Walkability and Healthy Aging in Place for Older Adults in Edmonton, Alberta

by

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Abstract

Background: Abundant evidence links the built environment (BE) and physical activity levels in older adults. Yet, the relationship of BE and other domains that are conducive for healthy aging and aging in place, have been insufficiently studied. This study investigated the relationship of macro-level neighbourhood walkability characteristics and older adults' ability to "age healthily in place" as indicated by sense of belonging, sense of agency, physical functioning, and self-reported health (SRGH), with purposive walking mediating the relationships.

Methods: Data from 213 community-dwelling older adults were collected from the Edmonton region in the winter season. Walk Score was used to assess neighbourhood walkability, IPAQ for purposive walking, Social Provisions Scale (SPS) for belonging, Personal Agency Scale for agency, PF-10 for physical functioning, and 1-item SRGH measure for health. Mediation analyses with ordinal logistic regressions were conducted to examine the association of neighbourhood walkability, purposive walking, and these outcomes.

Results: Macro-level walkability was not associated with belonging, physical functioning, or self-rated general health. There was a very small effect size for walkability on agency (OR = 0.98). Moreover, walkability was not associated with purposive walking. Purposive walking was also not associated with any of the criterion variables when adjusting for covariates.

Conclusion: Walkability was not associated with purposive walking and healthy aging components for older adults in Edmonton, Canada. Other factors may account for our findings and warrants further investigation regarding walking and healthy aging for seniors in automobile-oriented winter cities. In particular, attitudes and age-related changes in neighbourhood preference may provide insights to the unique findings of this study.

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List of Abbreviations

Aging in place	AIP
Built environment	BE
Comparative self-rated health	C-SRH
Healthy aging in place	HAIP
Moderate-to-vigorous physical activity	MVPA
Physical functioning	PF
Self-rated general health	SRGH
Street Smart Walk Score	SSWS
World Health Organization	WHO

Chapter 1: Introduction

The older adult population is growing at a staggering rate around the world, and the increasing burden of chronic non-communicable diseases in this population is a global concern (Suzman & Beard, 2011). Much of the issue can be attributed to the increasing disability and dependency of this population that must be addressed through sustainable interventions. Since seniors carry out most of their daily activities at home and their immediate outdoor environment (Oswald, Hieber, Wahl, & Mollenkopf, 2005), their neighbourhood environment has a major impact on their health and well-being. With healthy aging being a global topic of discussion, the WHO has called for an age-friendly world through the creation of age-friendly communities (AFC). Such communities increase accessibility and inclusivity for older people by adapting the built environment, which is the "external physical environment where we live, work study, and play" (Tam, 2018, p. 6), and services to the different needs and capacities of the aging population (WHO, 2007). In the WHO's guide for global age-friendly cities (WHO, 2007), the condition and availability of built environment features such as walkways, pavements, outdoor seating, ramps, and railings on stairs are recognized in playing a vital role in the active aging of seniors. By indirectly influencing individual factors through environmental interventions, the functional ability of seniors may be enhanced to permit them to age healthily in their own homes.

A major goal of aging in place and healthy aging for community-dwelling seniors is independently and comfortably living in one's own home (WHO, 2015). In the northern city of Edmonton, Canada, a survey indicated that 82% of seniors desire to stay at home, but the proportion of seniors who reported the likelihood of staying in their own homes at each subsequent decade of age decreases substantially (City of Edmonton, 2016). In this survey, 78% of seniors expected to remain at home in their 70s, 62% in their 80s, and 36% in their 90s. Based on these results, healthy aging and aging in place need to be addressed by targeting the human-made environment to support both lifestyle recommendations as well as the functional ability of seniors in our communities.

An abundance of urban planning and health research has indicated positive associations between neighbourhood walkability and physical activity levels, specifically walking (Barnett et al., 2017; Farkas, Wagner, Nettel-Augirre, Friedenreich, & McCormack, 2019). Both macro-level (i.e., mixed land use, street connectivity, and residential density) and street-level (i.e., pedestrian infrastructure, green space) walkability features have been associated with greater walking levels among people of all ages (Mirzaei, Kheyroddin, Behzadfar, & Mignot, 2018; Procter-Gray et al., 2015), with most of these studies having macro-level neighbourhood characteristics as the central focus. Notwithstanding, the relationship of these macro-level walkability features and important domains that allow older adults to live independently – namely, sense of belonging, agency, and physical functioning – are insufficiently studied. This thesis aims to address this gap. By better understanding the relationship of macro-level walkable characteristics and these essential domains for healthy aging, both policymakers and residents can make informed and active choices in creating and choosing health conducive environments to support our older adult population.

Chapter 2: Literature Review

To better understand the current state of the literature on aging and the built environment, a literature review on these topics were conducted. Databases searched include: Pubmed, MEDLINE, Web of Science, PsycINFO, CINAHL Plus, DynaMed, JSTOR, and Scopus. Databases were searched for relevant literature with a combination of the keywords: “built environment”, “walkability”, “physical activity”, “walking”, “older adults”, “seniors”, “winter”, “belonging”, “agency”, “physical functioning”, and “health”. In addition to peer-reviewed articles, relevant grey literature from the City of Edmonton, Government of Canada, Statistics Canada, Public Health Agency of Canada (PHAC), and World Health Organization (WHO) was examined. Current findings on the literature are summarized below and provide rationale for the need of my study.

Advanced Aging – A Concern Across the Globe

Developed countries are experiencing a steadily increasing senior population as the baby-boom generation ages (Toepoel, 2013). In the last decade, and for the first time in history, Canada’s population of seniors now exceeds the number of children in the country (Statistics Canada, 2017b). Canadian seniors accounted for 16.9% of the total population in 2016 and this percentage is expected to increase to 24% by 2036 (Puxty et al., 2019). The report from Statistics Canada (2017b) further highlights the difference between current Canadian lifespan and that of Canadians in 1871. Life expectancy in 1871 was 40 years and one in three Canadians would age to 65 while current Canadian life expectancy is over 82 years and nine in ten are expected to live to 65 years of age.

Other countries including the USA, Australia, New Zealand, and Japan have also experienced a surge in life expectancy of about 30 years in the 20th century (Christensen, Doblhammer, Rau, & Vaupel, 2008). This lengthening of life expectancy can be attributed to the advances in housing, income, nutrition, education, sanitation, and medicine (Oeppen & Vaupel, 2002). Improvements in the field of medicine, such as medical technology and antibiotics, also had a significant impact on life expectancy by reducing early mortality from infectious diseases (Lichtenberg, 2017). In addition to advances in medicine, historical analysis of health data supports improvements in social determinants of health and public health interventions, such as sanitation, control of infectious diseases and food safety, as the principal, though publicly undervalued, force in the significant life expectancy increase since the mid-1800s (Lindsay, Merrill, & Hedin, 2014).

At the current rate of aging, the proportion of the world's older adult population is expected to more than double from 2017 to 2050 (United Nations, 2017). A major concern regarding the substantial growth of the senior population revolves around multimorbidity, the co-occurrence of diseases that have an important effect beyond any one particular disease (St John, Tyas, Menec, Tate, & Griffith, 2019). The prevalence and multimorbidity of chronic non-communicable diseases in the aging process, including heart disease, hypertension, arthritis, and diabetes, increase the risk for disability among the older population (Tuckett, Banchoff, Winter, & King, 2017; St John et al., 2019). This observation of increased risk for chronic non-communicable diseases and disability is in line with the "usual aging" process which is age-intrinsic, non-pathological but high-risk to disease and disability, and associated with normal functional decline with progressing age (Rowe & Kahn, 1987; Lu, Pikhart, Sacker, 2019).

On top of the issue of a globally increasing aging population, prevalence of non-communicable diseases, such as heart disease and cancer, is on the rise globally and the leading cause of morbidity and disability (World Health Organization [WHO], 2002; WHO, 2017). Furthermore, progressing age is associated with numerous physiological changes and an increased risk of chronic diseases (WHO, 2015). This interaction of age and increased risk to multimorbidity and disability can lead to "frailty" which is defined in the field of gerontology as "a dynamic state affecting an individual who experiences losses in one or more domains of human functioning (physical, psychological, social) that are caused by the influence of a range of variables and which increases the risk of adverse outcomes" (Gobbens, Luijkx, & van Assen, 2013, p. 85). Frailty has often been associated with progressing age (Fried et al., 2001), as well as a broad range of sociodemographic, physical, biological, lifestyle and psychological factors that can contribute to frailty in community-dwelling seniors (Feng et al., 2017). The state of frailty significantly impacts the functional trajectory of community-dwelling seniors and has been described as a transition state between successful aging, which will be further explored in this literature review, and disability (WHO, 2015; Cesari et al., 2016). Frailty is a major concern as it is not "usual aging" but a status of extreme vulnerability to stressors that expose individuals to a higher risk of adverse outcomes including hospitalization, institutionalization, and mortality (Bilotta et al., 2011; Fried, Ferrucci, Darer, Williamson, & Anderson, 2004; Sánchez-García et al., 2017).

With older people being most susceptible to disease and disability, governments across the world expect increased public expenditure in healthcare and old age pensions (Christensen, McGue, Petersen, Jeune, & Vaupel, 2008). Alongside healthcare costs, governments will be challenged in determining how to balance access, quality and appropriateness of care for older people (Canadian Institute of Health Information, 2016). To address this issue, the WHO has advocated for healthy aging and aging in place such that seniors may experience not only longer life but also better quality of life in the later years of living.

The older population should not be seen as a liability; rather, improving the quality of life for our senior population is a worthwhile goal as this population consists of invaluable members of our society who have and continue to contribute significantly to our communities (WHO, 2015). The health of Canadian seniors is of paramount importance. Seniors remain significant contributors to society as volunteers and caregivers to spouses, family, friends and neighbours, which can aid in a significant reduction in social and health care service costs (Milan & Hamm, 2003). In 2013, 38% of seniors aged 65 to 74 volunteered and contributed on average 231 hours compared to the national average of 156 hours (Sinha, 2015). Canadians in this age group also made donations averaging $715 in 2013 compared to $513 for all Canadians (Canada Mortgage and Housing Corporation, 2018). Also, an increasing number of Canadian seniors remain in the labour force and delay retirement to dampen economic consequences from loss in labour and services that would accompany the demographic shifts between employed and unemployed (Edwards & Mawani, 2006). In 2015, one in five Canadians aged 65 and older participated in the work force (Statistics Canada, 2017a). Additionally, the wealth of their knowledge, experience and skills have also been translated into meaningful involvement in their communities. So, in addition to impacting seniors themselves, there is a need to ensure good health in the later years of life that enables our seniors to continue their significant and well appreciated contributions to our communities.

Policy Responses to Aging Concerns

Healthy Aging

With a demographic shift to an older population, research and policies involving older adults have become more focused on healthy aging and aging in place for community-dwelling older adults. In the aging literature, healthy aging has been used interchangeably with "active aging", "successful aging", "productive aging", or "aging well" (Lu, Pikhart, & Sacker, 2019). Although often used synonymously, these terms have slight variances in definitions. The most widely used definition of successful aging is "a low probability of disease and disease-related disability, high cognitive and physical functional capacity, and active engagement with life" (Rowe and Kahn, 1987). The strengths of this definition rests in the multi-dimensional perspective of aging but has limitations as it excludes individuals with pre-existing health conditions yet have potential for improved health. Productive aging is a less commonly used term given its vague and restrictive definition that emphasizes vitality and active contribution to the community, family, or work (Schulte, Grosch, Scholl, & Tamers, 2019). On the other hand, aging well has been commonly utilized in the aging literature and consists of a variety of definitions. Aging well is multidimensional and has been defined as having good health and the physical autonomy to do things for oneself and to go where one pleases (Bélanger et al., 2018; Bowling, 2007).

Despite the common use of the term "healthy aging", little consensus exists on its definition. In this thesis, the definition of healthy aging will be derived from the WHO (2015): "The process of developing and maintaining the functional ability that enables well-being in older age" (p.28). With functional ability referring to the interaction of individual and environmental characteristics that enable people to do what they value (WHO, 2015), this definition of healthy aging embraces a holistic view on health and is relevant to the senior population. It recognizes the greater likelihood of developing and accumulating comorbid conditions during the aging process and that seniors may still experience health and well-being through meaningful interaction with others and their environment. Additionally, the environment itself can also contribute to the prevention, delay, and management of the chronic diseases of aging. For example, two very important protective factors for prevalent non-communicable diseases are physical activity and healthy diets, and a growing body of evidence is showing these factors to be associated with supportive environmental factors (Task Force on Community Preventive Services, 2005; The Community Guide, 2016). Given the holistic view and consideration of interaction between individuals and their environment, this thesis will use "healthy aging" in place of "aging well".

Focusing on a holistic meaning for health in healthy aging, health and well-being are easily interchanged. In this way, health is also inclusive of happiness, life satisfaction and fulfillment (WHO, 2015). The goal of healthy aging shifts the focus of healthcare and public health from merely life expectancy to also include health expectancy. Health expectancy entails not only the quantity of life but also quality of life as measured by health status and functional ability (Bushnik, Tjepkema, & Martel, 2018). As more people expect longer health spans, there has been an increased interest globally in prioritizing the enabling of older adults to maintain their mobility, independence, and participation while ensuring their physical, psychological and social health (Bowling & Gabriel, 2004). This process of optimizing opportunities for health, participation and security for healthy aging is termed active aging (WHO, 2002). Currently, action to improve health and minimize development of chronic diseases involves moulding individual behaviours, environments, and public policies to support opportunities for healthy living (WHO, 2015).

Healthy aging is a promising goal for society in resolving immediate and future concerns regarding extended lifespan. Although life expectancy has substantially increased in developed countries, older ages are associated with greater disability, chronic diseases, and dependence that limit feelings of health. In 2014, seniors accounted for 46% of healthcare expenditure from all provinces and territories in Canada; the healthcare spending on this age group is expected to increase progressively (Canadian Institute of Health Information, 2016). By appropriately preventing and managing chronic diseases and disability through healthy aging, healthcare spending for seniors can be minimized through "compression of morbidity", the severity reduction and postponement of chronic diseases and disability into later life (Edwards & Mawani, 2006).

Aging in Place

As older adults experience a decline in capacity that accompanies progressing age, they are often required to make transitions in their living environments. These transitions can include adapting to their current residence, modifying their home environments to suit their functional needs, or relocating to more supportive environments (Perry et al., 2014). For older adults, there is a preference to remain in their own homes and avoid relocation (Feldman, Oberlink, Simantov, & Gursen, 2004). This is known as "aging in place" (AIP), which is closely related to the concepts of built environment and healthy aging, and aligns with the wishes of 85% of older Canadians (Canada Mortgage and Housing Corporation, 2015). Additionally, it provides policymakers, city designers, and public health workers an avenue to tackle the key healthcare problems that come with aging.

AIP entails safely, independently, and comfortably living in one's own home for as long as possible (WHO, 2015), and "home" encompasses more than the physical house but also social and symbolic factors such as the neighbourhood and community that fosters a sense of attachment, meaning and security (Oswald, Jopp, Rott & Wahl, 2011). In the aging literature, there are varying conceptions of where one can "age in place". Some literature has emphasized solely on long-term family homes (Barret, Hale, & Gauld, 2012), a familiar surrounding (Houben, 2001), or in the community where individuals can exercise some level of independence excluding residential care (Davey, de Joux, Nana, & Arcus, 2004). Other literature does not explicitly exclude assisted living facilities so long as the place is an accessible dwelling where supportive neighbours and services are available and they are able to receive family and friends (Van Wezemael & Gilroy, 2007). Despite these variations, there is a general consensus that AIP is not compatible with institutionalization (Houben, 2001; Davey et al., 2004). A key component of the AIP concept is *"aging at home"* rather than *"aging in a home"*, with an emphasis on the capacity of the place to become the individual's home, being situated in the community and fulfilling the person's needs (McDermott, Linahan, & Squires, 2009).

AIP is an attainable and worthwhile goal (Vasunilashorn et al., 2012) and should also be considered as "an adaptive process of ongoing person-place transactions over time" (Scharlach & Moore, 2016, p. 420). Prolonging seniors' ability to stay in their residences can offset the demand for long-term care and its associated cost (Scharlach & Lechning, 2012), while allowing seniors to maintain their sense of independence and positive self-image (Rubinstein & Parmelee, 1992). As feelings of sentiment, familiarity and safety develop from living at home, people, particularly seniors, grow attached to and prefer living in their own homes. In a study by Wiles and colleagues (2012) that explored the meaning of AIP in older people, participants voiced the importance of having a choice in where and how they will age in place. Furthermore, the study indicated familiarity, security and a sense of emotional attachment is often brought forth by the community, contacts, and services around the home. Therefore, there is a need to consider transportation, recreational opportunities, amenities for social interaction, physical activity, cultural engagement, and ongoing activity for AIP (Wahl & Weisman, 2003).

Although AIP presents many promising benefits to the older population and society as a whole, policymakers and researchers should be cautious in pushing for AIP. In a review by Vasunilashorn and colleagues (2012), a few studies have described negative experiences of AIP and referred to these experiences as being "stuck in place". Being "stuck in place" implies an individual stay involuntarily due to lack of alternatives to change their living situation and this may be directly or indirectly detrimental to their safety, health, and wellbeing as they age (Scharlach & Diaz-Moore, 2016). These consequences of AIP are often not paid due attention as it often afflicts the minority, particularly those who are female, living alone, economically disadvantaged, have less than high school education, or come from an ethnic minority (Scharlach & Diaz-Moore, 2016; Torres-Gil & Hofland, 2012). These segments of the older adult population will be at higher risk of detrimental outcomes of AIP, including loneliness, social isolation, restricted mobility, and limited access to supports and services (Lehning & Greenfield, 2017).

With many public policies pushing for AIP as the only option in addressing issues surrounding the increasing aging population, Dalmer (2019) describes the choice of AIP as an illusion. This notion contradicts the desire of older adults in having a choice of where and how they will age in place (Wiles et al., 2012). Thus, current AIP concepts that emphasize remaining in one's home for "as long as possible" have evident limitations, not including the potential negative consequences. Recognizing the caveats of the current AIP concept, this thesis will coin a new term "healthy aging in place" that will be further explored. This concept will shift the focus from staying in a long-term family home for as long as possible to the choice in where and how older adults age, as well as the potential for healthy aging in their own homes.

Aiming for Healthy Aging in Place

For older adults to age healthily in their communities, they must experience more than the absence of chronic non-communicable diseases which is often not feasible with progressing age (WHO, 2015). In a study by Bélanger et al. (2018), Canadian older adults described important domains that allowed them to age well, with some of these domains including: health, social relations, self-mastery, and physical functioning (PF). Self-mastery refers to "a general positive attitude towards aging and one's ability to adapt and continue on with meaningful activities despite aging" (Bélanger et al., 2018, p. 860) and will be referred to as sense of agency in this thesis. Recognizing that these domains are also paramount for AIP (Wiles et al. 2012), this thesis takes the domains for aging well together to coin a new term "healthy aging in place" (HAIP) as living in one's own home and community for as long as possible with a sense of belonging, agency, PF, and health. The focus of HAIP should not be on only keeping seniors in their current homes for as long as possible but emphasize the choice and potential of older adults in living in their own homes with comfort, independence, and health, whether that means remaining in their own long-term homes or moving into homes with age-friendly features that would promote prolonged independent living. This recommendation for AIP is crucial as it recognizes the need to minimize relocation into residential care facilities which can be complex and stressful for the elderly (Walker & McNamara, 2013). Additionally, this concept acknowledges the potential of older adults to live in their communities with a degree of independence regardless if they relocate from their long-term family home.

Belonging is the positive and subjective experience that one's environment creates such that "space" is transformed into "place" and "home" (Rowles & Watkins, 2003). Furthermore, belonging is the feeling of attachment, being socially connected, and feeling appreciated and accepted (Jakubec et al., 2019). Closely related to this concept is social isolation and loneliness, which is often associated with a decreased sense of belonging (Medical Advisory Secretariat, 2008). Social isolation refers to objective characteristics such as the lack of meaningful and sustained communication (Wenger et al., 1996), while loneliness is the unpleasant subjective experience when an individual's network of social relationships is perceived to be deficient (Sarason, 2013). For seniors who desire to age in place, belonging is crucial as it can improve their social and physical well-being (Cramm & Nieboer, 2015). Belonging is especially important for older adults as they are vulnerable to decline in social networks from "retirement, loss of loved ones and other relationships, declining health and increasing disability, sensory loss, and mobility restrictions" (Medical Advisory Secretariat, 2008, p. 12).

Agency is the goal-directed behaviours to achieve desired outcomes (Smith et al., 2000). Based on several gerontology studies, reduction in sense of agency has been observed with increasing age (Mirowsky, 1995; Moore, 2016). Additionally, decreased sense of agency has been associated with poor health with the key factor in this relationship being physical impairment (Langer & Rodin 1976; Rodin & Langer, 1977; Mirowsky, 1995; Moore, 2016). Other studies have also shown that restricting senior's control of their actions can have detrimental health consequences, while health may be promoted when agency is enhanced (Rodin, 1986).

PF refers to the physical capacity in functional ability described previously (WHO, 2015) and is essential for HAIP as it relates to the psychophysical well-being and autonomy of older adults (Fave et al., 2018). Related to PF is disability which is defined as “limitation in the capacity to perform a given function” (National Research Council, 2012, p. 63). As the older adult population tends to experience a decline in PF with increasing age (Manini, 2011), this age group has the greatest diversity in PF (WHO, 2015). PF and disability have a reciprocal relationship with health. Health influences PF as the presence of chronic diseases, such as hypertension, diabetes, heart disease, and arthritis, can result in disability (National Research Council, 2012). Similarly, PF can influence health when individuals remain physically active which helps to maintain and promote health (Jantunen et al., 2017).

A Sustainable Intervention – Physical Activity

For HAIP to occur, interventions must target both lifestyle choices and environments that support positive health practices. Lifestyle recommendations by the WHO (2002) include “physical activity, healthy eating, not smoking and using alcohol and medications wisely” (p.22). Physical activity is “any bodily movement produced by contraction of skeletal muscle that increases energy expenditure above the basal level” and should be distinctly recognized from exercise which is “a form of physical activity that is planned, structured, repetitive, and performed with the goal of improving health or fitness” (Piercy et al., 2018, p. 29). According to the National Institutes of Health (NIH) (n. d.), there are four main types of physical activity: aerobic, muscle-strengthening, bone-strengthening, and stretching activities. Aerobic activities, such as brisk walking, running, cycling, and swimming, activate the body’s large muscles in an extended span of time; muscle-strengthening activities involve muscles working or resisting against force through resistance training or weight lifting; bone-strengthening activities enhance bone growth and strength through forces on the bones; stretching activities promote flexibility by increasing the range of motion for the joints (Piercy et al., 2018). In addition to types of physical activity, the intensity of these activities determines health benefits (Piercy et al., 2018). Light-intensity activities are effortless and performed throughout the day; moderate-intensity activities require moderate effort and produces a noticeable increase in heart rate; vigorous-intensity activity requires excessive effort and results in a significant increase in breathing rate and heart rate (NHI, n. d.; WHO, 2020a).

Physical activity has a significant role in ensuring good health while physical inactivity has been a primary cause of chronic diseases and is the fourth leading cause of mortality worldwide (Berger, Lee, & Silver, 2007; Booth, Roberts, & Lave, 2012; Kohl et al., 2012). Moderate-to-vigorous physical activity (MVPA) has been associated with decreased risk of depression and mental disorders (Bernard et al., 2018), diabetes (Gill & Cooper, 2008; Grøntved et al., 2014; Yerramalla et al., 2020), cardiovascular disease (Glazer et al., 2014; Sternfeld et al., 2019), various cancers (Booth et al., 2012), and obesity (Ross et al., 2000; Irwin et al., 2003; Slentz et al., 2005). In Slentz et al. (2005), low amounts of moderate physical activity (equivalent to walking 11 miles per week) prevented increases in visceral fat. Another study by Ross et al. (2000) concluded moderate physical activity through walking reduced body weight and body fat in post-menopausal women. Additionally, MVPA has been noted in reducing symptoms of rheumatoid arthritis (Cairns & McVeigh, 2009). With physical activity as an effective and cost-efficient intervention in the prevention and management of chronic diseases (Abu-Omar et al., 2017), the WHO (2020b) recommends at least 150 minutes of moderate-intensity or 75 minutes of vigorous-intensity aerobic physical activity each week.

As Bauman et al. (2016) described, "[physical activity] is the most important determinant of 'active aging' and has a major role in improving the quality of life, in reducing disability, and in the 'compression of morbidity' in later life" (p. S269). One of the most common forms of moderate-intensity physical activity in the older adult population is walking, given its accessibility and ease (Paul, Carlson, Carroll, Berrigan, & Fulton, 2015). Walking can be categorized as either leisure or purposive walking (Procter-Gray et al., 2015; Mirzaei et al., 2018; Farkas et al., 2019). Purposive walking refers to walking primarily for the purpose of transport to destinations while leisure walking is done specifically for the purpose of fitness, health, or recreation (Hekler, Castro, Buman, & King, 2013). Systematic reviews have confirmed a range of health benefits from walking: positive effects on fitness, weight loss, blood pressure, depression, and cardiovascular disease risk prevention (Hanson & Jones, 2015). Physical activity through walking has also been shown to have benefits in falls, bone density, cognition (including protective effects against dementia), and management and prevention of chronic diseases which are particularly important in seniors (Elsawy & Higgins, 2010). Following these lifestyle recommendations can mitigate functional disability from chronic diseases and allow seniors to age healthily in place and assist in the prevention of these diseases in the first place. It should also be noted that supportive and well-designed residential environments play a crucial role in promoting these sustainable lifestyle changes and hence HAIP (WHO, 2007; Stoeckel & Litwin, 2015; Bjørnarå et al., 2017).

The Built Environment and Health

Healthy aging and AIP go beyond healthcare through acknowledgement that health is a product of not only medical treatments and lifestyle choices but also living conditions known collectively as the social determinants of health (Mikkonen & Raphael, 2010). A modifiable determinant of health that has recently been of considerable interest is the built environment (BE), which constitutes the physical environment where we live, work and play that we design and construct (Frank & Engelke, 2005). The BE can be described as:

> not only green spaces and parks but also the presence and conditions of sidewalks, traffic flow, cleanliness and maintenance of public spaces, perceptions of safety and community security, zoning and land use mix, and population density. It includes underground (eg, watershed) and overhead areas (eg, power lines) … Thus the BE encompasses many things. (Renalds, Smith, & Hale, 2010, p. 68).

Although there are many benefits for those living in cities, including proximity and access to essential services, cities can promote unhealthy lifestyles such as sedentary behaviour and consumption of convenience foods which increases risk for non-communicable chronic diseases and obesity (WHO, 2014; Spence et al., 2009). A globally growing body of evidence indicate that the way cities are designed unequivocally affects health, whether it is the walkability of communities or access to green public spaces (Wolch, Byrne, & Newell, 2014). In an umbrella review by Bird et al. (2018) that examined the relationship between the BE and health, improved neighbourhood walkability features such as street connectivity, mixed-land use and compact residential design was associated with greater physical activity, social engagement and mobility in older adults. Additionally, in the review, better housing quality was also associated with positive general health outcomes. Already, there is an emergence of guidelines for designing environments that promote physical activity and health, whether that is the public streets or school environment (City of New York, 2010; Brittin et al., 2015). Although focus on BE deviates from the traditional "downstream" approach to health that examines individual patients and the physical causes of poor health, it provides great opportunities in addressing issues of aging by changing community health through intersectoral "upstream" action (Kelly et al., 2016; Lee et al., 2019).

Creating Cities that Promote Health

As the BE is increasingly recognized as a determinant of health, policymakers across the globe have begun focusing on creating healthier cities (WHO, 2007). There are various but similar concepts for city designs that promote health, these include: universal design (Harsritanto, 2018), walkable communities (Talen & Koschinsky, 2013), complete streets (Gregg & Hess, 2019), active design (City of New York, 2010), smart growth communities (Knaap & Talen, 2005; Durand, Andalib, Dunton, Wolch, & Pentz, 2011), and age-friendly communities (AFCs) (WHO, 2007). Although there are slight variations in these concepts, there is a general focus on increasing accessibility for pedestrians of all ages and abilities through intersectoral partnership and change in the BE (Greenfield, 2015; Kelly et al., 2016; Lee et al., 2019). Furthermore, these environmental designs significantly reduce physical inactivity through active transportation and soft mobility (Rundle et al., 2014; Bartley et al., 2019), particularly walking which is one of the most common forms of leisure-time physical activity among Canadians (Statistics Canada, 2017b). Soft mobility is defined as human-powered and non-motorized means of moving around (Cowan & Rogers, 2005), while active transportation extends this definition to include public transit use as it typically involves a degree of active travel (Rissel, Curac, Greenaway, & Bauman, 2012). Undoubtedly, active transportation, such as walking, cycling, and taking public transit, has been linked to better health (Brown et al., 2019) and the BE plays an important role in promoting active transport (Noyes et al., 2014). For environmental designs that promote physical activity and better health, there must be modifications that influence both residents' objective and subjective experience of public buildings and spaces, including the street scape (Duncan, Spence, & Mummery, 2005). These BE changes typically involve accessibility, aesthetic appeal, and sense of safety from injury and crime (Duncan et al., 2005; City of New York, 2010; WHO, 2007).

Creating walkable communities entail modifications to public spaces that are pedestrian-oriented rather than auto-oriented (The Community Guide, 2016; City of New York, 2013; Tam, 2018). To design walkable environments, there is a need to consider three macro-level characteristics of the objective environment that promote walking through increased accessibility: mixed land use, urban densification, and street connectivity (Cerin et al., 2017). Mixed land use refers to the diversity of land use from residential to commercial purposes, such as retail stores, malls, office buildings, or medical centers (Healthy Spaces & Places, 2009). Urban densification is increasing the density of people living in urban areas through increased residential or population density (Designing Buildings Ltd., 2020), while street connectivity is how well streets connect people to their destinations, often impacted by the degree of intersection density (Mecredy, Pickett, & Janssen, 2011). In a systematic review by Cerin and colleagues (2017), there was strong evidence supporting positive associations between walking for transport and these macro-level characteristics. Because these aspects of the BE increase pedestrian route directness to destinations and hence reduce within-neighbourhood transportation distances by foot, they are associated with increases in the frequency of purposive walking and pedestrian activity over automotive transport (Cerin et al., 2020).

In addition to the macro-level environment characteristics described previously, there are many other BE features that support walkability and focus on priority access for pedestrians. Some of these BE features are related to priority concerns of the older adult population, such as falls prevention and security from crime and traffic (Johns Hopkins Center for Injury Research and Policy et al., 2013; Pollack et al., 2014; McMurray & Clendon, 2015). Presence and quality of pedestrian facilities, such as quality of sidewalks, walking trails, cross walks, and benches are also important in promoting walking (Van Cauwenberg et al., 2012). These pedestrian facilities are especially important for the older adult population as it provides safety from fall injury and traffic (WHO, 2007; John Hopkins Center for Injury Research and Policy et al., 2013). Sidewalk features that support pedestrian accessibility and age-friendly communities include even, well-maintained, unobstructed, and sufficiently wide sidewalks. Additionally, universal accessibility of the sidewalks can be ensured with dropped curbs and raised crosswalks. Although benches do not directly prevent falls, it provides resting spots for those with disability and have difficulty walking for extended periods of time. Outdoor lighting is another BE feature that is paramount for age-friendly communities as it may prevent fall injury and improve sense of security from crime (Edwards & Dulai, 2018; Middleton, 2013).

Road designs and traffic calming, the deliberate reduction of traffic volume and speed, also contribute significantly to neighbourhood walkability (Designed to Move, 2015). As a part of road designs, safe street crossing is crucial in ensuring pedestrian safety and promoting pedestrian activity. Based on regulations from many countries including Canada, the United States, and United Kingdom, pedestrian crosswalks are designed for walking speeds of 1.2 m/s (Transportation Association of Canada, 1998; Brown et al., 2015). However, progressing age is strongly associated with decreased gait speed (Romero-Ortuno et al., 2009), and many older adults are unable to safely cross streets in the allocated time (Asher et al., 2012; Eggenberger et al., 2017). Street crossing can thus be perceived as dangerous and deters older adults from engagement with their physical environment (Grant, Edwards, Sveistrup, Andrew, & Egan, 2010). To remedy this issue, crossing time can be increased and road width can be minimized to reduce crossing distances (Webb, Bell, Lacey, & Abell, 2017; City of New York, 2010). Other BE features that can improve perception of safety include auditory and visual signals, marked pedestrian crossings, and elevated crosswalks (WHO, 2007). Additionally, traffic calming features can be incorporated to promote safe pedestrian crossing. Traffic calming features range from minor modifications to local streets to area-wide changes (Litman, 2003). Examples of these features include curb extensions, medians, raised speed reducers, and inclusion of bike lanes (City of New York, 2010). These designs have been noted in preventing pedestrian road traffic injury and increasing pedestrian activity (Stoker et al., 2015; Morrison, Thomson, & Petticrew, 2004).

Open public spaces, such as parks and green spaces, play a crucial role in recreational walking and physical activity among older adults (Kaczynski & Henderson, 2007; Pleson et al., 2014). Furthermore, proximity (Kaczynski & Henderson, 2007), attractiveness (Van Cauwenberg et al., 2015), size (Zandieh, Martinez, & Flacke, 2019), and number of green spaces can influence physical activity and walking levels (Kaczynski et al., 2014). To create public spaces that endorse pedestrian activity of older adults, clean and accessible public toilets and water fountains should also be available (WHO, 2007). Similarly, temporary large-scale street closures can increase available open public spaces and subsequently promote physical activity even among individuals who usually do not meet physical activity recommendations (Wolf et al., 2015).

Thriving in Winter Cities

Winter cities, typically northern, urban centres “that experience a long, dark, cold, and/or snowy winter” (Stout et al., 2018), face a greater challenge in promoting neighbourhood walkability and use of public spaces (Davies, 2015). In winter cities, normally accessible routes can become inaccessible due to weather conditions. Moreover, poorly designed and unmaintained streets can have profound effects on the older adult population, particularly their physical and social activity levels (Kimura, Kobayashi, Nakayama, & Kakihana, 2015; Clarke, Yan, Keusch, & Gallagher, 2015).

Although physical activity levels are reduced with decreases in ambient temperature (Chan, Ryan, & Tudor-Locke, 2006; Togo, Watanabe, Park, Shephard, & Aoyagi, 2005), the greatest concern for older adults regarding winter accessibility were icy surfaces (Li, Hsu, & Fernie, 2013; Clarke et al., 2015). Compounded with changes in gait pattern, strength, vision, and balance that accompanies progressing age, unstable walking surfaces of winter streets can exacerbate the risk of falls among older adults (Public Health Agency of Canada, 2014).

Experience of falls is a major problem in community-dwelling seniors and risk for falling increases as people age which results in serious consequences including negative health outcomes and admission to institutional care (Boelens, Hekman, & Verkerke, 2013). According to the Public Health Agency of Canada (2014), falls are defined as "a sudden and unintentional change in position resulting in an individual landing at a lower level such as on an object, the floor, or the ground, with or without injury" (p. 3). Falls are the leading cause of injury-related hospitalizations for Canadian seniors and 20% to 30% of seniors are estimated to experience a fall each year with 20% of these cases resulting in death (Public Health Agency of Canada, 2014). The most common type of injury from falls are broken and fractured bones that account for 37% of cases, and injuries from falls often result in disability and dependence (Do, Chang, Kuran, & Thompson, 2015). As falls often result in injuries and disabilities that limit ones' ability to perform daily activities of living (Public Health Agency of Canada, 2014), incompatibility between competence of the senior and demands of the environment can create anticipation for falling. Presently, there is evidence supporting frailty, history of falls, fear of falling, use of mobility aid, and physical inactivity as significantly relevant risk factors of falling (Ambrose, Paul, Hausdorff, 2013; Letts et al., 2010). A history of falling is considered a major risk factor for future falls, and fear of falling has often been associated with greater risk of falls (Rubenstein & Josephson, 2002). According to a systematic review by Zijlstra et al. (2007), fear of falling is prevalent among both senior fallers and non-fallers. The literature further reveals that fear of falling can result in a loss in confidence and manifest as decreased physical and social activity which further contributes to the senior risk of falling. Another study performed a meta-analysis on environmental risk factors and determined mobility aids as significantly increasing risk of falls; this is especially the case when assistive devices were not appropriately used or did not adequately suit the needs of a senior (Letts et al., 2010). Challenges of mobility-aid use may be magnified with winter weather conditions as mobility devices become stuck or lose traction on ice or snow (Ripat, Brown, & Ethans, 2015; Li et al., 2013). Furthermore, wet gait-stabilizing devices, such as canes and walkers, can lose traction with smooth indoor flooring and result in fall injuries (Public Health Agency of Canada, 2014). Thus, understanding that these major fall risk factors are more prominent in winter conditions, it is necessary to consider weather conditions when designing for accessible and walkable winter cities.

In the mid-20th century, a "Winter Cities" movement emerged with an emphasis on creating "climate-responsive" urban designs that should be in "contact with nature, year-round usability, user participation, cultural continuity, and the creation of comfortable micro-climatic conditions throughout much of the city's open spaces" (Pressman, 1986, p. 521). Since the introduction of this movement, the Winter Cities approach garnered little attention until its reemergence in policymaking and academia in the 1980s (Chapman, Nilsson, Rizzo, & Larsson, 2019). Alongside the increased interest in walkable environments in the disciplines of urban planning and health research, it has been increasingly recognized that "climate-insensitive" city designs face challenges in promoting public space activity and active transportation in settlements that face seasonal climate variations (Chapman, Nilsson, Rizzo, & Larsson, 2018). A noteworthy advocate and contributor to the Winter City movement was Canadian planner and professor Norman Pressman, whose work focused on three climate-sensitive design principles: optimizing solar access, reducing negative effects of wind, and managing snowfall and gathering (Pressman, 1995; Chapman et al., 2019). Eventually, his work led to a powerful resource for the Winter Cities movement, Edmonton's Winter Design Guidelines that emphasize creation of sustainable and active winter cities where residents can thrive (Winter City Edmonton, 2016). In the guidelines, enhancing white space – environmental snow and ice – is acknowledged as a potential facilitator for active winter cities. Examples of practical advice from this resource include site planning, landscaping, and use of evergreen vegetation to enhance aesthetics of white space, reduce cold winds, and minimize snow and ice on pedestrian facilities. Maximizing solar access and use of artificial light is underscored in ensuring energy sustainability, pedestrian safety, and promoting pedestrian activity. Certainly, design of white spaces can either promote or diminish the well-being of older adults as "[p]laces matter for health" (Project for Public Spaces, 2016, p. 2), and placemaking is more than transforming the objective environment but also the subjective experience of community members (Finlay, 2018).

Although not mentioned in the Edmonton's Winter City Guidelines, macro-level environment characteristics described previously, such as urban densification, mixed land use, and street connectivity, have an evermore important role in promoting pedestrian activity in the winter season. When compared to neighbourhoods characterized by suburbanization where the population is widely dispersed over a large geographical area, compact and mixed-use neighbourhoods present more favourable conditions for pedestrian activity. Neighbourhoods with these walkable principles reduce cost of snow clearance and improve the efficiency of services like public transit (Pressman, 1988). Likewise, the public spaces within compact neighbourhoods are less likely to be characterized by icy sidewalks and windswept cul-de-sacs as their suburban counterparts (Stout et al., 2018). Moreover, these macro-level characteristics make soft mobility more feasible and appealing by sheltering pedestrians from cold wind and reducing travel distance to local destinations (Bergum & Beaubien, 2009).

The Aging Well Model

The field of environmental gerontology emerged and took an impressive expansion in the later half of the 20th century; this expansion is largely due to the surge in interest and recognition of the significant impact that environments have on the senior population (Wahl & Weisman, 2003). Most notably, Lawton's seminal work and passion in the study of environmental gerontology had given rise to the ecological theory of aging (ETA) which (as cited in Wahl, Iwarsson, & Oswald, 2012) states that old age is a "critical stage in the life course that is profoundly influenced by the physical environment" (p.307). Perhaps one of Lawton's, most impressive contribution to this field was the development of the environmental press paradigm which had set the foundation for future research and evidence-based interventions in tackling the global issue of aging. The environmental press model presents aging as a process of continual adaptation between individuals and their physical environment (Perry, Andersen, & Kaplan, 2013). Perry et al. (2013) further elaborates on the theory as an exchange of adaptation between the demands of the environment and the individual's competence which constitutes their physical health, cognitive and functional abilities; an imbalance between the demands of the environment and the individual's ability to adjust leads to active modifications of the environment or relocations to a more supportive environment. Of important note is the "person-environment (P-E) fit". P-E fit elucidates the degree of congruence between the individual and environment through appraisal of the interaction between factors in these two categories. Rooted in theory, the study of aging populations and their environments blossomed and led to evidence-based interventions in the form of housing design, institutional living modifications and age-friendly communities that improved the health and well-being of seniors (Wahl & Weisman, 2003).

To investigate the relationship between neighbourhood walkability, senior belonging, agency, PF, and health, this thesis adopts Wahl and colleagues' (2012) aging well model as the theoretical framework of this study. In the aging well paradigm (Wahl et al., 2012), Lawton's environmental-press model was extended to include the complex and dynamic interaction of P-E fit, belonging, agency, life course effects, and cohort-related or cultural context in creating a sense of identity, autonomy and well-being. Altogether, the developmental outcomes of identity, well-being and autonomy allow people to age well (Wahl et al., 2012). Bringing these factors together, I examined how macro-level walkability characteristics correlate with belonging, agency, PF, and health of older adults through their interaction with the environment, namely purposive walking. The consideration of these factors will be important in further understanding the role of neighbourhood environments and HAIP for older adults.

Existing Evidence for Walkability and HAIP Components

Already, there is a vast number of studies supporting the positive effects of neighbourhood walkability on physical activity, namely purposive walking, for people across all ages (Hajna et al., 2015a; Hajna et al., 2015b; Barnett et al., 2017; Colley et al., 2019). Although research on the BE has largely focused on the relationship between neighbourhood walkability and physical activity levels, there is a steadily growing body of evidence investigating the relationship of walkable environments and the domains of HAIP: sense of belonging, agency, PF, and health (Lee & Tan, 2019; Ivory et al., 2015; Fogal et al., 2019; Yu et al., 2017). Most studies presume walking as the principal mechanism of walkable communities in enhancing belonging, agency, PF, and health, while some studies have evidence of purposive walking as the mediator in this relationship (Du Toit et al., 2007).

One available tool that evaluates walkability in public health and urban planning research is the Street Smart Walk Score (SSWS). SSWS is a tool that calculates a score for the walkability of a specific location based on the macro-level environment characteristics: mixed land use, intersection density, and pedestrian route directness (Front Seat, 2020; Duncan, 2013). Since its initial release, Walk Score has been increasingly used for commercial and research purposes due to its ease of use, inexpensiveness, public accessibility, and ability to assess neighbourhood walkability as a composite measure (Carr et al., 2011; Duncan 2013). Although Walk Score does not evaluate all aspects of walkability (i.e., pedestrian infrastructure, crime rate, weather conditions) and is therefore unable to be used as a global estimate of walkability (Hall & Ram, 2018), it provides a good assessment of neighbourhood density and access to amenities. In urban planning and public health research, most studies examined solely the relationship between Walk Score and physical activity levels, and Walk Score is often positively associated with purposive walking (Winters et al., 2015; Towne et al., 2016; Hirsch et al., 2017; Hall & Ram, 2018; Camhi et al., 2019; Twardzik et al., 2019). More recently, a few studies have gone further to investigate the relationship of Walk Score and health outcomes, such as weight (Chiu et al., 2015) and chronic diseases (Zeglinski-Spinney et al., 2018).

Walkability and Belonging

BE features, such as green space, the streetscape, or nearby amenities, can instill feelings of belonging directly through residential satisfaction and indirectly through its impact on social interactions (Schellenberg, Lu, Schimmele, & Hou, 2018). A crucial but underappreciated aspect of the BE are "third places" or "bumping places" which are public spaces or the streetscape where people have casual interactions with friends, neighbours, and strangers (Lee & Tan, 2019). Although third places are mainly associated with weak social ties (Alidoust & Bosman, 2019), the casual relationships have a significant role in the feelings of social connection and compensate for deficits in relationships with close others, such as family and friends (Lee & Tan, 2019). In more walkable neighbourhoods, residents may increase time spent walking in their local communities which enables more casual interactions with others in these third places (Wilkerson et al., 2012). Wilkerson et al. (2012) found positive BE features (i.e., sidewalks, front porches, absence of litter and graffiti) to be associated with increased interaction between neighbours. In a New Hampshire study (Rogers et al., 2011), living in walkable communities was associated with greater social capital which are the resources developed when people connect with others in meaningful ways (Hanibuchi et al., 2012), while a study in Ireland (Leyden, 2003) found living in walkable, mixed-use neighbourhoods to be associated with increased trust among neighbours, social engagement and capital. Most importantly, the BE can influence residents' sense of belonging and attachment without operating through social interaction. The BE features that reduce crime can also promote a better sense of community and belonging amongst residents (Curley, 2010). Despite the evidence that indicate BE features such as crime rate and green space can impact sense of belonging, no studies found have explored the effect of other neighbourhood features such as pedestrian route directness, residential and intersection density on sense of belonging in community-dwelling seniors.

Walkability and Agency

Although the BE and agency are observed in a dynamic relationship in environmental gerontology, focus on agency has often leaned towards intentional behaviours that aim to change the environment while the impact of physical environment on agency has oftentimes been underexamined. As Rainham et al. (2010) described, context can influence people's activities and sense of control, whether it is local governments exerting influence through zoning rules or changes to public transport. Thus, there is a need to examine the physical neighbourhood environment as a facilitator or barrier for agency and target it through policy action rather than individual behaviours alone to try to change one's environment. There are many features within a neighbourhood and in multi-residential buildings outside of an individual's control. Already, evidence has implicated this notion as walkable communities provide opportunities for residents to exert agency, whether it is through physical activity to maintain health, social interaction to fulfill social needs, or shopping in nearby areas to attain needs of daily living (Cubukcu, 2013). Also, rather than individuals themselves being the sole influences of their social interactions, the availability and accessibility to amenities such as green space, recreation facilities, shopping, school or churches also provide people with agency in social interactions (Lee, Jordan, & Horsley, 2015). Ivory et al. (2015) found that neighbourhood walkability influenced resident choices regarding where they engaged with their communities and public places. In another study by Rantakokko and colleagues (2010), the quality of life was worse for seniors who reported fear of moving outdoors and had unmet physical activity needs due to outdoor barriers such as the terrain, traffic, and distances. This study indirectly underscored the role of the neighbourhood environment as a major contributor to senior agency rather than a target of agency.

Walkability and Physical Functioning

Accompanying progressing age, older adults typically experience a natural decline in PF that may be slowed or prevented through environmental interventions (WHO, 2015). However, there are a minimal number of studies on the relationship between walkable neighbourhoods and PF, and evidence for this relationship has only begun to emerge in the last decade and a half. Brown et al. (2008) was one of the first to investigate the association of neighbourhood features and PF. In their study, "eyes on the street" – the visual contact among residents who care about the happenings in their community – promoted through buildings with greater proportion of frontage or the building fronts facing the main road created a perceived safer environment. Additionally, older adults living in neighbourhoods with positive front entrance features had higher levels of PF. Another study by De Keijzer and colleagues (2019) found that proximity to and "higher greenness" of natural environments were associated with slower decline in walking speed and grip strength in older adults. Other studies have noted the enhanced PF of older adults in neighbourhoods with pedestrian infrastructure and aesthetics (Rachele et al., 2019), greater population density, nearby amenities, and mixed land use (Soma et al., 2017; Fogal et al., 2019; Koohsari et al., 2020).

Walkability and Health Outcomes

Countless studies have explored the associations of neighbourhood walkability with health; however, there is difficulty in making casual inferences for the observations. This is in part due to the cross-sectional design of most studies and the problem of neighbourhood self-selection bias (Berry et al., 2010). The issue of neighbourhood self-selection bias arises when residents who tend to be more active and healthier choose to live in or relocate into walkable neighbourhoods, thus masking the degree of influence from neighbourhood walkability (Frank, Kerr, Rosenberg, & King, 2010). Regardless, this may indicate the protective role of walkable neighbourhoods in not only promoting physical activity and better health outcomes, but also preserving positive walking attitudes necessary for sustained physical activity levels.

Along with more studies supporting the association between neighbourhood walkability and walking (Hajna et al., 2015a; Barnett et al., 2017), there has been emerging evidence for the positive relationships between walkability and health outcomes (Loo et al., 2017). To date, neighbourhood walkability has been associated with decreased weight (Chiu et al., 2015; Barbosa et al., 2019), risk for CVD (Howell et al., 2019) and chronic diseases (Zeglinski-Spinney et al., 2018). Moreover, a recent longitudinal study of Canadians concluded neighbourhood walkability to decrease BMI of Canadian men (Wasfi. Dasgupta, Orpana, & Ross, 2016). Among older adults, living in neighbourhoods with greater walkability was also associated with reaching centenarian age (Bhardwaj et al., 2020).

The Missing Link between Walkability and HAIP

The literature that investigates neighbourhood walkability and walking levels has largely examined walkability in terms of macro-level environment characteristics (i.e., street connectivity, residential density, and mixed land use) (Barnett et al., 2017; Farkas et al., 2019; Barbosa et al., 2019), while the few studies that examined neighbourhood walkability and dimensions for HAIP, such as belonging, agency, and PF, have mainly examined walkability on the micro-level (i.e., pedestrian infrastructures). As such, there are insufficient studies on how macro-level walkable characteristics contribute to these healthy aging dimensions (Rachele et al., 2019). My thesis aims to bridge this gap by investigating the relationship of macro-level walkability characteristics, as measured by Walk Score, and sense of belonging, agency, PF, and health in older adults. By better understanding these relationships, decisions regarding neighbourhood designs may become more valuable for health researchers, policymakers, and residents.

Chapter 3: Methods

Study Design and Participants

A cross-sectional quantitative study was conducted to investigate the association of neighbourhood walkability, as measured by Walk Score, with factors of HAIP, such as belonging, agency, PF, and health. Data was collected from a convenience sample of community-dwelling seniors (n = 236) in the Edmonton region between November 2, 2019 and March 27, 2020. Of the 236 participants, 213 cases (90.3%) were used in the analyses. Cases with less than half of the questionnaire completed (n = 6) and cases with missing values for both postal code and street address (n = 17) were excluded. The cases with no response for postal code and street address were omitted in the analysis as the primary predictor variable Walk Score cannot be generated. Regarding response rate, 330 hard-copy survey questionnaires were distributed with 180 completed questionnaires returned, indicating a 54.5% response rate for paper survey modality. All other questionnaires were completed online (n = 33). Response rate for completion online is unknown as online surveys were widely distributed as an online weblink to all members and visiting seniors of partnered facilities via newsletters and posters.

The inclusion criteria for participation were age 65 years or over, ability to communicate in English, living within the Edmonton Metropolitan Area and not living in institutional care. The age of 65 years was set as the lower threshold for age following many studies on healthy aging and AIP as most policies governing the Canadian senior population affect individuals at and above this age (Government of Canada, 2014; Shenkin, Harrison, Wilkinson, Dodds, & Ioannidis, 2017). Ethics approval was attained from the University of Alberta's research ethics board; informed consent was implied by completion and submission of the survey questionnaire, and all data were de-identified.

The Edmonton Metropolitan Region is located in Western Canada and includes municipalities surrounding Edmonton, such as the Parkland, Sturgeon, Leduc, and Strathcona County. This region has a total population size of about 1.8 million and is characterized by snowfall and cold weather in the months between November to April (World Population Review, 2020). As a multicultural city, Edmonton encounters the common issue of ethnic segregation, which is the spatial segregation of ethnic groups (Kaplan & Woodhouse, 2005). Additionally, the Edmonton region constitutes a vast suburban area characterized by suburban sprawl outside of the city core. Therefore, it was paramount to have a wide distribution of participants throughout the Edmonton region to capture the diversity of residents from differing ethnic and neighbourhood backgrounds.

Measures

Demographics

Prior research has indicated potential effects of sociodemographic factors on older adults' ability to age in place (Scharlach & Diaz-Moore, 2016). Hence, data on age, sex, marital status, education, employment status, minority or Indigenous status, and housing characteristics were collected. Coding and description of these factors are described in Table 1.

Marital status was recorded as married or living with a partner, never married, separated, or divorced. Marital status was then dichotomized as 1 = *married or living with a partner* and 0 = *otherwise* which included widowed, never married, separated, or divorced. This dichotomy in marital status is supported in studies that have observed better health and mortality outcomes in married persons compared to unmarried persons (Robards, Evandrou, Falkingham, &

Vlanchantoni, 2012). Other studies have concluded positive associations between successful aging and being married or not living alone (Hornby-Turner, Peel, & Hubbard, 2017).

Response options for employment status include full-time employed, part-time employed, unemployed, and retired. Past studies that have dichotomized employment status have observed significant differences between employed and unemployed seniors, with employed seniors reporting better health and exhibiting better avoidance of chronic disease and physical impairment (Hamid, Momtaz, & Ibrahim, 2012; Hornby-Turner et al., 2017). As such, employment was analyzed as 1 = *employed,* where employment refers to part-time or full-time employment, and 0 = *unemployed* which includes unemployed or retired.

Minority and Indigenous status, derived from response to a question on ethnicity, was examined as previous studies have highlighted differences in healthy aging between non-Hispanic White and ethnic minority groups (Angel & Angel, 2006; Thorpe & Whitfield, 2017). Indigenous status was recorded as Indigenous seniors are one of Canada's most vulnerable citizens with a significant number living on low income, having multiple chronic conditions and disabilities, and experiencing poorer health as a result of colonization, intergenerational effects, and trauma from the residential school era (Health Council of Canada, 2013). Indigenous status was recoded as 1 = *Indigenous* and 0 = *non-Indigenous*; ethnic minority status was recoded as 1 = *ethnic minority* and 0 = *White*.

As age and income are often underreported due to privacy concerns (Yang, Zhao, & Dhar, 2010), these sociodemographic characteristics were record as closed-ended responses. Past studies have indicated that response rate for these items can be improved by implementation of closed-ended responses than open-ended responses (Griffith, Cook, Guyatt, & Charles, 1999; Desai & Reimers, 2018). As such, age was recorded on 4-year intervals starting from 65 years until 99 years, with the highest category as *100 years or over*. For the analyses, age was not transformed. Income was categorized on an ordinal scale, starting at *below $25,000* to *over $100,000* with each category increasing by $25,000 increments until $100,000. As income was not normally distributed, it was transformed into a dichotomous variable through median split, with 0 = *below $25,000* and 1 = *over $25,000*.

Housing characteristics are potentially important to account for as they relate to population density, mixed land use, and walkability which in turn impact health (Brown et al., 2009). In a study by Anh and colleagues (2020), persons who rented and lived in multifamily housing scored lower on well-being domains related to AIP compared to homeowners and single-family housing residents. Thus, homeownership and housing type were examined. Homeownership was record as 0 = *renter* and 1 = *homeowner*. There are 6 options for residence type, from *detached single-family home* to *apartment or condo with more than 13 storeys*. These categories were dichotomized as 0 = *single-family home* and 1 = *multi-family home*.

Disability and Mobility-Aid Use

Disability and mobility-aid use were also considered as these factors are associated with negative health outcomes (Satariano et al., 2012; Krahn, Walker, & Correa-De-Araujo, 2015). Disability is associated with obesity, physical inactivity, and poorer health outcomes (Krahn et al., 2015). For disability, participants reported the degree to which they experienced a condition that limited their daily activities. This was reported on a 3-item scale from *never* to *sometimes* to *always*. For mobility-aid use, participants reported whether they used a cane, walker, or wheelchair. The responses for these measures were 0 = *no*, 1 = *sometimes*, or 2 = *always*. In the analysis, these measures were then collapsed into one measure, mobility-aid use, with the same response items. The highest degree reported for use of these three mobility aids (always > sometimes > no) was recorded for mobility-aid use.

Neighbourhood Walkability

Neighbourhood walkability was measured by SSWS. SSWS was calculated on a publicly available website developed by Front Seat Management, a software development company based in Seattle, WA (Front Seat, 2020). This tool was developed initially for real estate purposes but has gained overwhelming attention in the public health and urban planning sector. Walk Score calculates the purposive "walking potential" of a location based on geographical information system (GIS) indicators in the neighbourhood (Hall & Ram, 2018). Updated data sources for Walk Score include Google, Localeze, Factual, Great Schools, road networks and parks from OpenStreetMap, Education.com, public transportation agencies, US Census, and the Walk Score user community (Carr et al., 2010; Duncan, 2011). The tool uses network distances, which is the length of shortest path between two locations in a spatial network, by following the streets to a variety of nearby amenities in the network to generate a score from 0 to 100 (Front Seat, 2020). There are 5 categories of facilities: educational, retail, food, recreational, and entertainment. The closer in neighbourhood proximity of the five categories of amenities, the higher the Walk Score. The SSWS metric also considers other pedestrian friendliness factors such as walking distance, intersection density, and average block length (Duncan, 2013). As described by Duncan (2013), the composite measure of neighbourhood walkability is important as single component measures of neighbourhood walkability often show fewer effects and are much more inconsistent in terms of significance of direction of effect.

Since the release of Walk Score in 2007, this tool has garnered an abundance of support and interest in research and public policymaking (Hall & Ram, 2018). The Walk Score tends to be less biased than self-report measures and to be easier to use and more cost effective than environmental audits or GIS data (Carr et al., 2011). The objective measure of Walk Score eliminates biased samples of respondents and same source bias evident in self-reported measures (Diez Roux, 2007). The Walk Score index is also seen as a potentially favourable alternative to environmental audits and GIS data as it avoids the requirement of specialized training and costly, labour and time-intensive aspects found in the other two walkability assessment methods (Matthews, Moudon, & Daniel, 2009). Moreover, Walk Score has strengths as a composite measure of macro-level neighbourhood walkability that is often associated with the purposive walking potential of the neighbourhood assessed (Duncan, 2013; Hall & Ram, 2018).

Two measures of walkability, a continuous and dichotomous measure, were generated from Walk Score. Walk Score values were calculated from participants' reported home address and/or postal code to generate a continuous measure ranging from 0 to 100. "Walkability" in this study partitions the participants into two categories: individuals who are living in a walkable neighbourhood and those in a car-dependent neighbourhood based on their Walk Score. Home addresses with a Walk Score of 50 to 100 were designated with the label *walkable*, while addresses with a Walk Score of less than 50 were labeled as *car-dependent*. This categorization follows Redfin (2019) Walk Score categorization indices, where 0 – 49 Walk Score is "car-dependent" and 50 – 100 is "somewhat walkable" to "Walker's Paradise". Previous studies highlight stronger evidence for validity of Walk Score when the score is dichotomized (Hall & Ram, 2018).

Online Modality

Use of technology such as computers or smartphones may have an impact on the variables of interest in this study. For instance, higher use of social technology has been associated with better self-rated health, fewer chronic illnesses, fewer depressive symptoms, and lower risk for loneliness among older adults (Chopik, 2016). A recent report by the Task Force on Research and Development for Technology to Support Aging Adults Committee and National Science & Technology Council (2019) underscored the role of technology in improving independence and social connections of older adults. Moreover, studies have indicated internet use is more prevalent among younger seniors (aged 65 to 74 years), those with higher levels of educational attainment, and a non-ethnic minority status (Gordon & Crouch, 2019). Thus, survey modality was accounted for. Participants who completed the survey questionnaire online automatically received a completion timestamp on REDCap, while participants who completed the hardcopy questionnaires and had their data input as “did not receive a timestamp”. Using online completion timestamps as a reference for online survey completion, the data was categorized as being completed either “online” or “paper”.

Walking

Purposive walking was assessed as past studies have frequently noted the positive association between macro-level walkability characteristics and walking for transport (Hall & Ram, 2018; Mirzaei et al., 2018; Farkas et al., 2019). Purposive walking from place to place in the last 7 days was measured through two items from the International Physical Activity Questionnaire (IPAQ) (Craig et al., 2003). The first item asked about days per week and the second asked about minutes per day. The product of the two indicated purposive walking in minutes per week.

Sense of Belonging

The Social Provisions Scale (SPS) (Cutrona et al., 1987) was employed to measure sense of belonging. Adopting the multidimensional concept of sense of belonging from Jakubec and colleagues (2019), this questionnaire had nine items (Questions #6 – 14, Appendix A). Each item assessed this concept by using a 4-point agreement scale, ranging from 1 (*strongly disagree*) to 4 (*strongly agree*). These items were combined to form a single, reliable scale for *sense of belonging* as indicated by the high Cronbach's alpha value (α = .925). SPS has been validated and is one of the most utilized tools to measure social provisions (Orpana, Lang, & Yurkowski, 2019). Social provisions are the function of social relationships, and include functions such as attachment, social integration, opportunity for nurturance, reassurance of worth, reliable alliance, and guidance (Cobb, 1979). Furthermore, the dimensions of the SPS resonate with the older adults' perspective of belonging (Jakubec et al., 2019).

Sense of Agency

The Personal Agency Scale (Smith et al., 2000) was used to examine sense of agency which is a person's feeling of control over their actions to achieve a desire outcome. This instrument is composed of eight items (Questions #15 – 22, Appendix A) on a 4-point Likert-type scale, ranging from 1 (*never)* to 4 (*often)*. Following the methods of Smith and colleagues, the average of all items was calculated to develop the continuous variable *sense of agency* with a score ranging from 1 to 4. Previous studies have demonstrated acceptable internal consistency for this scale (Cronbach's alpha of 0.78 and split-half reliability value of 0.73; Smith et al., 2000). In this study, a Cronbach's alpha of 0.858 was noted, suggesting good internal reliability.

Physical Functioning

Nine items (question #28, Appendix A) from the PF-10 instrument assessed the PF of participants. The PF-10 instrument, a subscale of the SF-36 survey developed by Ware & Sherbourne (1992), is a widely used tool in a number of epidemiological studies examining older adults and has been supported as a reliable and valid measure of PF in seniors (Mishra et al., 2011). Furthermore, the items from SF-36 captures components of PF that are relevant and not present in other independence assessment tools when examining the relationship of neighbourhood environments and PF of seniors such as moderate or vigorous activities, climbing stairs, and walking a block or a mile. The nine items in this study generated a reliable scale with a high Cronbach's alpha value (alpha = .925) for the variable *physical functioning*. To create a single item representing the PF variable, scores for each item was first transformed to a scale with a range of 0 to 100. The average of these rescaled scores was then calculated to generate the grand score for PF (RAND Corporation, n. d.).

Self-Rated Measures of Health

Self-rated health measures are simple, easy, valid, and reliable indicators of health status (Bombak, 2013). This study employed two 1-item health measures: self-rated general health (SRGH) and comparative health measure (C-SRH). The SRGH has been frequently used in epidemiological research (Van Ginneken & Groenewold, 2012) and has been associated with physician assessments of health (LaRue, Bank, Jarvik, & Hetland, 1979) and mortality (Idler & Benyamini, 1997). Though limited in assessing morbidity (Sen, 2002), SRGH is still adequate as a broad assessment for health status which is aligned with the holistic concept of health (Subramanian, Subramanyam, Selvaraj, & Kawachi, 2009). Although there are several variations of the 1-item SRGH measure, the SRGH measure from the 2018 Canadian Community Health Survey (CCHS) was used. It has five response items on an ordinal scale from *poor* to *excellent*.

The C-SRH measure in this study assessed health on a 5-item scale, from 1 (much worse now than 1 year ago*)* to 5 (much better now than 1 year ago*)*. This C-SRH measure was adopted from the 2018 CCHS and differs from past studies of comparative self-rated health measures. Typically, such SRH measures assessed participants' perception of their health relative to other persons in their same age group rather than their own health a year prior (Eriksson, Undén, Elofsson, 2001; DeSalvo, Bloser, Reynolds, He, & Muntner, 2006).

Procedures

Participants were recruited through newsletters, posters, and information booths circulated through senior centers across the Edmonton Metropolitan Region, Edmonton Federation of Community Leagues (EFCL), and Edmonton-based Alberta Seniors Communities & Housing Association (ASCHA) member facilities. EFCL is a non-profit organization that assists Edmonton community leagues and ASCHA is an association that advocates for owners and operators of seniors housing. Once participants agreed to participate in the study, they were offered the opportunity to complete a 10- to 15-minute survey either by paper or online. Those who wished to complete the questionnaire by paper were provided with a hardcopy questionnaire and prepaid stamped return envelope by the researcher, while participants who desired to complete the survey online were given a web link to a site on REDCap which is a secure web application for building and managing online surveys and databases (REDCap, n. d.). Questions from the online and paper questionnaire (see Appendix A) were identical. Data from completed hard-copy questionnaires were manually inputted into REDCap by the researcher.

To ensure high data quality, verification of data was done through a continuous sampling plan (CSP) as described by King and colleagues (2000). CSP is an effective alternative method to double data entry that can be performed by a single data entry personnel, hence reducing time and financial cost while ensuring a gain in data quality (Fong, 2001; King & Lashley, 2000). In this study, a visual record verification check was performed in SPSS with the first ten records of the dataset by comparison with the corresponding hard-copy questionnaire. Correct entry of these first ten records was followed by verification of every tenth record until an incorrect record was found. Upon encountering incorrect data, the data was corrected and all subsequent data was checked until ten correct records were found whereby every tenth record was checked again. This cycle was repeated until the entire dataset had undergone CSP.

Data Analysis

This thesis examined the association of neighbourhood walkability with belonging, agency, PF, and SRGH in older adults. To understand these relationships, I hypothesized that purposive walking mediates the relationship between neighbourhood walkability and PF, belonging, agency, SRGH, and C-SRH. By assessing health with C-SRH, walkability may be examined for its association with health improvement or decline over time. In the final two hypotheses, I speculated age would moderate the effect of neighbourhood Walk Score on sense of belonging and sense of agency among community-dwelling seniors. Hypotheses and analytical tests are summarized in Table 2.

Descriptive statistics were first explored for each variable. Normality of data distribution was first assessed for all continuous and ordinal variables with Shapiro-Wilk tests. The mean ± standard deviation was reported for normally distributed variables, while median, 25^{th} and 75^{th} percentiles were reported for non-normally distributed variables. The mediator variable (purposive walking) and criterion variables (belonging, agency, and PF) were dichotomized through median splits for the analysis to accommodate for non-normality and observed ceiling effects, while walkability was analyzed as a continuous variable. Frequencies and percentages were reported for categorical variables. To illustrate the distribution of participants across the city and surrounding areas, a map of the Edmonton region was generated through EasyMapMaker (Figure 1). EasyMapMaker was developed by TC Cloud Solutions LCC and utilizes Google Maps to geocode addresses (EasyMapMaker, 2019).

Bivariate correlations were then performed to highlight relationships between the variables. Spearman's correlation coefficients were computed for correlation between ordinal criterion variables (SRGH and C-SRH) and all other variables. Point-biserial correlation coefficients described the bivariate relationship of continuous variables and dichotomous variables, while chi-square tests of association were performed to assess the correlation between two dichotomous variables.

To achieve statistical power of 0.80 in the initially proposed analyses based on assumptions of medium effect size ($\delta = 0.3$) and a significance level of 0.05 for multiple regression analyses, a sample size of 180 was required (Cohen, 1988). However, due to non-normality of the criterion variables, ordinal logistic regression analyses were performed to understand the mediating relationships of macro-level neighbourhood walkability, purposive walking, and criterion variables (MacKinnon & Dwyer, 1993), adjusting for significant covariates identified in previous preliminary tests. Statistical power of ordinal logistic regression analyses was calculated using G*Power. Following procedures from Kenny (2018), covariates associated with either the predictor, mediator, or criterion variables were adjusted for in the regression models of all pathways. Significant covariates that resulted in poor model fit were removed. For each criterion variable, regression models were generated to examine the mediating effect of physical activity in a hierarchal manner. These regression models were categorized into three groups, pathways *c*, *a*, and *b & c',* based on pathways in the mediation relationship (Figure 2). Pathway *c* examined the relationship between walkability and the criterion variable without the mediating variable walking. Pathway *a* examined the relationship of walkability and the mediator walking, while the last pathway *b & c'* examined the effect of walkability and purposive walking on the criterion variable. For pathways *c* and *b & c'*, the first regression model in each of these sets explored the main relationships without covariates. In the second regression model of these pathways, covariates were adjusted for. For each model, regression model fit was described by chi-square and p-values from likelihood ratio tests. Odds ratio and p-values from ordinal logistic regressions were reported.

To ensure coefficients were comparable, log odds ratios were standardized by multiplying the odds ratio by the standard deviation of the predictor and dividing by the standard deviation of the outcome variable (MacKinnon & Dwyer, 1993). With the indirect effects described as the "reduction of effect of the causal variable on the outcome" (Kenny, 2018), the indirect effect was calculated as the product of standardized coefficient *a* and *b*. To assess statistical significance of the indirect effect for each criterion variable, the Monte Carlo method for assessing mediation (MCMAM) was used with the unstandardized log odds and variances. 95% confidence intervals for indirect effects from the MCMAM were reported alongside indirect effects.

For the last two hypotheses that predicted a moderating effect of age on the relationship of neighbourhood walkability and older adults' sense of belonging and agency, 2-way ANOVAs were performed to assess the interaction effect of age and walkability for each criterion variable.

In all tests, $p < 0.05$ was considered statistically significant. Statistical analyses performed in this study was done with IBM's SPSS software (version 25).

Chapter 4: Results

There was an approximately normal distribution for Walk Scores ($\bar{x}$ = 43.39, SD = 25.1) with a range of 0 – 97 (Table 3). Quartiles of Walk Score also support this notion (Table 4). Additionally, there was an approximately even proportion of participants living in walkable (mean Walk Score = 66.82) and car-dependent (mean Walk Score = 24.51) neighbourhoods, 57.7% and 42.3% respectively (Table 2). A vast majority (95.3%) of the participants provided their home or street address for calculation of Walk Score, while 4.7% of participants provided only their postal code. The majority of respondents (52.1%) fell into the younger senior category (age 65-74 years) and 46.9% in the older senior category (age 75 years or over). A greater proportion of respondents were female (71.8%), about half (53.5%) were married, and nearly two-thirds had completed some form of college or university education (63%). The majority of the participants were retired or unemployed (88.7%), Caucasian (82.2%), and completed the survey questionnaires by paper (83.1%). The median length of time spent walking from place to place was 120 minutes/week (25^{th} percentile = 17.5 and 75^{th} percentile = 300.0) which is less than the recommended level of moderate-intensity physical activity (150 minutes/week) (WHO, 2020b). 45% of respondents reported 150 minutes or more of purposive walking. About half of participants reported having a condition that limited their daily activities with 48.8% and 7% reported a disability sometimes and always. Most participants reported not using a mobility aid (76.5%). Regarding housing, a vast majority of participants owned their homes (76.5%); 57.7% of participants lived in single-family homes, while 38.0% lived in multi-family homes. Participants had lived in their homes, on average, for 21.9 years (median = 20 years). The shortest period lived in at a residence was 0.5 years and the longest period was 62 years.

Compared to the Canadian senior population (Statistics Canada, 2017), 52% of participants were between 65 to 74 years old (compared to 57% of Canadian seniors), 23% were 70 to 74 (compared to 17%), 16% were 80 to 84 (compared to 13%), 7% were 85 to 89 (compared to 8%), and 1% were 90 to 94 years (compared to 4%). Also, 54% of participants were married compared to 63% of Canadian seniors, 89% retired or unemployed compared to 80%, 82% non-visible minority compared to 87%, 77% homeowners compared to 75%, and 58% lived in single-family housing compared to 56%. Importantly, the majority of the participants were female (72%) and had higher education (6% did not complete high school) compared to the Canadian senior population where 55% were female and 23% did not complete high school.

Apart from C-SRH, participants had, on average, high scores in all criterion variables (Table 3). On average, respondents rated higher than mid-point of the scales for sense of belonging (median = 32 on a scale from 9 to 36), sense of agency (median = 3.88 on scale of 1 to 4), PF (median = 77.78 on a scale from 0 to 100), and SRGH (median = 4.00 on a scale of 1 to 5). For C-SRH, most participants did not report a decline or improvement in health relative to the previous year (median = 3.00, range 1 to 5).

Bivariate associations are described in Table 5. Interestingly, walkability was not correlated with sense of belonging, PF, SRGH, C-SRH, or purposive walking, but walkability was significantly correlated with several covariates. Specifically, it was negatively correlated with income (-0.33), being married (-0.24), male (-0.16) and a homeowner (-0.34), while there was a positive correlation with being employed (0.17). As expected, multifamily residence was positively associated with walkability (0.28) and related to living at the residence for a shorter amount of time (-0.18). Purposive walking was correlated with belonging (0.16), PF (0.26), SRGH (0.25), disability condition (-0.17) and mobility-aid use (-0.15).

Ordinal Logistic Regressions

Subsequent ordinal logistic regression analyses were performed to assess the mediating relationship of walkability, purposive walking, and criterion variables belonging, agency, PF, SRGH, and C-SRH. The ordinal logistic regressions were slightly underpowered ($1\text{-}\beta = 0.77$) (Table 2). The regression models were limited to only include covariates that had a statistically significant relationship with walkability, purposive walking, or the criterion variables as observed in the bivariate analyses. These covariates include sex, marital status, employment status, homeownership, tenure length, housing type, and disability condition.

For all criterion variables, the ordinal logistic regression models assessing the relationship between walkability and walking (pathway *a*) was the identical because statistically significant covariates from bivariate correlations are consistent in the mediation relationship across all criterion variables (Table 6). In model 1, walkability alone resulted in poor model fit ($\chi^2 = 0.23$, $p = 0.635$). When adjusting for all significant covariates, the final model for this relationship did not predict walking better than the intercept-only model ($\chi^2 = 11.29$, $p = 0.186$). However, the effect of walkability on walking was identical ($OR = 1.00$, $p > 0.05$) to that of model 2 which had good model fit when only adjusting for covariate disability ($\chi^2 = 7.07$, $p = 0.029$). Hence, the walkability coefficient from model 3 was used for mediation analyses.

Hypothesis 1

The first regression models for each pathway had poor model fit ($p > 0.05$) (Table 7a). However, adjusting for covariates resulted in better prediction of belonging scores over and above the intercept-only model in both path *c* and *b & c'*. In model 2 of the direct pathway *c*, walkability did not significantly influence belonging (standardized $\beta = 0.290$, OR = 1.01, $p = 0.157$). Although the final model of path *b & c'* had good model fit when adjusting for covariates ($\chi^2 = 22.03$, $p = 0.009$), both walkability and walking had a non-significant effect on sense of belonging (standardized $\beta = 0.253$, OR = 1.01, $p = 0.516$, and standardized $\beta = 0.246$, OR = 1.28, $p = 0.472$, respectively). Overall, the indirect effect of walkability on sense of belonging was not statistically significant ($\beta = 0.037$, 95% CI [-0.005, 0.008]) (Figure 3, Table 7b).

Hypothesis 2

In the direct pathway *c*, the first model containing only walkability had good model fit ($\chi^2 = 4.61$, $p = 0.032$) (Table 8a). The effect of walkability was statistically significant but minimal (OR = 0.99, $p = 0.34$). When adjusting for covariates, model fit was maintained ($\chi^2 = 18.33$, $p = 0.019$). However, walkability did not have a statistically significant effect on agency (standardized $\beta = -0.723$, OR = 0.99, $p = 0.140$).

In the pathways *b & c'*, model 1 that examined the effect of walkability and walking alone on agency scores had good model fit ($\chi^2 = 7.39$, $p = 0.025$). Similar to the direct pathway, walkability had a statistically significant but minimal impact on agency (OR = 0.99, $p = 0.025$). The effect of walking was not statistically significant (OR = 1.61, $p = 0.113$). When adjusting for covariates in model 2, the likelihood-ratio test supported good model fit ($\chi^2 = 17.99$, $p = 0.035$). Though statistically significant, the effect of walkability remained minimal (standardized β = -

0.751, OR = 0.98, $p = 0.048$). The effect of walking was not statistically significant (standardized $\beta = 0.187$, OR = 1.21, $p = 0.578$). Based on the Monte Carlo method, the indirect effect was also non-significant ($\beta = 0.028$, 95% CI [-0.005, 0.008]) (Figure 4, Table 8b).

Hypothesis 3

In model 1 of direct pathway *c*, model fit was poor when examining the effect of walkability alone ($\chi^2 = 1.83$, $p = 0.176$) (Table 9a). Inclusion of covariates in model 2 improved the model fit ($\chi^2 = 61.01$, $p < 0.001$), but effect of walkability on PF was non-significant (standardized $\beta = -0.243$, OR = 0.99, $p = 0.433$).

When a cumulative odds ordinal logistic regression analysis was run to determine the effect of walkability and walking on PF scores, the model predicted PF scores over and above the intercept-only model ($\chi^2 = 8.07$, $p = 0.018$). The effect of walkability was not statistically significant (OR = 0.99, $p = 0.194$), while walking had a statistically significant effect on prediction of PF scores (OR = 2.14, $p = 0.011$). When adjusting for covariates, the final model had good model fit ($\chi^2 = 49.83$, $p < 0.001$). In this final model, both walkability and walking did not significantly predict PF scores (standardized $\beta = -0.350$, OR = 0.99, $p = 0.398$, and standardized $\beta = 0.707$, OR = 2.04, $p = 0.056$, respectively). Overall, the indirect effect of walkability on PF was not statistically significant ($\beta = 0.107$, 95% CI [-0.009, 0.015]) (Figure 5, Table 9b).

Hypothesis 4

Ordinal logistic regression analyses were run to examine the direct effect of walkability on SRGH. Model 1 that examined only the effect of walkability on SRGH had poor model fit ($\chi^2 = 0.010$, $p = 0.921$) (Table 10a), but inclusion of statistically significant covariates from the preliminary tests improved model fit ($\chi^2 = 50.89$, $p < 0.001$). However, walkability did not significantly predict SRGH scores (standardized $\beta = 0.185$, OR = 1.01, $p = 0.455$).

For path *b & c'*, there was good model fit when examining the effect of walkability and walking on SRGH as supported by the likelihood-ratio test ($\chi^2 = 8.63$, $p = 0.013$) (Table 10a). Although walkability did not predict SRGH (OR = 1.00, $p = 0.705$), the odds of reporting better SRGH was 2.23 ($p = 0.004$) times greater for participants who had high levels of walking than those who had low levels of walking. When adjusting for covariates in model 2, the final model maintained good model fit ($\chi^2 = 46.10$, $p < 0.001$). However, the effect of both walkability and walking was not statistically significant (standardized $\beta = 0.100$, OR = 1.00, $p = 0.750$, and standardized $\beta = 0.566$, OR = 1.77, $p = 0.062$, respectively). Based on the Monte Carlo method for assessing mediation, the indirect effect was not statistically significant ($\beta = 0.085$, 95% CI [-0.009, 0.015]) (Figure 6, Table 10b).

Hypothesis 5

We were unable to assess the relationship between walkability and C-SRH as this criterion variable was not significantly correlated with walkability, walking, and all covariates (Table 5). Likelihood-ratio tests assessing model fit for pathways *c* ($\chi^2 = 3.84$, $p = 0.871$) and *a & c'* ($\chi^2 = 3.43$, $p = 0.945$) also supported this notion as all models had poor model fit (Table 11).

Analysis for Interaction Effect

Hypothesis 6 & 7

I was unable to observe the interaction effects of age and walkability on sense of belonging and agency due to ceiling effects of the criterion variables. The ineffectiveness of 2-

way ANOVAs in examining interaction effects when ceiling effects are present has been noted by Šimkovic and Träuble (2019).

Chapter 5: Discussion

This study attempted to bridge the gap in the literature regarding the impact of macro-level neighbourhood walkability, as measured by Walk Score, on components of HAIP among older adults living in Edmonton, Canada. As past studies have frequently and indirectly associated neighbourhood walkability with better aging components and outcomes through increased physical activity (Marquet, Hipp, & Miralles-Guasch, 2017; Yen et al., 2014; Merom et al., 2015; Frank et al., 2010), a key strength of my study was the direct investigation of the relationship between neighbourhood walkability and these HAIP components through the aging well model (Wahl et al., 2012). Overall, the findings do not support the previously identified effects of neighbourhood walkability for seniors in Edmonton.

Through the aging well model (Wahl et al., 2012), I examined the effect of neighbourhood environment on domains associated with healthy aging (i.e., belonging, agency, PF, and self-reported general health - SRGH) beyond clinical health outcomes. I hypothesized that the influence of neighbourhood walkability on these HAIP components would be mediated by purposive walking. Based on this hypothesis, the mediation relationship was examined in three parts, the association between: neighbourhood walkability and HAIP components; neighbourhood walkability and purposive walking; purposive walking and HAIP components. First and foremost, findings did not support these hypotheses as walkability was either not associated with, or had minimal effect on, the HAIP components. Secondly, contrary to previous studies that examined the relationship between neighbourhood walkability and purposive walking (Hirsch et al., 2017; Towne et al., 2016; Brown et al., 2013; Camhi et al., 2019), neighbourhood walkability was not associated with purposive walking (minutes/week) in my study. The lack of association between macro-level walkability and walking was remarkable as walking behaviour was the proposed mechanism for the effect of walkable communities on healthy aging. Thirdly, despite walkability having a non-significant or minimal effect on the HAIP components, I was surprised to find that purposive walking was not correlated with the criterion variables when adjusting for covariates, particularly disability. When unadjusted, only PF and SRGH were significantly associated with walking. These results are consistent with Procter-Gray and colleagues' (2015) study where purposive walking was associated with individual health and physical abilities. Reporting of disability by participants in my study was the only consistent factor that significantly lowered the odds ratio for all HAIP components. To understand the lack of association between my variables of interest, I explore three potential explanations for my findings: limitations of the Walk Score measure, residential relocation by older seniors, and the moderating effects of walking attitudes on the relationship between neighbourhood walkability and walking.

Complexity of the Walkability Concept

Although absence of association between Walk Score and purposive walking in our study contradicts many studies that explored the relationship between Walk Score and walking among older adults (Yen et al., 2014; Towne et al., 2016; Hirsch et al., 2017; Clarke et al., 2017), this finding supports the complexity of walkability as a concept and how other walkability factors may attenuate or even outweigh the effect of crucial neighbourhood walkability characteristics measured by Walk Score (i.e., pedestrian route directness, intersection density, and mixed land use). In a systematic review by Hall and Ram (2018), they underscored the complexity of walkability and the partial validity of Walk Score in evaluating walkability. This is further supported by Carr and colleagues' (2010) who assessed Walk Score as a global estimate of neighbourhood walkability. Though Walk Score was significantly correlated with many objective measures of the physical environment, it was also positively correlated with reported crimes which indicated its inability to serve as a global measure of walkability. Anecdotal evidence in our study may provide insights into the non-significant correlation between Walk Score and walking. Although not formally assessed, several participants in my study commented on crime rates in their neighbourhood as deterrents to walking regardless of their neighbourhood Walk Score. This anecdotal evidence is consistent with other peer-reviewed studies that have supported safety from crime as a crucial factor for physical activity and walking behaviours in local environments (Barnett et al., 2017; Lopez & Hynes, 2006).

Age-related Relocation

Even though my study did not find any significant association between neighbourhood walkability and the HAIP components, the results may indicate a changing role of neighbourhood walkability in the life-course of older adults. I observed that progressing age is associated with declines in mobility and physical ability, and older seniors tend to live in multifamily residences in higher walkability neighbourhoods and for a shorter tenure length. This may suggest older seniors relocate to adapt to their physical decline which is in line with distinctions between residential movers and stayers identified by Wiseman and Roseman (1979). Although the findings differ from those of Van Holle et al. (2016) where PF was positively associated with purposive walking for older residents in high-walkable neighbourhoods, my results are in line with their conjecture that high-walkable environments play a protective and supportive role in older adults' declining PF. Reasons to relocate to neighbourhoods with higher walkability may reflect declines in health and functional ability and the need to accommodate these changes by improving access to local amenities (Edmonston & Lee, 2014). Thus, potential positive effects of neighbourhood walkability may be masked by residential movers who are likely to already experience a lower sense of agency, belonging, PF, and self-rated health.

Potential Determinants of Walking Attitudes

Another explanation for the non-significant relationship between macro-level neighbourhood walkability, walking and HAIP components may involve attitudes to active transport. Past studies have highlighted the importance of walking attitudes and perceptions of the BE in moderating the positive effects of neighbourhood walkability on purposive walking (Berry et al., 2010; Joh et al., 2012; Chan et al., 2019). In Berry et al. (2010), attitudes to walking in walkable neighbourhoods moderated the effect of walkable neighbourhoods on BMI levels and walking levels. In their study, residential movers who chose their neighbourhoods for ease of walking did not experience the greater increase in BMI than those who rated walking as not important. Joh et al. (2012) identified differential effects of neighbourhood walkability on walking among persons with different walking attitudes. Specifically, residents with positive walking attitudes walked more when living in communities with nearby amenities than their counterparts with negative walking attitudes. In Chan et al. (2019), the perceived environment moderated the effects of neighbourhood walkability such that positive BE perceptions could offset the effect of low neighbourhood walkability on walking. Thus, the combination of suburban sprawl, winter conditions, and potential fear of neighbourhood crime in my study may create unfavourable attitudes to walking among Edmonton seniors which can undermine the positive effects of walkable neighbourhoods and purposive walking.

As this study was conducted in a winter city, participants have frequently noted the winter conditions as a major deterrent to walking which may further explain the non-significant association between walkability and purposive walking. For example, one participant commented how she needed to drive to a senior center adjacent to her residence because the snow and windrows (piles of snow left on roadsides after snow plowing) impeded her ability to get around by walking with a mobility aid. This is in line with a previous qualitative study done in Edmonton where older adults identified ice, snow, and windrows as major impediments for their mobility in winter (Garvin, Nykiforuk, & Johnson, 2012). Aside from uncleared snowfall, snow windrows can trap pedestrians on sidewalks (Garvin et al., 2012). Other literature also supports winter accessibility as one of the greatest concerns for older adults living in urban centers that experience cold, snowy, and/or icy conditions (Li et al., 2013; Garvin et al., 2012; Clarke et al., 2015; Clarke et al., 2017). In the study by Li and colleagues (2013), presence of snow and ice impacted frequency of outdoor excursions. Similarly, car-dependent neighbourhoods became inaccessible to walking in Vancouver when it snowed (Clarke et al., 2017). More importantly, Clarke et al. found that weather conditions changed the degree of association between neighbourhood walkability and senior mobility: even older adults living in very walkable neighbourhoods walked to fewer destinations in the presence of snow. It should be noted that environmental conditions in Edmonton are less favourable for pedestrian activity than Vancouver, one of Canada's most walkable cities (Redfin, 2020). In addition to being characterized by extensive sprawl and low population density of about 1, 200 people per square kilometer (Clark et al., 2010; World Population Review, 2020), Edmonton experiences considerably more snow than Vancouver (Shirgaokar & Gillespie, 2016). These conditions may exacerbate the undermining effect of winter conditions on the walkable characteristics measured by Walk Score.

Wasfi, Steinmetz-Wood, & Kestens (2017) found the association between neighbourhood walkability and purposive walking to vary based on population center size. More specifically, there was a positive association between neighbourhood walkability and purposive walking for older adults living in large population centers (population ≥ 500,000), but this association was absent for older adults in medium population centers (100,000 ≤ pop. < 500,000). Thus, population density of urban centers may influence perceptions of the BE and attitudes to transportation modes which may explain the results in my study. Although the Edmonton has population of about 1, 500,000 (World Population Review, 2020), the harsh climate conditions, low population density design of many neighbourhoods, suburban sprawl design of the region, and a car-focused culture (Montemurro et al., 2011; Turcotte, 2012) may more strongly encourage automotive transport over active transportation, which may ultimately obscure the relationship between neighbourhood walkability, purposive walking, and HAIP components. The issue of car culture is highlighted by a study in Winnipeg, Canada, where the tendency to drive is paramount (Menec et al., 2016). In that study, many middle-aged and older adults did not think having nearby amenities as important, but even those who reported proximity to amenities as very important still drove. Since Edmonton and Alberta have been shown to have a car culture (Montemurro et al., 2011; Turcotte, 2012), we could expect a decreased emphasis on the valuing of walkability and purposive transportation-related walking among Edmonton seniors. Although not prompted to do so, some participants in my study made written comments in favour of car-oriented and less dense neighbourhoods. Out of all provinces in Canada, Alberta had the second highest proportion (83%) of seniors with a driver's licence (Turcotte, 2012). In the study by Montemurro et al. (2011), older Edmontonians described walking primarily for leisure or exercise purposes more commonly than for active transportation to destinations. Moreover, their study participants identified Edmonton winters as a barrier to walking and the ability to drive in their neighbourhood as a crucial factor in their neighbourhood choice. Montemurro et al.

concluded that seasonal variations, particularly winter temperature and conditions, influence walking behaviour regardless of neighbourhood features. Similarly, Edmonton seniors in Garvin and colleagues' (2012) study emphasized public facilities, pseudo-public and private spaces as alternatives to public open spaces and streets for winter gatherings and socialization. The literature and my study's anecdotal evidence supports the notion that purposive walking and the public streetscape may be less of a priority than car use for Edmonton seniors, which can add to potential explanations of the non-significant association between purposive walking and the HAIP components. For instance, seniors who do not get to destinations by active transport, but drive, may still preserve their sense of belonging and agency by staying connected with their communities and going where they please (Jakubec et al., 2019; Rapoport et al., 2017). This may be the case for the seniors in my study since the vast majority of study participants still lived in single family homes, which are negatively correlated with walkability in my study, and participants had been living in their homes for an average of nearly 22 years.

Strengths and Limitations of the Study

This is the first quantitative study that I am aware of to investigate the relationship between neighbourhood walkability, sense of belonging, agency, PF and SRGH among older adults. Past research on these direct relationships were of exclusively qualitative designs, while most quantitative studies on this topic only examined the relationship between neighbourhood walkability and walking or walking and health outcomes, such as diabetes (Funk & Taylor, 2013), cardiovascular disease (Murtagh et al., 2010), BMI and mental health (Hanson & Jones, 2015). Other strengths include the theory-based investigation employing the multidimensional aging well model (Wahl et al., 2012) and use of validated tools, such as Walk Score for walkability, the International Physical Activity Questionnaire (IPAQ) for purposive walking

(Craig et al., 2003), Social Provisions Scale (SPS) for sense of belonging (Cutrona et al., 1987), Agency Scale for agency (Smith et al., 2000), PF-10 for PF (Ware & Sherbourne, 1992), and the 1-item SRGH measure for health (CCHS, 2018). Taking a multidimensional approach to healthy aging, this study recognized that older adults may experience healthy aging even in the face of comorbidities and reflects important domains for aging well as identified by Canadian seniors (Bélanger et al., 2018). Additionally, another strength of the study was the spread of data collected across the Edmonton region sampling residents from a diversity of urban forms.

Nevertheless, our study is subject to several limitations. First, the insufficient sample size resulted in underpowered ordinal logistic regression analyses ($1\text{-}\beta = 0.77$), indicating less than acceptable statistical power in identifying statistically significant effects. The current sample size would have been sufficient for the initially proposed multiple regression analyses. However, non-normality of the criterion variables dictated the need to perform ordinal logistic regression analyses instead of multiple regressions. I was unable to recruit more participants after March due to the time constraints of the study and the COVID pandemic. Second, this study was conducted with a cross-sectional design. It is often difficult to make inferences for causality from cross-sectional studies. Thus, we were unable to tease apart the effect of neighbourhood walkability on HAIP components and whether participants relocated to more walkable neighbourhoods to accommodate for declines in HAIP components (Wiseman & Roseman, 1979). Past studies on the BE have frequently noted limitations to cross-sectional designs as neighbourhood self-selection may explain walking behaviour in walkable neighbourhoods (Berry et al., 2010; Lu, Chen, Yang, & Gou, 2018). Second, since data were collected only in the winter season (i.e., November to March), I was unable to adjust for the winter season, which can play a significant role in the relationships I investigated (Garvin et al., 2012). Fourth, the generalizability of the findings may be limited because most of the participants were recruited through senior centers and this group may be biased towards better health, PF, and sense of belonging (Aday, Wallace, & Krabill, 2018; Wanchai & Phrompayak, 2019). However, this can also be a strength in my study as this group is more likely to be involved with their local communities and may accentuate the effects of neighbourhood walkability. Fourth, although macro-level walkability is primarily associated with purposive walking and not leisure walking (Van Holle et al., 2016; Cerin et al., 2017; Cerin et al., 2020), only purposive walking was assessed in this study when previous studies have indicated Edmonton seniors to walk primarily for leisure (Montemurro et al., 2011). Fifth, there are limitations with the measure Walk Score in measuring walkability as it does not consider other factors, such as weather conditions, street-scale walkability, and safety from crime and traffic (Hall & Ram, 2018). These other walkability features can play an important role in acting as facilitators or barriers to walking (Grant et al. 2010; Barnett et al., 2017; Rachele et al., 2019). Despite this limitation, Walk Score was a good measure for macro-level walkability in this study, especially given the large sample size, and time and monetary constraints of the study. For future studies, it will be important to consider inclusion of other measures such as walkability audits or self-reported measures that assess crime rate, winter conditions, and street-level walkability.

Conclusion

Healthy and active cities, through walkable neighbourhoods, is a potential intervention in addressing the issues surrounding the globally growing older adult population. This study adds to the growing body of quantitative evidence on neighbourhood walkability and aging. Older adults from neighbourhoods of varying macro-level walkability characteristics were not different in sense of belonging, agency, PF, or health. However, results from this study show older seniors with greater disability live in more walkable neighbourhoods for a shorter tenure length which suggests relocation to accommodate for functional declines. Therefore, although the BE's role in sense of agency and PF already occurring from these disabilities may be obscured in my study, the BE may play a protective role in preserving physical autonomy and functioning of older adults with declining functional ability by increasing access to local goods and services.

The inconsistency of my findings with many past quantitative studies on neighbourhood walkability and purposive walking highlights important factors to consider in this complex relationship. The findings suggest other factors may take precedence over intersection density, pedestrian-route directness, and mixed land use in influencing purposive walking behaviour and healthy aging among older adults residing in areas that experience seasonal climate variations that include harsh winter conditions. Participants of this study have frequently commented on winter climate conditions that deterred outdoor excursions and the importance of driving. Furthermore, as other studies have shown that purposive walking and pedestrian activity on public streets can be undervalued and decreased in cities with car-culture, the value of these macro-level walkability features as well as purposive walking itself may be diminished in the general population of older adults living in cities like Edmonton. Thus, they may only become more significant and appreciated once seniors experience physical declines and an inability to drive.

For future research, I recommend investigation of how seasonality, weather conditions, car-culture, and age-related relocation impact the relationship between neighbourhood walkability and HAIP. Research into whether neighbourhood preferences change over time for older adults, especially for those who experience functional decline or the loss of ability to drive, is needed to better understand the value of mixed use, higher density and walkable neighbourhoods, especially for seniors living in winter cities with a car culture.

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Figures

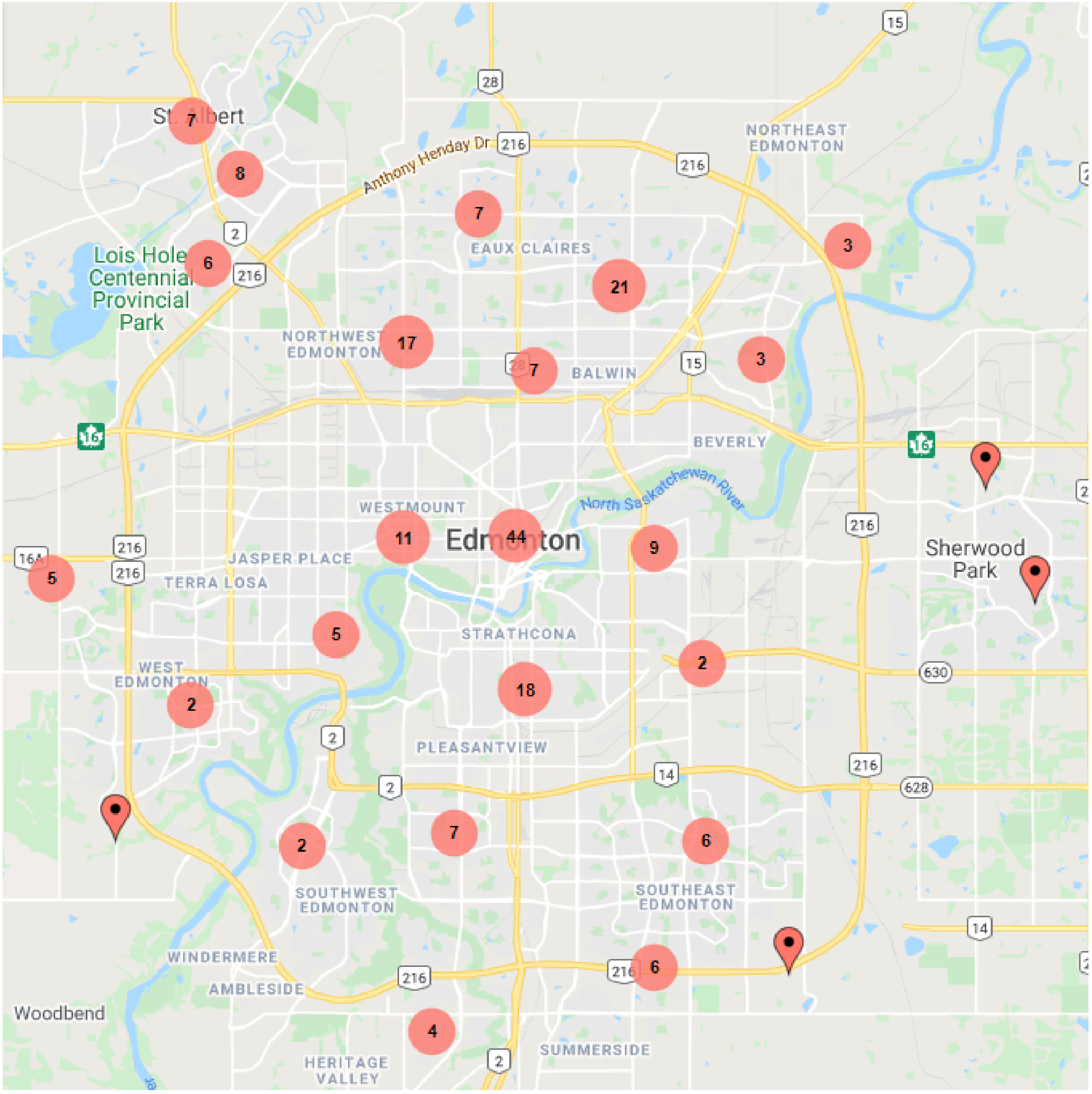

Figure 1. Map of Edmonton region with distribution of cases.

Numbers in peach circles indicate the number of participants living in specific geographical areas.

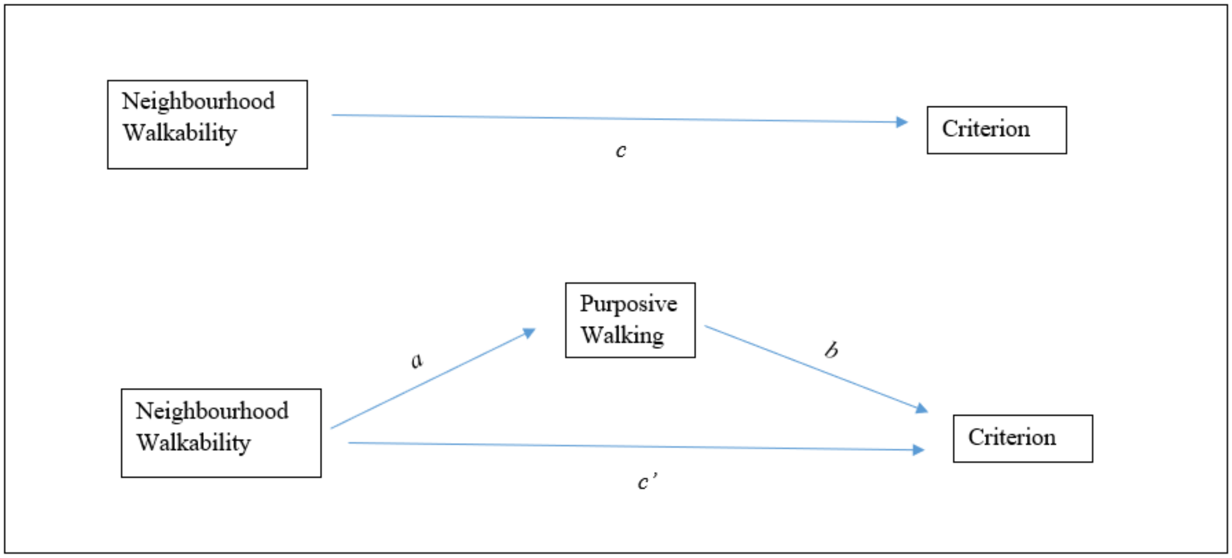

Figure 2. General hypothesized mediation relationship.

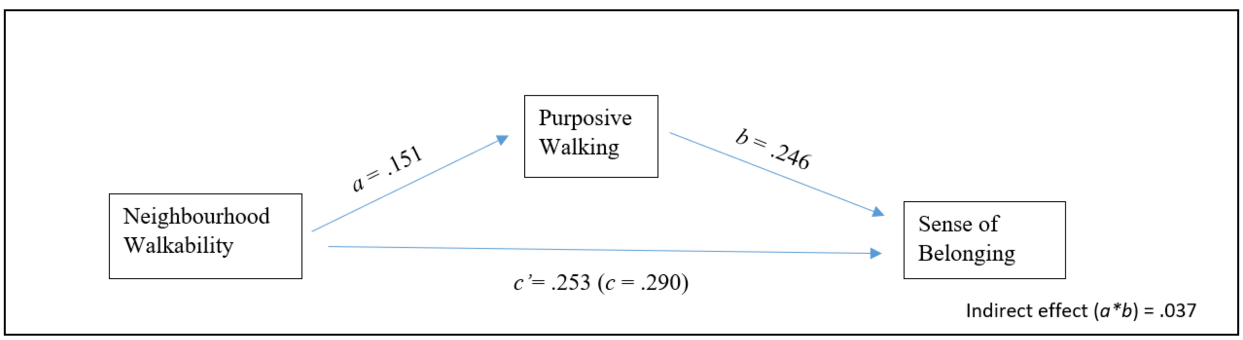

Figure 3. Mediation diagram for sense of belonging

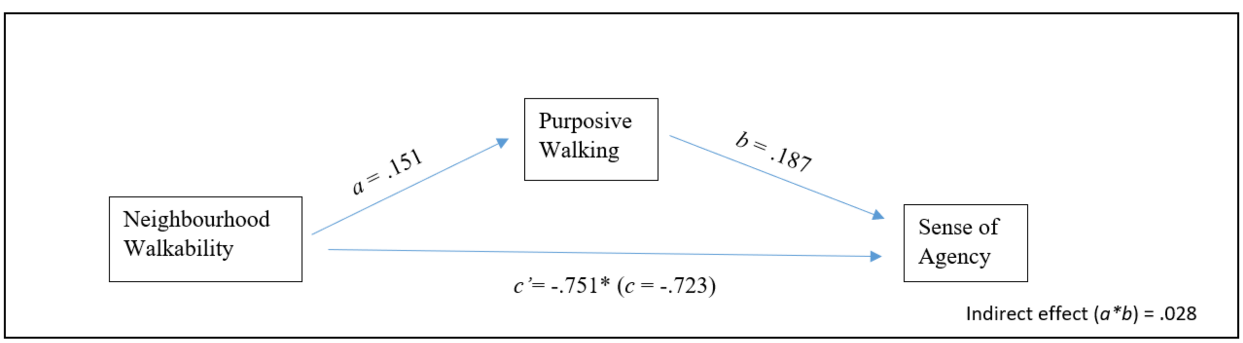

Figure 4. Mediation diagram for sense of agency

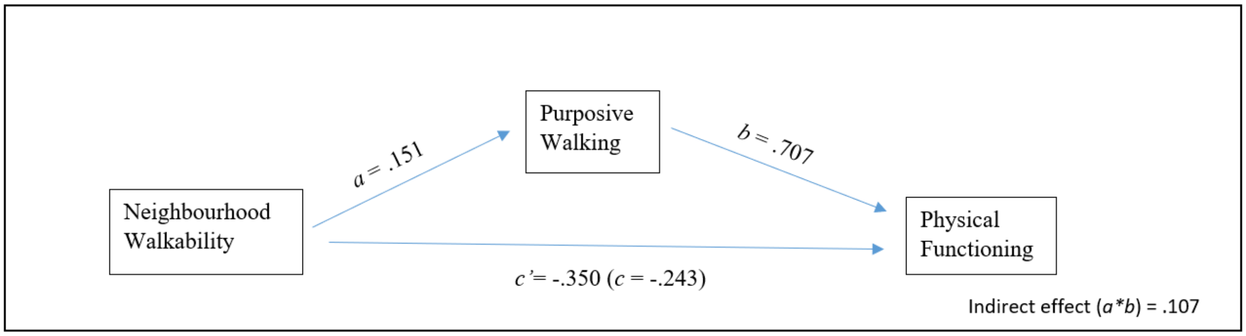

Figure 5. Mediation diagram for physical functioning

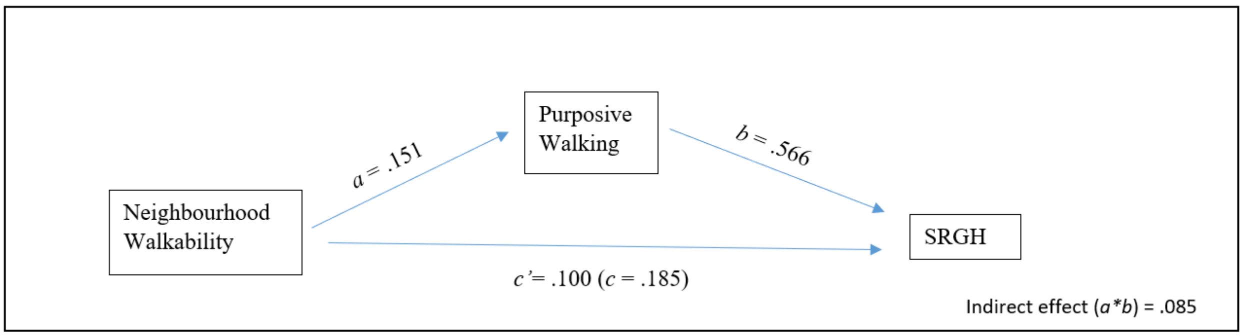

Figure 5. Mediation diagram for SRGH

Tables

Table 1. List of variables with Cronbach's alpha and scale details of items.

Variables (# items)	Survey question examples and scale details
Criterion variable	
Sense of belonging[d] (9) (*alpha* = .925)	Please indicate to what extent each statement describes your current relationships with other people. There are people I can depend on for help if I really need it. (4-point scale, 1 = strongly disagree, 4 = strongly agree)
Sense of agency[d] (8) (*alpha* = .858)	I get what I want or need by relying on my own efforts and ability. (4-point scale, 1 = Never, 4 = Often)
Physical functioning[d] (9) (*alpha* = .925)	The following items are about activities you might do during a typical day. Are you limited in any of these activities? If so, how much? (3-point scale, 1 = yes, limited a lot, 3 = No, not limited at all)
Self-rated general health (1)	To start, in general, would you say your health is: (5-point scale, 1 = poor, 5 = excellent)
Comparison self-rated health (1)	Compared to one year ago, how would you say your health is now? (5-point scale, 1 = much worse now (than 1 year ago), 5 = much better now than 1 year ago)
Predictor variables	
Walkability (1)[a]	(continuous scale, 0-100)
Walkability (1)[b]	Dummy variable calculated from Walk Score (0 = car-dependent, 1 = walkable)
Mediating variable	
Purposive walking[d] (2)	During the last 7 days, on how many days did you walk for at least 10 minutes at a time to go from place to place? How much time did you usually spend on one of those days walking from place to place? (continuous scale)[c]
Covariates	
Sex (1)	What is your sex? (0 = female, 1 = male)
Age (1)	What is your age? (1 = 65 – 74 years, 8 = 100 years or over)
Marital status – Married (1)[d]	What is your marital status? (0 = otherwise, 1 = married)
Education (1)	What is the highest level of education you have completed? (1 = Did not complete high school, 4 = Completed graduate education)
Minority status (1)[d]	Are you: (0 = white, 1 = otherwise)

Indigenous status (1)[d]	Are you: (0 = otherwise, 1 = Indigenous)
Employment status (1)[d]	What is your current employment status? (0 = unemployed, 1 = employed)
Income (1)[d]	What is your annual household income after taxes? (5-point scale, 1 = below $20,000, 5 = Over $100,000)
Survey mode – online[e]	(0 = paper, 1 = online)
Homeownership (1)	Do you own your residence or rent? (0 = rent, 1 = own)
Housing type – Multifamily home (1)[d]	In what type of residence do you live? (0 = single-family home, 1 = multifamily home)
Housing tenure length (1)	How long have you lived in this residence? (continuous variable in years)
Mobility-aid use (3)[f]	Do you use the following: cane / walker / wheelchair? (3-point scale, 0 = No, 2 = Yes, always)
Disability (1)	Do you have any condition that limits your ability to participate in your activities of daily living? (3-point scale, 0 = No, never, 2 = Yes, always)

[a] Continuous variable calculated from address and/or postal code through walkscore.com.
[b] 0-49 is car-dependent and 50-100 is walkable.
[c] Measured as minutes per week.
[d] Variables transformed into dichotomous variables.
[e] Variable generated based on online completion timestamp on REDCap.
[f] Three variables transformed into single variable.

Table 2. Hypotheses and analytical tests

Research Question: How does neighbourhood walkability correlate with sense of belonging, agency, physical functioning, and health among older adults?			
	Hypotheses	**Analytical Test**	**Power (1-β)**
1.	Neighbourhood walkability will influence sense of belonging among older adults, through its influence on purposive walking.	Ordinal logistic regression	0.77
2.	Neighbourhood walkability will influence sense of agency among older adults, through its influence on purposive walking.	Ordinal logistic regression	0.77
3.	Neighbourhood walkability will influence physical functioning among older adults, through its influence on purposive walking.	Ordinal logistic regression	0.77
4.	Neighbourhood walkability will influence self-rated general health among older adults, through its influence on purposive walking.	Ordinal logistic regression	0.77
5.	Neighbourhood walkability will influence 1-year health comparisons among older adults, through its influence on purposive walking.	Ordinal logistic regression	-
6.	Age will moderate the effect of neighbourhood walkability on sense of belonging among older adults.	2-way ANOVA	-
7.	Age will moderate the effect of neighbourhood walkability on sense of agency among older adults.	2-way ANOVA	-

Table 3. Descriptive statistics for explanatory and criterion variables

Variables	n (%)	Mean (SD)	Median (25%, 75%)	Range
Total number of participants (N) = 213 (100%)				
Predictor				
Walk Score	213	42.39 (25.1)	44.00	0 – 97
Car-dependent	123 (57.7%)	24.51 (14.47)		
Walkable	90 (42.3%)	66.82 (12.90)		
Mediator				
Purposive Walking (mins/wk)[a]	189 (88.7%)	-	120.0 (17.5, 300.0)	0 - 1890
Low	92 (43.2%)	30.6 (33.49)		
High	97 (45.5%)	416.3 (367.2)		
Covariates				
Address	213	-		
Postal Code only	10 (4.7%)			
Street/Home address	203 (95.3%)			
Sex	213	.28 (0.45)	-	0 – 1
Female	153 (71.8%)			
Male	60 (28.2%)			
Age	211	-	2 (2, 3)	1 – 7
65 – 69 years	44 (20.7%)			
70 – 74 years	67 (31.5%)			
75 – 79 years	48 (22.5%)			
80 – 84 years	34 (16.0%)			
85 – 89 years	15 (7.0%)			
90 – 94 years	3 (1.4%)			
Older/Younger seniors	211	.47 (0.50)	-	0 – 1
Under 75 years	111 (52.1%)			
75 years or over	100 (46.9%)			
Marital Status	211	-	-	-
Married or living with a partner	114 (53.5%)			0 – 1
Separated or divorced	37 (17.4%)			0 – 1
Widowed	49 (23%)			0 – 1
Never been married	11 (5.2%)			0 – 1
Education	206	-	3 (2, 3)	1 – 4
Did not complete high school	13 (6.1%)			
Completed high school	59 (27.7%)			
Completed college or university	103 (48.4%)			
Completed graduate education	31 (14.6%)			
Employment status	211	.10 (0.31)	-	0 – 1
Employed	22 (10.3%)			
Retired / Unemployed	189 (88.7%)			
Ethnicity	210	0.17 (0.37)	-	0 – 1
Caucasian	175 (82.2%)			
Minority	35 (16.4%)			
Indigenous	9 (4.2%)	0.04 (0.20)	-	0 – 1
Income	151 (70%)	-	2 (2, 3)	1 – 6
Below $25,000	31 (13.6%)			
$25,000 - $49,999	52 (24.4%)			

$50,000 - $74,999	37 (17.4%)			
$75,000 - $100,000	17 (8.0%)			
Over $100,000	14 (6.6%)			
Homeownership	202	0.81 (0.40)	-	0 – 1
Own	163 (76.5%)			
Rent	39 (18.3%)			
Housing Type	204	0.40 (0.49)	-	0 – 1
Single-family home	123 (57.7%)			
Multi-family home	81 (38.0%)			
Housing Tenure (years)	207	21.92 (16.49)	20.00	0.50 – 62.00
Survey Modality	213	0.17 (0.38)	-	0 – 1
Online	36 (16.9%)			
Paper	177 (83.1%)			
Mobility-aid use	213	-	0 (0, 0)	0-2
Always	11 (5.2%)			
Sometimes	39 (18.3%)			
No	163 (76.5%)			
Disability	213	-	1 (0, 1)	0 – 2
Always	15 (7%)			
Sometimes	104 (48.8%)			
Never	94 (44.1%)			
Criterion Variables				
Sense of belonging[a]	205	-	32.0 (27.0, 34.0)	9 – 36
Low	96 (45.1%)	27.00 (3.94)		
High	109 (51.2%)	34.32 (1.51)		
Sense of agency[a]	213	-	3.88 (3.63, 4.0)	1 – 4
Low	94 (44.1%)	3.49 (.37)		
High	119 (55.9%)	3.96 (.06)		
Physical functioning[a]	212	-	77.9 (50.0, 88.9)	0 – 100
Low	112 (52.6%)	47.59 (22.46)		
High	100 (46.9%)	91.97 (6.51)		
Health (SRGH)	212	-	4.00 (3.00, 4.00)	1 – 5
Comparison self-rated health (C-SRH)	210	-	3.00 (3.00, 3.00)	1 – 5

[a] dichotomization based on median split

Table 4. Walk Score quartiles

Quartiles	Walk Score Range
1st	0 – 19
2nd	20 – 43
3rd	44 – 62
4th	63 – 97

Table 5. Bivariate correlations[a]

	1	2	3	4	5	6	7	8	9	10	11	12
1. Walkability	1											
2. Walking	.016	1										
3. Belonging	.005	.157*	1									
4. Agency	-.106*	.096	.305**	1								
5. PF	-.086	.262**	.172*	.265**	1							
6. SRGH	-.007	.248**	.374**	.230**	.504**	1						
7. C-SRH	.008	.080	.141*	.170**	.181**	.259**	1					
8. Tenure Length	-.179**	.077	.234**	.132	.138*	.140*	-.026	1				
9. Age	.065	-.044	-.048	-.060	-.245**	-.127	-.077	.069	1			
10. Education	-.077	-.036	.057	-.086	.094	.122	-.097	-.017	-.182	1		
11. Disability	.046	-.169*	-.257**	-.238**	-.568**	-.440**	-.071	-.126	.078	-.049	1	
12. Mobility aid	.087	-.154*	-.108	-.182*	-.491**	-.349**	-.107	-.138*	.256**	-.045	.424**	1
13. Sex	-.163*	.082	.045	.045	.108	.014	.047	-.119	-.009	.181**	.004	-.079
14. Married	-.236**	-.028	.124	.025	.173*	.148*	-.013	.212**	-.286**	.255**	-.184**	-.187**
15. Income	-.326**	-.170*	.110	.127	.262**	.201*	-.052	.188*	-.197*	.366**	-.176*	-.211**
16. Employed	.172*	.063	.032	.021	.122	.026	.036	-.079	-.074	-.005	-.073	-.032
17. Minority	.089	.045	-.002	-.215**	-.096	-.060	.017	-.143*	-.187**	-.123	-.062	-.039
18. Indigenous	.082	-.074	.086	-.095	-.113	-.050	.109	-.124	-.019	-.316**	.090	.065
19. Survey mode	.113	-.029	.150*	-.090	.046	.101	.030	-.011	-.251**	.234**	-.013	-.052
20. Homeowner	-.336**	-.048	.125	.150*	.191**	.157*	-.053	.468**	-.133	.075	-.119	-.279**
21. Housing Type	.284**	.048	.113	-.048	-.183**	-.098	.044	-.605**	.175*	.020	.081	.189**

Spearman's and point biserial correlations with 2-tailed significant testing. * = $p < 0.05$; ** = $p < 0.01$.
[a] Bivariate correlations were not calculated between two dichotomous covariates (variables 15-21).

Table 6. Ordinal logistic regression models for effect of walkability on walking.

	Path *a*					
	Model 1		Model 2		Model 3	
	χ^2	p-value	χ^2	p-value	χ^2	p-value
Final Model Fit	.23	.635	7.07*	.029	11.29	.186
	OR	p-value	OR	p-value	OR	p-value
Predictor						
Walkability	1.25	.635	1.00	.544	1.00	.656
Mediator						
Walking						
Covariates						
Sex					1.04	.911
Married					.56	.143
Employed					.60	.320
Homeownership					1.61	.369
Tenure length					1.01	.419
Housing type					1.15	.761
Disability			.52*	.010	.49*	.012

*p < .05. **p < .01

Table 7a. Ordinal logistic regression models for sense of belonging.

	Path *c*				Path *b* & *c'*			
	Model 1		Model 2		Model 1		Model 2	
	χ^2	p-value	χ^2	p-value	χ^2	p-value	χ^2	p-value
Final Model Fit	.499	.480	23.08**	.003	2.50	.287	22.03**	.009
	OR	p-value	OR	p-value	OR	p-value	OR	p-value
Predictor								
Walkability	1.00	.481	1.01	.157	1.00	.775	1.01	.516
Mediator								
Walking					1.59	.123	1.28	.472
Covariates								
Sex			1.57	.244			1.60	.270
Married			1.07	.855			1.23	.627
Employed			1.03	.952			1.10	.862
Homeownership			1.81	.257			1.58	.423
Tenure length			1.03*	.040			1.02	.093
Housing type			1.70	.257			2.22	.112
Disability			0.43**	.002			.40**	.002

*p < .05. **p < .01

Table 7b. Path coefficients for mediating effect on sense of belonging.

Testing paths	Unstandardized coefficient β	SE (unstandardized coefficient)	Standardized coefficient β	p-value	Monte Carlo (95% CI)
Path *c*					
Walkability			.290		
Path *a*					
Walkability	.003	.007	.151	.656	
Path *b* & *c'*					
Walkability (c')	.005	.008	.253	.516	
Walking (*b*)	.248	.345	.246	.472	
Indirect effect (a*b)			.037		(-.005, .008)

Table 8a. Ordinal logistic regression models for sense of agency.

	Path *c*				Path *b* & *c'*			
	Model 1		Model 2		Model 1		Model 2	
	χ^2	p-value	χ^2	p-value	χ^2	p-value	χ^2	p-value
Final Model Fit	4.61*	.032	18.33*	.019	7.39*	.025	17.99*	.035
	OR	p-value	OR	p-value	OR	p-value	OR	p-value
Predictor								
Walkability	.99*	.034	.99	.140	.99*	.025	.98*	.048
Mediator								
Walking					1.61	.113	1.21	.578
Covariates								
Sex			1.33	.440			1.39	.423
Married			.60	.181			.54	.137
Employed			.47	.140			.51	.196
Homeownership			1.51	.409			1.42	.511
Tenure length			1.01	.461			1.01	.551
Housing type			1.07	.871			1.21	.684
Disability			.49**	.006			.48*	.013

*p < .05. **p < .01

Table 8b. Path coefficients for mediating effect on sense of agency.

Testing paths	Unstandardized coefficient β	SE (unstandardized coefficient)	Standardized coefficient β	p-value	Monte Carlo (95% CI)
Path *c*					
Walkability			-.723		
Path *a*					
Walkability	.003	.007	.151	.656	
Path *b* & *c'*					
Walkability (c')	-.015	.008	-.751*	.048	
Walking (*b*)	.188	.338	.187	.578	
Indirect effect (a*b)			.028		(-.005, .008)

Table 9a. Ordinal logistic regression models for physical functioning.

	Path *c*				Path *b* & *c'*			
	Model 1		Model 2		Model 1		Model 2	
	χ^2	p-value	χ^2	p-value	χ^2	p-value	χ^2	p-value
Final Model Fit	1.83	.176	61.01**	< .001	8.07*	.018	49.83**	<.001
	OR	p-value	OR	p-value	OR	p-value	OR	p-value
Predictor								
Walkability	.99	.178	.99	.433	.99	.194	.99	.398
Mediator								
Walking					2.14*	.011	2.04	.056
Covariates								
Sex			2.95*	.013			2.52*	.041
Married			1.13	.768			1.41	.428
Employed			2.55	.117			3.01	.072
Homeownership			1.54	.468			1.49	.524
Tenure length			.99	.662			.99	.551
Housing type			.80	.667			.88	.817
Disability			.15**	< .001			.21**	< .001

*p < .05. **p < .01

Table 9b. Path coefficients for mediating effect on physical functioning.

Testing paths	Unstandardized coefficient β	SE (unstandardized coefficient)	Standardized coefficient β	p-value	Monte Carlo (95% CI)
Path *c*					
Walkability			-.243		
Path *a*					
Walkability	.003	.007	.151	.656	
Path *b* & *c'*					
Walkability (c')	-.007	.008	-.350	.398	
Walking (*b*)	.712	.372	.707	.056	
Indirect effect (a*b)			.107		(-.009, .015)

Table 10a. Ordinal logistic regression models for SRGH.

	Path *c*				Path *b* & *c'*			
	Model 1		Model 2		Model 1		Model 2	
	χ^2	p-value	χ^2	p-value	χ^2	p-value	χ^2	p-value
Final Model Fit	.010	.921	50.89**	< .001	8.63*	.013	46.10**	< .001
	OR	p-value	OR	p-value	OR	p-value	OR	p-value
Predictor								
Walkability	1.00	.920	1.01	.455	1.00	.705	1.00	.750
Mediator								
Walking					2.23**	.004	1.77	.062
Covariates								
Sex			1.21	.565			1.18	.646
Married			.89	.718			.93	.841
Employed			.89	.809			1.04	.942
Homeownership			1.76	.213			1.64	.309
Tenure length			1.00	.726			1.00	.934
Housing type			.89	.768			.90	.794
Disability			.19**	< .001			.21**	< .001

*p < .05. **p < .01

Table 10b. Path coefficients for mediating effect on SRGH.

Testing paths	Unstandardized coefficient β	SE (unstandardized coefficient)	Standardized coefficient β	p-value	Monte Carlo (95% CI)
Path *c*					
Walkability			.185		
Path *a*					
Walkability	.003	.007	.151	.656	
Path *b* & *c'*					
Walkability (c')	.002	.007	.100	.750	
Walking (*b*)	.57	.305	.566	.062	
Indirect effect (a*b)			.085		(-.009, .015)

Table 11. Model fit for ordinal logistic regression models of C-SRH

	χ^2	df	p-value
Model 1 (Path *c*)	3.84	8	.871
Model 2 (Paths *a* & *c'*)	3.43	9	.945

Appendix – Survey Questionnaire

Research Study: Aging Healthily in Place for Independent Living Seniors in a Northern City

Please answer the following questions about your neighbourhood and yourself. Please answer as honestly and completely as possible and provide only one answer for each item. There are no right or wrong answers. Your information will be kept confidential and stored securely.

1. a) In what type of residence do you live?
   - A. Detached single-family home
   - B. Townhouse or row house of 1-3 storeys
   - C. Apartment or condo of 1-3 storeys
   - D. Apartment or condo of 4-6 storeys
   - E. Apartment or condo of 7-12 storeys
   - F. Apartment or condo with more than 13 storeys

   b) How long have you lived in this residence?

   ___________ years

   c) Do you own your residence or rent? A. Own B. Rent

2. What is your postal code?

   ____

3. What is your street address?

   ____

4. Do you live in a Christenson residence? A. Yes B. No

5. Do you use any of the following:

	Yes, always	Yes, sometimes	No
a) Cane			
b) Walker			
c) Wheelchair			

The next questions are about your current relationships with friends, family members, and neighbours in your neighbourhood. Please indicate to what extent each statement describes your current relationships with other people.

6. There are people I can depend on to help me if I really need it.
   A. Strongly agree
   B. Agree
   C. Disagree
   D. Strongly disagree

7. There are people who enjoy the same social activities I do.
   A. Strongly agree
   B. Agree
   C. Disagree
   D. Strongly disagree

8. I have close relationships that provide me with a sense of emotional security and wellbeing.
   A. Strongly agree
   B. Agree
   C. Disagree
   D. Strongly disagree

9. There is someone I could talk to about important decisions in my life.
   A. Strongly agree
   B. Agree
   C. Disagree
   D. Strongly disagree

10. I have relationships where my competence and skills are recognized.
   A. Strongly agree
   B. Agree
   C. Disagree
   D. Strongly disagree

11. There is a trustworthy person I could turn to for advice if I were having problems.

A. Strongly agree
B. Agree
C. Disagree
D. Strongly disagree

12. I feel a strong emotional bond with at least one other person.

A. Strongly agree
B. Agree
C. Disagree
D. Strongly disagree

13. There are people who admire my talents and abilities.

A. Strongly agree
B. Agree
C. Disagree
D. Strongly disagree

14. There are people I can count on in an emergency.

A. Strongly agree
B. Agree
C. Disagree
D. Strongly disagree

For the following questions, please circle one answer that best applies to you.

15. I get what I want or need by relying on my own efforts and ability.

A. Never B. Rarely C. Sometimes D. Often

16. I control what happens to me by making choices in my best interest.

A. Never B. Rarely C. Sometimes D. Often

17. Using the right resources or tools helps me to achieve my goals.

A. Never B. Rarely C. Sometimes D. Often

18. When necessary, I learn new skills to accomplish my goals.

A. Never B. Rarely C. Sometimes D. Often

19. Being flexible enables me to achieve my goals.

A. Never B. Rarely C. Sometimes D. Often

20. Careful planning enables me to get what I want or need.

A. Never B. Rarely C. Sometimes D. Often

21. I control things by managing my affairs properly.

A. Never B. Rarely C. Sometimes D. Often

22. Once I decide on a goal, I do whatever I can to achieve it.

A. Never B. Rarely C. Sometimes D. Often

These questions are about how you traveled from place to place, including to places like work, stores, movies, and so on.

Think only about **bicycling** and **walking** you might have done to travel to and from work, to do errands, or to go from place to place.

23. a) During the **last 7 days**, on how many days did you **bicycle** for at least 10 minutes at a time to go from **place to place**?

________________ **days per week**

b) How much time did you usually spend on one of those days to bicycle from place to place?

_____________ **hours per day**

____________ **minutes per day**

24. a) During the **last 7 days**, on how many days did you **walk** for at least 10 minutes at a time to go from **place to place**?

___________ **days per week**

b) How much time did you usually spend on one of those days walking from place to place?

___________ **hours per day**

___________ **minutes per day**

This survey deals with various aspects of your health. By health, we mean not only the absence of disease or injury but also physical, mental and social well-being.

25. To start, in general, would you say your health is:

A. Excellent B. Very good C. Good D. Fair E. Poor

26. Do you have any condition that limits your ability to participate in your activities of daily living?

A. Yes, always
B. Yes, sometimes
C. No, never

27. Compared to one year ago, how would you say your health is now?

A. Much better now than 1 year ago
B. Somewhat better now (than 1 year ago)
C. About the same as 1 year ago
D. Somewhat worse now (than 1 year ago)
E. Much worse now (than 1 year ago)

28. The following items are about activities you might do during a typical day. Are you limited in any of these activities? If so, how much?

	Yes, limited a lot	Yes, limited a little	No, not limited at all
a) Vigorous activities, such as running, lifting heavy objects, participating in strenuous sports			
b) Moderate activities, such as moving a table, pushing a vacuum cleaner, bowling, or playing golf			
c) Lifting or carrying groceries			
d) Climbing several flights of stairs			
e) Climbing one flight of stairs			
f) Bending, kneeling, or stooping			
g) Walking more than a mile			
h) Walking several blocks			
i) Walking one block			

29. Rate the importance of each of the following reasons in your decision for choosing your current neighbourhood.

	Did not consider	Not at all important	Somewhat important	Very Important	Don't Know
a) Closeness to public transport					
b) Closeness to a grocery store or farmers market					
c) Closeness to other stores and services					
d) Closeness to schools					
e) Closeness to recreational facilities, parks, or trails					
f) Quality of recreational facilities, parks, or trails					
g) Access to community association					
h) Attractiveness of landscapes					
i) Cleanliness of streets					
j) Sense of community					
k) Affordability					
l) To be in a healthy building					
m) To be in a healthy neighbourhood					

n) Safety from crime					
o) Safety from traffic					
p) Other ______________________					
q) Other ______________________					

30. What is your age?
    A. 65 – 69 years
    B. 70 – 74 years
    C. 75 – 79 years
    D. 80 – 84 years
    E. 85 – 89 years
    F. 90 – 94 years
    G. 95 – 99 years
    H. 100 years or over

31. What is your sex?

    A. Male B. Female C. Prefer not to answer

The next two questions are about height and weight.

32. How tall are you without shoes on?
    _____________ inches OR _____________ cm

33. How much do you weigh?
    ____________ pounds OR _____________ kg

34. What is your current employment status?

A. Employed full-time
B. Employed part-time
C. Unemployed
D. Retired

35. What is your marital status?

A. Married or living with a partner
B. Separated or divorced
C. Widowed
D. Never been married

36. What is the highest level of education you have completed?

A. Did not complete high school
B. Completed high school
C. Completed College or University
D. Completed Graduate education (Master's or PhD)
E. Other (specify): ______________________

37. People living in Canada come from many different cultural and racial backgrounds. Are you?

A. Aboriginal (e.g. North American Indian, Métis or Inuit)
B. White
C. Chinese
D. South Asian (e.g. East Indian, Pakistani, Sri Lankan)
E. Black
F. Filipino
G. Latin American
H. Arab
I. Southeast Asian (e.g. Vietnamese, Cambodian, Laotian, Thai)
J. West Asian (e.g. Iranian, Afghan)
K. Korean
L. Japanese
M. Other- Specify ____________

38. What is your annual household income after taxes? This may include income from employment, pension, government support or any interests on investments and assets.

A. Below $25,000
B. $25,000 - $49,999
C. $50,000 - $74,999
D. $75,000 - $ 100,000
E. Over $100,000
F. Prefer not to say

This concludes the survey. Thank you for time!