26	0.98	1.62	1.09	0.79	1.51	1.71*	1.12	2.61
Micro-scale Score Total	1.39*	1.01	1.91	1.18	0.77	1.82	1.92*	1.14	3.23

Model A: adjusted for age, sex, education, having a dog, city, neighborhood income, health conditions, and the Walkscore
Model B: adjusted for age, sex, education, having a dog, city, neighborhood income, and the Walkscore
Model C: adjusted for age, sex, education, having a dog, city, neighborhood income, and the Walkscore

6.6.3 Stratification

In the sample without health conditions, the residential and high-volume driveways score (OR: 0.67, CI: 0.50-0.89) was the only item that was associated with odds of walking for leisure. In the sample of participants with health conditions, the attractive segment score (OR:1.74, CI:1.16-2.60) was the only item associated with odds of walking for leisure. The traffic calming section score (OR:1.38, CI:1.00-1.92, $p<0.05$), the aesthetics section score (OR:1.71, CI:1.12-2.61) and the grand micro-scale score were also associated with higher odds of walking for leisure in this sample (OR: 1.92, CI: 1.14-3.23) (Table 6.2).

6.7 DISCUSSION

In this study, the Virtual-STEPS tool, a reliable tool created for the surveillance of the micro-scale environment of streetscapes using GSV (Steinmetz-Wood, Velauthapillai, et al., 2019), was used to audit neighborhood environments, in order to evaluate the association between features of the micro-scale environment and walking for leisure in older adults. Our findings suggest that environments that have calm streets with little traffic and pleasant aesthetics support prolonged leisure walking such that older adults can meet physical activity recommendations (150 minutes of walking per week). Living in an area where streets have many traffic lanes, as well as in an area with many residential or high-volume driveways discouraged older adults from walking for leisure. In contrast, pleasant aesthetics including the attractive segment score and living in an area with nature areas encouraged walking for leisure. After stratifying for health conditions, the traffic calming section score, and the number of traffic lanes were only associated with leisure walking in older adults with health conditions emphasizing the sensitivity of older adults with health conditions to traffic calming measures. Participants with health conditions also appeared to be sensitive to the aesthetics of their neighborhood, as the aesthetics section score was only associated with walking for leisure in older adults with health conditions.

The grand micro-scale score was associated with walking for leisure in the full sample and had a larger effect size than the individual items. This suggests that it may be the combined effect of many streetscape elements that has the greatest effect on leisure walking in older adults. After stratifying the sample by health conditions, the grand score was only associated with leisure walking in the sample of older adults with health conditions. This suggests that older adults with health conditions may be particularly sensitive to the quality of their environment. In line with previous studies that have found individuals with health impairments to be particularly sensitive to their built environments (Clarke et al., 2008; Eisenberg et al., 2017), the results emphasize how a disadvantageous micro-scale environment may impede older adults with health conditions from maintaining their independence and active lifestyle, undermining their ability to age in place.

Our findings indicating that the micro-scale environment has an influence on walking for leisure, contrasts with those of a previous study that found that the relationship between the grand micro-scale score and walking for leisure were non-significant or in the opposite direction (Cain et al., 2014). This contrast could be explained by several factors including differences in context (Canadian versus the United-States), or difference in the items included in the micro-scale score. Studies conducted with older adults have also found that features of the micro-scale environment may encourage walking for leisure, including: building aesthetics (Cain et al., 2014; Cerin et al., 2013), natural sights, absence of signs of crime/disorder, absence of litter (Cerin et al., 2013), absence of parking lots, building height setback, building height road width ratio, and wide one-way street design (Cain et al., 2014).

Our findings suggesting that nature areas and aesthetically pleasing segments encourage leisure walking are in line with a systematic review and meta-analysis that found strong evidence linking a pleasant aesthetic environment to walking for leisure in older adults. The study also indicated that other features of the micro-scale environment were too infrequently studied to draw firm conclusions (Van Cauwenberg et al., 2018) emphasizing the importance of continuing to strengthen the evidence base. There is also limited research on virtually assessed micro-scale features and their association with walking outcomes in older adults. One previous study examining the effect of micro-scale items on walking outcomes found that aesthetic and pedestrian infrastructure items influenced walking for leisure. The study of 2,224 older adults revealed that there was a significant positive association between sidewalk characteristics, presence of gardens and flowers, and walking for leisure (Christman et al., 2019).

6.7.1 Strengths and limitations

This study has many strengths. Our study was conducted in an age-group that may be especially sensitive to the quality of their streetscape. The modifiable nature of micro-scale features can also facilitate the application of findings to neighborhood environments. Virtual audits also allowed us to have a larger geographic coverage for audits compared to many previous studies. We performed audits for a large sample of streets from many geographic regions with 5% of street segments sampled from each FSA. Our efficient tool with only 39 items (after excluding shade), contrasts with most other audit tools with an average of 92.2 items per tool (Burton et al., 2011; Clifton et al., 2007; Cunningham et al., 2005; Day et al., 2006; Griew et al., 2013; Hoehner et al., 2007; Millstein et al., 2013; Pikora et al., 2002; Sallis, Cain, et al., 2015), also facilitated reaching an extensive geographic coverage.

This study has limitations. There were temporal inconsistencies in the year and season of images used for audits. GSV image dates would change unpredictably during the audits due to the timing and frequency of videos taken by Google. GSV images are taken with a car mounted camera, therefore the virtual audits may have included features that are not visible to pedestrians (Steinmetz-Wood, Velauthapillai, et al., 2019). Image quality can also influence assessments of the finer details of streetscapes (e.g., quality of sidewalks and curb cuts). Internet surveys also have disadvantages. Social surveys can attract healthier respondents (selection bias) (Pietilä et al., 1995; Søgaard et al., 2004) and social desirability or recall difficulties can lead to an under or over reporting of behaviors. As is true for most studies that sample neighborhoods, it is possible that respondents engaged in leisure walking outside of their neighborhoods or on street segments that were not sampled.

6.8 CONCLUSION

This study examined the influence of the micro-scale environment on walking in older adults, an age group that may be especially vulnerable to the facilitators or barriers present in their neighborhood environment. This study provides evidence that multiple items from the Virtual-STEPS tool including traffic calming, and aesthetic features were associated with walking for leisure for at least 150 minutes per week. After stratification, the traffic calming section score was only associated with leisure walking in older adults with health conditions emphasizing the sensitivity of older adults with health conditions to traffic calming measures. Participants with health conditions were also sensitive to the aesthetics of their neighborhood, whereby the aesthetics section score was only associated with walking for leisure in older adults with health conditions. Stratification also revealed that the grand micro-scale score was only associated with leisure walking in older adults with health conditions suggesting that they are particularly sensitive to the micro-scale environment. Modifying the micro-scale environment is a relatively cost-effective method of changing the environment with modifications having the potential to fit within the budget of municipal governments. This implies that modifying multiple dimensions of the micro-scale environment could be a policy amenable option for increasing physical activity and improving the health of some of the most vulnerable members of society.

7 **CHAPTER SEVEN|** MANUSCRIPT 5: WHERE DID COVID-19 LEAVE THE AGE-FRIENDLY SUBURB? EXPLORING OLDER ADULTS' PERCEPTIONS OF THE ENVIRONMENTAL INFLUENCES ON WALKING

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7.1 PREAMBLE

This manuscript addressed the fifth objective of this dissertation, *to explore how older adults' perceptions of their neighborhood environment influence their walking behavior.* We recruited older adults from suburban neighborhoods based on the results of the previous manuscript that revealed that micro-scale features of the environment individually and collectively promoted walking for leisure in older adults independent of the macro-scale environment of neighborhoods. A separate analysis that consisted of stratifying the sample of older adults by macro-scale walkability (Walkscore ≥50/ Walkscore <50) also demonstrated that the grand micro-scale score was significantly associated with walking for leisure in areas with a low macro-scale walkability (Table 1E, Appendix E). This suggests that improving the micro-scale environment of neighborhoods could be a feasible method of promoting walking even in areas where the macro-scale environment (e.g., density) is low. Semi-structured interviews in adults from suburban neighborhoods revealed that micro-scale features such as aesthetics (parks, waterfront, trees, gardens), pedestrian infrastructure (sidewalks, walking paths, and benches), and building characteristics (pleasing building design, building maintenance) were perceived as facilitators to walking, whereas traffic as well as unsafe intersections were perceived as barriers.

7.2 ABSTRACT

7.2.1 Background

Strategies to promote walking in car-dependent neighborhoods could help older adults to maintain long-term independence and health. However, there is a need to better understand older adults' experiences of walking within this context. In our study, we draw on the experiences of older adults, to better understand the neighborhood environmental influences on walking within suburban neighborhoods during the Corona Virus Disease 2019 (COVID-19) pandemic.

7.2.2 Methods

Older adults (n=23) from suburban areas within Montreal's Census Metropolitan Area were recruited to participate in semi-structured interviews. To avoid in-person contact with participants, we recruited our participants over Facebook by posting flyers in community-oriented Facebook groups. Thematic analysis was conducted using MAXQDA. A combination of inductive and deductive methods was used to derive categories and themes from the data.

7.2.3 Results

Aesthetics (parks, waterfront, trees, gardens), pedestrian infrastructure (sidewalks, walking paths, and benches), proximity to shops/facilities, building characteristics (pleasing building design, building maintenance) were perceived as facilitators to walking, whereas traffic as well as unsafe intersections were perceived as barriers to walking. Older adults also reported avoiding crowded parks and crowded or narrow boardwalks, sidewalks, and walking paths due to difficulties with physical distancing.

7.2.4 Conclusion

Our results suggest that aesthetically pleasing environments with walk-friendly pedestrian

infrastructure, little traffic, and safe intersections encourage walking in older adults. Findings could help to inform initiatives to design age-friendly environments within suburban municipalities.

7.3 INTRODUCTION

Studies have emphasized the importance of maintaining an active lifestyle to promote healthy aging (Boutros, Morais, & Karelis, 2019; Cerin, Nathan, Van Cauwenberg, & Barnett, 2019; Müller, Ansari, Ebrahim, & Khoo, 2016). Physical activity can decrease risk of obesity, high diastolic blood pressure (Gennuso, Gangnon, Matthews, Thraen-Borowski, & Colbert, 2013), type 2 diabetes, breast cancer, colon cancer (Lee et al., 2012), depression (Lindwall, Larsman, & Hagger, 2011; Strawbridge, Deleger, Roberts, & Kaplan, 2002), coronary heart disease (Batty, 2002), and can slow physical (Pluijm et al., 2007) and cognitive decline (Liu-Ambrose et al., 2016; Sofi et al., 2011). Most older adults do not engage in enough physical activity for it to benefit their health. The prevalence of meeting physical activity guidelines is generally low (Cerin et al., 2019), with only 12% of older adults in Canada meeting the Canadian physical activity guidelines of 150 minutes of moderate to vigorous physical activity per week (Statistics Canada, 2015).

Socioecological models of physical activity (Sallis, Owen, et al., 2015; Sallis et al., 2008) and a significant body of evidence (Barnett et al., 2017; Hajna et al., 2015; McCormack & Shiell, 2011; Saelens & Handy, 2008b; Steinmetz-Wood & Kestens, 2015; Van Cauwenberg et al., 2011; Wasfi et al., 2017) suggests that neighborhood-built environments are important contributors to physical activity. It is important that neighborhood environments are well-adapted to accommodate the mobility needs of older adults. Especially when losing access to a private automobile, as well as physical or cognitive decline, may result in older adults' physical activity being particularly susceptible to the hazards or resources available in their neighborhood environment (Cerin et al., 2019). Engaging in physical activity in an environment that is ill-adapted to their physical activity needs can also be a significant threat to older adults' health and safety. Older adults are overrepresented in adverse outcomes that can result from environments that are ill-adapted to their needs. For example, ill-designed environments can contribute to falls (Li et al., 2006), a leading cause of injury in this age-group (CIHI, 2019). Older adults are also overrepresented in pedestrian road crashes (Lord, Cloutier, Garnier, & Christoforou, 2018) as up to 50% of pedestrian injuries from OECD countries are seniors (International Transport Forum, 2011).

Older adults' relationship with the environment is shaped by age-related changes such as impaired sight, hearing, and physical capacity (Moran et al., 2017), and older adults' environmental needs may be sensitive to these changes. Exploring older adults' experiences and perceptions of the built environment with an aim to develop a more holistic understanding of their relationship with their environments could help us to better inform the design of communities to encourage active living (Lee & Dean, 2018).

In Canada, suburban neighborhoods have a higher proportion of older adults than urban neighborhoods (Channer, Hartt, & Biglieri, 2020) and most older adults would like to remain in their neighborhoods as they age (Kerr et al., 2012; Rosenbloom, 2001). Familiarity with a place can help older adults to develop adaptive strategies to maintain their mobility as they age (Franke, Winters, McKay, Chaudhury, & Sims-Gould, 2017). However, the car-dependency of many suburban neighborhoods means that suburban municipalities could face challenges in providing opportunities for maintaining mobility and physical activity for this population (Mitra et al., 2015).

Given the convergence of the COVID-19 pandemic with widespread sedentary behavior in the Canadian population, a contributor to the obesity epidemic, it is increasingly important that suburban municipalities are sensitive to the physical activity needs of the older adult population. Older adults are at increased risk of complications from COVID-19 (Government of Canada, 2020), but physical activity could help older adults to be resilient to the effects of the pandemic on their health. Physical activity may improve the immune system's response to viral infections (Nieman & Wentz, 2019) and older adults engaging in physical activity during a self-isolation period are more likely to be optimistic about their situation (Carriedo, Cecchini, Fernandez-Rio, & Méndez-Giménez, 2020) and less likely to have depressive symptoms (Callow et al., 2020; Carriedo et al., 2020). A sedentary lifestyle is a risk factor for conditions such as heart disease, high blood pressure, diabetes, and obesity (Batty, 2002; Gennuso et al., 2013; Lee et al., 2012), conditions that put older adults at risk of having a severe COVID-19 infection (Government of Canada, 2020).

Walking is a safe, accessible (Hillsdon & Thorogood, 1996), and popular form of physical activity in older adults (Kerr et al., 2012; Lim & Taylor, 2005; Päivi et al., 2010). Because walking is linked to many positive health benefits (Omura, Ussery, Loustalot, Fulton, & Carlson, 2019; Smith, Wingard, Smith, Kritz-Silverstein, & Barrett-Connor, 2007; Tomata, Zhang, Sugawara, & Tsuji, 2019; Wallis et al., 2017; Williams & Thompson, 2013) promoting walking in the older adult population could be an important method of reducing the disproportionate demand for health care services that is projected for Canada's elderly population (Wister & Speechley, 2015).

The demand for age-friendly neighborhoods will likely increase in the years to come. COVID-19 has given new meaning to ageing in place, as it has exposed the vulnerability of old age homes to infectious diseases, and has once again brought the poor conditions of care and quality of life in nursing homes to the forefront (Estabrooks et al., 2020; Hsu et al., 2020). This means that in the future many older adults will likely be looking for ways to remain in their own home for as long as possible. Strategies to promote walking in car-dependent neighborhoods such as improving the urban design of these neighborhoods could help older adults to maintain long-term independence, health, and accordingly to age in place.

In our study, we draw on the lived experiences of older adults, to better understand the neighborhood environmental influences on walking within suburban neighborhoods. Further, we explored older adults' perceptions within the unique context of the Corona Virus Disease 2019 (COVID-19) pandemic. The COVID-19 pandemic has changed behavior and social norms (e.g., wearing masks, and social distancing). An understanding of how perceptions of the environment and walking behavior have changed within this age group (65+), especially when adults aged 60+ are considered to be at higher risk of serious illness from the virus (Government of Canada, 2020), could be instrumental for informing future urban planning, as well as public health policy and practice in Canada.

7.4 METHODS

7.4.1 Context and participants

Older adults (n=23) from Montreal's Census Metropolitan Area were recruited to participate in an interview. Participants had to be at least 65 years old, dwelling in the community (e.g., adults living in seniors' residences were not included in the sample), be able to leave their dwelling without assistance, and live in a suburban neighborhood. Consistent with previous classifications and notions of suburban neighborhoods (Channer et al., 2020; Moos & Walter-Joseph, 2017), participants lived in forward sortation areas (first three digits of the postal code) with a low population density (<4000 people per km^2). They also lived within forward sortation areas with a high reliance on cars for commuting, as according to the 2016 census the percentage of commuters that relied on a car to commute within the FSAs of participants ranged from 71 to 94%. They also all lived within an FSA with an average Walkscore® lower than 50, whereby all neighborhoods with a Walkscore® lower than 50 are considered car-dependent neighborhoods. The Walk Score® is an index based on the distance between that location and different types of amenities. It also incorporates measures of population density, block length, and intersection density (http://www.walkscore.com/methodology.shtml).

The McGill University Research Ethics Board approved the study (REB File # 187-1019). Our plan was to recruit participants in-person from community centers for in-person semi-structured interviews beginning in April 2020. However, in March 2020, in Montreal, Quebec, the lockdown due to the COVID-19 pandemic began and all in-person research at McGill was suspended. In April 2020, we then applied to amend our recruitment strategy and interviewing methods to ensure that participants could be recruited and interviewed without potentially jeopardizing their health. Amendments to the recruitment and interviewing process were approved by the Research Ethics Board in July 2020.

To avoid in-person contact with participants, we recruited our participants over Facebook by posting flyers in community-oriented Facebook groups. This is a Facebook group that was created to promote community events or for networking between community members. We also had help from community organizations that shared the flyer on their Facebook pages and in their newsletters. The Facebook posts and flyers included a description of the study, the research teams contact information, and a link to the research team's website. In areas where there were no community-oriented Facebook groups, we would post our flyers in free or for sale groups or send the flyer to administrators of Facebook pages that were directed at people from the area of interest. 9 participants were recruited over Facebook, and 2 participants were recruited through newsletters. After the interview was finished, participants were asked to send information about the study to other potential participants, which resulted in another 12 participants being recruited through snowball sampling.

7.4.2 Data collection

In July and August 2020, semi-structured interviews of approximately 30-60 minutes in length were conducted over the phone or via a web-conferencing service. Before starting the interviews, all interviewees were asked to review and sign a consent form that discussed the research objectives, described the length of the interview, the confidentiality of the data, provided the researchers contact information, and asked participants for consent to record the interview. Semi-structured interviews were used to explore the interplay between older adults' environment and their walking behavior. The semi-structured interview guide included questions on physical activity, transport behavior, and the built environment. Participants were also asked how the COVID-19 pandemic might have affected their physical activity and how COVID-19 might have affected how they spend their time in their neighborhood. Finally, participants were asked questions pertaining to their socio-demographic characteristics. Interviews were recorded and transcribed verbatim by the interviewer. Participants were provided with a $25 gift certificate to compensate them for their time.

7.5 ANALYSIS

Our approach to thematic analysis combined both inductive and deductive methods. Our codes and themes were guided by those that had been identified in our literature reviews, but also by those that emerged frequently in our review of the transcripts. The first author began by reading through the interviews and writing short memos and continued reflexive memoing throughout the analysis process. The second step to the analysis, involved a descriptive phase, with the identification of codes using the surface meanings of what was said by participants. The codes were then categorized to identify *prevailing themes.* This was followed by an interpretation phase, where the data was interpreted by comparing it to previous literature and by trying to understand the meanings and significance of the patterns that were revealed in the analysis. The analysis was not linear, but recursive, which involved moving back and forth through the different phases (Braun & Clarke, 2006). Peer debriefing was used to enhance the rigor of the analysis (Lincoln & Guba, 1985). The first author and an impartial researcher with experience in qualitative methods independently coded four interviews. The researchers then compared the codes and themes generated in both instances and critically assessed whether they agreed with the themes that were generated. The first author then continued to code the rest of the transcripts and discussed the themes that were generated with the impartial researcher and in group meetings. Analyses were performed using MAXQDA software.

7.6 RESULTS

7.6.1 Sample

We interviewed 23 participants. Participants had an age range of 65 to 81 years, with 30.4% of participants (n=7) aged 75 years or older. Most participants were female (78.3%), and most participants (91.3%) had a car; although 1 participant had a car but no driver's license, as only her husband drove the car. Most participants had a university degree or above (47.8%) and a few participants (21.7%) required mechanical support such as braces, a cane, or crutches to walk around their neighborhood. Except for 1 participant, all participants in the sample were retired. All participants used a car or public transportation to get around in their neighborhood. There was 1 participant that only walked for utilitarian purposes, 5 participants that walked both for utilitarian purposes and for leisure or exercise, and the remaining 17 participants only walked for leisure or exercise purposes.

Table 7.1: Sociodemographic characteristics of the 23 older adults living in suburban neighborhoods.

	N	Average (SD) or %
Age	23	71.6 (4.4)
Sex		
Female	18	78.3
Male	5	21.7
Car		
Yes	21	91.3
No	2	8.7
Education		
Highschool or below	5	21.7
Greater than high school but less than University	7	30.4
University and above	11	47.8
Mechanical support (e.g., braces, a cane, or crutches)		
Yes	5	21.7
No	18	78.3
Income		
Less than $20,000	1	4.3
$20,000 or more but less than $40,000	2	8.7
$40,000 or more but less than $60,000	5	21.7
$60,000 or more but less than $80,000	4	17.4
$80,000 or more but less than $100,000	2	8.7
$100,000 or more	4	17.4
I prefer not to answer	5	21.7

7.6.2 Built environment

7.6.2.1 Aesthetics

Enjoyment of parks and greenspaces were mentioned by almost all older adults as enablers to walking. Participants liked parks with trees that provide enough shade during the summer, with pedestrian walkways, and seating (e.g., benches, picnic tables). Having many trees along the streets in their neighborhood was also viewed as an enabler to walking, as it is aesthetically pleasing and provides shade. Gardens were also considered pleasant sights to look at during walks. Participants mentioned a preference for walking in places with a view of the water. The waterfront was picturesque and was a “cooler” place to walk during the summer. Some participants mentioned how they would rather drive to wooded areas with trails, other parks, or areas along the waterfront than walk around in their residential area. For example, Participant 16, a 65-year-old woman that requires mechanical support to walk, stated:

> Sure, I mean even if this is a residential area where I live, I don't walk the streets, it doesn't appeal to me, it just turns me right off. You are just walking in circles looking at houses, which again does not appeal to me. But when I am out you know forest wise or even under the (name of walking path) at least you are surrounded by grass, not a lot of trees there, you know. But at least you are not just going through, I almost feel like I am going through a gauntlet when I am walking on the street, you know. I will even take the car, put my walker in there and my crutches and go for example to (name of park) to walk around there.

However, paying for parking at some of the municipally run parks was viewed as a barrier for older adults on a limited income.

7.6.2.2 Pedestrian infrastructure

Participants mentioned sidewalks as enablers to walking in residential areas. Sidewalks helped older adults to feel protected from the cars and sidewalks that were wide and well maintained were described as walk-friendly. However, participants commented on how they were not bothered when sections of their neighborhood didn't have sidewalks, as long as there was little traffic in the area in question: "So they don't have sidewalks as a rule other than on the main arteries, but that isn't really a detriment because there isn't much traffic (Participant 5, 75-year-old man)." A few participants mentioned that they preferred that their street not have a sidewalk, as streets without sidewalks gave the neighborhood more of a "country" feel. Walking/bicycling paths were described as enablers to walking. Participants mentioned how many pedestrians use the bicycle paths in their area as walking paths and how often pedestrians would use the bicycle paths even when a sidewalk was available nearby. Some participants described seating/park benches as a facilitator to walking. Benches were viewed as particularly important to participants that required mechanical support, or that had health issues that interfered with walking. Nature trails with many benches were viewed as a particularly attractive option for walking. A few participants also described clean bathrooms available nearby, street lighting, and crosswalks as features that promote walking.

7.6.2.3 Traffic and traffic calming infrastructure

Participants described traffic from cars, buses, and trucks as a hazard. Participants mentioned that they did not want to walk on streets where they would have to worry about getting hit by a car or where they had to listen to the noise from heavily travelled streets. In fact, little traffic was described as one of the benefits of living in a suburban neighborhood. A few participants also described how highways and busy streets made sections of their neighborhood inaccessible by foot, but that safe crossings and overpasses could increase accessibility. Unsafe crossings at major intersections were viewed as a barrier to walking by some participants. Intersections with pedestrian signals that allowed for sufficient time to cross the street were viewed as safer, as well as intersections that allowed for pedestrians to cross in all four directions, as there was a lower risk of being hit by a car that is turning. For example, Participant 14, a 76-year-old woman that requires mechanical support to walk, described one of the advantages of the municipality she used to live in:

> The one advantage we had in (name of municipality) was that when it was time for a pedestrian to cross in all four directions, the lights turned red, so you could cross in any direction, no cars were turning, no cars were moving, they were all at a halt. Because we have a lot of pedestrians that are getting killed because a truck or some bus or somebody is turning.

7.6.2.4 Destinations/shops

Having facilities such as libraries or shops nearby was viewed as an enabler by the participants who walked for utilitarian purposes. A few participants that mentioned shops also described how they would often avoid commercial areas on foot, as they tended to have more traffic and noise and instead would only visit these areas by car:

> Well, I generally don't walk to the shopping center, you know because it is a busy street and it’s not particularly pretty walking down (Name of street) and I definitely would not walk to (Name of area) or anything like that (Participant 13, a 67-year-old woman).

A few participants also reported walking less to many facilities during the pandemic due to them being closed.

7.6.2.5 Safety from crime

A few participants discussed how when they are walking, they gravitate towards the places where they feel safe. A few participants also mentioned that they would not walk alone in the streets after dark.

7.6.2.6 Building Characteristics

Building inaccessibility was a barrier mentioned by a few older adults. Many shops/facilities in their neighborhood were viewed as not very easily accessible to individuals with mobility impairments. Pleasing building design and well-maintained properties were described as features that encourage walking: “The homes are all pretty attractive. Their different, they are all not cookie-cutter houses. So they are fun to walk and look at all the different ones and all the public buildings are all very well maintained” (Participant 10, 68-year-old woman).

7.6.3 COVID-19, physical distancing, and physical activity

Almost half of the participants reported that their physical activity was affected by the COVID-19 pandemic. This was most often due to cancelled exercise classes or reduced access to indoor facilities, although a few participants reported walking less since the beginning of the pandemic. Similarly, a few participants reported that feelings of social isolation due to the COVID-19 restrictions would sometimes reduce their motivation to walk or leave the house. Almost half of the participants mentioned that physical distancing had affected their walking behavior. Some participants described how they plan their walking routes or the days and times that they would walk according to physical distancing (e.g., avoid popular boardwalks on weekends, only go walking in the early morning). Participants reported avoiding crowded or narrow streets/paths or walking in crowded parks. For example, Participant 2, a 70-year-old woman stated:

> At the beginning of the pandemic, my husband and I were walking down to (name of street), you know the main street. We would walk along there to walk along the water and come back. But in May when the water got nice and too many people from other parts of the city were wanting to do the same thing and it just became too crowded down there. And we were nervous, and we couldn't physically distance, so we stopped going down there.

Narrow sidewalks were especially worrisome when older adults were forced to walk in the street to ensure physical distancing. A few participants reported walking less in malls and other indoor facilities such as gyms. Some of these participants were worried about how COVID-19 might limit their physical activity during the winter, as participants walked in these facilities during the winter to avoid icy streets and sidewalks that would put them at risk of falling. A few of these participants had multiple falls in the past and were anxious about what they would be doing during the winter months to prevent a loss of muscle mass and fitness. A few participants described a sense of collective efficacy in their neighborhood with respect to the COVID-19 restrictions. Participants felt that people within their community had similar beliefs or values with respect to obeying the safety measures and this reinforced their sense of safety within their community:

> We haven't had many cases in (name of municipality) and I feel that the community is adhering to all the you know wearing masks and staying six feet apart and so forth. I think the people in the community are respecting what is being asked of them. Umm, so from that aspect, I feel that it is a safe community to be in (Participant 8, 69-year-old woman).

7.7 DISCUSSION

This study explored the lived experiences of older adults, using semi-structured interviews to better understand the neighborhood environmental influences on walking within suburban neighborhoods. This study was conducted during the summer in Montreal within the unique context of the Corona Virus Disease 2019 (COVID-19) pandemic and provided a better understanding of how the pandemic influenced perceptions of the environment and walking behavior within this age group (65+).

Similar to what has been identified in previous research (Lockett et al., 2005; Mitra et al., 2015; Moran et al., 2014; Van Cauwenberg, Van Holle, et al., 2012; Yoo & Kim, 2017), aesthetics, pedestrian infrastructure, and traffic calming were the built environment related themes that arose most frequently in the analysis. Aesthetics positively contributed to older adults' experiences of walking. Parks, greenspaces, and the waterfront were attractive and a "quieter" or "cooler" place to walk. Pedestrian infrastructure including sidewalks, walking paths, and benches were also perceived as facilitators. Our findings also indicated that participants reported avoiding streets with heavy traffic and described unsafe or busy intersections as a barrier. In line with previous research (Mitra et al., 2015; Van Cauwenberg, Van Holle, et al., 2012), proximity to shops and other facilities was also viewed as a facilitator by the older adults that reported walking for utilitarian purposes.

There were some differences in reported barriers and facilitators to walking compared to previous research and some of our findings appear as if they may be unique to the suburban car-dependent context. For example, consistent with previous research sidewalks were viewed as a facilitator (Mitra et al., 2015; Van Cauwenberg, Van Holle, et al., 2012), however, in our study some participants did not believe that sidewalks were necessary on streets with little traffic. Our findings also suggest that some older adults prefer to drive to places that they consider aesthetically pleasing such as trails to walk, rather than walking near their residence.

As was expected, the COVID-19 pandemic presented unique barriers to walking for older adults. Crowded parks and crowded or narrow boardwalks, sidewalks, and walking paths were avoided due to difficulties with physical distancing with some older adults reporting only walking on specific days or times of the day to avoid encountering other people during their walks. Participants did not only fear getting the virus if they walked to close to another person on the sidewalk, but also feared being hit by a car if they were forced to walk on the street to maintain physical distancing. Older adults' fear of falling during Canadian winters has been discussed in previous research (Lockett et al., 2005). However, in our study participants discussed the potential future interaction between the COVID-19 pandemic and the harsh Canadian winter. Participants were concerned about not having access to any safe spaces to walk or exercise during the winter due to the risk of getting COVID-19 in indoor facilities.

Scholars agree that it is a combination of environmental and personal factors that interact to determine trajectories of healthy aging (Clarke & Nieuwenhuijsen, 2009) implying that the neighborhood environment may hold considerable clout in the establishment of these trajectories. Some of the built environment features identified in this analysis including aesthetics, traffic calming measures, or modifying the pedestrian infrastructure of a neighborhood are relatively modifiable compared to other aspects of the built environment (e.g., density) and as a result changing these features within a neighborhood could be a relatively cost-effective (Cain et al., 2014; Steinmetz-Wood et al., 2020; Steinmetz-Wood, Velauthapillai, et al., 2019) method of promoting walking in the older adult population. In line with the age-friendly cities movement (World Health Organization, 2018), and with the perceptions of several participants, suburban municipalities should consider adapting suburban neighborhoods to accommodate the mobility needs of older adults, all the while fostering community engagement through consultations with older adults to better understand their specific needs and those of the community. As was so eloquently stated by Participant 7, a 72-year-old woman, older adults should not have to struggle for age-friendly community status:

> I have a lot of experience as an activist, but now that I am over 70, I am thinking, do I need to keep working this hard at activism, should this not just be part of our culture, you know it seems like it is overdue to have something like an age-friendly community status. I am willing to work towards it because I think that is the sort of thing that could make a big difference.

7.8 CONCLUSION

This paper explored older adults' perceptions of the neighborhood environmental influences on walking within suburban neighborhoods. Three main themes were identified: aesthetics, pedestrian infrastructure, and traffic and traffic calming infrastructure. Aesthetics (parks, waterfront, trees, gardens) and pedestrian infrastructure (sidewalks, walking paths, and benches) were perceived as walk friendly, whereas traffic as well as unsafe intersections were perceived as barriers to walking. The COVID-19 pandemic has introduced unique barriers to walking. Older adults avoided crowded parks, and crowded or narrow boardwalks, sidewalks, and walking paths due to difficulties with physical distancing with some older adults reporting only walking on specific days or times of the day to avoid encountering other people during their walks.

We acknowledge that most participants were women, had a university degree, and were of medium or high SES. Our findings should be interpreted with the unique socio-demographic, and geographic context of our sample in mind. Similar to other qualitative studies that perform in-depth data collection in a small sample of participants, the results should not be generalized to all older adults within the Canadian context.

Given the convergence of the COVID-19 pandemic with widespread sedentary behavior, it is increasingly important that suburban municipalities are sensitive to the physical activity needs of the older adult population. Physical activity may improve the immune system response to viral infections and older adults engaging in physical activity during a self-isolation period are less likely to have depressive symptoms. A sedentary lifestyle can also lead to medical conditions that can put older adults at increased risk of getting severe COVID-19 infection.

The number of older adults that would prefer to grow old in their own home is likely to increase in the years to come. COVID-19 has given new meaning to ageing in place. The virus has exposed the vulnerability of old age homes to infectious diseases and has once again highlighted the poor conditions of care in these homes. Within this context, designing suburban neighborhoods to promote the mobility, as well as the physical and mental health of older adults remains a challenge. Our findings could inform planners and public health practitioners when designing neighborhood environments to promote walking for older adults.

8 **CHAPTER EIGHT|** CONCLUSION

This dissertation sought to better understand the relationship between the micro-scale environment and the walking behavior of older adults. This was achieved by meeting the following five objectives:

1) *Explore and document best-practice approaches for mixed-methods studies on the built environment and health.*
2) *Create and validate a virtual auditing tool for the measurement of micro-scale features of the built environment that may influence walking behavior.*
3) *Evaluate the individual and collective influence of items from the Virtual-STEPS tool on walking outcomes (utilitarian walking and walking for leisure).*
4) *Evaluate the individual and collective influence of items from the Virtual-STEPS tool on walking for leisure in older adults.*
5) *Explore how older adults' perceptions of their neighborhood environment influence their walking behavior.*

This final chapter outlines the substantive and methodological contributions, the limitations of the research, and the policy implications of this dissertation.

8.1 SUBSTANTIVE CONTRIBUTIONS TO KNOWLEDGE

The first substantive contribution of this dissertation was to document best-practice approaches for mixed-methods studies on the built environment and health. The first manuscript provided an overview of mixed methods research designs and concrete techniques for the integration of diverse methods. Recommendations for mixed methods research in the field of built environment – health research, were discussed by drawing on specific examples from the mixed methods literature. The review concluded by emphasizing that reporting a research design and an integration strategy in mixed methods studies in this field could help to strengthen our ability to gain new insights into the multidimensional nature of the relationship between the built environment and health.

Another substantive contribution was the creation of the Virtual-STEPS auditing tool. An examination of the reliability of the Virtual-STEPS tool demonstrated that it is a reliable tool for the assessment of the micro-scale environment of neighborhoods. Most items in the tool had a percentage agreement between virtual and field audits, and for inter-rater agreement of 80% or higher. Kappa and ICC statistics indicated high reliability between virtual and field audits, with 50.0% of items with almost perfect agreement and 32.5% of items with substantial agreement. Kappa and ICC statistics also indicated high inter-rater reliability with 42.5% of items with almost perfect agreement and 27.5% items with substantial agreement.

The relationship between Virtual-STEPS items and walking outcomes was first tested in a sample of 1,403 adults from Montreal and Toronto neighborhoods, that had provided information on residential self-selection in the second wave of the internet survey. To our knowledge, this study was the first to account for residential self-selection when examining the effect of the micro-scale environment on walking outcomes. Multilevel logistic regression analyses revealed that after mutual adjustment for the four micro-scale section scores (pedestrian infrastructure, building characteristics, traffic calming, and aesthetics) aesthetics and favorable building characteristics encouraged walking for leisure (≥150 minutes per week), with aesthetics having a slightly stronger effect size. Individual micro-scale features within these sections were also associated with walking for leisure; building height in the building characteristics section and the attractive segment score from the aesthetics section were associated with higher odds of walking for leisure, and the litter score was associated with a lower odds of walking for leisure.

This analysis also revealed that the grand micro-scale score was associated with walking for leisure (≥150 minutes per week) even after accounting for residential self-selection and the macro-scale environment (Walkscore). Conversely, the association between the micro-scale environment and utilitarian walking (≥150 minutes per week) was inconclusive. The results suggest that the built environment determinants of these two dimensions of the environment may differ, whereas the macro-scale environment (e.g., density) of places may encourage utilitarian walking, our results suggest that the cumulative effect of micro-scale features, features that are measured at the street-scale and tend to act on a pedestrians pleasure or comfort when walking (e.g., sidewalks, nature areas, building design) promote walking for leisure (Steinmetz-Wood et al., 2020).

Multilevel logistic regression analysis of 605 older adults from Montreal and Toronto that participated in the first wave of the internet survey indicated that individual micro-scale features encourage walking for leisure (≥150 minutes) including the presence of nature areas and the attractive segment score, whereas the total number of lanes, and having many residential and high-volume driveways in a neighborhood discouraged walking for leisure. The traffic calming section score and the grand micro-scale score were associated with higher odds of walking for leisure in older adults, even after controlling for the macro-scale environment. Stratifying by health conditions revealed that the traffic calming total section score and the grand micro-scale score were only associated with walking for leisure in the sample with health conditions. The aesthetics section score was also associated with greater odds of walking for leisure in the sample of older adults with health conditions. These results imply that older adults that have health conditions that interfere with physical activity may be particularly sensitive to the micro-scale environment of neighborhoods.

In our exploration of older adults' perceptions of their neighborhood environments, semi-structured interviews in older adults from suburban neighborhoods revealed that micro-scale features such as aesthetics (parks, waterfront, trees, gardens), pedestrian infrastructure (sidewalks, walking paths, and benches), and building characteristics (pleasing building design, building maintenance) were perceived as facilitators to walking, whereas traffic as well as unsafe intersections were perceived as barriers to walking. These findings reveal that older adults from suburban neighborhoods perceived that many micro-scale features (e.g., parks, waterfront, trees, walking paths, benches, pleasing building design) features that are relatively modifiable compared to macro-scale features (e.g., density), as enablers to walking. Although, quantitative studies are needed to determine if the results could be generalized to the population of older adults from suburban neighborhoods, the findings point to altering the micro-scale environment of neighborhoods, as a feasible and more cost-effective solution for increasing physical activity in neighborhoods in areas where the macro-scale walking friendliness is unfavorable.

Some results from the semi-structured interviews appear to be unique to the car-dependent context of the research. For example, although sidewalks were viewed as a facilitator, some participants did not believe that sidewalks were necessary on streets with little traffic. Our findings also suggest that some older adults from suburban neighborhoods preferred to drive to places that they consider aesthetically pleasing such as trails to walk, rather than walking near their residence. The semi-structured interviews were conducted in the summer of 2020, during the COVID-19 pandemic. The pandemic introduced unique barriers to walking for older adults. Crowded parks and crowded or narrow boardwalks, sidewalks, and walking paths were avoided due to difficulties with physical distancing, with some older adults reporting only walking on specific days or times of the day to avoid encountering other people during their walks.

8.2 METHODOLOGICAL CONTRIBUTIONS TO KNOWLEDGE

In this dissertation, an explanatory mixed methods design was adopted. Integration of the quantitative and qualitative phases involved results from the quantitative phase in older adults (i.e., multilevel logistic regression analysis performed in the 605 older adults that participated in the internet survey) guiding the sampling of qualitative participants. Older adults from suburban neighborhoods were recruited for semi-structured interviews, as the multilevel logistic regression analysis revealed that micro-scale features of the environment individually and collectively promoted walking for leisure in older adults, even after controlling for the macro-scale environment of neighborhoods. A separate analysis that consisted of stratifying the sample of older adults by macro-scale walkability (Walkscore ≥50/ Walkscore <50) also demonstrated that the grand micro-scale score was significantly associated with walking for leisure in areas with a low macro-scale walkability (Table 1D, Appendix D). This implies that improving the micro-scale environment of neighborhoods could be a feasible method of promoting walking even in areas where the macro-scale environment (e.g., density) is poor (e.g., suburban neighborhoods). Qualitative results supported this hypothesis with many micro-scale environment features of the environment being perceived as facilitators to walking by older adults living in suburban neighborhoods.

Another methodological innovation of this thesis was the creation of a virtual auditing tool specifically designed to audit the micro-scale environment of neighborhoods. Most previous studies have conducted in-person audits, an approach that requires auditors to visit each auditing site in-person. Virtual audits are performed online and are less resource intensive allowing for auditing of dispersed, large, or distant areas. Many previous tools are also lengthy with an average of 92.2 items per tool (Burton et al., 2011; Clifton et al., 2007; Cunningham et al., 2005; Day et al., 2006; Griew et al., 2013; Hoehner et al., 2007; Millstein et al., 2013; Pikora et al., 2002; Sallis, Cain, et al., 2015) limiting their application in surveillance initiatives. We created the Virtual-STEPS tool, a concise audit tool with 39 items (if you exclude shade), with the potential to audit the micro-scale environment of neighborhoods at the municipal, provincial, or national scales. Virtual auditing allowed us to maximize coverage of neighborhoods with 5% of street segments audited from within 128 forward sortation areas located in Montreal and Toronto.

Finally, the sampling strategy of the internet survey was novel in that to ensure that there was a diversity in physical activity levels and the macro-scale environmental features of participants' neighborhoods, walking to work trips from the Montreal Origin destination survey (Origine-Destination, 2013), the Transportation Tomorrow Survey (Data Management Group, 2011), and geographic information system (GIS) methods were used to stratify neighborhoods in the Montreal and Toronto area by high walking-friendly/high walking, high walking-friendly/low walking, low walking-friendly/high walking and low walking friendly/low walking.

8.3 LIMITATIONS

This research did have some limitations. In the review of mixed methods studies in the built environment and health field, an exploratory search of the literature was performed that suggested that less than half of mixed methods studies report their research design and report integrating their findings. Although the exploratory search can provide an approximation of the prevalence of studies that follow these guidelines, a systematic review of the literature would need to be performed, to obtain a precise estimate.

In the manuscript that assessed the reliability of the Virtual-STEPS tool, several items had high percent agreement, but a Kappa could not be calculated (e.g., bollards, broken/boarded windows) due to a low prevalence in the selected streets. These items were retained in the tool, as we still considered them to be important contributors to the walkability of neighborhoods. One item, shade, asked auditors to assess whether 30% or more of the segment was shaded from the sun. This item was removed from the tool, as it had poor inter-rater reliability suggesting that raters had considerable difficulty agreeing on whether 30% of a street segment was shaded.

Disadvantages of virtual audits have been discussed in the literature. Virtual audits do not incorporate sensory inputs such as noise levels, soundscape, and scent (Lafontaine et al., 2017) and GSV images may also change unpredictably, resulting in temporal inconsistencies in the images used for audits. Compared to field audits, evaluating finer details of streetscapes such as condition (e.g., quality of sidewalks and curb cuts) and maintenance (e.g., landscape maintenance) can be difficult. Further, GSV provides a view that is a bit higher than the typical pedestrian view with the images recorded from a car-mounted camera. The use of virtual audits with GSV therefore can in some cases result in the inclusion of features that will not necessarily influence the pedestrian experience such as including features on the other side of a large fence in microscale assessments when these features may not be visible by pedestrians (Steinmetz-Wood, Velauthapillai, et al., 2019).

Internet surveys also have limitations. Social surveys can attract healthier respondents (selection bias) (Pietilä et al., 1995; Søgaard et al., 2004) and social desirability or recall difficulties could lead to the under or over reporting of walking behavior. Respondents also may feel less pressure to reply with thorough commentaries without the presence of an interviewer (Keusch, 2015; McGuirk & O'Neill, 2010; Reja, Manfreda, Hlebec, & Vehovar, 2003). The older adults that were recruited likely have internet proficiency and this may not perfectly represent the population of older adults; although the proportion of older adults in Canada that use the internet has been increasing with the proportion of seniors that use the internet jumping from 48% in 2012 to 71% in 2018 (Statistics Canada, 2019).

It is possible that individuals living in areas with a favorable micro-scale environment could over-report walking for leisure. Our study audited the micro-scale environment of FSAs. As is true in other studies that collect built environment data at the neighborhood level, it is possible that respondents engaged in leisure walking outside of their FSA or on street segments that were not sampled. It is also possible that a favorable micro-scale environment could encourage walking to occur at a slower pace. For example, individuals that walk for leisure might stop to sit/chat on benches. Our survey questions did not account for the intensity of the leisure walking performed. Future studies examining the influence of the micro-scale environment of neighborhoods on walking could combine accelerometers with GPS monitoring to allow for a more precise estimate of the intensity of walking and exactly how much walking is occurring in and outside of the neighborhood.

With respect to the qualitative study, it was difficult to recruit over Facebook in areas without community-oriented Facebook groups. In areas where there were no community-oriented Facebook groups, the flyers would be posted in free or for sale groups or the flyer would be sent to administrators of Facebook pages that were directed at people from the area of interest. This only resulted in the recruitment of one participant. However, snowball sampling did result in the recruitment of participants from areas without community-oriented Facebook groups.

Most participants were women, had a university degree, and were of medium or high SES. Therefore, the findings should be interpreted with the unique socio-demographic, and geographic context of our sample in mind. As is true in other qualitative studies that perform data collection in a small sample of participants, the results should not be generalized to all older adults within the Canadian context.

8.4 POLICY IMPLICATIONS

The cost of physical inactivity to Canada is 946 million dollars of which 70% (660 million) of this economic burden is supported by the public sector (Ding et al., 2016). The costs to the healthcare system are projected to increase as the population ages (Wister & Speechley, 2015), emphasizing the importance of designing effective interventions to increase physical activity. This thesis provides evidence that suggests that favorable micro-scale environments encourage walking for leisure in the older adult population and that older adults with health conditions may be particularly sensitive to these environments.

This evidence has five key policy implications. The first is environmental interventions are increasingly being proposed as an alternative to individual interventions to increase physical activity. Most interventions that target physical activity behaviors have adopted individual level approaches (Sallis et al., 2006). However, individual level interventions only target high-risk individuals and not the underlying environmental and societal factors (Rose, 2001) that are the root causes of population level inactivity (Cohen, Scribner, & Farley, 2000). Further, the prevalence of individuals that do not meet physical activity recommendations is high (68% for adults 18 to 39 years old; 82% for adults 40 to 59 years old; 88% for adults 60 to 79 years old) (Statistics Canada, 2015) implying that interventions that can affect whole populations are needed.

Environmental and policy interventions may be promising avenues for bringing about sustainable population level changes in physical activity. Socio-ecological models of health promotion posit that the determinants of walking consist of individual, social, and physical environmental factors (Pikora, Giles-Corti, Bull, Jamrozik, & Donovan, 2003). Evaluations of public health campaigns targeting individual and social determinants of walking suggest that the success of physical activity promoting interventions are dependent on built environment design (Merom, Bauman et al. 2009, Gebel, Bauman et al. 2011, Barnes, Giles-Corti et al. 2013) stressing the importance of 'activity friendly' environments. Further, a systematic review on the cost-effectiveness of population oriented physical activity interventions found that changing the built environment was the most cost-effective method of increasing physical activity levels in large populations (Laine et al., 2014). This form of population level intervention will often require significant financial investments, but can have long sustainable impacts through time (Laine et al., 2014). Built environment interventions can also encourage physical activity throughout the lifecycle and into older age, which could help to offset health care burden.

The second is that modifying multiple dimensions of the micro-scale environment could be a policy amenable alternative to modifying the macro-scale environment of neighborhoods. Research examining the built environment determinants of walking in older adults finds that macro-scale features of the built environment influence utilitarian walking (Barnes et al., 2016; Carlson et al., 2012; King et al., 2011; Shimura et al., 2012; Thielman et al., 2015; Van Holle et al., 2014). These findings, however, are difficult for practitioners to apply to existing neighborhood settings. Changing the existing neighborhood layout is an arduous process and requires community residents to agree to their neighborhoods being completely reconstructed (Sallis, Cain, et al., 2015). This type of re-development is often well beyond the scope of local scale municipal budgets. Altering the micro-scale built environment is a relatively cost-effective and efficient method of creating an environment that is conducive to walking – repairing a sidewalk or installing benches is less costly and time consuming compared to reconfiguring the neighborhood layout.

The third policy implication is that modifying the micro-scale environment of neighborhoods could be a feasible method of increasing walking, even in neighborhoods where the macro-scale environment is unfavorable such as suburbs. An unfavorable macro-scale environment will not support utilitarian walking in the older adult population but providing a favorable micro-scale environment has the potential to increase leisure walking in these areas. In Canada, the higher proportion of older adults living in suburban neighborhoods compared to urban neighborhoods (Channer et al., 2020) emphasizes the importance of developing interventions that can be applied to car-dependent neighborhoods. Most older adults would like to remain in their neighborhoods as they age (Kerr et al., 2012; Rosenbloom, 2001). Therefore, it is important that suburban neighborhoods provide opportunities for physical activity to enable older adults to maintain their health and independence. The design of suburban neighborhoods to promote healthy aging should consider the views of older adults living within suburban neighborhoods, as these will likely differ from those of older adults living within centrally located urban neighborhoods.

The fourth policy implication is that designing favorable built environments is also important from an environmental justice perspective. Elderly, individuals of low socioeconomic status, and minorities disproportionately bear the burden associated with poor urban design (Dannenberg et al., 2003). This implies that designing contextually appropriate urban interventions to promote healthy aging in the Canadian population is paramount. The frailty that accompanies old age may render older adults' mobility particularly vulnerable to micro-scale features of the built environment implying that disadvantageous micro-scale physical environments may offset the benefits of favorable macro-scale walkability (Cain et al., 2014; Thornton et al., 2016) in this age group. Further, disadvantageous micro-scale environments may impede older adults with health conditions from maintaining their independence and active lifestyle potentially exacerbating the burden of a population that already disproportionately bears the burden associated with poor urban design (Manuscript 4).

The fifth policy implication is that strategies to promote walking in the older adult population such as improving the built environment of neighborhoods could help older adults to maintain long-term independence, health, and accordingly to age in place. The number of older adults that would like to age in their neighborhoods' is likely to increase in the years to come and municipalities will need to accommodate the needs of this aging population. Poor conditions of care in nursing homes are not a new phenomenon. In Canada, over a ten year period, over 150 reports of unacceptable or in some cases inhumane conditions have been highlighted in the media (Estabrooks et al., 2020). However, the COVID-19 pandemic has changed the way that generations of adults will perceive nursing homes for years to come, as it has revealed the vulnerability of old age homes to infectious diseases, while bringing the poor conditions of care and quality of life in nursing homes to the forefront at a global scale (Estabrooks et al., 2020; Hsu et al., 2020).

The coupling of the COVID-19 pandemic, with widespread sedentary behavior in the Canadian population (Statistics Canada, 2015) further highlights the need to encourage municipalities to ensure that their neighborhood environments can accommodate the physical activity needs of older adult populations. Older adults are at increased risk of complications from COVID-19 (Government of Canada, 2020), but physical activity can help older adults to increase resilience to the virus. Physical activity has many physical health benefits including improving the immune systems response to viral infections (Nieman & Wentz, 2019), as well as mental health benefits such as reducing risk of experiencing depressive symptoms (Callow et al., 2020; Carriedo et al., 2020). A sedentary lifestyle is also a risk factor for conditions such as heart disease, high blood pressure, diabetes, and obesity (Batty, 2002; Gennuso et al., 2013; Lee et al., 2012), conditions that put older adults at risk of having more severe COVID-19 infection (Government of Canada, 2020).

8.5 CONCLUDING REMARKS

In this dissertation, the micro-scale environment was the focus of analyses using an explanatory mixed methods study design comprised of virtual audits of pedestrian streetscapes, social surveys, and in-depth interviews. The body of evidence in this thesis made an original contribution to the literature by providing a better understanding of the influence of the micro-scale environment on walking in older adults. The Virtual-STEPS tool was created and was found to be a reliable tool with high reliability between virtual and field audits and high inter-rater reliability. Testing the relationship between Virtual-STEPS items and walking outcomes in a population of adults that had provided information on residential self-selection revealed that the micro-scale environment promoted walking for leisure in adults even after accounting for residential self-selection and the macro-scale environment of neighborhoods. Multilevel logistic regression analyses in the sample of older adults revealed that the micro-scale environment was associated with walking for leisure, even after accounting for the macro-scale environment of neighborhoods. This finding coupled with results from the qualitative analysis revealing that older adults from suburban neighborhoods perceived many micro-scale features (e.g., parks, waterfront, trees, walking paths, benches, pleasing building design) as enablers to walking, suggests that altering the micro-scale environment of neighborhoods could be a feasible solution for increasing physical activity in neighborhoods even in areas where macro-scale walking friendliness is unfavorable (e.g., suburban neighborhoods). Multilevel logistic regression analyses in the sample of older adults also revealed a strong association between the micro-scale environment and walking for leisure in older adults with health conditions suggesting that this sub-group may be particularly sensitive to the condition of their environment.

Most older adults would prefer to age in place. Given how the COVID-19 pandemic has brought the vulnerability of old age homes to infectious diseases, and poor conditions of care in nursing homes to the forefront at a global scale, the number of older adults that would like to age in their neighborhoods' is likely to increase in the years to come. However, designing neighborhood environments to promote healthy aging by supporting the mobility, mental health, and physical health of older adults still remains a daunting challenge for both public health practitioners and urban planners. Interventions that modify the micro-scale features of streets have the potential to promote leisure walking, an inexpensive and readily accessible form of physical activity, and improve health status in older adults, a vulnerable population group, that disproportionately bears the burden associated with poor urban design.

9 REFERENCES

CIHI (2019). Slips, trips and falls: Our newest data reveals causes of injury hospitalizations and ER visits in Canada. Retrieved from https://www.cihi.ca/en/slips-trips-and-falls-our-newest-data-reveals-causes-of-injury-hospitalizations-and-er-visits-in

Alexander, D. S., Alfonso, M. L., & Hansen, A. R. (2015). Childhood obesity perceptions among African American caregivers in a rural Georgia community: A mixed methods approach. *Journal of community health, 40*(2), 367-378.

Auchincloss, A. H., Roux, A. V. D., Mujahid, M. S., Shen, M., Bertoni, A. G., & Carnethon, M. R. (2009). Neighborhood resources for physical activity and healthy foods and incidence of type 2 diabetes mellitus: the Multi-Ethnic study of Atherosclerosis. *Archives of internal medicine, 169*(18), 1698-1704.

Bader, M. D., Mooney, S. J., Bennett, B., & Rundle, A. G. (2017). The promise, practicalities, and perils of virtually auditing neighborhoods using Google street view. *The ANNALS of the American Academy of Political and Social Science, 669*(1), 18-40.

Bader, M. D., Mooney, S. J., Lee, Y. J., Sheehan, D., Neckerman, K. M., Rundle, A. G., & Teitler, J. O. (2015). Development and deployment of the Computer Assisted Neighborhood Visual Assessment System (CANVAS) to measure health-related neighborhood conditions. *Health & place, 31*, 163-172.

Badland, H. M., Opit, S., Witten, K., Kearns, R. A., & Mavoa, S. (2010). Can virtual streetscape audits reliably replace physical streetscape audits? *Journal of Urban Health, 87*(6), 1007-1016.

Balfour, J. L., & Kaplan, G. A. (2002). Neighborhood environment and loss of physical function in older adults: evidence from the Alameda County Study. *American Journal of Epidemiology, 155*(6), 507-515.

Barnes, R., Winters, M., Ste-Marie, N., McKay, H., & Ashe, M. C. (2016). Age and retirement status differences in associations between the built environment and active travel behaviour. *Journal of Transport & Health, 3*(4), 513-522.

Barnett, D. W., Barnett, A., Nathan, A., Van Cauwenberg, J., & Cerin, E. (2017). Built environmental correlates of older adults' total physical activity and walking: a systematic review and meta-analysis. *International Journal of Behavioral Nutrition and Physical Activity, 14*(1), 103.

Barrington-Leigh, C., & Millard-Ball, A. (2015). A century of sprawl in the United States. *Proceedings of the National Academy of Sciences, 112*(27), 8244-8249.

Batty, G. D. (2002). Physical activity and coronary heart disease in older adults: a systematic review of epidemiological studies. *The European Journal of Public Health, 12*(3), 171-176.

Beard, J. R., Officer, A., de Carvalho, I. A., Sadana, R., Pot, A. M., Michel, J.-P., Mahanani, W. R. (2016). The World report on ageing and health: a policy framework for healthy ageing. *The Lancet, 387*(10033), 2145-2154.

Beard, J. R., & Petitot, C. (2010). Ageing and urbanization: Can cities be designed to foster active ageing? *Public Health Reviews, 32*(2), 427.

Boarnet, M. G., Forsyth, A., Day, K., & Oakes, J. M. (2011). The street level built environment and physical activity and walking: Results of a predictive validity study for the Irvine Minnesota Inventory. *Environment and Behavior, 43*(6), 735-775.

Boone-Heinonen, J., Gordon-Larsen, P., Guilkey, D. K., Jacobs Jr, D. R., & Popkin, B. M. (2011). Environment and physical activity dynamics: the role of residential self-selection. *Psychology of sport and exercise, 12*(1), 54-60.

Boot, C. R., de Kruif, A. T. C., Shaw, W. S., van der Beek, A. J., Deeg, D. J., & Abma, T. (2016). Factors important for work participation among older workers with depression, cardiovascular disease, and osteoarthritis: a mixed method study. *Journal of occupational rehabilitation, 26*(2), 160-172.

Boutros, G. E. H., Morais, J. A., & Karelis, A. D. (2019). Current Concepts in Healthy Aging and Physical Activity: A Viewpoint. *Journal of aging and physical activity, 27*(5), 755-761.

Braun, V., & Clarke, V. (2006). Using thematic analysis in psychology. *Qualitative research in psychology, 3*(2), 77-101.

Brownson, R. C., Brennan, L. K., Evenson, K. R., & Leviton, L. C. (2012). Lessons from a mixed-methods approach to evaluating Active Living by Design. *American journal of preventive medicine, 43*(5), S271-S280.

Brownson, R. C., Hoehner, C. M., Day, K., Forsyth, A., & Sallis, J. F. (2009). Measuring the built environment for physical activity: state of the science. *American journal of preventive medicine, 36*(4), S99-S123. e112.

Bryman, A. (2006). Integrating quantitative and qualitative research: how is it done? *Qualitative research, 6*(1), 97-113.

Bryman, A. (2007). Barriers to integrating quantitative and qualitative research. *Journal of Mixed Methods Research, 1*(1), 8-22.
Burton, E. J., Mitchell, L., & Stride, C. B. (2011). Good places for ageing in place: development of objective built environment measures for investigating links with older people's wellbeing. *BMC public health, 11*(1), 839.
Cain, K. L., Millstein, R. A., Sallis, J. F., Conway, T. L., Gavand, K. A., Frank, L. D., Adams, M. A. (2014). Contribution of streetscape audits to explanation of physical activity in four age groups based on the Microscale Audit of Pedestrian Streetscapes (MAPS). *Social Science & Medicine, 116*, 82-92.
Callow, D. D., Arnold-Nedimala, N. A., Jordan, L. S., Pena, G. S., Won, J., Woodard, J. L., & Smith, J. C. (2020). The mental health benefits of physical activity in older adults survive the COVID-19 pandemic. *The American Journal of Geriatric Psychiatry, 28*(10), 1046-1057.
Campbell, D. T. (1978). Qualitative knowing in action research. *The social contexts of method*, 184-209.
Cao, X., Mokhtarian, P. L., & Handy, S. L. (2009). Examining the impacts of residential self-selection on travel behaviour: a focus on empirical findings. *Transport reviews, 29*(3), 359-395.
Carlson, J. A., Sallis, J. F., Conway, T. L., Saelens, B. E., Frank, L. D., Kerr, J., King, A. C. (2012). Interactions between psychosocial and built environment factors in explaining older adults' physical activity. *Preventive medicine, 54*(1), 68-73.
Carr, L. J., Dunsiger, S. I., & Marcus, B. H. (2010). Walk score™ as a global estimate of neighborhood walkability. *American journal of preventive medicine, 39*(5), 460-463.
Carr, L. J., Dunsiger, S. I., & Marcus, B. H. (2011). Validation of Walk Score for estimating access to walkable amenities. *British journal of sports medicine, 45*(14), 1144-1148.
Carriedo, A., Cecchini, J. A., Fernandez-Rio, J., & Méndez-Giménez, A. (2020). COVID-19, Psychological Well-being and Physical Activity Levels in Older Adults During the Nationwide Lockdown in Spain. *The American Journal of Geriatric Psychiatry, 28*(11), 1146-1155.
Cerin, E., Lee, K.-y., Barnett, A., Sit, C. H., Cheung, M.-c., & Chan, W.-m. (2013). Objectively-measured neighborhood environments and leisure-time physical activity in Chinese urban elders. *Preventive medicine, 56*(1), 86-89.
Cerin, E., Nathan, A., Van Cauwenberg, J., & Barnett, A. (2019). Urban Environments for Healthy Ageing: A Global Perspective. In A. P. Lane (Ed.): Routledge.
Cerin, E., Nathan, A., Van Cauwenberg, J., Barnett, D. W., & Barnett, A. (2017). The neighbourhood physical environment and active travel in older adults: a systematic review and meta-analysis. *International Journal of Behavioral Nutrition and Physical Activity, 14*(1), 1-23.
Cerin, E., Saelens, B. E., Sallis, J. F., & Frank, L. D. (2006). Neighborhood Environment Walkability Scale: validity and development of a short form. *Medicine & Science in Sports & Exercise, 38*(9), 1682-1691.
Cervero, R., & Kockelman, K. (1997). Travel demand and the 3Ds: density, diversity, and design. *Transportation Research Part D: Transport and Environment, 2*(3), 199-219.
Channer, N. S., Hartt, M., & Biglieri, S. (2020). Aging-in-place and the spatial distribution of older adult vulnerability in Canada. *Applied Geography, 125*, 102357.

Chatterji, S., Byles, J., Cutler, D., Seeman, T., & Verdes, E. (2015). Health, functioning, and disability in older adults—present status and future implications. *The Lancet, 385*(9967), 563-575.

Chiang, Y.-C., Sullivan, W., & Larsen, L. (2017). Measuring neighborhood walkable environments: a comparison of three approaches. *International journal of environmental research and public health, 14*(6), 593.

Chodzko-Zajko, W. J. (2014). Exercise and physical activity for older adults. *Kinesiology Review, 3*(1), 101-106.

Chrisinger, B. (2016). A mixed-method assessment of a new supermarket in a food desert: contributions to everyday life and health. *Journal of Urban Health, 93*(3), 425-437.

Christensen, P., Mikkelsen, M. R., Nielsen, T. A. S., & Harder, H. (2011). Children, mobility, and space: using GPS and mobile phone technologies in ethnographic research. *Journal of Mixed Methods Research, 5*(3), 227-246.

Christman, Z. J., Wilson-Genderson, M., Heid, A., & Pruchno, R. (2019). The Effects of Neighborhood Built Environment on Walking for Leisure and for Purpose Among Older People. *The Gerontologist*.

Chudyk, A. M., Winters, M., Gorman, E., McKay, H. A., & Ashe, M. C. (2014). Agreement between virtual and in-the-field environment audits of assisted living sites. *Journal of aging and physical activity, 22*(3), 414-420.

Clark, M. I., Berry, T. R., Spence, J. C., Nykiforuk, C., Carlson, M., & Blanchard, C. (2010). Key stakeholder perspectives on the development of walkable neighbourhoods. *Health & place, 16*(1), 43-50.

Clarke, P., Ailshire, J., Melendez, R., Bader, M., & Morenoff, J. (2010). Using Google Earth to conduct a neighborhood audit: reliability of a virtual audit instrument. *Health & place, 16*(6), 1224-1229.

Clarke, P., Ailshire, J. A., Bader, M., Morenoff, J. D., & House, J. S. (2008). Mobility disability and the urban built environment. *American Journal of Epidemiology, 168*(5), 506-513.

Clarke, P., Ailshire, J. A., & Lantz, P. (2009). Urban built environments and trajectories of mobility disability: findings from a national sample of community-dwelling American adults (1986–2001). *Social Science & Medicine, 69*(6), 964-970.

Clarke, P., & Nieuwenhuijsen, E. R. (2009). Environments for healthy ageing: A critical review. *Maturitas, 64*(1), 14-19.

Clifton, K. J., Smith, A. D. L., & Rodriguez, D. (2007). The development and testing of an audit for the pedestrian environment. *Landscape and Urban Planning, 80*(1-2), 95-110.

Cohen, D. A., Scribner, R. A., & Farley, T. A. (2000). A structural model of health behavior: a pragmatic approach to explain and influence health behaviors at the population level. *Preventive medicine, 30*(2), 146-154.

Cohen, J. (1960). A coefficient of agreement for nominal scales. *Educational and psychological measurement, 20*(1), 37-46.

Colabianchi, N., Coulton, C. J., Hibbert, J. D., McClure, S. M., Ievers-Landis, C. E., & Davis, E. M. (2014). Adolescent self-defined neighborhoods and activity spaces: Spatial overlap and relations to physical activity and obesity. *Health & place, 27*, 22-29.

Collins, D., & Evans, J. (2016). Health Geography. In *International Encyclopedia of Geography: People, the Earth, Environment and Technology*: John Wiley & Sons, Ltd.

Colombier, C. (2018). Population ageing in healthcare–a minor issue? Evidence from Switzerland. *Applied Economics, 50*(15), 1746-1760.

Crane, M., Rissel, C., Greaves, S., Standen, C., & Wen, L. M. (2016). Neighbourhood expectations and engagement with new cycling infrastructure in Sydney, Australia: Findings from a mixed method before-and-after study. *Journal of Transport & Health, 3*(1), 48-60.
Creatore, M. I., Glazier, R. H., Moineddin, R., Fazli, G. S., Johns, A., Gozdyra, P., Manuel, D. G. (2016). Association of neighborhood walkability with change in overweight, obesity, and diabetes. *Jama, 315*(20), 2211-2220.
Creswell, & Plano Clark, V. (2007). Designing and conducting mixed methods research.
Creswell, J. W., & Clark, V. L. P. (2011). Designing and conducting mixed research methods. In: Thousand Oaks, California: SAGE.
Cunningham, G. O., Michael, Y. L., Farquhar, S. A., & Lapidus, J. (2005). Developing a reliable senior walking environmental assessment tool. *American journal of preventive medicine, 29*(3), 215-217.
Curtis, J. W., Curtis, A., Mapes, J., Szell, A. B., & Cinderich, A. (2013). Using google street view for systematic observation of the built environment: analysis of spatio-temporal instability of imagery dates. *International journal of health geographics, 12*(1), 53.
Dannenberg, A. L., Jackson, R. J., Frumkin, H., Schieber, R. A., Pratt, M., Kochtitzky, C., & Tilson, H. H. (2003). The impact of community design and land-use choices on public health: a scientific research agenda. *American journal of public health, 93*(9), 1500-1508.
Data Management Group. (2011). Transportation Tomorrow Survey.
Day, K., Boarnet, M., Alfonzo, M., & Forsyth, A. (2006). The Irvine–Minnesota inventory to measure built environments: development. *American journal of preventive medicine, 30*(2), 144-152.
Dickerson, A. E., Molnar, L. J., Bédard, M., Eby, D. W., Berg-Weger, M., Choi, M., Myers, A. (2017). Transportation and aging: An updated research agenda to advance safe mobility among older adults transitioning from driving to non-driving. *The Gerontologist, 59*(2), 215-221.
Ding, D., Lawson, K. D., Kolbe-Alexander, T. L., Finkelstein, E. A., Katzmarzyk, P. T., van Mechelen, W., Committee (2016). The economic burden of physical inactivity: a global analysis of major non-communicable diseases. *The Lancet, 388*(10051), 1311-1324.
DiSantis, K. I., Hillier, A., Holaday, R., & Kumanyika, S. (2016). Why do you shop there? A mixed methods study mapping household food shopping patterns onto weekly routines of black women. *International Journal of Behavioral Nutrition and Physical Activity, 13*(1), 11.
Dishman, R. K., & Buckworth, J. (2007). Increasing physical activity: A quantitative synthesis. *Essential readings in sport and exercise psychology*, 348-355.
Doyle, L., Brady, A.-M., & Byrne, G. (2009). An overview of mixed methods research. *Journal of research in nursing, 14*(2), 175-185.
Dulin-Keita, A., Clay, O., Whittaker, S., Hannon, L., Adams, I. K., Rogers, M., & Gans, K. (2015). The influence of HOPE VI neighborhood revitalization on neighborhood-based physical activity: A mixed-methods approach. *Social Science & Medicine, 139*, 90-99.
Eisenberg, Y., Vanderbom, K. A., & Vasudevan, V. (2017). Does the built environment moderate the relationship between having a disability and lower levels of physical activity? A systematic review. *Preventive medicine, 95*, S75-S84.
Enders, C. K. (2010). *Applied missing data analysis*: Guilford press.

Estabrooks, C. A., Straus, S. E., Flood, C. M., Keefe, J., Armstrong, P., Donner, G. J., Wolfson, M. C. (2020). Restoring trust: COVID-19 and the future of long-term care in Canada. In: Canadian Science Publishing, Ottawa, ON.

Evenson, K. R., Sallis, J. F., Handy, S. L., Bell, R., & Brennan, L. K. (2012). Evaluation of physical projects and policies from the Active Living by Design partnerships. *American journal of preventive medicine, 43*(5), S309-S319.

Ewing, R., Handy, S., Brownson, R. C., Clemente, O., & Winston, E. (2006). Identifying and measuring urban design qualities related to walkability. *Journal of Physical Activity and Health, 3*(s1), S223-S240.

Farkas, B., Wagner, D., Tang, K., Friedenreich, C., Nettel-Aguirre, A., & McCormack, G. (2017). The Associations between Neighbourhood Built Characteristics and Physical Activity among Adults: A Systematic Review of Canadian Evidence (breakout presentation). *Journal of Transport & Health, 7*, S32.

Federal/Provincial/Territorial Advisory Committee on Population Health. (1999). *Toward a Healthy Future: Second Report on the Health of Canadians: Prepared by the Federal, Provincial and Territorial Advisory Committee on Population Health for the Meeting of Minister of Health, Charlottetown, PEI, September 1999*: Minister of Public Works and Government Services Canada.

Fédération Canadienne des Municipalités. (2015). *Les aînés et le logement: le prochain défi*.

Feinstein, A. R., & Cicchetti, D. V. (1990). High agreement but low kappa: I. The problems of two paradoxes. *Journal of clinical epidemiology, 43*(6), 543-549.

Ferrer, R. L., Cruz, I., Burge, S., Bayles, B., & Castilla, M. I. (2014). Measuring capability for healthy diet and physical activity. *The Annals of Family Medicine, 12*(1), 46-56.

Fetters, M. D., Curry, L. A., & Creswell, J. W. (2013). Achieving integration in mixed methods designs—principles and practices. *Health services research, 48*(6), 2134-2156.

Fetters, M. D., & Freshwater, D. (2015). *The 1+1=3 Integration Challenge.* Los Angeles, CA: SAGE Publications.

Frank, J. W. (1995). Why" population health"? *Canadian journal of public health/ Revue canadienne de santé publique, 86*(3), 162.

Frank, L. D., Sallis, J. F., Saelens, B. E., Leary, L., Cain, K., Conway, T. L., & Hess, P. M. (2010). The development of a walkability index: application to the Neighborhood Quality of Life Study. *British journal of sports medicine, 44*(13), 924-933.

Franke, T., Winters, M., McKay, H., Chaudhury, H., & Sims-Gould, J. (2017). A grounded visualization approach to explore sociospatial and temporal complexities of older adults' mobility. *Social Science & Medicine, 193*, 59-69.

Gennuso, K. P., Gangnon, R. E., Matthews, C. E., Thraen-Borowski, K. M., & Colbert, L. H. (2013). Sedentary behavior, physical activity, and markers of health in older adults. *Medicine and science in sports and exercise, 45*(8), 1493.

Glass, T. A., & Balfour, J. L. (2003). Neighborhoods, aging, and functional limitations. *Neighborhoods and health, 1*, 303-334.

Government of Canada. (2013). What is the Population Health Approach? Retrieved from https://www.canada.ca/en/public-health/services/health-promotion/population-health/population-health-approach/what-population-health-approach.html#key_elements

Government of Canada. (2020). Coronavirus disease (COVID-19): Prevention and risks. Retrieved from https://www.canada.ca/en/public-health/services/diseases/2019-novel-coronavirus-infection/prevention-risks.html#r

Greene, J. C., Caracelli, V. J., & Graham, W. F. (1989). Toward a conceptual framework for mixed-method evaluation designs. *Educational evaluation and policy analysis, 11*(3), 255-274.

Griew, P., Hillsdon, M., Foster, C., Coombes, E., Jones, A., & Wilkinson, P. (2013). Developing and testing a street audit tool using Google Street View to measure environmental supportiveness for physical activity. *International Journal of Behavioral Nutrition and Physical Activity, 10*(1), 103.

Guell, C., Panter, J., & Ogilvie, D. (2013). Walking and cycling to work despite reporting an unsupportive environment: insights from a mixed-method exploration of counterintuitive findings. *BMC public health, 13*(1), 497.

Hacking, I., & Hacking, J. (1999). *The social construction of what?* Harvard university press.

Hajna, S., Kestens, Y., Daskalopoulou, S. S., Joseph, L., Thierry, B., Sherman, M., Bacon, S. L. (2016). Neighbourhood walkability and home neighbourhood-based physical activity: an observational study of adults with type 2 diabetes. *BMC public health, 16*(1), 957.

Hajna, S., Ross, N. A., Brazeau, A.-S., Bélisle, P., Joseph, L., & Dasgupta, K. (2015). Associations between neighbourhood walkability and daily steps in adults: a systematic review and meta-analysis. *BMC public health, 15*(1), 768.

Hajna, S., Ross, N. A., Griffin, S. J., & Dasgupta, K. (2017). Lexical neutrality in environmental health research: Reflections on the term walkability. *BMC public health, 17*(1), 940.

Handy, S., Cao, X., & Mokhtarian, P. (2005). Correlation or causality between the built environment and travel behavior? Evidence from Northern California. *Transportation Research Part D: Transport and Environment, 10*(6), 427-444.

Haselwandter, E. M., Corcoran, M. P., Folta, S. C., Hyatt, R., Fenton, M., & Nelson, M. E. (2015). The built environment, physical activity, and aging in the United States: a state of the science review. *Journal of aging and physical activity, 23*(2), 323-329.

Hawkesworth, S., Silverwood, R. J., Armstrong, B., Pliakas, T., Nanchalal, K., Jefferis, B. J., Ramsay, S. E. (2018). Investigating associations between the built environment and physical activity among older people in 20 UK towns. *J Epidemiol Community Health, 72*(2), 121-131.

Heesch, K. C., Sahlqvist, S., & Garrard, J. (2012). Gender differences in recreational and transport cycling: a cross-sectional mixed-methods comparison of cycling patterns, motivators, and constraints. *International Journal of Behavioral Nutrition and Physical Activity, 9*(1), 106.

Heinen, E., Mackett, R., van Wee, B., Ogilvie, D., & Panter, J. (2018). Residential self-selection in quasi-experimental and natural experimental studies. *Journal of Transport and Land Use, 11*(1), 939-959.

Hennessy, E., Kraak, V. I., Hyatt, R. R., Bloom, J., Fenton, M., Wagoner, C., & Economos, C. D. (2010). Active living for rural children: community perspectives using PhotoVOICE. *American journal of preventive medicine, 39*(6), 537-545.

Herrmann, T., Gleckner, W., Wasfi, R. A., Thierry, B., Kestens, Y., & Ross, N. A. (2019). A pan-Canadian measure of active living environments using open data. *Health reports, 30*(5), 16-25.

Hesse-Biber, S. N. (2010). *Mixed methods research: Merging theory with practice*: Guilford Press.

Hillsdon, M., & Thorogood, M. (1996). A systematic review of physical activity promotion strategies. *British journal of sports medicine, 30*(2), 84-89.

Hirsch, J. A., Diez Roux, A. V., Moore, K. A., Evenson, K. R., & Rodriguez, D. A. (2014). Change in walking and body mass index following residential relocation: the multi-ethnic study of atherosclerosis. *American journal of public health, 104*(3), e49-e56.
Hirsch, J. A., Moore, K. A., Clarke, P. J., Rodriguez, D. A., Evenson, K. R., Brines, S. J., Roux, A. V. D. (2014). Changes in the built environment and changes in the amount of walking over time: longitudinal results from the multi-ethnic study of atherosclerosis. *American Journal of Epidemiology, 180*(8), 799-809.
Hoehner, C. M., Ivy, A., Ramirez, L. K. B., Handy, S., & Brownson, R. C. (2007). Active neighborhood checklist: a user-friendly and reliable tool for assessing activity friendliness. *American journal of health promotion, 21*(6), 534-537.
Hoehner, C. M., Ramirez, L. K. B., Elliott, M. B., Handy, S. L., & Brownson, R. C. (2005). Perceived and objective environmental measures and physical activity among urban adults. *American journal of preventive medicine, 28*(2), 105-116.
Honold, J., Lakes, T., Beyer, R., & van der Meer, E. (2016). Restoration in urban spaces: Nature views from home, greenways, and public parks. *Environment and Behavior, 48*(6), 796-825.
Hsu, A. T., Lane, N., Sinha, S. K., Dunning, J., Dhuper, M., Kahiel, Z., & Sveistrup, H. (2020). Understanding the impact of COVID-19 on residents of Canada's long-term care homes—ongoing challenges and policy responses. London: International Long-Term Care Policy Network, 24.
Inoue, S., Ohya, Y., Odagiri, Y., Takamiya, T., Kamada, M., Okada, S., Sallis, J. F. (2011). Perceived neighborhood environment and walking for specific purposes among elderly Japanese. *Journal of epidemiology*, 1110120263-1110120263.
International Transportation Forum. (2011). Pedestrian safety, urban space and health: Research report summary document.
Ivankova, N. V., Creswell, J. W., & Stick, S. L. (2006). Using mixed-methods sequential explanatory design: From theory to practice. *Field methods, 18*(1), 3-20.
Jacobs, J. (1961). The death and life of great American cities. New-York, NY: Vintage.
Johnson, R. B., Onwuegbuzie, A. J., & Turner, L. A. (2007). Toward a definition of mixed methods research. *Journal of Mixed Methods Research, 1*(2), 112-133.
Kawachi, I., & Berkman, L. F. (2003). *Neighborhoods and health*: Oxford University Press.
Keddem, S., Barg, F. K., Glanz, K., Jackson, T., Green, S., & George, M. (2015). Mapping the urban asthma experience: Using qualitative GIS to understand contextual factors affecting asthma control. *Social Science & Medicine, 140*, 9-17.
Kelly, C. M., Wilson, J. S., Baker, E. A., Miller, D. K., & Schootman, M. (2013). Using Google Street View to audit the built environment: inter-rater reliability results. *Annals of Behavioral Medicine, 45*(1), 108-112.
Kerr, J., Rosenberg, D., & Frank, L. (2012). The role of the built environment in healthy aging community design, physical activity, and health among older adults. *Journal of Planning Literature, 27*(1), 43-60.
Keusch, F. (2015). Why do people participate in Web surveys? Applying survey participation theory to Internet survey data collection. *Management Review Quarterly, 65*(3), 183-216.
Kikuchi, H., Nakaya, T., Hanibuchi, T., Fukushima, N., Amagasa, S., Oka, K., Inoue, S. (2018). Objectively measured neighborhood walkability and change in physical activity in older Japanese adults: a five-year cohort study. *International journal of environmental research and public health, 15*(9), 1814.

King, A. C., Sallis, J. F., Frank, L. D., Saelens, B. E., Cain, K., Conway, T. L., Kerr, J. (2011). Aging in neighborhoods differing in walkability and income: associations with physical activity and obesity in older adults. *Social Science & Medicine, 73*(10), 1525-1533.

King, D. (2008). Neighborhood and individual factors in activity in older adults: results from the neighborhood and senior health study. *Journal of aging and physical activity, 16*(2), 144-170.

Kipke, M. D., Iverson, E., Moore, D., Booker, C., Ruelas, V., Peters, A. L., & Kaufman, F. (2007). Food and park environments: neighborhood-level risks for childhood obesity in east Los Angeles. *Journal of Adolescent Health, 40*(4), 325-333.

Kwasnicka, D., Dombrowski, S. U., White, M., & Sniehotta, F. (2016). Theoretical explanations for maintenance of behaviour change: a systematic review of behaviour theories. *Health psychology review, 10*(3), 277-296.

Labonte, R., Polanyi, M., Muhajarine, N., Mcintosh, T., & Williams, A. (2005). Beyond the divides: Towards critical population health research. *Critical Public Health, 15*(1), 5-17.

Lafontaine, S. J., Sawada, M., & Kristjansson, E. (2017). A direct observation method for auditing large urban centers using stratified sampling, mobile GIS technology and virtual environments. *International journal of health geographics, 16*(1), 6.

Laine, J., Kuvaja-Köllner, V., Pietilä, E., Koivuneva, M., Valtonen, H., & Kankaanpää, E. (2014). Cost-effectiveness of population-level physical activity interventions: a systematic review. *American journal of health promotion, 29*(2), 71-80.

Lamb, K. E., Thornton, L. E., King, T. L., Ball, K., White, S. R., Bentley, R., Daniel, M. (2020). Methods for accounting for neighbourhood self-selection in physical activity and dietary behaviour research: a systematic review. *International Journal of Behavioral Nutrition and Physical Activity, 17*, 1-22.

Landis, J. R., & Koch, G. G. (1977). The measurement of observer agreement for categorical data. *biometrics*, 159-174.

Langlois, M., van Lierop, D., Wasfi, R. A., & El-Geneidy, A. M. (2015). Chasing sustainability: Do new transit-oriented development residents adopt more sustainable modes of transportation? *Transportation Research Record, 2531*(1), 83-92.

Langlois, M., Wasfi, R. A., Ross, N. A., & El-Geneidy, A. M. (2016). Can transit-oriented developments help achieve the recommended weekly level of physical activity? *Journal of Transport & Health, 3*(2), 181-190.

Lee, Shiroma, E. J., Lobelo, F., Puska, P., Blair, S. N., & Katzmarzyk, P. T. (2012). Effect of physical inactivity on major non-communicable diseases worldwide: an analysis of burden of disease and life expectancy. *The Lancet, 380*(9838), 219-229.

Lee, E., & Dean, J. (2018). Perceptions of walkability and determinants of walking behaviour among urban seniors in Toronto, Canada. *Journal of Transport & Health, 9*, 309-320.

Leedahl, S. N., Chapin, R. K., & Little, T. D. (2014). Multilevel examination of facility characteristics, social integration, and health for older adults living in nursing homes. *Journals of Gerontology Series B: Psychological Sciences and Social Sciences, 70*(1), 111-122.

Lehning, A. J. (2012). City governments and aging in place: Community design, transportation and housing innovation adoption. *The Gerontologist, 52*(3), 345-356.

Li, F., Harmer, P., Cardinal, B. J., Bosworth, M., Johnson-Shelton, D., Moore, J. M., Vongjaturapat, N. (2009). Built environment and 1-year change in weight and waist

circumference in middle-aged and older adults: Portland Neighborhood Environment and Health Study. *American Journal of Epidemiology, 169*(4), 401-408.
Li, W., Keegan, T. H., Sternfeld, B., Sidney, S., Quesenberry Jr, C. P., & Kelsey, J. L. (2006). Outdoor falls among middle-aged and older adults: a neglected public health problem. *American journal of public health, 96*(7), 1192-1200.
Liddle, J., Turpin, M., Carlson, G., & McKenna, K. (2008). The needs and experiences related to driving cessation for older people. *British Journal of Occupational Therapy, 71*(9), 379-388.
Lim, K., & Taylor, L. (2005). Factors associated with physical activity among older people—a population-based study. *Preventive medicine, 40*(1), 33-40.
Lincoln, Y. S., & Guba, E. (1985). Naturalistic Inquiry. Beverly Hills, California: Sage publications.
Lindwall, M., Larsman, P., & Hagger, M. S. (2011). The reciprocal relationship between physical activity and depression in older European adults: A prospective cross-lagged panel design using SHARE data. *Health Psychology, 30*(4), 453.
Liu-Ambrose, T., Best, J. R., Davis, J. C., Eng, J. J., Lee, P. E., Jacova, C., Cheung, W. (2016). Aerobic exercise and vascular cognitive impairment: a randomized controlled trial. *Neurology, 87*(20), 2082-2090.
Liu, L., Silva, E. A., Wu, C., & Wang, H. (2017). A machine learning-based method for the large-scale evaluation of the qualities of the urban environment. *Computers, Environment and Urban Systems, 65*, 113-125.
Lockett, D., Willis, A., & Edwards, N. (2005). Through seniors' eyes: an exploratory qualitative study to identify environmental barriers to and facilitators of walking. *Canadian Journal of Nursing Research, 37*(3), 48-65.
Loh, V. H., Rachele, J. N., Brown, W. J., Ghani, F., Washington, S., & Turrell, G. (2019). The potential for walkability to narrow neighbourhood socioeconomic inequalities in physical function: A case study of middle-aged to older adults in Brisbane, Australia. *Health & place, 56*, 99-105.
Lord, S., Cloutier, M.-S., Garnier, B., & Christoforou, Z. (2018). Crossing road intersections in old age—With or without risks? Perceptions of risk and crossing behaviours among the elderly. *Transportation research part F: traffic psychology and behaviour, 55*, 282-296.
Mah, S. M., Sanmartin, C., Riva, M., Dasgupta, K., & Ross, N. A. (2020). Active living environments, physical activity and premature cardiometabolic mortality in Canada: a nationwide cohort study. *BMJ open, 10*(11), e035942.
Martínez-Andrés, M., García-López, Ú., Gutiérrez-Zornoza, M., Rodríguez-Martín, B., Pardo-Guijarro, M. J., Sánchez-López, M., Martínez-Vizcaíno, V. (2012). Barriers, facilitators and preferences for the physical activity of school children. Rationale and methods of a mixed study. *BMC public health, 12*(1), 785.
Mathers, C. D., Stevens, G. A., Boerma, T., White, R. A., & Tobias, M. I. (2015). Causes of international increases in older age life expectancy. *The Lancet, 385*(9967), 540-548.
McCormack, G. R., & Shiell, A. (2011). In search of causality: a systematic review of the relationship between the built environment and physical activity among adults. *International Journal of Behavioral Nutrition and Physical Activity, 8*(1), 125.
McGuirk, P. M., & O'Neill, P. (2010). Using Questionnaires in Qualitative Human Geography. In I. Hay (Ed.), *Qualitative Research Methods in Human Geography* (10 ed.): Oxford University Press.

Meade, M. S. (2010). *Medical geography*: Wiley Online Library.
Mertens, D. M., Bazeley, P., Bowleg, L., Fielding, N., Maxwell, J., Molina-Azorin, J. F., & Niglas, K. (2016). Expanding thinking through a kaleidoscopic look into the future: Implications of the Mixed Methods International Research Association's Task Force Report on the future of mixed methods. *Journal of Mixed Methods Research, 10*(3), 221-227.
Michael, Y. L., Keast, E. M., Chaudhury, H., Day, K., Mahmood, A., & Sarte, A. F. (2009). Revising the senior walking environmental assessment tool. *Preventive medicine, 48*(3), 247-249.
Millington, C., Thompson, C. W., Rowe, D., Aspinall, P., Fitzsimons, C., Nelson, N., Collaboration, S. T. S. P. A. R. (2009). Development of the Scottish walkability assessment tool (SWAT). *Health & place, 15*(2), 474-481.
Millstein, R. A., Cain, K. L., Sallis, J. F., Conway, T. L., Geremia, C., Frank, L. D., Kerr, J. (2013). Development, scoring, and reliability of the Microscale Audit of Pedestrian Streetscapes (MAPS). *BMC public health, 13*(1), 403.
Mitra, R., Siva, H., & Kehler, M. (2015). Walk-friendly suburbs for older adults? Exploring the enablers and barriers to walking in a large suburban municipality in Canada. *Journal of aging studies, 35*, 10-19.
Moffatt, S., White, M., Mackintosh, J., & Howel, D. (2006). Using quantitative and qualitative data in health services research–what happens when mixed method findings conflict? *BMC Health Services Research, 6*(1), 28.
Mooney, S. J., Wheeler-Martin, K., Fiedler, L. M., LaBelle, C. M., Lampe, T., Ratanatharathorn, A., DiMaggio, C. J. (2020). Development and validation of a Google Street View pedestrian safety audit tool. *Epidemiology, 31*(2), 301.
Moos, M., & Walter-Joseph, R. (2017). Still Detached and Subdivided?: Suburban ways of Living in 21st Century North America. Berlin: Jovis Verlag GmbH.
Moran, M., Van Cauwenberg, J., Hercky-Linnewiel, R., Cerin, E., Deforche, B., & Plaut, P. (2014). Understanding the relationships between the physical environment and physical activity in older adults: a systematic review of qualitative studies. *International Journal of Behavioral Nutrition and Physical Activity, 11*(1), 79.
Moran, M. R., Werner, P., Doron, I., HaGani, N., Benvenisti, Y., King, A. C., Motro, H. (2017). Exploring the Objective and Perceived Environmental Attributes of Older Adults' Neighborhood Walking Routes: A Mixed Methods Analysis. *Journal of aging and physical activity, 25*(3), 420-431.
Müller, A. M., Ansari, P., Ebrahim, N. A., & Khoo, S. (2016). Physical activity and aging research: a bibliometric analysis. *Journal of aging and physical activity, 24*(3), 476-483.
Nieman, D. C., & Wentz, L. M. (2019). The compelling link between physical activity and the body's defense system. *Journal of sport and health science, 8*(3), 201-217.
Norman, G. J., Carlson, J. A., O'Mara, S., Sallis, J. F., Patrick, K., Frank, L. D., & Godbole, S. V. (2013). Neighborhood preference, walkability and walking in overweight/obese men. *American Journal of Health Behavior, 37*(2), 277-282.
Northcutt Bohmert, M. (2016). The role of transportation disadvantage for women on community supervision. *Criminal justice and behavior, 43*(11), 1522-1540.
O'Cathain, A., Murphy, E., & Nicholl, J. (2008). The quality of mixed methods studies in health services research. *Journal of Health Services Research & Policy, 13*(2), 92-98.

O'Cathain, A., Murphy, E., & Nicholl, J. (2010). Three techniques for integrating data in mixed methods studies. *Bmj, 341*.
Odgers, C. L., Caspi, A., Bates, C. J., Sampson, R. J., & Moffitt, T. E. (2012). Systematic social observation of children's neighborhoods using Google Street View: a reliable and cost-effective method. *Journal of Child Psychology and Psychiatry, 53*(10), 1009-1017.
Omura, J. D., Ussery, E. N., Loustalot, F., Fulton, J. E., & Carlson, S. A. (2019). Peer Reviewed: Walking as an Opportunity for Cardiovascular Disease Prevention. *Preventing chronic disease, 16*.
Origine-Destination. (2013). L'enquête Origine Destination 2013.
Ottoni, C. A., Sims-Gould, J., Winters, M., Heijnen, M., & McKay, H. A. (2016). "Benches become like porches": Built and social environment influences on older adults' experiences of mobility and well-being. *Social Science & Medicine, 169*, 33-41.
Pace, R., Pluye, P., Bartlett, G., Macaulay, A. C., Salsberg, J., Jagosh, J., & Seller, R. (2012). Testing the reliability and efficiency of the pilot Mixed Methods Appraisal Tool (MMAT) for systematic mixed studies review. *International journal of nursing studies, 49*(1), 47-53.
Päivi, M., Mirja, H., & Terttu, P. (2010). Changes in physical activity involvement and attitude to physical activity in a 16-year follow-up study among the elderly. *Journal of aging research, 2010*, 1-7.
Park, Y., Quinn, J., Florez, K., Jacobson, J., Neckerman, K., & Rundle, A. (2011). Hispanic immigrant women's perspective on healthy foods and the New York City retail food environment: A mixed-method study. *Social Science & Medicine, 73*(1), 13-21.
Perchoux, C., Chaix, B., Cummins, S., & Kestens, Y. (2013). Conceptualization and measurement of environmental exposure in epidemiology: accounting for activity space related to daily mobility. *Health & place, 21*, 86-93.
Pietilä, A.-M., Rantakallio, P., & Läärä, E. (1995). Background factors predicting non-response in a health survey of northern Finnish young men. *Scandinavian journal of social medicine, 23*(2), 129-136.
Pikora, T., Giles-Corti, B., Bull, F., Jamrozik, K., & Donovan, R. (2003). Developing a framework for assessment of the environmental determinants of walking and cycling. *Social Science & Medicine, 56*(8), 1693-1703.
Pikora, T. J., Bull, F. C., Jamrozik, K., Knuiman, M., Giles-Corti, B., & Donovan, R. J. (2002). Developing a reliable audit instrument to measure the physical environment for physical activity. *American journal of preventive medicine, 23*(3), 187-194.
Plascak, J. J., Schootman, M., Rundle, A. G., Xing, C., Llanos, A. A., Stroup, A. M., & Mooney, S. J. (2020). Spatial predictive properties of built environment characteristics assessed by drop-and-spin virtual neighborhood auditing. *International journal of health geographics, 19*(1), 1-20.
Pluijm, S. M., Visser, M., Puts, M. T., Dik, M. G., Schalk, B. W., van Schoor, N. M., . . . Deeg, D. J. (2007). Unhealthy lifestyles during the life course: association with physical decline in late life. *Aging clinical and experimental research, 19*(1), 75-83.
Pluye, P., Bengoechea, E. G., & Granikov, V. (2018). A world of possibilities in mixed methods: review of the combinations of strategies used to integrate qualitative and quantitative phases, results and data. *Int J Mult Res Approaches, 10*, 41-56.
Pluye, P., Grad, R. M., Johnson-Lafleur, J., Granikov, V., Shulha, M., Marlow, B., & Ricarte, I. L. M. (2013). Number needed to benefit from information (NNBI): proposal from a

mixed methods research study with practicing family physicians. *The Annals of Family Medicine, 11*(6), 559-567.
Pluye, P., Grad, R. M., Levine, A., & Nicolau, B. (2009). Understanding divergence of quantitative and qualitative data (or results) in mixed methods studies. *International Journal of Multiple Research Approaches, 3*(1), 58-72.
Pluye, P., & Hong, Q. N. (2014). Combining the power of stories and the power of numbers: mixed methods research and mixed studies reviews. *Annual review of public health, 35*, 29-45.
Porter, A. K., Wen, F., Herring, A. H., Rodríguez, D. A., Messer, L. C., Laraia, B. A., & Evenson, K. R. (2018). Reliability and One-Year Stability of the PIN3 Neighborhood Environmental Audit in Urban and Rural Neighborhoods. *Journal of Urban Health*, 1-9.
Procter-Gray, E., Leveille, S. G., Hannan, M. T., Cheng, J., Kane, K., & Li, W. (2015). Variations in Community Prevalence and Determinants of Recreational and Utilitarian Walking in Older Age. *Journal of aging research, 2015*, 1-11.
Reichwein, B., Wolmarans, L., Nantayi, L., Nassali, F., Kakinda, A., Musumba, D., Baatsen, P. (2015). SegWeigh: A mixed-method approach to segmenting potential contraceptive user groups and meeting Family Planning 2020 goals. *International Journal of Gynecology & Obstetrics, 130*(S3).
Reja, U., Manfreda, K. L., Hlebec, V., & Vehovar, V. (2003). Open-ended vs. close-ended questions in web questionnaires. *Developments in applied statistics, 19*, 159-177.
Rodgers, S. E., Bailey, R., Johnson, R., Poortinga, W., Smith, R., Berridge, D., Jones, N. (2018). *The revised Residential Environment Assessment Tool.* Paper presented at the Health impact, and economic value, of meeting housing quality standards: a retrospective longitudinal data linkage study.
Rose, G. (2001). Sick individuals and sick populations. *International journal of epidemiology, 30*(3), 427-432.
Rosenbloom, S. (2001). Sustainability and automobility among the elderly: An international assessment. *Transportation, 28*(4), 375-408.
Rundle, A. G., Bader, M. D., Richards, C. A., Neckerman, K. M., & Teitler, J. O. (2011). Using Google Street View to audit neighborhood environments. *American journal of preventive medicine, 40*(1), 94-100.
Rydin, Y., Bleahu, A., Davies, M., Dávila, J. D., Friel, S., De Grandis, G., Howden-Chapman, P. (2012). Shaping cities for health: complexity and the planning of urban environments in the 21st century. *The Lancet, 379*(9831), 2079-2108.
Saelens, B., & Handy, S. (2008a). Built environment correlates of walking: a review. *Medicine & Science in Sports & Exercise, 40*(7), S550.
Saelens, B. E., & Handy, S. L. (2008b). Built environment correlates of walking: a review. *Medicine and science in sports and exercise, 40*(7 Suppl), S550.
Saelens, B. E., Frank, L. D., Auffrey, C., Whitaker, R. C., Burdette, H. L., & Colabianchi, N. (2006). Measuring physical environments of parks and playgrounds: EAPRS instrument development and inter-rater reliability. *Journal of Physical Activity and Health, 3*(s1), S190-S207.
Sallis, Cain, K., Conway, T., Gavand, K., Millstein, R., Geremia, C., King, A. (2015). Peer Reviewed: Is Your Neighborhood Designed to Support Physical Activity? A Brief Streetscape Audit Tool. *Preventing chronic disease, 12*.

Sallis, J., Owen, N., & Fisher, E. (2015). Ecological models of health behavior. *Health behavior: Theory, research, and practice, 5*, 43-64.
Sallis, J., Owen, N., & Fisher, E. B. (2008). *Ecological models of health behavior*. Danvers, MA: John Wiley & Sons.
Sallis, J. F., Cerin, E., Conway, T. L., Adams, M. A., Frank, L. D., Pratt, M., Cain, K. L. (2016). Physical activity in relation to urban environments in 14 cities worldwide: a cross-sectional study. *The Lancet, 387*(10034), 2207-2217.
Sallis, J. F., Cervero, R. B., Ascher, W., Henderson, K. A., Kraft, M. K., & Kerr, J. (2006). An ecological approach to creating active living communities. *Annual review of public health, 27*, 297-322.
Sallis, J. F., Saelens, B. E., Frank, L. D., Conway, T. L., Slymen, D. J., Cain, K. L., Kerr, J. (2009). Neighborhood built environment and income: examining multiple health outcomes. *Social Science & Medicine, 68*(7), 1285-1293.
Sayer, A. (2000). Realism and social science London: SAGE.
Schmidt, T., Kerr, J., & Schipperijn, J. (2019). Associations between neighborhood open space features and walking and social interaction in older adults—A mixed methods study. *Geriatrics, 4*(3), 41.
Schoner, J., & Cao, X. (2014). Walking for purpose and pleasure: influences of light rail, built environment, and residential self-selection on pedestrian travel. *Transportation Research Record, 2464*(1), 67-76.
Shigematsu, R., Sallis, J., Conway, T., Saelens, B., Frank, L., Cain, K., King, A. (2009). Age differences in the relation of perceived neighborhood environment to walking. *Medicine & Science in Sports & Exercise, 41*(2), 314.
Shimura, Sugiyama, Winkler, & Owen. (2012). High neighborhood walkability mitigates declines in middle-aged and older adults' walking for transport. *Journal of Physical Activity and Health, 9*(7), 1004-1008.
Shrout, P. E. (1998). Measurement reliability and agreement in psychiatry. *Statistical methods in medical research, 7*(3), 301-317.
Smith, J. K., & Heshusius, L. (1986). Closing down the conversation: The end of the quantitative-qualitative debate among educational inquirers. *Educational researcher, 15*(1), 4-12.
Smith, T. C., Wingard, D. L., Smith, B., Kritz-Silverstein, D., & Barrett-Connor, E. (2007). Walking decreased risk of cardiovascular disease mortality in older adults with diabetes. *Journal of clinical epidemiology, 60*(3), 309-317.
Sofi, F., Valecchi, D., Bacci, D., Abbate, R., Gensini, G., Casini, A., & Macchi, C. (2011). Physical activity and risk of cognitive decline: a meta-analysis of prospective studies. *Journal of internal medicine, 269*(1), 107-117.
Søgaard, A. J., Selmer, R., Bjertness, E., & Thelle, D. (2004). The Oslo Health Study: The impact of self-selection in a large, population-based survey. *International journal for equity in health, 3*(1), 3.
Stamler, J. (1985). *The multiple risk factor intervention trial*. Paper presented at the Primary and Secondary Prevention of Coronary Heart Disease.
Stathi, A., Gilbert, H., Fox, K. R., Coulson, J., Davis, M., & Thompson, J. L. (2012). Determinants of neighborhood activity of adults age 70 and over: a mixed-methods study. *Journal of aging and physical activity, 20*(2), 148-170.

Statistics Canada. (2009). More information on postal code. Retrieved from http://www12.statcan.ca/census-recensement/2006/ref/dict/geo035a-eng.cfm
Statistics Canada. (2011). Canada's rural population since 1851. *Census in Brief.* Retrieved from http://www12.statcan.gc.ca/census-recensement/2011/as-sa/98-310-x/98-310-x2011003_2-eng.cfm
Statistics Canada. (2014). Population projections: Canada, the provinces and territories, 2013 to 2063. *The Daily* Retrieved from http://www.statcan.gc.ca/daily-quotidien/140917/dq140917a-eng.htm
Statistics Canada. (2015). Directly measured physical activity of adults, 2012 and 2013. *Health Facts Sheets.* Retrieved from http://www.statcan.gc.ca/pub/82-625-x/2015001/article/14135-eng.htm
Statistics Canada. (2019). Canadian Internet Use Survey. Retrieved from https://www150.statcan.gc.ca/n1/daily-quotidien/191029/dq191029a-eng.htm
Steinmetz-Wood, M., El-Geneidy, A., & Ross, N. A. (2020). Moving to policy-amenable options for built environment research: The role of micro-scale neighborhood environment in promoting walking. *Health & place, 66*, 102462.
Steinmetz-Wood, M., & Kestens, Y. (2015). Does the effect of walkable built environments vary by neighborhood socioeconomic status? *Preventive medicine, 81*, 262-267.
Steinmetz-Wood, M., Pluye, P., & Ross, N. A. (2019). The planning and reporting of mixed methods studies on the built environment and health. *Preventive medicine*, 105752.
Steinmetz-Wood, M., Velauthapillai, K., O'Brien, G., & Ross, N. A. (2019). Assessing the micro-scale environment using Google Street View®: The Virtual Systematic Tool for Evaluating Pedestrian Streetscapes (Virtual-STEPS). *BMC public health*.
Stewart, M., Makwarimba, E., Barnfather, A., Letourneau, N., & Neufeld, A. (2008). Researching reducing health disparities: Mixed-methods approaches. *Social Science & Medicine, 66*(6), 1406-1417.
Stokols, D. (1992). Establishing and maintaining healthy environments: toward a social ecology of health promotion. *American psychologist, 47*(1), 6-22.
Strawbridge, W. J., Deleger, S., Roberts, R. E., & Kaplan, G. A. (2002). Physical activity reduces the risk of subsequent depression for older adults. *American Journal of Epidemiology, 156*(4), 328-334.
Sugiyama, T., Howard, N. J., Paquet, C., Coffee, N. T., Taylor, A. W., & Daniel, M. (2015). Do relationships between environmental attributes and recreational walking vary according to area-level socioeconomic status? *Journal of Urban Health, 92*(2), 253-264.
Suzman, R., Beard, J. R., Boerma, T., & Chatterji, S. (2015). Health in an ageing world—what do we know? *The Lancet, 385*(9967), 484-486.
Tashakkori, A., & Teddlie, C. (2003). Issues and dilemmas in teaching research methods courses in social and behavioural sciences: US perspective. *International Journal of Social Research Methodology, 6*(1), 61-77.
Tavakol, M., & Dennick, R. (2011). Making sense of Cronbach's alpha. *International journal of medical education, 2*, 53.
Teddlie, C., & Tashakkori, A. (2012). Common "core" characteristics of mixed methods research: A review of critical issues and call for greater convergence. *American Behavioral Scientist, 56*(6), 774-788.
Thielman, J., Rosella, L., Copes, R., Lebenbaum, M., & Manson, H. (2015). Neighborhood walkability: differential associations with self-reported transport walking and leisure-time

physical activity in Canadian towns and cities of all sizes. *Preventive medicine, 77*, 174-180.
Thornton, C. M., Conway, T. L., Cain, K. L., Gavand, K. A., Saelens, B. E., Frank, L. D., Sallis, J. F. (2016). Disparities in pedestrian streetscape environments by income and race/ethnicity. *Social Science & Medicine, 2*, 206-216.
Tomata, Y., Zhang, S., Sugawara, Y., & Tsuji, I. (2019). Impact of time spent walking on incident dementia in elderly Japanese. *International Journal of Geriatric Psychiatry, 34*(1), 204-209.
Tremblay, M. S., Warburton, D. E., Janssen, I., Paterson, D. H., Latimer, A. E., Rhodes, R. E., Zehr, L. (2011). New Canadian physical activity guidelines. *Applied Physiology, Nutrition, and Metabolism, 36*(1), 36-46.
Troped, P. J., Tamura, K., McDonough, M. H., Starnes, H. A., James, P., Ben-Joseph, E., . . . Laden, F. (2017). Direct and indirect associations between the built environment and leisure and utilitarian walking in older women. *Annals of Behavioral Medicine, 51*(2), 282-291.
Tyson, L. (2014). Critical theory today: A user-friendly guide: Routledge.
United Nations. (2014). Social Affairs, World Urbanization Prospects: The 2014 Revision.
Van Cauwenberg, J., Clarys, P., De Bourdeaudhuij, I., Van Holle, V., Verté, D., De Witte, N., Deforche, B. (2012). Physical environmental factors related to walking and cycling in older adults: the Belgian aging studies. *BMC public health, 12*(142).
Van Cauwenberg, J., De Bourdeaudhuij, I., De Meester, F., Van Dyck, D., Salmon, J., Clarys, P., & Deforche, B. (2011). Relationship between the physical environment and physical activity in older adults: a systematic review. *Health & place, 17*(2), 458-469.
Van Cauwenberg, J., Nathan, A., Barnett, A., Barnett, D. W., & Cerin, E. (2018). Relationships between neighbourhood physical environmental attributes and older adults' leisure-time physical activity: A systematic review and meta-analysis. *Sports medicine, 48*(7), 1635-1660.
Van Cauwenberg, J., Van Holle, V., De Bourdeaudhuij, I., Clarys, P., Nasar, J., Salmon, J., Deforche, B. (2014). Using manipulated photographs to identify features of streetscapes that may encourage older adults to walk for transport. *PloS one, 9*(11), e112107.
Van Cauwenberg, J., Van Holle, V., De Bourdeaudhuij, I., Van Dyck, D., & Deforche, B. (2016). Neighborhood walkability and health outcomes among older adults: The mediating role of physical activity. *Health & place, 37*, 16-25.
Van Cauwenberg, J., Van Holle, V., Simons, D., Deridder, R., Clarys, P., Goubert, L., Deforche, B. (2012). Environmental factors influencing older adults' walking for transportation: a study using walk-along interviews. *International Journal of Behavioral Nutrition and Physical Activity, 9*(1), 85.
Van Dyck, D., Cardon, G., Deforche, B., Owen, N., & De Bourdeaudhuij, I. (2011). Relationships between neighborhood walkability and adults' physical activity: How important is residential self-selection? *Health & place, 17*(4), 1011-1014.
Van Dyck, D., Teychenne, M., McNaughton, S. A., De Bourdeaudhuij, I., & Salmon, J. (2015). Relationship of the perceived social and physical environment with mental health-related quality of life in middle-aged and older adults: mediating effects of physical activity. *PloS one, 10*(3), e0120475.
Van Holle, V., Van Cauwenberg, J., Van Dyck, D., Deforche, B., Van de Weghe, N., & De Bourdeaudhuij, I. (2014). Relationship between neighborhood walkability and older

adults' physical activity: results from the Belgian Environmental Physical Activity Study in Seniors (BEPAS Seniors). *International Journal of Behavioral Nutrition and Physical Activity, 11*(110), 1-9.
Vanwolleghem, G., Van Dyck, D., Ducheyne, F., De Bourdeaudhuij, I., & Cardon, G. (2014). Assessing the environmental characteristics of cycling routes to school: a study on the reliability and validity of a Google Street View-based audit. *International journal of health geographics, 13*(1), 19.
Waal, D. (2005). *On pragmatism*. CA Belmont: Waldsworth.
Walford, N., Samarasundera, E., Phillips, J., Hockey, A., & Foreman, N. (2011). Older people's navigation of urban areas as pedestrians: Measuring quality of the built environment using oral narratives and virtual routes. *Landscape and Urban Planning, 100*(1-2), 163-168.
Wallis, J., Webster, K., Levinger, P., Singh, P., Fong, C., & Taylor, N. (2017). A walking program for people with severe knee osteoarthritis did not reduce pain but may have benefits for cardiovascular health: a phase II randomised controlled trial. *Osteoarthritis and cartilage, 25*(12), 1969-1979.
Wasfi, R., Steinmetz-Wood, M., & Kestens, Y. (2017). Place matters: A longitudinal analysis measuring the association between neighbourhood walkability and walking by age group and population center size in Canada. *PloS one, 12*(12), e0189472.
Wasfi, R. A., Dasgupta, K., Orpana, H., & Ross, N. A. (2016). Neighborhood walkability and body mass index trajectories: longitudinal study of Canadians. *American journal of public health*.
Wendler, M. C. (2001). Triangulation using a meta-matrix. *Journal of advanced nursing, 35*(4), 521-525.
Williams, P. T., & Thompson, P. D. (2013). Walking versus running for hypertension, cholesterol, and diabetes mellitus risk reduction. *Arteriosclerosis, thrombosis, and vascular biology, 33*(5), 1085-1091.
Wister, A. V., & Speechley, M. (2015). Inherent Tensions Between Population Aging and Health Care Systems: What Might the Canadian Health Care System Look Like in Twenty Years? *Journal of Population Ageing, 8*(4), 227-243.
World Health Organization. (2015a). Ageing and Health Retrieved from http://www.who.int/mediacentre/factsheets/fs404/en/
World Health Organization. (2015b). *World Report on Ageing and Health* (9241565047). Retrieved from Switzerland:
World Health Organization. (2018). WHO Global Network for Age-friendly Cities and Communities. *Ageing and life-course.* Retrieved from http://www.who.int/ageing/projects/age_friendly_cities_network/en/
Yang, Y., Xu, Y., Rodriguez, D. A., Michael, Y., & Zhang, H. (2018). Active travel, public transportation use, and daily transport among older adults: the association of built environment. *Journal of Transport & Health, 9*, 288-298.
Yen, I. H., Michael, Y. L., & Perdue, L. (2009). Neighborhood environment in studies of health of older adults. *American journal of preventive medicine, 37*(5), 455-463.
Yin, L., Cheng, Q., Wang, Z., & Shao, Z. (2015). 'Big data'for pedestrian volume: Exploring the use of Google Street View images for pedestrian counts. *Applied Geography, 63*, 337-345.

Yin, L., & Wang, Z. (2016). Measuring visual enclosure for street walkability: Using machine learning algorithms and Google Street View imagery. *Applied Geography, 76*, 147-153.

Yoo, S., & Kim, D. H. (2017). Perceived urban neighborhood environment for physical activity of older adults in Seoul, Korea: a multimethod qualitative study. *Preventive medicine, 103*, S90-S98.

Zandieh, R., Martinez, J., Flacke, J., Jones, P., & Van Maarseveen, M. (2016). Older adults' outdoor walking: Inequalities in neighbourhood safety, pedestrian infrastructure and aesthetics. *International journal of environmental research and public health, 13*(12), 1179.

Zhu, W., Sun, Y., Kurka, J., Geremia, C., Engelberg, J. K., Cain, K., Adams, M. A. (2017). Reliability between online raters with varying familiarities of a region: Microscale Audit of Pedestrian Streetscapes (MAPS). *Landscape and Urban Planning, 167*, 240-248.

APPENDIX A| SUPPLEMENTARY MATERIAL FOR MANUSCRIPT 1

Table 1A: Self-identified mixed methods studies from a Scopus search of the literature on the built environment and health.

#	Title	Authors	Year	Specified mixed methods design	Mixed methods design	Described integration procedure[a]	Specified integrating in methods[b]	Type of integration
1	Population cardiovascular health and urban environments: the Heart Healthy Hoods exploratory study in Madrid, Spain	Usama Bilal, Julia Díez, Silvia Alfayate, Pedro Gullón, Isabel del Cura, Francisco Escobar, María Sandín, and Manuel Franco	2016	NO	N/A	YES	YES	Comparison
2	Mapping the Racial Inequality in Place: Using Youth Perceptions to Identify Unequal Exposure to Neighborhood Environmental Hazards	Samantha Teixeira, and Anita Zuberi	2016	NO	N/A	YES	NO	Connection
3	The Role Of Transportation Disadvantage For Women On Community Supervision	Miriam Northcutt Bohmert	2016	YES	Sequential explanatory	YES	YES	Connection and assimilation
4	Beyond Broken Windows: Youth Perspectives on Housing Abandonment and its Impact on Individual and Community Well-Being	Samantha Teixeira	2016	NO	N/A	YES	YES	Comparison
5	Moving to Location Affordability? Housing Choice Vouchers and Residential Relocation in the Portland, Oregon, Region	Andrée Tremoulet, Ryan Dann, and Arlie Adkins	2016	NO	N/A	YES	NO	Connection

6	A Mixed-Method Assessment of a New Supermarket in a Food Desert: Contributions to Everyday Life and Health	Benjamin Chrisinger	2016	NO	N/A	NO	NO	N/A
7	Neighbourhood expectations and engagement with new cycling infrastructure in Sydney, Australia: Findings from a mixed method before-and-after study	Melanie Crane, Chris Rissel, Stephen Greaves, Chris Standen, and Li Ming Wen	2016	YES	Multiphase emergent	YES	YES	Comparison
8	Using a Household Food Inventory to Assess the Availability of Traditional Vegetables among Resettled African Refugees	Catherine Gichunge, Shawn Somerset, and Neil Harris	2016	YES	Sequential explanatory	YES	YES	Connection
9	Beyond the Supermarket Solution: Linking Food Deserts, Neighborhood Context, and Everyday Mobility	Jerry Shannon	2016	NO	N/A	NO	NO	N/A
10	A social assessment of urban parkland: Analyzing park use and meaning to inform management and resilience planning	Lindsay K. Campbell, Erika Svendsen, Nancy Sonti, and Michelle Johnson	2016	NO	N/A	NO	NO	N/A
11	Restoration in Urban Spaces: Nature Views From Home, Greenways, and Public Parks	Jasmin Honold, Tobia Lakes, Reinhard Beyer, and Elke van der Meer	2016	NO	N/A	YES	NO	Assimilation

12	Urban regeneration as population health intervention: a health impact assessment in the Bay of Pasaia (Spain)	Elena Serrano, Isabel Larrañaga, Maite Morteruel, María Dolores Baixas de Ros, Mikel Basterrechea, Dolores Martinez, Elena Aldasoro, and Amaia Bacigalupe	2016	NO	N/A	YES	YES	Comparison
13	Bicycling crashes on streetcar (tram) or train tracks: mixed methods to identify prevention measures	Kay Teschke, Jessica Dennis, Conor Reynolds, Meghan Winters, and Anne Harris	2016	NO	N/A	NO	NO	N/A
14	Why do you shop there? A mixed methods study mapping household food shopping patterns onto weekly routines of black women	Katherine Isselmann DiSantis, Amy Hillier, Rio Holaday, and Shiriki Kumanyika	2016	NO	N/A	YES	YES	Comparison and connection
15	Older Adults' Outdoor Walking: Inequalities in Neighbourhood Safety, Pedestrian Infrastructure and Aesthetics	Razieh Zandieh, Javier Martinez, Johannes Flacke, Phil Jones, and Martin van Maarseveen	2016	YES	Concurrent (convergent)	NO	YES	Comparison
16	Successful public places: A case study of historical Persian gardens	Raheleh Rostami, Hasanuddin Lamit, Seyed Meysam Khoshnavac, and Rasoul Rostamid	2016	YES	Explanatory	YES	YES	Connection, comparison, assimilation
17	Mapping U.S.long-haul truck drivers' multiplex networks and risk topography in inner-city neighborhoods	Yorghos Apostolopoulos, Sevil Sönmez , Michael Kenneth Lemke, and Richard Rothenberg	2015	NO	N/A	NO	NO	N/A
18	Risky Business: Sustainability and Industrial Land Use across Seattle's Gentrifying Riskscape	Troy Abel, Jonah White, and Stacy Clauson	2015	NO	N/A	NO	NO	N/A

19	Middle School Students' Perceptions of Safety: A Mixed-Methods Study	Shannon Sweeney, and Leigh Ann Von Hagen	2015	NO	N/A	NO	NO	N/A
20	Liveable streets in Hanoi: A principal component analysis	Peter Sanders, Mark Zuidgeest, and Karst Geurs	2015	NO	N/A	NO	NO	N/A
21	Food deserts or food swamps? A mixed-methods study of local food environments in a Mexican city	Susan Bridle-Fitzpatrick	2015	NO	N/A	NO	YES	Comparison
22	Improving walking conditions for older adults. A three-step method investigation	Julie Runde Krogstad, Randi Hjorthol, and Aud Tennøy	2015	NO	N/A	YES	NO	Connection
23	Mapping the urban asthma experience: Using qualitative GIS to understand contextual factors affecting asthma control	Shimrit Keddem, Frances Barg, Karen Glanz, Tara Jackson, Sarah Green, and Maureen George	2015	YES	Sequential exploratory	YES	YES	Connection and assimilation
24	"I grew up on a bike": Cycling and older adults	Meghan Winters, Joanie Sims-Gould, Thea Franke, and Heather McKay	2015	NO	N/A	NO	NO	N/A
25	Childhood Obesity Perceptions Among African American Caregivers in a Rural Georgia Community: A Mixed Methods Approach	Dayna Alexander, Moya Alfonso, and Andrew Hansen	2015	YES	Concurrent (convergent)	NO	NO	N/A
26	Implications of supermarket expansion on urban food security in Cape Town, South Africa	Stephen Peyton, William Moseley, and Jane Battersby	2015	NO	N/A	NO	NO	N/A

27	Mechanisms underpinning use of new walking and cycling infrastructure in different contexts: mixed-method analysis	Shannon Sahlqvist, Anna Goodman, Tim Jones, Jane Powell, Yena Song, and David Ogilvie	2015	NO	N/A	YES	YES	Connection and comparison
28	Views From the Path: Evaluating Physical Activity Use Patterns and Design Preferences of Older Adults on the Bolin Creek Greenway Trail	Catherine Dorwart	2015	NO	N/A	NO	NO	N/A
29	An Ecological Approach to Exploring Rural Food Access and Active Living for Families With Preschoolers	Brandy Buro, Abby Gold, Dawn Contreras, Ann Keim, Amy Mobley, Renee Oscarson, Paula Peters, Sandy Procter, and Carol Smathers	2015	NO	N/A	NO	NO	N/A
30	Measuring Capability for Healthy Diet and Physical Activity	Robert Ferrer, Inez Cruz, Sandra Burge, Bryan Bayles, Martha Castilla	2014	NO	N/A	YES	NO	Connection
31	Successful Strategies for Discharging Medicaid Nursing Home Residents With Mental Health Diagnoses to the Community	Skye Leedahl, Rosemary Chapin, Carrie Wendel, Beth Anne Baca, Leslie Hasche, and Grace Townley	2014	YES	Concurrent (convergent)	NO	YES	Comparison
32	Place Attachment Among Older Adults Living in Four Communities in Flanders, Belgium	Tine Buffel, Liesbeth De Donder, Chris Phillipson, Nico De Witte, Sarah Dury, and Dominique Verté	2014	YES	Explanatory	YES	NO	Connection
33	Beyond Proximity: The Importance of Green Space Useability to Self-Reported Health	May Carter, and Pierre Horwitz	2014	YES	Explanatory	YES	YES	Connection and comparison
34	Exploring the age-friendliness of purpose-built retirement communities: evidence from England	Jennifer Lidle, Thomas Scharf, Bernadette Bartlam, Miriam Bernard, and Julius Sim	2014	NO	N/A	NO	NO	N/A

35	The effect of changing micro-scale physical environmental factors on an environment's invitingness for transportation cycling in adults: an exploratory study using manipulated photographs	Lieze Mertens, Veerle Van Holle, Ilse De Bourdeaudhuij, Benedicte Deforche, Jo Salmon, Jack Nasar, Nico Van de Weghe, Delfien Van Dyck, and Jelle Van Cauwenberg	2014	NO	N/A	NO	NO	N/A
36	Does rapid urbanization aggravate health disparities? Reflections on the epidemiological transition in Pune, India	Mareike Kroll, Erach Bharucha, and Frauke Kraas	2014	NO	N/A	YES	YES	Comparison
37	Addressing Rural Health Disparities Through Policy Change in the Stroke Belt	Stephanie Jilcott Pitts, Tosha Smith, Linden Maya Thayer, Sarah Drobka, Cassandra Miller, Thomas Keyserling, and Alice Ammerman	2013	NO	N/A	NO	NO	N/A
38	Using a Health in All Policies Approach to Address Social Determinants of Sexually Transmitted Disease Inequities in the Context of Community Change and Redevelopment	Holly Avey, Elizabeth Fuller, Jane Branscomb, Karen Cheung, Phillip Jackson Reed, Naima Wong, Michael Henderson, and Samantha Williams	2013	NO	N/A	NO	YES	Comparison
39	Local Health Department Leadership Strategies for Healthy Built Environments	Heather Kuiper, Richard Jackson, Stefi Barna, and William Satariano	2012	NO	N/A	YES	NO	Connection, comparison, and assimilation
40	Using GIS and perceived distance to understand the unequal geographies of healthcare in lower-income urban neighbourhoods	Timothy Hawthorne, and Mei-Po Kwan	2012	NO	N/A	NO	NO	N/A
41	"We Don't Live Outside, We Live in Here": Neighborhood and Residential Mobility Decisions Among Low-Income Families	Peter Rosenblatt, and Stefanie DeLuca	2012	NO	N/A	NO	NO	N/A

42	Kaiser Permanente's Community Health Initiative in Northern California: Evaluation Findings and Lessons Learned	Allen Cheadle, Suzanne Rauzon, Rebecca Spring, Pamela Schwartz, Scott Gee, Esmeralda Gonzalez, Jodi Ravel, Coire Reilly, Anthony Taylor, and Dana Williamson	2012	NO	N/A	NO	NO	N/A
43	Determinants of Neighborhood Activity of Adults Age 70 and Over: A Mixed-Methods Study	Afroditi Stathi, Holly Gilbert, Kenneth Fox, Jo Coulson, Mark Davis, and Janice Thompson	2012	YES	Explanatory	YES	YES	Connection, comparison and assimilation
44	Food Deserts and a Southwest Community of Baltimore City	Jessica Childs, and Laura Lewis	2012	NO	N/A	YES	NO	Assimilation
45	Evaluation of Physical Projects and Policies from the Active Living by Design Partnerships	Kelly Evenson, James Sallis, Susan Handy, Rich Bell, and Laura Brennan	2012	NO	N/A	NO	NO	N/A
46	A University, Community Coalition, and Town Partnership to Promote Walking	Sarah Griffin, Joel Williams, Powell Hickman, Amber Kirchner, and Hugh Spitler	2011	NO	N/A	NO	NO	N/A
47	Mapping and characterising children's daily mobility in urban residential areas in Turku, Finland	Nora Fagerholm, and Anna Broberg	2011	NO	N/A	NO	NO	N/A
48	Hispanic immigrant women's perspective on healthy foods and the New York City retail food environment: A mixed-method study	Yoosun Park, James Quinn, Karen Florez, Judith Jacobson, Kathryn Neckerman, and Andrew Rundle	2011	YES	Convergence	NO	NO	N/A
49	''Food is directed to the area'': African Americans' perceptions of the neighborhood nutrition environment in Pittsburgh	Supriya Kumar, Sandra Quinn, Andrea M. Kriska, and Stephen Thomas	2011	NO	N/A	NO	NO	N/A

50	City Governments and Aging in Place: Community Design, Transportation and Housing Innovation Adoption	Amanda Lehning	2011	YES	Explanatory	YES	NO	Connection

APPENDIX B| SUPPLEMENTARY MATERIAL FOR MANUSCRIPT 2

Table 1B: Reliability of 300-meter segments with segments over 300 meters.

	300-meter with over 300-meter segments	
Item	**Percent agreement**	**Kappa or ICC**
Pedestrian Infrastructure		
Presence of Sidewalks	100	1.00
Sidewalk Continuity	100	1.00
Sidewalk Buffer	100	1.00
Sidewalk Quality	96.9	0.89
Pedestrian Sign/Timer	100	1.00
Pedestrian Crossing Sign	100	1.00
Crosswalk Markings	100	1.00
Benches	96.9	0.89
Streetlights	96.9	0.96
Curb Cuts	100	1.00
Curb Cut Quality	100	1.00
Tactile Paving	100	1.00
Traffic Calming and Streets		
Traffic Lights	100	1.00
Traffic Island	100	1.00
Stop Lines	100	1.00
Stops Signs	100	1.00
Curb Extension	100	N/A
Speed Bump	100	1.00
Bollards	100	N/A
Number of Traffic Lanes	100	1.00
Number of Parking Lanes	100	1.00
Driveways	87.5	0.75
Building Characteristics		
Building Height	93.8	0.85
Building Setback	90.6	0.80
Building Design Variation	90.6	0.803
Transit		
Presence of Transit	100	1.00
Type of Transit	100	1.00
Transit Facilities	96.9	0.90
Bicycling Infrastructure		
Bike Lanes	96.9	0.87

Bike Buffer	96.9	0.65
Bike Facilities	100	1.00
Aesthetics		
Presence of Trees	84.4	0.71
Shade	96.9	0.94
Nature Areas	100	1.00
Landscaping	96.9	0.93
Landscape Maintenance	96.9	0.93
Presence of Litter	100	1.00
Graffiti	100	1.00
Broken/Boarded Windows	100	1.00
Attractive Segment	96.9	0.96

Table 2B: Prevalence of built environment features in the selected street segments.

	GSV vs field				Inter-rater			
	GSV	**% or mean(SD)**	**Field**	**% or mean(SD)**	**Rater 1**	**% or mean(SD)**	**Rater 2**	**% or mean(SD)**
Pedestrian Infrastructure								
Presence of Sidewalks								
Absent	7	17.95	7	17.95	28	47.46	27	45.76
Present - 1 side	3	7.69	3	7.69	6	10.17	6	10.17
Present - Both sides	29	74.36	29	74.36	25	42.37	26	44.07
Sidewalk Continuity								
Absent	10	25.64	12	30.77	30	50.85	33	55.93
Present	29	74.36	27	69.23	29	49.15	26	44.07
Sidewalk Buffer								
Absent	38	97.44	38	97.44	59	100	59	100
Present	1	2.56	1	2.56	0	0	0	0
Sidewalk Maintenance								
Absent	23	58.97	22	56.41	39	66.1	38	64.41
Present	16	41.03	17	43.59	20	33.9	21	35.59
Pedestrian Sign/Timer								
Absent	34	87.18	34	87.18	57	96.6	57	96.6
Present	5	12.82	5	12.82	2	3.3	2	3.3
Pedestrian Crossing Sign								
Absent	36	92.31	33	84.62	55	93.2	58	98.3
Present	3	7.69	6	15.38	4	6.78	1	1.69
Crosswalk Markings								
Absent	20	51.28	19	48.72	46	77.97	44	74.58
Present	19	48.72	20	51.28	13	22.03	15	25.42
Benches								
Absent	29	74.36	29	74.36	53	10.17	52	11.86

Present	10	25.64	10	25.64	6	89.83	7	88.14
Streetlights								
None	3	7.69	1	2.56	9	15.25	8	13.56
Some	22	56.41	14	35.9	25	42.37	32	54.24
Many	14	35.9	24	61.54	25	42.37	19	32.2
Curb Cuts								
Absent	9	23.08	8	20.51	28	52.54	31	47.46
Present	30	76.92	31	79.49	31	47.46	28	52.54
Curb Cut Quality								
Poor	37	94.87	35	89.74	54	91.53	58	98.31
Good	2	5.13	4	10.26	5	8.47	1	1.69
Tactile Paving								
Absent	10	25.64	9	23.08	37	37.29	31	47.46
Present	29	74.36	30	76.92	22	62.71	28	52.54
Traffic Calming								
Traffic Lights								
Absent	32	82.05	32	82.05	54	91.5	54	91.5
Present	7	17.95	7	17.95	5	8.5	5	8.5
Traffic Island								
Absent	35	89.74	36	92.31	49	16.95	52	11.86
Present	4	10.26	3	7.69	10	83.05	7	88.14
Stop Lines								
Absent	13	33.33	13	33.33	37	37.29	36	38.98
Present	26	66.67	26	66.67	22	62.71	23	61.02
Stops Signs								
Absent	14	35.9	14	35.9	14	23.72	16	27.12
Present	25	64.1	25	64.1	45	76.27	43	72.88
Curb Extension								
Absent	38	97.44	37	94.87	57	96.61	58	98.31
Present	1	2.56	2	5.13	2	3.39	1	1.69
Speed Bump								
Absent	38	97.44	37	94.87	58	98.31	57	96.61
Present	1	2.56	2	5.13	1	1.69	2	3.39
Bollards								
Absent	36	92.31	35	89.74	58	98.31	59	100
Present	3	7.69	4	10.26	1	1.69	0	0
Driveways								
None	9	23.08	8	20.51	8	13.56	6	10.17
Some	14	35.9	13	33.33	21	35.59	21	35.59
Many	16	41.03	18	46.15	30	50.85	32	54.24
Number of Traffic Lanes	39	1.92(0.81)	39	1.92 (0.81)	59	2.00(0.59)	59	2.03(0.67)
Number of Parking Lanes	39	1.15(0.74)	39	1.03(0.84)	59	1.10(0.82)	59	0.93(0.72)

Building Characteristics								
Building Height								
N/A	1	2.56	2	5.13	3	5.08	3	5.08
1-2 Stories	17	43.59	16	41.03	42	71.19	40	67.8
3-5 Stories	14	35.9	15	38.46	11	18.64	14	23.73
6 + Stories	7	17.95	6	15.38	3	5.08	2	3.39
Building Setback								
N/A	2	5.13	2	5.13	3	5.08	3	5.08
0m	4	10.26	3	7.69	7	11.86	5	8.47
0-3m	6	15.38	7	17.95	2	3.39	7	11.86
3-10m	19	48.72	19	48.72	29	49.15	26	44.07
>10m	8	20.51	8	20.51	17	28.81	18	30.51
Building Design Variation								
N/A	1	2.56	2	5.13	3	5.08	3	5.08
None	5	12.82	5	12.82	0	0	3	5.08
Some	25	64.1	24	61.54	47	79.66	37	62.71
A lot	8	20.51	8	20.51	9	15.25	16	27.12
Transit								
Presence of Transit								
Absent	32	82.05	32	82.05	53	10.17	52	11.86
Present	7	17.95	7	17.95	6	89.83	7	88.14
Type of Transit								
N/A	32	82.05	32	82.05	53	89.83	52	88.14
Bus/tram	6	15.38	7	17.95	5	8.47	6	10.17
Metro	1	2.56	0	0	1	1.69	1	1.69
Train	0	0	0	0	0	0	0	0
Transit Facilities								
N/A	32	82.05	32	82.05	53	89.83	52	88.14
Bench or shelter	2	5.13	2	5.13	1	1.69	1	1.69
Both	3	7.69	3	7.69	3	5.08	3	5.08
None	2	5.13	2	5.13	2	3.39	3	5.08
Bicycling Infrastructure								
Bike Lanes								
Absent	32	82.05	31	79.49	53	89.83	52	88.14
Present	7	17.95	8	20.51	6	10.17	7	11.86
Bike Buffer								
Absent	38	97.44	38	97.44	58	98.31	58	98.31
Present	1	2.56	1	2.56	1	1.69	1	1.69
Bike Facilities								
Absent	30	76.92	30	76.92	53	89.83	53	89.83
Present	9	23.08	9	23.08	6	10.17	6	10.17
Aesthetics								
Presence of Trees								

None	1	2.56	1	2.56	3	5.08	5	8.47
Few	8	20.51	7	17.95	6	10.17	3	5.08
Some	22	56.41	19	48.72	17	28.81	35	59.32
Many	8	20.51	12	30.77	33	55.93	14	23.73
Shade								
Absent	25	64.1	25	64.1	12	79.66	40	32.2
Present	14	35.9	14	35.9	47	20.34	19	32.2
Nature Areas								
Absent	27	69.23	22	56.41	35	59.32	34	57.63
Present	12	30.77	17	43.59	24	40.68	25	42.37
Softscape Features								
None	1	2.56	0	0	0	0	0	0
Some	13	33.33	19	48.72	21	35.59	32	54.24
Many	25	64.1	20	51.28	38	64.41	27	45.76
Softscape Maintenance								
Absent	5	12.82	3	7.69	7	11.86	9	15.25
Present	34	87.18	36	92.31	52	88.14	50	84.75
Presence of Litter								
None	13	33.33	12	30.77	25	42.37	18	30.51
Some	24	61.54	25	64.1	27	45.76	38	64.41
Many	2	5.13	2	5.13	7	11.86	3	5.08
Graffiti								
None	28	71.79	24	61.54	45	76.27	47	79.66
Some	9	23.08	12	30.77	11	18.64	10	16.95
A lot	2	5.13	3	7.69	3	5.08	2	3.39
Broken/Boarded Windows								
Absent	37	94.87	32	82.05	58	98.31	59	100
Present	2	5.13	7	17.95	1	1.69	0	0
Attractive Segment								
Unattractive	11	28.21	12	30.77	13	22.03	11	18.64
Neutral	9	23.08	12	30.77	24	40.68	12	20.34
Attractive	19	48.72	15	38.46	22	37.29	36	61.02

Question 1C: Self-selection Questions

The phrasing of the question and 11 of the 19 items were from the Neighborhood Quality of Life Study. We added additional items to capture aspects of the micro-scale environment that were not included in the original question.

Please rate on a 1-5 scale how important each of the following reasons was in your decision to move to your neighborhood. For each reason please choose a number between 1 and 5, where 1=not at all important and 5=very important.

	Not at all important 1	2	Somewhat important 3	4	Very important 5	Prefer not to answer (99)
1. Affordability/Value	◯	◯	◯	◯	◯	◯
2. Closeness to open space (e.g., parks)	◯	◯	◯	◯	◯	◯
3. Closeness to job or school	◯	◯	◯	◯	◯	◯
4. Closeness to public transportation	◯	◯	◯	◯	◯	◯
5. Desire for nearby shops and services	◯	◯	◯	◯	◯	◯
6. Ease of walking	◯	◯	◯	◯	◯	◯
7. Ease of biking	◯	◯	◯	◯	◯	◯
8. Sense of community	◯	◯	◯	◯	◯	◯
9. Safety from crime	◯	◯	◯	◯	◯	◯
10. Quality of schools	◯	◯	◯	◯	◯	◯
11. Closeness to recreational facilities	◯	◯	◯	◯	◯	◯
12. Access to freeways	◯	◯	◯	◯	◯	◯
13. Presence of nature (e.g., trees, water)	◯	◯	◯	◯	◯	◯

14. Attractiveness of the neighborhood (e.g., landscaping, upkeep)	○	○	○	○	○	○
15. Pedestrian infrastructure (e.g., sidewalks, curb cuts, pedestrian crossing signs, cross walk markings)	○	○	○	○	○	○
16. Traffic calming infrastructure (e.g., traffic lights, stop signs, curb extensions, speed bumps, bollards)	○	○	○	○	○	○
17. Bicycling infrastructure (e.g., bike lanes)	○	○	○	○	○	○
18. Characteristics of the buildings (e.g., building height, building design)	○	○	○	○	○	○
19. Other: ________	○	○	○	○	○	○

Question 2C: Walking for Leisure

Now we are interested in knowing about any physical activity you do for exercise or leisure. In the past week, have you done any of the following types of physical activity for exercise or leisure?

Do NOT report any walking or running you did to go to and from places, such as walking to work, school, or for shopping.

Please choose all that apply:

❑ Walking my dog (1)
❑ Walking for leisure or exercise outdoors (without my dog) (2)
❑ Walking for leisure or exercise outdoors (3)
❑ Walking for leisure or exercise in indoor facilities (e.g.: gym, recreation centre, shopping mall, etc.) (4)
❑ Running for leisure or exercise (5)
❍ I didn't do any walking or running for leisure or exercise (6)
❍ Prefer not to answer (99)

Question 3C: Walking to Work

Now we are interested in knowing about any transport you do for work, on days when you work outside of home. In a typical week, which of the following type(s) of transport do you use to get to and/or from work?

Only include types of transport you used for more than 10 minutes for any trip.

For example, if to get to work you drive on some days and the other days you walk at least ten minutes to get to the metro and then take the metro the rest of the way to work, "choose" drive, walk, and metro.

❑ Walk (1)
❑ Bicycle (2)
❑ Jog or run (3)
❑ Commuter train (e.g. RTM, GO Train) (4)
❑ Metro, Subway, or Rapid Transit (6)
❑ Streetcar (8)
❑ Bus (e.g. STM, STL, RTL, TTC, York Region Transit, Miway) (9)

- ❑ Car: I am the driver (11)
- ❑ Car: I am a passenger (e.g., carpool, taxi, etc.) (12)
- ❑ Other specify: (13)____________
- ❍ I only work from home
- ❍ Prefer not to answer (99)

Question 3C: Walking to School

Now we are interested in knowing about any transport you do for school, on days when you go to school. In a typical week, which of the following types of transport do you use to get to and/or from school?

Only include types of transport you used for more than 10 minutes for any trip.

For example, if to get to school you drive on some days and the other days you walk at least ten minutes to get to the metro and then take the metro the rest of the way to school, "choose" drive, walk, and metro.

Please choose all that apply:

- ❑ Walk (1)
- ❑ Bicycle (2)
- ❑ Jog or run (3)
- ❑ Commuter train (e.g. RTM, GO Train) (4)
- ❑ Metro, Subway, or Rapid Transit (6)
- ❑ Streetcar (8)
- ❑ Bus (e.g. STM, STL, RTL, TTC, York Region Transit, Miway) (9)
- ❑ Car: I am the driver (11)
- ❑ Car: I am a passenger (e.g., carpool, taxi, etc.) (12)
- ❑ Other specify: (13)____________
- ❍ I only take classes from home
- ❍ Prefer not to answer (99)

Question 4C: Walking for Shopping, Eating out, to run Errands, or for Personal reasons

In a typical week, do you use any of the following types of transport to go somewhere for SHOPPING, EATING OUT, to run ERRANDS, or for PERSONAL reasons?

Only include types of transport you used for more than 10 minutes for any trip.

Please choose all that apply:

- ❑ Walk (1)
- ❑ Bicycle (2)
- ❑ Jog or run (3)
- ❑ Commuter train (e.g. RTM, GO Train) (4)
- ❑ Metro, Subway, or Rapid Transit (6)
- ❑ Streetcar (8)
- ❑ Bus (e.g. STM, STL, RTL, TTC, York Region Transit, Miway) (9)
- ❑ Car: I am the driver (11)
- ❑ Car: I am a passenger (e.g., carpool, taxi, etc.) (12)
- ❑ Other specify: (13)____________
- ❍ Prefer not to answer (99)

Table 1C: Formula for the computation of each item score in the Virtual-STEPS tool.

Item	Formula
<u>Pedestrian Infrastructure</u>	
Presence of Sidewalks Score	(1*proportion of segments with sidewalks present on two sides) + (0.5*proportion of segments with sidewalks present on one side) + (0*proportion of segments with sidewalks present on no sides)
Sidewalk Continuity Score	(1*proportion of sidewalks that are continuous) + (0*proportion of sidewalks that are not continuous)
Sidewalk Buffer Score	(1*proportion of segments with sidewalks that have a buffer) + (0*proportion of segments with sidewalks that do not have a buffer)
Sidewalk Maintenance Score	(1*proportion of sidewalks that are maintained) + (0*proportion of sidewalks that are not maintained)
Sidewalk Total Score	Presence of sidewalks score + sidewalk continuity score + sidewalk buffer score + sidewalk maintenance score
Pedestrian Sign/Timer Score	(1*proportion of segments with a pedestrian sign/timer) + (0*proportion of segments without a pedestrian sign/timer)
Pedestrian Crossing Sign Score	(1*proportion of segments with a pedestrian crossing sign) + (0*proportion of segments without a pedestrian crossing sign)
Cross Walk Markings Score	(1*proportion of segments with crosswalk markings) + (0*proportion of segments without crosswalk markings)
Pedestrian Crossing Infrastructure Score	Pedestrian sign/timer score + pedestrian crossing sign score + cross walk markings score
Benches Score	(1*proportion of segments with benches) + (0*proportion of segments without benches)
Streetlights Score	(1*proportion of segments with many streetlights) + (0.5*proportion of segments with some streetlights) + (0*proportion of segments with zero street lights)
Curb Cuts Presence Score	(1*proportion of segments with curb cuts) + (0*proportion of segments without curb cuts)
Curb Cut Quality Score	(1*proportion of segments with good curb cut quality) + (0*proportion of segments without good curb cut quality)
Tactile Paving Score	(1*proportion of segment with curb cuts with tactile paving) + (0*proportion of segments without curb cuts with tactile paving)
Curb Cut Score	Curb cut presence score + curb cut quality score + curb cut tactile paving score

Pedestrian Infrastructure Score Total	(0.5*sidewalk total score) + (0.66*pedestrian crossing infrastructure score) + (2*benches Score) + (2*streetlight score) + (0.66*curb cuts score)
Traffic Calming	
Traffic Lights Score	(1*proportion of segments with traffic lights) + (0*proportion of segments without traffic lights)
Traffic Island Score	(1*proportion of segments with traffic islands) + (0*proportion of segments without traffic islands)
Stop Lines Score	(1*proportion of segments with stop lines) + (0*proportion of segments without stop lines)
Stops Signs Score	(1*proportion of segments with stop signs) + (0*proportion of segments without stop signs)
Curb Extension Score	(1*proportion of segments with curb extensions) + (0*proportion of segments without curb extensions)
Speed Bump Score	(1*proportion of segments with speed bumps) + (0*proportion of segments without speed bumps)
Bollards Score	(1*proportion of segments with bollards) + (0*proportion of segments without bollards)
Number of types of traffic calming devices	
2+	(1*proportion of segments with two or more types of traffic calming devices) + (0*proportion of segments with less than two types of traffic calming device)
3+	(1*proportion of segments with three or more types of traffic calming devices) + (0*proportion of segments with less than three types of traffic calming device)
Number of traffic lanes	
3+	(1*proportion of segments with three or more traffic lanes) + (0*proportion of segments with less than three traffic lanes)
4+	(1*proportion of segments with four or more traffic lanes) + (0*proportion of segments with less than four traffic lanes)
Number of parking lanes	
1	(1*proportion of segments with one or more parking lanes) + (0*proportion of segments with less than one parking lane)
2	(1*proportion of segments with one or more parking lanes) + (0*proportion of segments with less than one parking lane)
Total Number of Lanes Score	
3+	(1*proportion of segments with three or more total lanes) + (0*proportion of segments with less than three total lanes)
4+	(1*proportion of segments with four or more total lanes) + (0*proportion of segments with less than four total lanes)
Driveways Score	(1*proportion of segments with many driveways) + (0.5*proportion of segments with some driveways) + (0*proportion of segments with no driveways)

Traffic Calming Score	(10*((1-proportion of segments with four or more total lanes) + (1- driveways score) + (proportion of segments with three or more traffic calming devices)))/3
Building Characteristics	
Building Height Score	(1* proportion of segments with buildings that are six or more stories tall) + (0.5*proportion of segments with buildings that are three to five stories tall) + (0*proportion of segments with buildings that are less than 3 stories)
Building Setback Score	(1*proportion of segments with a building setback over ten meters) + (0.66 *proportion of segments with a building setback greater than three, but less than or equal to ten meters) + (0.33*proportion of segments with a building setback greater than zero, but less than or equal to three) + (0*proportion of segments with a building setback of zero meters)
Building Design Variation Score	(1* proportion of segments with a lot of building design variation) + (0.5*proportion of segments with some building design variation) + (0* proportion of segments with no building design variation)
Building Characteristics Score	(10*(building height score+(1-building setback score) + building design score))/3
Aesthetics	
Presence of Trees Score	(1*proportion of segments with many trees) + (0.66*proportion of segments with some trees) + (0.33*proportion of segments with few trees) + (0*proportion of segments with no trees)
Nature Areas Score	(1* proportion of segments with nature areas) + (0*proportion of segments without nature areas)
Landscaping Score	(1*proportion of segments with a lot of landscaping) + (0.5* proportion of segments with some landscaping) + (0*proportion of segments with no landscaping)
Landscape Maintenance Score	(1*proportion of segments with maintained landscaping) + (0* proportion of segments with landscaping that is not maintained)
Landscaping Score	Landscaping score + landscape maintenance score
Presence of Litter Score	(1*proportion of segments with a lot of litter) + (0.5*proportion of segments with some litter) + (0*proportion of segments with no litter)
Graffiti Score	(1*proportion of segments with a lot of graffiti) + (0.5*proportion of segments with some graffiti) + (0*proportion of segments with no graffiti)
Broken/Boarded Windows Score	(1*proportion of segments with broken/boarded windows) + (0*proportion of segments without broken/boarded windows)
Social Disorder Score	Presence of litter score + graffiti score + broken/boarded windows score
Attractive Segment Score	(1*proportion of segments that are attractive) + (0.5*proportion of segments that are neutral) + (0*proportion of segments that are unattractive)
Aesthetics Score	10*((presence of trees score) + (nature areas score) + (attractive segment score) + (0.5*landscaping score) + (1-graffiti score) + (1-litter score) + (1-broken windows score)/7

Table 2C: Sociodemographic and neighborhood characteristics of the participants that dropped out of the study after wave 1.

	N	**% or mean (SD)**
Age	789	45.07 (16.92)
Sex		
Female	432	54.75
Male	355	44.99
Cars	789	1.45 (1.03)
Health issues		
Health problems affect physical activity	423	53.61
No health problems that affect physical activity	305	38.66
Education		
Less than a bachelor's degree	404	51.2
Bachelor's degree	238	30.16
Above bachelor's degree	138	17.49
Dog owner		
Yes	201	25.48
No	586	74.27
Micro-scale score	789	18.57 (2.12)
Walkscore	789	56.52 (23.98)
≥150 minutes per week of leisure walking		
Yes	241	30.5
No	543	68.82
≥150 minutes per week of utilitarian walking		
Yes	184	23.32
No	597	75.67

Table 3C: Descriptive statistics by neighborhood strata for participants (n=1,342) that participated in both waves of the survey and did not move into a new forward sortation area between wave 1 and wave 2.

	Neighborhood Strata			
	High walking/High walkability	**High walking/Low walkability**	**Low walking/High walkability**	**Low walking/Low walkability**
	N or mean (SD)	**N or mean (SD)**	**N or mean (SD)**	**N or mean (SD)**
Age	49.56(16.13)	57.87 (15.91)	51.62 (16.54)	56.07 (16.39)
Sex				
Female	173	187	172	148
Male	160	162	166	174
Cars	0.58 (0.70)	1.57 (0.93)	1.48 (0.90)	1.76 (0.91)
Health issues				
No health problems that affect physical activity)	184	170	169	171
Health problems affect physical activity	129	170	144	136
Education				
Less than a bachelor's degree	136	220	203	206
Bachelor's degree	105	78	83	77
Above bachelor's degree	89	50	50	37
Dog owner				
Yes	42	86	68	82
No	288	263	268	240
Residential self-selection	3.90 (0.74)	3.87 (0.81)	3.77(0.81)	3.76 (0.87)
Grand micro-scale score	21.30 (0.74)	17.65 (1.39)	17.74 (1.06)	16.52 (1.77)
Pedestrian infrastructure section score	5.56 (0.61)	3.44 (1.31)	4.28 (1.07)	2.51 (1.53)
Traffic calming section score	4.26 (0.97)	3.92 (0.75)	3.42 (0.75)	3.89 (0.64)
Building characteristics section score	5.29 (0.94)	2.94 (0.72)	2.99 (0.44)	2.70 (0.39)
Aesthetics section score	6.19 (0.77)	7.34 (0.76)	7.03 (0.49)	7.41 (0.58)
Walking for leisure for at least 150 minutes				
Yes	136	114	96	86
No	195	227	237	233
Walking for utilitarian purposes for at least 150 minutes				
Yes	159	51	60	22
No	174	294	278	300

Table 4C: Multilevel logistic regression models for the relationship between micro-scale characteristics of participants neighborhoods and walking for leisure for at least 150 minutes per week.

	Column A (n=1,324)		Column B (n=1,324)	
	≥150 minutes per week of walking for leisure		≥150 minutes per week of walking for leisure	
Item	**OR**	**95%CI**	**OR**	**95%CI**
Pedestrian infrastructure				
Presence of sidewalks score	0.909	0.736-1.121	0.897	0.726-1.108
Sidewalk buffer score	1.077	0.891-1.302	1.068	0.882-1.293
Sidewalk maintenance score	0.988	0.821-1.189	0.982	0.815-1.182
Pedestrian crossing infrastructure score	1.089	0.923-1.284	1.075	0.911-1.269
Benches score	1.171	0.980-1.398	1.155	0.966-1.381
Streetlights score	0.846	0.719-0.995*	0.841	0.714-0.991*
Curb cuts presence score	0.928	0.762-1.132	0.928	0.762-1.132
Curb cut quality score	1.029	0.890-1.190	1.0315	0.891-1.194
Tactile paving score	1.002	0.845-1.189	0.986	0.831-1.171
Pedestrian infrastructure total score	0.983	0.793-1.218	0.965	0.778-1.198
Traffic calming				
Number of types of traffic calming devices score				
3+	1.067	0.937-1.216	1.062	0.931-1.211
Number of traffic lanes score				
3+	1.006	0.875-1.156	1.013	0.881-1.165
Number of parking lanes score				
1+	0.842	0.739-0.956	0.835	0.732-0.952
Total number of lanes score				
4+	0.958	0.834-1.101	0.958	0.832-1.103
Driveways score	0.925	0.808- 1.06	0.929	0.810-1.065
Traffic calming total score	1.097	0.957-1.256	1.089	0.949-1.249
Building characteristics				
Building height score	1.291	1.068-1.559*	1.291	1.068-1.561*
Building setback score	0.9198	0.756-1.120	0.906	0.7438-1.104
Building design variation score	0.952	0.840-1.077	0.951	0.840-1.077
Building characteristics total score	1.188	0.968-1.457	1.197	0.975-1.469
Aesthetics				
Presence of trees score	1.061	0.935-1.204	1.054	0.929-1.197
Nature areas score	1.122	0.985-1.277	1.136	0.997-1.296
Landscaping score	1.043	0.898-1.212	1.043	0.897-1.213
Landscape maintenance score	1.063	0.936-1.208	1.062	0.933-1.208
Presence of litter score	0.786	0.668-0.926*	0.782	0.664- 0.922*
Graffiti score	1.059	0.877- 1.279	1.058	0.875- 1.279
Social disorder score	0.896	0.735- 1.093	0.889	0.729- 1.085
Attractive segment score	1.199	1.024- 1.404*	1.205	1.029- 1.412*
Aesthetics total score	1.223	1.028-1.456*	1.232	1.034-1.468*

Micro-scale score	1.143	1.041-1.256*	1.14	1.037-1.253*

Each row is an individual model. Column A adjusted for age, gender, education, dog owner, neighborhood income, city, physical or mental health issues that could prevent individuals from being physically active, and the Walkscore. Column B adjusted for all covariates from A and self-selection.
*p<0.05

Table 5C*:* Multilevel logistic regression models for the relationship between micro-scale characteristics of participants neighborhoods and walking for transport for at least 150 minutes per week.

	Column A (n=1338)		Column B (n=1338)	
	≥150 minutes per week of walking for transport		≥150 minutes per week of walking for transport	
Item	**OR**	**95%CI**	**OR**	**95%CI**
Pedestrian infrastructure				
Presence of sidewalks score	0.840	0.640-1.100	0.830	0.632-1.090
Sidewalk buffer score	0.918	0.741-1.137	0.910	0.734-1.130
Sidewalk maintenance score	0.798	0.632-1.009	0.793	0.626-1.004
Pedestrian crossing infrastructure score	0.902	0.756-1.077	0.892	0.747-1.065
Benches score	0.955	0.796-1.147	0.947	0.787-1.138
Streetlights score	0.840	0.682-1.035	0.845	0.684-1.043
Curb cuts presence score	0.896	0.691-1.161	0.883	0.681-1.146
Curb cut quality score	0.999	0.856-1.167	1.002	0.857-1.171
Tactile paving score	0.920	0.740-1.144	0.907	0.729-1.128
Pedestrian infrastructure total score	0.790	0.602-1.037	0.779	0.593-1.024
Traffic calming				
Number of types of traffic calming devices score				
3+	0.983	0.853-1.133	0.978	0.848-1.128
Number of traffic lanes score				
3+	0.859	0.743-0.993*	0.866	0.748-1.003
Number of parking lanes score				
1+	0.891	0.755-1.050	0.886	0.750-1.048
Total number of lanes score				
4+	0.865	0.738-1.014	0.868	0.739-1.020
Driveways score	0.988	0.842-1.159	1.002	0.852-1.179
Traffic calming total score	1.042	0.897-1.210	1.024	0.879-1.192
Building characteristics				

Building height score	1.053	0.864-1.283	1.051	0.861-1.282
Building setback score	1.104	0.879-1.389	1.077	0.855-1.357
Building design variation score	1.009	0.870-1.171	0.999	0.861-1.160
Building characteristics total score	0.988	0.789-1.239	0.995	0.792- 1.249
Aesthetics				
Presence of trees score	1.008	0.875-1.161	0.995	0.864-1.147
Nature areas score	1.147	0.973-1.352	1.156	0.979-1.366
Landscaping score	1.110	0.944-1.305	1.104	0.938-1.299
Landscape maintenance score	0.977	0.843-1.133	0.977	0.842-1.135
Presence of litter score	0.791	0.647-0.966*	0.790	0.646-0.966*
Graffiti score	1.041	0.852-1.271	1.033	0.844-1.263
Social disorder score	0.926	0.746-1.149	0.916	0.738-1.139
Attractive segment score	1.081	0.900-1.298	1.079	0.898-1.297
Aesthetics total score	1.128	0.929-1.370	1.128	0.928-1.371
Micro-scale score	1.014	0.905-1.138	1.006	0.896-1.129

Each row is an individual model. Column A adjusted for age, gender, education, number of cars, neighborhood income, city, physical or mental health issues that could prevent individuals from being physically active, and the Walkscore. Column B adjusted for all covariates from A and self-selection.
*p<0.05

APPENDIX D| SUPPLEMENTARY MATERIAL FOR PREAMBLE 6.1

Table 1D: Prevalence of walking for utilitarian purposes and walking for leisure in the sample of older adults from wave 1 of the internet survey.

	Full sample (n=605)		**Sample without health conditions (n=296)**		**Sample with health conditions (n=284)**	
	n	**%**	**n**	**%**	**n**	**%**
Walking for utilitarian purposes (≥150 minutes per week)						
Yes	100	16.5	61	20.6	37	13.0
No	503	83.1	234	79.1	246	86.62
Walking for leisure (≥150 minutes per week)						
Yes	204	33.7	126	42.6	68	23.9
No	388	64.1	164	55.4	211	74.3

Table 2D: Multilevel logistic regression models of the relationship between micro-scale characteristics of participants neighborhoods and walking for utilitarian purposes for at least 150 minutes per week.

	Model A (n=603): Full sample		
	Walking for utilitarian purposes		
		CI	
Item	**OR**	**Lower limit**	**Upper limit**
<u>Pedestrian Infrastructure</u>			
Presence of Sidewalks Score	1.02	0.66	1.60
Sidewalk Buffer Score	0.61*	0.41	0.91
Sidewalk Maintenance Score	0.87	0.57	1.32
Pedestrian Crossing Infrastructure Score	0.95	0.69	1.30
Benches Score	0.92	0.66	1.27
Streetlights Score	1.02	0.71	1.47
Curb Cuts Presence Score	0.95	0.61	1.48
Curb Cut Quality Score	1.18	0.92	1.52
Tactile Paving Score	1.05	0.73	1.50
Pedestrian Infrastructure Score Total	0.88	0.54	1.42
<u>Traffic Calming</u>			
Number of Types of Traffic Calming Devices Score			
3+	0.77*	0.60	0.99
Number of Traffic Lanes			
3+	0.88	0.68	1.13
Total Number of Lanes Score			
4+	0.91	0.70	1.18
Driveways Score	0.85	0.65	1.10
Traffic Calming Score Total	1.05	0.81	1.37
<u>Building Characteristics</u>			
Building Height Score	1.07	0.76	1.49
Building Setback Score	0.75	0.52	1.08
Building Design Variation Score	0.98	0.76	1.27
Building Characteristics Score Total	1.20	0.84	1.73

Aesthetics			
Presence of Trees Score	0.82	0.63	1.06
Nature Areas Score	1.21	0.93	1.57
Landscaping Score	0.91	0.69	1.22
Landscape Maintenance Score	0.91	0.72	1.15
Presence of Litter Score	0.67*	0.47	0.95
Graffiti Score	1.30	0.93	1.80
Social Disorder Score	1.06	0.73	1.55
Attractive Segment Score	1.09	0.80	1.48
Aesthetics Score Total	1.00	0.72	1.38
Micro-scale Score Total	1.08	0.69	1.69

Adjusted for age, sex, education, number of cars, city, neighborhood income, physical or mental health conditions that could prevent individuals from being physically active, and the Walkscore

Missing values for education (n=6) and physical or mental health conditions that could prevent individuals from being physically active (n=25) were imputed using multiple imputation with 5 imputations. Sex, age, education, neighborhood income, number of cars, health problems that affect physical activity, and city were used as predictors in the predictor matrix.

APPENDIX E| SUPPLEMENTARY MATERIAL FOR PREAMBLE 7.1

Table 1E: Multilevel logistic regression results for the association between the grand micro-scale environment score and walking for leisure in older adults from areas with a low Walkscore (<50).

	≥150 minutes per week of walking for leisure
	OR(CI)
Micro-scale walkability Score	1.42 (1.09-1.84)
Macro-scale walkability Score	0.83 (0.64-1.07)
Age	0.97 (0.92- 1.02)
Gender (Ref. Female)	
Male	1.07 (0.66-1.73)
Health Problems (Ref. No health problems that affect walking)	
Health problems affect walking	0.38 (0.24-0.61)
Education (Ref. Highschool or below)	
CEGEP or Trade school	1.01 (0.57-1.79)
Bachelor's degree or above	1.41 (0.57- 1.79)
Dog ownership (Ref. Does not own a dog)	
Dog owner	2.40 (1.35-4.27)
Observations	376

APPENDIX F| ETHICS CERTIFICATES

McGill

Research Ethics Board Office
James Administration Bldg.
845 Sherbrooke Street West. Rm 325
Montreal, QC H3A 0G4

Tel: (514) 398-6831

Website: www.mcgill.ca/research/researchers/compliance/human/

Research Ethics Board I
Certificate of Ethical Acceptability of Research Involving Humans

REB File #: 20-0617

Project Title: Urban Policy Prescriptions to Increase Walking: Learning From Highly Walkable Neighbourhoods

Principal Investigator: Prof. Nancy Ross

Department: Geography

Co-investigator(s): Prof. Ahmed El-Geneidy, Madeleine Steinmetz-Wood

Approval Period: **September 21, 2017 to September 20, 2018**

The REB-I reviewed and approved this project by delegated review in accordance with the requirements of the McGill University Policy on the Ethical Conduct of Research Involving Human Participants and the Tri-Council Policy Statement: Ethical Conduct for Research Involving Humans.

Deanna Collin
Ethics Review Administrator, REB I & II

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* Approval is granted only for the research and purposes described.
* Modifications to the approved research must be reviewed and approved by the REB before they can be implemented.
* A Request for Renewal form must be submitted before the above expiry date. Research cannot be conducted without a current ethics approval. Submit 2-3 weeks ahead of the expiry date.
* When a project has been completed or terminated, a Study Closure form must be submitted.
* Unanticipated issues that may increase the risk level to participants or that may have other ethical implications must be promptly reported to the REB. Serious adverse events experienced by a participant in conjunction with the research must be reported to the REB without delay.
* The REB must be promptly notified of any new information that may affect the welfare or consent of participants.
* The REB must be notified of any suspension or cancellation imposed by a funding agency or regulatory body that is related to this study.
* The REB must be notified of any findings that may have ethical implications or may affect the decision of the REB.

McGill

Research Ethics Board Office
James Administration Bldg.
845 Sherbrooke Street West. Rm 325
Montreal, QC H3A 0G4

Tel: (514) 398-6831
Fax: (514) 398-4644
Website: www.mcgill.ca/research/research/compliance/human/

Research Ethics Board 1
Certificate of Ethical Acceptability of Research Involving Humans

REB File #: 187-1019

Project Title: Healthy aging in the neighborhood: exploring the relationship between the suburban environment and mobility in older adults

Principal Investigator: Madeleine Steinmetz-Wood

Department: Geography

Status: Ph.D. Student

Supervisor: Prof. Nancy Ross

Approval Period: **November 18, 2019 to November 17, 2020**

The REB-1 reviewed and approved this project by delegated review in accordance with the requirements of the McGill University Policy on the Ethical Conduct of Research Involving Human Participants and the Tri-Council Policy Statement: Ethical Conduct for Research Involving Humans.

Deanna Collin
Senior Ethics Review Administrator

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* Approval is granted only for the research and purposes described.
* Modifications to the approved research must be reviewed and approved by the REB before they can be implemented.
* A Request for Renewal form must be submitted before the above expiry date. Research cannot be conducted without a current ethics approval. Submit 2-3 weeks ahead of the expiry date.
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* The REB must be notified of any findings that may have ethical implications or may affect the decision of the REB.