Outdoor walking and physical activity and their relationship with neighbourhood walkability in older adults with self-reported difficulty in walking outdoors

by

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A Thesis submitted to the Faculty of Graduate Studies of
The University of Manitoba
In the partial fulfilment of the requirements of the degree of

MASTER OF SCIENCE

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Abstract

Introduction: Neighbourhood walkability has been suggested to influence walking behaviors. However, few studies focused on their relationships in Canadian older adults. The aims of this study were (1) to compare outdoor walking and moderate-to-vigorous physical activity time (MVPA) time in older adults with self-reported difficulty in different cities in Canada; (2) to estimate the associations between outdoor walking and subscale scores and the total scores of neighbourhood walkability; and (3) to estimate the associations between MVPA time and subscale scores and the total scores of neighbourhood walkability.

Methods: This was a secondary data analysis of the Getting Older adults OUTdoors (GO-OUT) study. We used data from the baseline evaluation from 190 participants who had self-reported difficulty in outdoor walking in Edmonton (n=51), Winnipeg (n=53), Toronto (n=50), and Montreal (n=36). We compared the between-city differences in outdoor walking and MVPA time. We also attempted to use parametric tests to investigate the relationships between neighbourhood walkability, assessed by Neighbourhood Environmental Walkability Scale (NEWS), and outdoor walking and MVPA. Since the assumptions of normality, homogeneity of variances and homoscedasticity were all violated, Kruskal-Wallis test and Spearman's rho were conducted.

Results: We found (1) significant differences in MVPA time but not outdoor walking time between participants who resided in Edmonton, Winnipeg, Toronto, and Montreal, and (2) significant but weak associations between land-use mix diversity and land-use mix access, and outdoor walking (Spearman's rho = 0.172 to 0.233) and (3) between residential density, land-use mix access and street connectivity and MVPA time (Spearman's rho = -0.235 to 0.208).

Conclusion: Several aspects of neighbourhood walkability play a significant role in outdoor walking and MVPA time among community-dwelling older adults. Understanding the relationships between neighbourhood walkability and outdoor walking and MVPA can help identify facilitators and barriers to walking, which could in turn influence their walking habits in the neighbourhood.

Acknowledgements

I would like to thank Dr. Ng, Sheung Mei Shamay and Mr. Lau, Man Fung Dimon for being my referee for this program. Without your sincere support, I would not have come to Canada and pursued higher education.

I would also like to thank Dr. Nancy M. Salbach, Dr. Gina Sylvestre, and Dr. Sandra C. Webber for being the committee members. I appreciate the learning opportunities and inspirational questions provided by my committee. It is my pleasure to work on my thesis with you.

I would like to acknowledge Dr. Rasheda Rabbani for your expert opinions on data analysis. I would also like to thank Ms. Yixiu Liu for arranging the data sets and making suggestion on statistics for me. I would also like to thank Dr. James F. Sallis for your permission to incorporate the NEWS questionnaire and the scoring form in my thesis.

Thanks to Mr. Fong, Chun Kit Isaac, Ms. Lam, Pui Yan, and Ms. Lee, Ka Ying for motivating me to step out of my comfort zone and providing mental support across the ocean.

Last but not least, I would like to express my gratitude to Dr. Ruth Barclay for being my advisor. It has been a very long journey since April 2020. Thanks for inviting me to various research projects and organizing the readings course for me. I have also received numerous heartening advice from you. What I have learnt will be carried with me for the rest of my life.

This study is not funded but this is a secondary data analysis of a randomized controlled trial "Getting Older Adults OUTdoors (GO-OUT): A randomized controlled trial of a community-based outdoor walking program" funded by Canadian Institutes of Health Research (CIHR).

The relationship between neighbourhood walkability and outdoor walking in older adults with self-reported difficulty in walking outdoors

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Chapter 1: Literature Review

Aging has become one of the most important issues in Canada. The total number of older adults (≥ 65 years old) is estimated to reach 9.5 million by 2030, constituting 23 percent of Canadians. (1)Ageing is often accompanied with deterioration in physical and psychological functioning and the presence of cognitive disorders and chronic diseases, which may hinder safe navigation of the environment among older adults. (2, 3) As a result, the awareness of healthy aging is raised. Healthy aging is defined as "*the process of developing and maintaining the functional ability that enables wellbeing in older age.*" (4) Functional ability is influenced by an individual's intrinsic capacity, the environment, and the interaction between the two. By constructing the environment, individuals are able to be and do what they value. (4) Therefore, having a supportive home and neighbourhood environment may influence older adults' behaviours and health, and thereby promoting healthy aging. (3)

Neighbourhood walkability can be defined as the extent to which the built environment in a neighbourhood is pedestrian friendly and easy to walk. (5-7) Favorable environmental characteristics such as proximity to amenities, aesthetics, and safety may promote physical activities while unfavorable built characteristics such as absence of sidewalks and outdoor recreation may hamper physical activities within a neighbourhood. (8-10) In last decades, research has emerged to investigate the relationship between neighbourhood walkability (how walkable a neighbourhood is) and walking. It is a general agreement that residential density, street connectivity, proximity to amenities, land-use mix, public transit, the presence of sidewalks, safety and recreational facilities affect an individual's outdoor walking behaviors. (11, 12) However, recent research has shown that the relationships between neighbourhood walkability and walking are both region-specific (13, 14) and age-specific (15). Canadian studies have been concentrated in the provinces of British Columbia and Quebec, while studies in other provinces were less common. Also, only a few studies (13, 14, 16-19) were specific to older adults. Additionally, some of these studies (16-18) mainly investigated physical activity, as opposed to specific walking behaviours, in older adults. Whether older adults spend much time on outdoor walking and its relationships with neighbourhood walkability remained in question. As a result, it is crucial to conduct a study that identifies these research gaps and solves the existing problems.

The literature review in this chapter will go into the details of neighbourhood walkability and the patterns of walking behaviors in older adults. Specifically, the first part will go through the ICF model, importance of outdoor mobility, and how neighbourhood walkability contributes to outdoor mobility. The second part will discuss the importance of physical activity and outdoor walking, as well as their relationships with neighbourhood walkability.

1.1 The ICF framework

The International Classification of Functioning, Disability and Health (ICF) framework is a two-part model that describes the pathway of disability and functioning. (20) The first part illustrates body functions and structures, activity, and social participation. (20, 21) These factors are interrelated and affect one another. For instance, an individual who has sight problems (impairment) may complain of instability in walking (activity), and hence affecting their participation in church activities (participation). Specifically, participation refers to individuals' involvement in their life situations. (20) This concept is further expanded by Levasseur et al. (22 p2) in which social participation is defined as "*a person's involvement in social activities that provide social interactions within his/her community or society*". Levasseur et al. (23) identified social participation based on an individual's interaction with the environment, instead of the environment itself. Individuals have their own roles and tasks to perform within an environment to fulfill their social participation. Higher levels of social participation involve not only social contact with others, but also in community service or civic activities. (23)

The second part of the model includes two contextual factors: internal personal factors and external environmental factors. To illustrate, an individual's belief in his religion (personal factors) and supportive traffic crossing features (environmental factors) in a neighbourhood may affect how the individual views their health condition and participates in church activities (participation). Environmental factors encompass "the physical, social and attitudinal environment in which people live and conduct their lives". (20 p10) There are five domains in the environmental factors: (1) "Products and technology", (2) "Natural environment and human-made changes", (3) "Support and relationships", (4) "Attitudes", and (5) "Services, systems and policies" (20 p16). According to the ICF framework, the environment is related to capacity and performance. Capacity is defined to be "what a person does in a situation in which the effect of the context is absent or made irrelevant", and performance to be "what a person does in the actual environment". (20 p12) An individual's performance may be altered by the actual existing environmental facilitators or barriers when the individual is exposed to different environments.

Disability is viewed as a gap between an individual's capability and the environment's demands. (24, 25) Individuals have certain roles and tasks to perform within an environment. (26, 27) Their performance is affected by family, community, and society factors. Inability to fulfill these roles and tasks can be attributed to either individual changes, environmental changes, or combined individual-environmental changes. The individual and environmental variables are closely related and dynamic in nature. On the other hand, disability is the result of an alteration in the interaction between the individual and the environment, which leads to the inability to fulfill the expected roles and tasks in a social and physical environment. (28) An unfavorable environment becomes an environmental barrier for an individual to attain social roles and participate in social activities.

1.2 Outdoor mobility

Mobility is defined as the "*ability to move oneself (either independently or by using assistive devices or transportation) within environments that expand from one's home to the neighbourhood and to regions beyond*". (29 p444) In order to identify people with different levels of mobility, Patla et al. (30) suggested the mobility continuum. In this framework, ambulators were classified into 4 categories: "non-functional ambulator", "household ambulator", "limited community ambulator" and "independent community ambulator". The former two categories classify ambulators who are incapable of negotiating outdoor environments. On the contrary, limited community ambulators can execute some but not all tasks associated with moving through the outdoor environment while independent community ambulators can move through the environment independently. Each environment has its own requirements, and difficulties increase as one moves up the mobility continuum. One primary goal of rehabilitation is to empower an individual to regain mobility and proceed up the mobility continuum.

Webber et al. (29) proposed a conical model that illustrates mobility in seven life-space locations among older adults. This framework consists of three components: life-spaces where older people are mobile; the five determinants of mobility; and the gender, culture, and biographical influence. Life-spaces expand from an individual's room, to the individual's home (house and apartment), the outdoor area surrounding the home (yards and parking lots), the neighbourhood (adjacent streets and parks), the service community (shops, utilities and healthcare facilities), the surrounding area (within the individual's country), and finally the world, representing the increasing requirements for independent mobility as the individual moves farther away from home. (29) Mobility in each life-space is influenced by five determinants, including financial, psychosocial, environmental, physical, and cognitive factors. Lastly, gender, culture, and biographical influences play a role in modulating an individual's perception and behavior in life-spaces. As an individual grows from childhood to adulthood, they gain more experiences and knowledge and becomes more competent, and eventually their potential life-space is built up. On the other hand, a previous study suggested some older adults tend to stay inside their home or only engage in outdoor activities near their home. (31) As a result, the cone collapses in a top-down approach as the individual becomes less mobile. (29)

An adapted framework was developed based on the conical model. (32) According to Franke et al. (32), the original framework may be insufficient in illustrating the significance of subjective determinants in older adults' mobility because their subjective aspects, such as attitudes, perceptions and emotions, affect their mobility by altering the environment to achieve their needs. For instance, an individual who achieves a low score in one aspect (decreased physical ability) may compensate with an adaptation at another level (developing higher self-efficacy). Furthermore, biographical influences suggested in the original model were transformed into temporal factors. By doing so, the influence of macro-level historical change (wars), and micro-level individual life course transitions (getting married or divorced) and trajectories (education, occupation) will also be considered. (32) In this adapted model, mobility is viewed by putting multiple determinants on a sliding scale, instead of a static snapshot. (32) For instance, physical endurance deterioration may result in a lower rating in the physical domain. However, this can be compensated by developing stronger attitudes and perception so that the overall mobility does not change. In other words, mobility is deemed fluid and dynamic, and will fluctuate on a day-to-day basis and over the life course. (32)

1.3 Mobility decline and aging

Mobility decline can be sudden or progressive. (33) Sudden mobility decline is usually attributed to having a traumatic event, such as hip fractures and strokes, while progressive mobility decline is caused by worsening chronic health conditions, such as diabetes mellitus. (33) Modifiable risk factors, such as obesity, long-term use of medications, chronic conditions, physical inactivity, sedentary lifestyle, depression, and environmental barriers, can cause a progressive loss of mobility. (22, 33-35) They can seriously influence quality of life, leading to a multitude of issues, such as poorer balance, lower walking speed, higher risks of having osteoporosis-related fractures, osteoarthritis, falling and fall-related injuries. (31, 34, 35) Identifying persons who are not yet disabled but at high risk of developing disability is important to prevent disability progression. (36) It is also important to identify factors that influence everyday functions and mobility.

Patla et al. (30) suggested eight environmental dimensions important to outdoor mobility: distance, temporal factors (e.g. presence of stoplights), ambient conditions, physical load, terrain, attentional demands (e.g. presence of a travel companion), postural transitions (e.g. reaching and changing directions) and traffic density (e.g. presence of any unexpected collisions). (37) These dimensions reflect how built environmental factors and personal abilities affect mobility. These external demands have to be met for an individual to stay mobile in a community. Furthermore, mobility is not merely about safe walking in the environment, but also includes the ability to alter gait patterns in response to both expected and unexpected disturbances in the physical environment. (30) Some of the factors in this framework, such as distance, temporal factors, ambient conditions, physical load, terrain, and traffic density, are related to features in the built environment, which will be discussed in next section.

1.4 Built environmental factors

The built environment (which reflects the construct of walkability) influences an individual's walking behaviors in a neighbourhood. The built environment refers to characteristics of the physical context where an individual spends their time, including but not limited to land use patterns, physical infrastructure of roads, sidewalks, accessibility of facilities, directness of pathways, street connectivity, connections of transit services, traffic density, safety, and visual interest (aesthetics). (7, 38-42) Neighbourhoods with favorable built environmental factors may promote walking for transportation. (43) In the last few decades, researchers have been working to understand how built environmental characteristics affect individual walking behaviors, although many studies are not specific to older adults. The following sections discuss common built environmental characteristics.

1.4.1 Five dimensions (5Ds)

Five dimensions (5Ds) of the built environment (density, diversity, design, distance to transit and destination accessibility) were proposed to illustrate various components of the built environment. (44, 45) Density includes residential density and population density. It comprises urban elements that increase the number of pedestrians in the streets. (41, 44) It is commonly measured by the number of prevalent residential types in a neighbourhood, such as single-family housing, townhouses, and apartment buildings. (41, 44) High residential density in a neighbourhood is associated with longer physical activity or walking time. (7) In compact neighbourhoods, the origin and destination of a trip are often closer, which promotes non-motorized travel. (44) Better transit systems and fewer parking facilities found in compact neighbourhoods may also promote residents to have non-motorized travel. (44)

Diversity measures the degree of diversity of land uses within an area. (7) It is sometimes referred as land-use mix. Land-use mix is measured by the retail-floor area ratio, number of convenience stores, retail services, supermarkets, entertainment and recreational land uses, and proximity to these destinations. (7, 41, 44, 46) Destination accessibility, on the other hand, represents the degree of accessibility to activities outside of an individual's neighbourhood, such as public schools, hospitals, public libraries, shopping centers, churches, and banks. (45) Since both land-use mix and destination accessibility share a similar context, they are discussed together. Land-use mix is initially calculated based on the proportions of commercial, residential, and office areas in a neighbourhood. (47) This criteria was later expanded to consider residential, retail, recreational, office and institutional uses. (5) The calculation algorithm is based on the accessible area within an individual's neighbourhood, either using a 1-km network buffer or a circular buffer centered at the individual's home. (47, 48) Land-use mix was found to be associated with physical activity. (7) Convenience stores, restaurants, groceries, and utilities encourage residents to engage in more walking if these destinations are conveniently accessed. (41, 44) These relationships are also seen with older adults. (49)

Design comprises both natural and built elements, including but not limited to building orientation, landscaping, aesthetics, pedestrian amenities, sidewalks, and other micro-features. (46, 50) It is assessed by inspecting city patterns, intersection density (number of intersections along a street), number of dead-ends and cul-de-sacs, the link-to-node ratio (number of streets in an intersection), street network density, and route directness. (7, 39, 44, 45, 51) Theoretically, gridlike street networks offer relatively more direct routes and multiple route options, which can make walking more easily in a neighbourhood. (50, 52) The presence of cul-de-sacs in a neighbourhood, on the other hand, is unfavorable to outdoor walking. (53)

Although the primary consideration in choosing a route for transportation is minimizing time and distance, other elements also influence how pedestrians choose their routes. (52) A key feature in a good urban design is the presence of aesthetics. (39, 52) Neighbourhood aesthetics refers to the presence of trees, parks, reserves, gardens, and visual interest. (39, 51) These features make walking more pleasant by creating a sense of place, and thus encourage recreational walking. (7, 49, 51, 54) Many studies suggest that aesthetic qualities are associated with walking, although there is no common agreement on how to measure this attribute. (7, 40, 55) Also, some argue that drivers and motorists can also be rewarded by neighbourhood aesthetics the same way as those pedestrians are. (44) Therefore, neighbourhood aesthetics may be less important in deciding whether or not to walk in a neighbourhood. (52)

The presence and quality of sidewalks influence walking behaviors. (7, 49, 52) Sidewalks with cracks, puddles, ice, snow, mud, leaves, or an uneven surface can lead to falls in older adults. (42) Narrow sidewalks with poor conditions also reduce the walkability of an area. (6, 7) The presence of sidewalks with separation from the main road, however, contributes to better traffic safety. In addition, traffic safety depends on pedestrian separation, buffering, traffic speed limits, and speed bumps. (39, 41, 42, 56) Separation of sidewalks from the main road can be achieved by having parked cars or grass strips. Careless driving is one of the most common concerns regarding traffic safety. (42) Drivers who do not follow traffic rules in residential areas will increase the perceived risk of traffic injuries. (42, 49) Traffic calming measures such as speed bumps and traffic circles help reduce traffic threats to pedestrians, as well as producing less noise and environmental pollutants, making the neighbourhood environment more walking friendly. (7, 42, 51) Apart from traffic safety, other crime security such as street lighting, the presence of graffiti, illicit activities, and wild animals, is also linked to safety. (41, 56) Other indirect aspects of crime security include homicide rates and the frequency of security patrols. (7, 41, 56) The presence of security patrols may increase the tendency of residents to walk in a neighbourhood.

The last 5Ds dimension, distance to transit, was originally suggested to examine how the presence of TransMilenio busway services induced walking in Bogota. (45) It was measured by the number of stops in an area and the shortest distance to reach the closest station. (7, 45) This dimension was later expanded to address the accessibility of public transport. (51) Walking is deemed as a part of an integrated transportation network, especially for people who do not own a motor vehicle and rely on public transportation to reach their destinations. (54) Although limited evidence support the connection between public transport services and health, transport services may contribute to user-friendliness of a neighbourhood by promoting social participation and social cohesion, especially among older adults. (51)

1.4.2 Proximity

Proximity reflects the distance between the origin and destination of a trip. (41, 46) The distance to reach services such as gyms, post offices, banks, supermarkets, stores, theaters, restaurants, government offices, and child-care facilities that are located within a 10-min walk are often considered. (41) With shorter distances to destinations, residents tend to walk to destinations more often so total walking time increases. (7) Proximity to amenities is also associated with less sedentary time and more MVPA time among adults. (7) Proximity is primarily determined by density and land-use mix. (43, 46, 57) If an individual lives in an area with high residential density and many compact buildings, it may be more convenient for the individual to walk and visit neighbours who live within a walking distance. On the other hand, older residences that are built above street-level shops in the past makes it more convenient for pedestrians to reach shops and amenities that are located below their home. (46) In modern urban design, however, commercial and residential land uses are purposefully designed and separated. It may become more difficult to walk from a residence to run errands in the nearest shopping center. Therefore, the more compact and richly mixed a neighbourhood is, the shorter the distances between origins and destinations. (46, 57)

1.4.3 Connectivity

Street connectivity reflects the ease of moving between origins and destinations within the existing street structure. (7, 43, 46, 57) Direct travel is fostered if there are fewer travel barriers, such as freeways, walls, restricted access, dead-end streets, back alleys, and physical obstacles. (41, 49, 53, 57) Higher connectivity means multiple direct and short routes are available to reach the same destination. (40, 41, 53) Connectivity is affected by land-use mix, route distance, route directness and intersection density. (41, 53)

Route distance refers to the average distance travelled by a pedestrian in a journey. (53) Pedestrians tend to choose a route that minimizes time and distance to reach the destination. (52) The usual walking distance a pedestrian walks in a single trip, such as walking to a transit station, is approximately 300 to 400 metres in British Columbia and some of the newly developed communities in the United States (53) On the other hand, route directness is measured by the pedestrian route directness ratio - the ratio of route distance to geodetic distance (or sometimes called crow-fly distance). (53) If the ratio approaches one, the neighbourhood will be regarded as a well-designed and more connective neighbourhood. Curvilinear street patterns with cul-de-sacs usually have higher pedestrian route directness ratio, and appear to be unfavorable to outdoor walking. (53) The actual walking distance in these areas was found to be longer than that with grid layouts. (41, 53)

Intersection density is the most commonly used attribute to describe street connectivity of a neighbourhood. (7) It measures the ratio of road intersections to number of road segments in a neighbourhood. It is also associated with physical activity time and walking time among adults. (7, 47) Higher intersection density means roads are more connected in a neighbourhood. Apart from intersection density, cul-de-sac density is often used to evaluate how connective a neighbourhood is. (7) Generally, neighbourhoods with grid layouts tend to have higher intersection density so they are more walking friendly. When designing pedestrian pathways, the linkage between adjacent streets, extensive pavements, and expanding street connections should be considered. (53)

1.4.4 Urban design qualities

The 5Ds of built environment only focus on macro-scale environmental features; micro-scale urban design qualities are not taken into consideration. (52) Urban design qualities were developed based on architecture, landscape architecture, park planning, and environmental psychology. (7, 58, 59) Urban design qualities comprise micro-scale elements such as legibility, transparency, complexity and imageability. For instance, legibility reflects signals and symbols a street network provides to give a sense of orientation and relative location. (58, 60) Transparency refers to the degree to which pedestrians can see or perceive human activity beyond street edges. (58, 60) It is influenced by physical context such as walls, windows, doors, and fences. Blank walls and reflective glasses are deemed factors that led to low transparency. (59) Complexity refers to the visual richness of a place. (58, 60) Street furniture such as streetlights, fountains, benches, pavements, and public art combines to make an area complex. Imageability refers to the qualities of a place that makes it distinctive, appreciable, and memorable. (58) A highly imageable place should be instantly recognizable to pedestrians who have visited or lived there. (59) Altogether, these urban design qualities affect residents' overall perceptions of the neighbourhood environment, and hence influence their walking behaviors. (7, 41)

1.5 Walkability

Although built environmental characteristics are sometimes referred as walkability, recent research has expanded the concept of walkability into a larger context. Neighbourhood walkability is a composite measure of the physical environment and reflects an individual's perception of their neighbourhood and the ease of walking in that neighbourhood. (5-7) In addition to the aforementioned built environmental features, walkability also reflects an individual's perception of the environment. (61, 62) It describes "*to what extent cities, neighbourhoods, routes or streets are nice to walk in, as well as pleasant and interesting, and hence invite to walking*". (63 p265) It is influenced by characteristics of pedestrians, their activities, and the physical context, and therefore implies one's preference for ideal environmental features. (56, 59, 61, 63) Subjective perception is shaped by personal experiences, attitudes, and interpretation of the environment, and therefore affects how an individual perceives and reacts to the condition of a place. (58, 59, 61, 64) Incorporating personal factors into neighbourhood walkability helps understand the interaction between individuals and their environments. (40, 42, 62) **Therefore, physical and social environmental characteristics, together with personal circumstances and home environments contribute to individuals' perception of neighbourhood walkability**. (62)

Ideally, a walkable neighbourhood should consist of tight connections between an individual's home and a diversity of facilities or amenities (better access and diversity), short and efficient routes to reach different destinations (better street connectivity), well-maintained pavements or sidewalks where pedestrians can walk safely (better infrastructure), pleasantness of nature (aesthetics) and higher residential density where amenities like groceries stores, banks, and clinics are more likely to be nearby. In contrast, a walkable neighbourhood should limit the number of walking barriers, such as absence of sidewalks or speed control of vehicles (safety), uneven terrains, absence of adequate lighting, slopes or hilliness (physical obstacles), limited parking spots (people have to rely on walking to get to the destinations), and dirt and litter (unpleasant to walk). Qualitative studies (42, 49, 54) have been done to reflect older adults' perceptions and expectations of ideal built environmental characteristics. Older adults depict their neighbourhood walking experience highly related to their health and well-being. (54) They appreciate the social contacts with their friends and neighbours during their walks. (42, 49, 54) They also like walking in streets they are familiar with or where historic buildings and monuments can be found. Some prefer walking along new and well-maintained routes with houses and avoid walking in abandoned streets where no other pedestrians are present. The presence of a large crowd, youngsters, immigrants, beggars and the homeless may discourage walking in a neighbourhood. (42, 49) Walking in areas that match their expectations makes their journeys more enjoyable while walking in the "unpreferable" areas is not appealing.

Interestingly, older adults' subjective perceptions may be contradicted by the objectively predicted outcomes. For example, controversies are raised regarding walking in cul-de-sacs. Some people prefer dead-end streets and cul-de-sacs than busy streets because they think these areas are safer and less noisy with little traffic, while some avoid cul-de-sacs because they do not lead to any destinations. (42, 49) Since the appraisal of the neighbourhood environment is determined by an individual's experiences, perceptions and knowledge, residents who live in the same environment may have different perceptions. (64) For instance, the presence of graffiti is often deemed as a barrier to walking since it may raise safety concerns. (41, 56, 65) It is associated with poor social cohesion and community interaction. (51) The absence of feelings of safety not only negatively affects older adults' neighbourhood satisfaction, but also affects their tendency to walk outdoors. However, the perception of graffiti varies from person to person. (66) Some graffiti writers regard their involvement in graffiti creation as contributing to aesthetic appeal and a sense of social recognition. (67) The sociality of shared peer activity also encourages graffiti writers to discuss graffiti and share their works with other writers. (67) Many graffiti writers acknowledge the subjective dimensions of graffiti and consider the eye-catching graffiti as art. (67) In this case, attitude plays an important role in aesthetic appreciation. Comparing opinions of the older adults and the graffiti writers leads to a debatable topic: whether "unfavorable" neighbourhood environmental characteristics will become "favorable" to another person and affect the person's tendency to walk in a neighbourhood.

Another example of environment-individual interactions can be manifested by graffiti management. Graffiti management is developed to combat “undesirable” graffiti writing. The management strategies include reactive approaches, such as graffiti removal, painting over graffiti and protective anti-graffiti coatings, and proactive approaches, such as establishing murals and street art, setting up legal spaces for graffiti and building virtual graffiti sites. (68) For instance, StreetARToronto (StART) was launched in Toronto to proactively replace graffiti vandalism with vibrant street art. (68, 69) The Graffiti Panel set up guidelines and approved graffiti designs if the graffiti art either matched the core values, such as cultural diversity, ecology and the environment, or makes walking, cycling, and driving appealing and enjoyable. (69) The process is a form of placemaking - collective actions by a community to transform public spaces in order to revitalize the community and promote well-being. (70) It also represents how the government, the community and residents in a neighbourhood react and interact to shape their neighbourhood environments. The concept of walkability is not limited to the built environmental features of a neighbourhood, but also related to subjective perceptions and emotions about the neighbourhood. The perceptions and emotions affect how an individual interacts and contributes to the community, which in turn affects other members’ perceptions and emotions in the neighbourhood.

1.6 Measures of Walkability

Methods used to measure walkability can be divided into Geographic Information Systems (GIS)-based analysis, systematic observations, and self-reported questionnaires. (61) GIS-based analysis assesses walkability by analysing geodata such as population, street networks, traffic volumes, road widths, and greenness indices. (61) Systematic observations such as environmental audits are carried out to objectively quantify urban space with regard to urban characteristics such as functionality, safety, and aesthetics. (58, 61, 64) They are designed to capture street-scale data that are not typically available from GIS, such as the presence of buffer zones and sidewalks. (2) Systematic observations can be done by using mobile or permanently-installed sensors to address people’s behavior and determine how people move within the targeted environment. (61) For instance, this can be achieved by setting a camera in public space to visualize pedestrians’ behaviors. The use of GIS-based analysis and systematic observations is often criticized for its lack of considerations of subjective factors, such as individual perception, sense of community and emotions, as well as social environmental factors. (40, 61, 62) Interviews and self-administered questionnaires, on the other hand, capture the extent to which individuals perceive access and barriers to various attributes of the environment. (64)

1.6.1 Geographic Information System (GIS)

Geographic information system (GIS) is a computerised tool that integrates data to capture, store, analyse and display spatially referenced information. (57, 64) To ensure location is recorded accurately, a specific coordinate system is employed to collect spatial data (latitude and longitude). (57) Geographic buffers are then created around the centroid to track variables of interest. (71) Studies commonly use GIS to analyse data of an area, such as population density, public transit, slope, and aesthetics to investigate the association between the built environment and physical activity. (64, 72)

Algorithms of these measures are determined and validated to provide a better estimation of neighbourhood walkability. Field validation shows moderate to high correlations between audit-derived walkability and GIS-derived land-use mix, street connectivity, and residential density. (73) Test–retest reliability, on the other hand, is partially dependent on how quickly the environment changes and partially on how consistent versions of GIS measures are maintained. (64) The quality of GIS-based data is also affected by expenses, personnel expertise, and region-specific measurement accuracy. (64, 72, 74) Inaccurate and incomplete data are threatening to the validity of GIS measures. (64)

1.6.2 Walkability Index

Frank et al. (5) suggested the use of Walkability Index to quantify built environment factors based on geographical data. Walkability Index composes four dimensions: net residential density, retail floor area ratio, intersection density and land-use mix. (5) Net residential density refers to the ratio of residential units to the land area dedicated to residential use. Retail floor area ratio is measured by dividing the retail building floor area footprint by retail land floor area footprint. Intersection density is measured by the ratio between the number of true intersections to the land area. Land use mix measures distributions of residential, retail, entertainment, office, and institutional areas. Values are normalised between 0 and 1, with 0 being single use and 1 indicating a completely evenly distributed floor area of the five domains. (5) Walkability Index can be also calculated from other variables, including population density, dwelling density (having adequate density to support the location of destinations in an area), availability of all retail services, and street. (71, 75) Other variables and calculation methods have also been suggested. (76-78)

The use of Walkability Index is limited by inconsistent measurement methods suggested by different studies. For instance, Chum et al. (79) found that among all components in their proposed Walkability Index, only land-use mix was associated with walking for transportation in the multivariate model. Although each of the other components (dwelling density and street connectivity) was significantly associated with walking for transportation, they were not correlated when these variables were computed in a multivariate model. In other words, the Walkability Index was largely driven by land-use mix in approximating the actual walking time for transportation. Since other components were not associated with walking for transportation, Walkability Index might not be a suitable index to measure neighbourhood walkability. This result, however, was contradicted by another study (71) where land-use mix was rejected from Walkability Index due to the relatively lower correlation between land-use mix and the Walkability Index. This may be explained by the distribution of population where high land use mix can be found in both densely populated areas and sparsely populated industrial and suburban residential areas in Toronto. It is also difficult to find a national-wide land-use dataset that could be used to develop the land-use measure. (75, 77, 80) It is therefore challenging to compare built environmental characteristics within and between cities using different datasets. (75) Developing a customized land-use measure, on the other hand, is not practical, owing to access cost, data processing, and knowledge requirements. (75, 80) Regarding the uncertainty of the available data and the inconsistency of calculation methods, Walkability Index may not be an ideal tool to compare neighbourhood walkability across cities.

1.6.3 Walk Score

The Walk Score was originally developed for real estate purposes and is maintained by Front Seat Management (www.frontseat.org), a software development company that is based in Seattle, WA. (72, 81) It combines data from Application Program Interface (API) and a geographically based algorithm to identify proximity to nine amenity categories: grocery stores, restaurants, coffee shops, banks services, schools, entertainment, bookstores, and parks. (81, 82) Each amenity is weighted equally and then summed and normalised to fit a 0 to 100 scoring scale. (72, 81, 83) If each of the nine amenities is located within a geodetic distance of 0.25 miles from a location, the location receives a perfect 100 score. (72) For amenities that are located beyond 0.25 miles, a portion of points are deducted. (82) The final score is then categorised into five indices: (1) car-dependent (car required for almost all errands; 0–24); (2) car-dependent (car required for most errands; 25–49); (3) somewhat walkable (50–69); (4) very walkable (70–89); or (5) walkers' paradise (90–100). (81, 82)

The Walk Score is renowned for its accessibility, low cost, international scale and use of up-to-date data that is constantly being monitored. (72, 82) It is correlated with residential density, traffic speed, intersection density, and the number of walkable amenities. (72, 81, 82) Field validation conducted in Alberta suggested a positive correlation between the Walk Score and the number of infrastructure and population density measured by street-level systematic observations. (82) Inter-rater reliability of the Walk Score is also supported. (82) However, the Walk Score is not comprehensive enough to cover other environmental features such as street characteristics, traffic safety, safety from crime, and aesthetics. (83) The use of geodetic distance in calculation also neglects street network connectivity. (82, 83) Furthermore, the Walk Score seems imperfect in reflecting pedestrians' subjective perception, and therefore cannot represent how interactions between pedestrians and the environment affect their walking behaviors. (40, 42, 62)

1.6.4 Audit Tools

Street-level audits are considered the gold standard in environmental assessment. (73) Audit tools allow systematic observations of urban space by measuring four environmental domains: functionality, urban design, safety, and aesthetics. (58, 61, 64, 84) Audit tools are commonly completed by in-person observations in which researchers systematically code built environmental characteristics while walking or driving through a neighbourhood, park, or trail. (64) Common audit instruments comprise measures of land use, street design, and safety. Although many audit tools are available, few of them were intentionally designed to assess the built environment for older adults. (2, 64)

The Senior Walking Environmental Audit Tool-Revised (SWEAT-R) is an audit tool that was specially designed for older adults. After being trained, field observers collect data of a pre-determined segments in neighbourhoods based on four domains: functionality, safety, aesthetics, and destination. (85, 86) Functionality reflects three structural aspects of the physical environment - buildings; sidewalks; and street life. Safety comprises personal and traffic safety. Aesthetics reflects the quality and visual richness of the environment while destination refers to the availability of services, transportation, and parking in the neighbourhood. (85) Audit results are quantified by counting the frequency of attributes in the environment. (62) The SWEAT-R is deemed relevant to older adults since it captures older adults-related environmental features such as the presence of benches and resting spots, readability of signage, and sidewalk widths. (85) Although inter-rater and intra-rater reliability were supported, construct validity is supported by limited evidence. (2, 85, 86)

One of the limitations in using audit instruments is the availability of resources, including time and manpower. (64) Some audit tools may not be comprehensive to let auditors rigorously understand the true walking experiences of pedestrians. (62) As a result, careful considerations should be made before deciding which audit tools to be used.

1.6.5 Neighbourhood Environment Walkability Scale (NEWS)

Self-reported environmental measures are commonly used in examining the association between the built environment and physical activity behaviors. (64) The perceived environmental measures can be carried out by interviews or by self-administered methods, either in person or by mail. (64) Responses are then aggregated to identify patterns in environmental features in accordance to geographic regions and population subgroups. (64)

Neighbourhood Environment Walkability Scale (NEWS) is one of the self-reported outcome measures that assesses individuals' perception about their neighbourhoods. A literature review conducted in 2009 revealed the most frequently and internationally-used questionnaire was NEWS. (64) It consists of the key environmental domains: functional, safety, aesthetic, and destination. (64, 87) In the original questionnaire, a total of 68 items assesses nine aspects of the environment: residential density, land use mix-diversity, land use mix-access, street connectivity, infrastructure for walking/cycling, aesthetics, traffic safety, crime safety and neighbourhood satisfaction. (88) Items in all subscales, except land use mix, are scored on a Likert scale. In the residential density category, individuals are asked how common a type of residence is in their immediate neighbourhood with responses, ranging from none to all. In neighbourhood satisfaction, individuals are asked how satisfied they are with characteristics in their neighbourhoods. The remaining subscales are scored on a four-point Likert scale (strongly disagree, somewhat disagree, somewhat agree, and strongly agree). In land use mix, on the other hand, individuals are asked to estimate time taken to get to the nearest facilities (supermarket, hardware store etc.).

The original *a priori* NEWS was probably not a favorable questionnaire in reflecting perceived environmental characteristics because, according to Cerin et al. (89), the factorial validity of the NEWS subscales were not examined. In view of this issue, NEWS was revised with confirmatory factor analyses (CFA) into NEWS-CFA. (89, 90) NEWS-CFA is composed of 67 items and covers 13 subgroups including residential density, land use mix, access to services, streets in neighbourhood, places for walking and cycling, neighbourhood surroundings, traffic hazards, neighbourhood safety, lack of parking, lack of cul-de-sacs, hilliness, physical barriers and social interaction while walking, with the exclusion of neighbourhood satisfaction from the original NEWS. The scoring system is based on the CFA results found in two studies. (89, 90) The complete NEWS-CFA questionnaire and scoring form can be found at https://drjimsallis.org/measure_news.html. Apart from independent subscale scores, a total score can be calculated. (91, 92) It is computed by adding up z-scores that are converted from subscale scores. Internal consistency, calculated by Cronbach's alpha (α), is high ($\alpha = 0.94$) for the total score and moderate to high ($\alpha = 0.44 - 0.94$) for subscale scores. (91, 92)

1.7 Walkability and health

Neighbourhood walkability influences residents' walking behaviors and outdoor activity participation. (57) In the presence of choice-enabling environments, individuals may recognize the importance of physical activity and attempt to maintain sufficient amounts of physical activity. (73) For instance, higher Walk Score (Walker's paradise) is associated with 89 minutes more walking for transportation per week but not walking for leisure among adults with a mean age of 50. (93) On the other hand, unfavorable built environment features contribute to the development of impairments, and hence lead to functional limitations and disability in older adults. For example, a study conducted in Ontario showed that low neighbourhood walkability was associated with a higher risk of developing a cardiovascular disease event among Canadians aged between 40 and 74. (94) Residential density, proximity to destinations, and land-use mix are associated with prevalence of obesity and diabetes among older Americans aged 65 or above. (10, 95) Poor housing and community designs are considered to be one of the barriers to physical activity. (96) The prevalence of neighbourhood environmental barriers, such as obstructions, uneven surfaces, and broken steps, is associated with a greater risk of falling among older adults. (36) Canadian adults aged 18 or above who live in an area of low neighbourhood walkability in Calgary tend to have longer leisure-based screen time, compared to those who lived in highly walkable neighbourhoods. (97) Also, older adults with functional limitations who live in lower-density areas report more self-care disability. (98) Additionally, mobility and social participation are positively associated with proximity to destinations and to the number of recreational facilities, social support, and neighbourhood safety among older adults who aged 65 or above. (22, 99)

More age-matched peers in a neighbourhood may promote walking and participation among older adults, since they may follow other older adults to be physically active and join activities. (99) High residential density indicates greater availability of local facilities and services where they can participate in volunteering or social functions in facilities such as senior centres and sports clubs. (99) It is therefore important to identify older adults' walking time and behaviors, and the relationship between environmental features and walking, so as to promote social cohesion and participation in older adults. (99) In the following sections, we will discuss the benefits of walking and the outcome measures.

1.8 Sedentary behavior and physical activity

Sedentary behavior is defined as any waking behavior with an energy expenditure ≤1.5 metabolic equivalents (METs) while in sitting, reclining or lying positions. (100) Prolonged sedentary time is associated with a greater risk for all-cause mortality, cardiovascular disease incidence, cancer incidence, obesity, and type 2 diabetes among adults. (101-105) Sedentary behavior is positively related to metabolic syndrome, waist circumference and obesity. (106) The risk of all-cause mortality seems to increase progressively as sitting time increases, while physical activity can only provide a partially protective effect. (101, 106) Prolonged sedentary behavior can be detrimental to older adults' health since they may not be aware of their sedentary time and the associated health consequences. (107) A systematic review found that every additional hour of sitting per day was associated with a 3% increase in the risk of all-cause mortality among older adults. (108) A barrier to reduce sedentary time may be an individual's perception of sedentary behavior since they often regard typical sedentary activities, such as watching television and sewing, as enjoyment. (107) Prolonged sedentary behavior is prevalent among Canadians, especially among older adults. The odds of accumulating more than five hours of sedentary behavior per day is 1.49-1.73 higher among older adults aged above 65, compared with adults in their early twenties. (109) The average sedentary time measured by accelerometers is approximately 586 minutes per day among Canadian older adults, although the detailed measurement parameters are not given. (110)

Physical activity is not an opposite concept of sedentary behavior. (111) Individuals can be considered physically active if they meet physical activity recommendations, while having a significant part of their time as sedentary. (111) Regular physical activity has been shown to provide health benefits to older adults. For older adults who have regular walking habits, a reduction in cardiovascular risks and mortality rate is found. (112) Regular physical activity reduces the risk of having cardiovascular diseases. (113-115) Engaging in regular physical activity is also associated with lower incidence of diabetes, better blood pressure values and lipid levels, better brain health, higher functioning scores, shorter 400-meter walk times and lower fear of falling scores. (115-117) More physically active older women are found to have greater self-efficacy for quality of life, which was more associated with positive physical and mental health status. (118) Despite similar health outcomes, sedentary behavior and physical activity are suggested to be two independent risk factors for poor health among older adults. (119)

Walking is recognised as the most common and accessible form of physical activity among older adults. (2, 120) With little requirement of sporting equipment, walking is a flexible physical activity that can be integrated into daily routines in accordance with personal needs and situations, such as brisk walking, walking to run errands, and walking for transportation and leisure. (77, 121) Studies have demonstrated the benefits of walking among older adults. For instance, regular walking has been found to improve aerobic fitness, body composition, cholesterol levels, physical functioning, and quality of life. (116, 122-126) Older adults who have regular walking habits have lower mortality rates (112, 125, 126) and are less likely to develop cardiovascular diseases (112, 125). Regular walking also reduces the chance of developing depression and anxiety (124, 127, 128), although evidence on self-esteem, psychological well-being, subjective well-being and psychological stress remains inconclusive. (128)

Prolonged sedentary time and physical inactivity among older adults could be a threat to the public health system, and as a result, the importance of reducing sedentary time in addition to getting adequate physical activity is emphasized. Consistent with guidelines suggested by World Health Organisation and other countries, Canadian Society for Exercise Physiology suggests accumulating at least 150 minutes of MVPA per week, at least two times of strengthening and balance exercises a week, and several hours of light physical activities (LPA) such as standing per day, along with regular sleep habits and limited sedentary time to eight hours or less. (129-133) Meanwhile, sedentary time should be limited to eight hours or less per day, with no more than three hours of recreational screen time and splitting long periods of sitting.

Walking in outdoor environments may provide additional health benefits. For instance, a systematic review reported that outdoor physical activity had a greater effect on mental wellbeing (mean age of participants is 25.22 years old), although the effect on physical wellbeing remained in question. (134) Walking outdoors also promotes physical and mental well-being such as vitality, better health status, and stress reduction. (135-137) Being outdoors also improves brain activity, cardiovascular fitness, endocrine functions, immune functions, and psychological health. (135-138) However, physical activity is not the only reason for going outdoors. Being in natural environments such as forests, mountains, seaside, and urban parks, may help individuals connect to nature and establish their experiential sense of oneness with the natural world. (135) They can be rewarded with attractive views in nature that are beneficial to their mental wellbeing. People who exercise in both outdoor (such as running on the street) and indoor environments (such as training in a fitness centre), report more positive affect and psychological well-being, compared with those who only did exercises in indoor settings. (135) This is not to say outdoor activity competes with indoor activity in promoting health. Instead, indoor physical activity may also be beneficial for people who need to monitor their training progression such as progression to using heavier weights for lifting training. (139) In other words, both going outdoors and staying indoors provide health benefits where one may consider splitting time doing exercises in both outdoor and indoor environment on a daily basis.

1.9 Measures of physical activity and outdoor walking

1.9.1 Accelerometry

An accelerometer is an electronic motion sensor that can be worn to measure body acceleration. (140) It is used to track wearers' physical activity and estimate their activity time. (140) ActiGraph (Pensacola, FL, USA) monitors are the most frequently used accelerometers. (141)

The use of accelerometers depends on two criteria: data collection protocols, where parameters are decided *a priori*, and data processing criteria, where parameters are considered *a posteriori*. (141) Data collection protocols include accelerometer axes, device placement and sampling frequency. (141) Accelerometers have evolved from uni-axial to tri-axial types. Tri-axial accelerometers collect three-dimensional data, including vertical, medio-lateral and antero-posterior axes. (141) Data are then calculated and transformed into a signal vector magnitude (SVM) using the Pythagoras theorem, (140-142) which can then be used to estimate wearers' intensity levels of activity within a period of time. (140) Furthermore, tri-axial accelerometers can also record activity counts based only on accelerations in the vertical plane, which can then be compared to cut-points to determine the intensity of activity. (143) Compared to using the vertical axis, a significantly higher LPA and MVPA time was found when SVM was used. (143) However, which parameter is more superior remains in question. Accelerometers are commonly placed at the hip in studies where participants are older adults. (141) The third element of data collection protocols is the sampling frequency. A sampling frequency of 90 Hz is suggested because of higher measurement accuracy. (141) However, some suggest a smaller sampling frequency to reduce data size and increase battery lasting time, when data processing time and accelerometer chip sizes are taken into consideration. (142)

Epoch length refers to the period of time for activity counts to be summed. (144) Different epoch lengths can lead to different results. (142, 144) For instance, if the epoch length is set to be 60 seconds while the intensity of activity varies between MVPA and sedentary activities within this period, only the average activity level within this period will be recorded. (142) In other words, short bursts of activity and short periods of sedentary behaviour within the epoch length will be combined into an overall average value. While using a longer epoch length, the estimation of physical activity levels is quite consistent during continuous physical activity. As the physical activity becomes intermittent (e.g. 15-second of walking and 15-second of resting), long epoch lengths tend to give more percentage errors. (144) Also, the levels of physical activity are underestimated as epoch length increased during walking. (144) This may be explained by the misclassification of short bursts of moderate physical activity bouts as low physical activity. In other words, shorter epoch length (<10 seconds) can give more accurate measurements of intermittent physical activity in younger populations when frequent change of movements is anticipated.

After data collection, results are then analysed with respect to data processing criteria. Data processing criteria include determining non-wear-time definition, cut-points, and low frequency extension (LFE) function. (141, 145) In some studies, accelerometers are usually removed during water-based activities and sleeping. (141) Therefore, wear time and non-wear time have to be determined. (141) In order to differentiate the two, more than 60 minutes of consecutive 0 counts per minutes (CPM) is regarded as non-wear time. (141) Some suggest extending to 90 minutes of 0 CPM since older are expected to have longer sedentary time and pastimes. (141, 145) Having at least 8, 10 or even up to 21 valid hours per day is regarded as a valid day, depending on the study protocol. (141, 146) Having at least four valid days is generally suggested. (141)

Cut-points are intensity thresholds that are used as a reference measure for estimating meaningful amounts of physical activity time. (142, 145) To discriminate intensity levels, Freedson et al. (147) suggested using 1952 CPM as the cut-point to represent three metabolic equivalents of tasks (3 METs). LPA corresponded to a range between 0 and 1951 CPM (<3 METs) while moderate and vigorous physical activity had at least 1952 CPM (3-6 METs) and ⩾5725 CPM (⩾6 METs) respectively. (147) This set of cut-points was originally established from data gathered in a group of younger adults and later tested in older adults in another study. (148) Copeland et al. (149) developed a second set of thresholds based on results from a sample of older adults and demonstrated the cut-point of differentiating LPA and MVPA to be 1041 CPM. Combining the two results, Hekler et al. (146) suggested the classification of "low-light" (> 100 and <1041 CPM), "high-light" (≥1041 and <1952 CPM) and MVPA (≥1952 CPM). Other studies suggested 1653 and 3017 CPM to distinguish light and moderate physical activity and MVPA respectively (150), and even up to 2751 and 9359 CPM to differentiate physical activity at 3 METs and 6 METs respectively (151) among older adults. Adding to the discrepancy in cut-points, Gennuso et al. (106) suggested using 760 CPM to differentiate MVPA and lifestyle physical activity among older adults because it may be better in reflecting their free-living moderate-intensity activity styles. Nonetheless, the use of absolute intensity thresholds may be misclassified because intrapersonal variations across individuals are not considered when using the absolute thresholds, which may in turn affect the activity patterns collected by accelerometers. (142) Different cut-point thresholds across studies make it difficult to make direct comparisons across studies. (142)

LFE refers to an ActiLife accelerometry feature that retains low-frequency acceleration signals that are commonly filtered out in default mode. (145) By adopting LFE, physical activity at lower intensities such as LPA, steps, and shuffling gait, can be captured. (145) This may increase the accuracy of measurement in participants who may engage in lower intensity activities throughout the day, such as older adults. (152, 153) However, some studies (145, 152, 153) suggest that using the LFE extension may significantly overestimate step counts, LPA and MVPA. Since the actual number of steps was not assessed in these studies, it cannot be determined whether LFE or default function is better in measuring the actual number of steps. (154) Other studies (154-157) show LFE improves the accuracy of estimating actual steps with less percent errors in individuals with gait speeds at or below 1.0 m/s.

1.9.2 Accelerometry-GPS

Walking is recognised as the most common and accessible form of physical activity among older adults. (2, 120) Knowing their outdoor walking time helps understand their physical activity behaviors. To measure time spent on outdoor walking, accelerometers are used in combination with Global Positioning System (GPS) recorders. GPS recorders receive signals from GPS satellites orbiting the earth. (158) By calculating the relative distance to three or more satellites (158), GPS devices record the wearer's geographical location coordinates, time, distance, speed, elevation, compass bearing, and signal-to-noise ratio (116, 159). The accuracy of GPS devices depends on spatial distribution of satellites, the environment of measurement, and the properties of GPS devices that vary across different manufacturers. (160) The Qstarz BT1000 is a commonly used GPS monitor. (161) It is renowned for its high accuracy, good signal acquisition time (time taken for a GPS device to locate positions at start-up or after periods of signal loss), large data storage, and long battery life. (161, 162) Dynamic positional accuracy test shows the median distance error from the centre of a lane is 3.9 m during walking. (161) Its accuracy, however, varies between environments, from 5.2 m in urban canyons to 0.7 m in open areas. (161) GPS monitors are not accurate in recording locations in dense urban environments with large and closely packed buildings because of signal reflection from building surfaces or shading by buildings or tree canopy. (161, 163, 164)

Outdoor walking time can be measured by matching total number of meaningful steps (measured by accelerometers) with the GPS locations (measured by GPS travel recorders) that indicate a subject is in “outdoor” environment (indicated by GIS). The combination of the three variables fosters analyses of spatial energetics which links behavioral and spatiotemporal resolution data to provide more specific information about activities within environmental contexts. (55, 165) To categorize cadence, 60-79, 80-99, and 100-119 steps per minutes are defined to be slow walking, medium walking, and brisk walking respectively, while ≥120 steps per minute are considered to be all faster forms of locomotion, such as running and skipping. (166, 167) However, these thresholds were developed based on data from adults aged ≥20 and therefore may not be applicable to older adults who complained difficulty in walking outdoors where their performance may already be affected by physical impairments. Another study (157) demonstrated that a threshold of ≥40 steps per minute demonstrated high sensitivity (1.00) and specificity (0.97) to differentiate meaningful walking bouts, compared to thresholds of ≥30, ≥35, ≥45, ≥50 steps per minute, as well as 760 CPM, measured by accelerometers. Therefore, ≥40 steps per minute may be an appropriate threshold to use to identify meaningful walking bouts among older adults with self-reported outdoor mobility limitations.

1.9.3 CHAMPS

The Community Healthy Activities Model Program for Seniors (CHAMPS) questionnaire was originally designed to provide physical activity outcome measures for a CHAMPS intervention study. (168) It was then revised and modified for the evaluation of physical activity levels among older adults. CHAMPS provides respondents with an extensive list of light, moderate, and vigorous physical activities, and asks them to report their weekly frequency and total amount of time on each type of activity in a typical week over the last four weeks. (169) Examples of activities include visiting with friends, going to the senior centre, doing volunteer work, attending church activities or club meetings, using a computer, dancing, woodworking, walking leisurely, golfing with a cart, attending a concert, playing cards, playing pool, playing a musical instrument, doing machinery, reading, light housework, yoga, stretching, conditioning exercises, walking briskly, uphill and downhill walking, jogging, skating, playing tennis, basketball, soccer or racquet, riding a bicycle, swimming, water exercises, aerobic exercise, strength training, conditioning training, heavy housework, and gardening. (168, 169) Six response options are given: “less than 1 hour”, “1 - 2.5 hours”, “3 - 4.5 hours”, “5 - 6.5 hours”, “7 - 8.5 hours” and “9 or more hours” per week. Midpoints of the score range of each item are calculated for data analysis. (168) The scoring algorithm estimates total caloric energy expenditure based on “all” physical activities and

MVPA. (146, 168-170) Furthermore, frequency and duration spent on those activities can also be calculated. For instance, frequency and duration of MVPA are calculated by isolating items 7, 9, 14-16, 19, 21, 23-26, 29-33, 36-38, and 40. (168) All these activities were suggested to have a MET of ≥3.

The CHAMPS questionnaire was designed to measure older adults' physical activity behaviors. It can also assess and distinguish specific behaviors such as walking to run errands versus walking for exercise, where objective measures cannot address. (146) However, the CHAMPS questionnaire is not without limitations. For instance, a previous study suggested the discrepancy of MVPA, high-light activity (2 to 3 METs), and total physical activity measured by the CHAMPS questionnaire and accelerometry was higher among participants who reported to be more active than those who reported to be less active. (146) In other words, participants tend to over-report MVPA and high-light activity. Also, light and moderate physical activities may be more difficult to recall than vigorous physical activities. (168) Although self-reported questionnaires have been reported to have many psychometric problems, such as response bias and participants making socially desirable responses, they are inexpensive, standardised and easy to carry out. (170)

1.9.4 CHAMPS-Outdoors

CHAMPS-Outdoors is an adaptation of the CHAMPS, to assess different aspects of outdoor walking among older adults. (171) It consists of five items. Four of them derive from the original CHAMPS (item 25-28) by incorporating the word "outdoors". (172) For instance, item 25 "How many total hours a week did you walk uphill or hike uphill (count only uphill part)?" becomes "How many total hours a week did you walk uphill or hike uphill OUTDOORS (count only uphill part)?". Modifications are also made in item 26 "Walk fast or briskly for exercise (do not count walking leisurely or uphill)", item 27 "Walk to do errands (such as to/from a store or to take children to school?)" and item 28 "Walk leisurely for exercise or pleasure?". In addition to the four items, participants are asked to list the activity they did if they walked outdoors for any other reasons in a typical week during the past four weeks (item 47). In one study, self-reported walking time measured by the CHAMPS-Outdoors questionnaire was found to be moderately correlated with the Accelerometry-GPS outdoor walking time and total steps (Spearman's rho = 0.33 and 0.33, p = 0.011 and 0.011, respectively). (171) However, over-reporting walking time was possible when self-reported questionnaires were used. (171) The results resemble another study (146) in which participants tended to over-report MVPA and high-light activity while under-reporting low-light and sedentary activity. In view of the disparity of results, CHAMPS-Outdoors and accelerometry may be used in simultaneously to estimate self-reported and objective measurement of outdoor walking time.

1.10 Association between neighbourhood walkability and physical activity

1.10.1 Among Canadian adults

In the last few decades, many studies have been done to investigate the relationships between neighbourhood walkability and outdoor walking in Canada. For instance, a systematic review summarised results from 25 studies that were conducted in Canada. (173) Mean age of participants ranged from 33.6 to 75.0 years. Research sites spanned across Canada - Quebec (thirteen studies), Alberta (nine studies), British Columbia (nine studies) and Ontario (six studies). In this review, the associations between each built environmental characteristic and walking were coded as “null” for non-correlated associations, “positive” or “negative” for statistically significant correlations. The associations made in the study were analysed according to four broad categories: functional, destination, safety, and aesthetics. The functional category is exemplified by street connectivity and residential density. Significant positive associations were found between functional characteristics and walking for transportation, in the aspects of overall walkability, connectivity and residential density, among the fourteen studies that discussed walking for transportation. However, among the seven studies that discussed functional features and walking for leisure, 31 of 32 associations were not significant. Only eight studies inspected the associations between functional features and walking for any purpose while 29 of 43 associations (67%) were found to be not significant.

Land use and proximity to destinations in the destination category were analysed by eleven studies. Out of the 42 comparisons made, 26 of them (62%) listed in six studies were not significant while 12 of them (29%) were positively correlated and 4 (10%) were negatively correlated. Destination-related characteristics were not correlated to walking for leisure (81%), and to walking for any purpose (73%). The third category, safety, was only tested in two studies. Among 16 associations that were made, only 2 (12%) were significantly correlated. With regard to the last category, aesthetics, a total of ten comparisons were made while 9 of them (90%) were not significant. To conclude, a majority of associations between outdoor walking and the four categories: functional, destination, safety, and aesthetics were found to be not significant. One limitation of this systematic review is the lack of data synthesis to present the results. Data synthesis was not feasible to be done due to various sample sizes and the heterogeneity of study designs across studies. (173) However, considering its extent, this systematic review is very close in reflecting the concurrent relationships between neighbourhood walkability and outdoor walking among Canadian adults.

In addition to the studies listed in the systematic review, two recently published studies (79, 92) were also captured. Nichani et al. (92) conducted a secondary data analysis based on Alberta's Tomorrow Project. A total of 14078 participants with a mean age of 55.0 participated in this study. Total walkability score (measured by NEWS-abbreviated) was found to be significantly and positively correlated with walking for transportation, walking for leisure, and moderate and vigorous physical activity time (measured by International Physical Activity Questionnaire (IPAQ) Long Form). On the other hand, Chum et al. (79) analysed results from a total of 2411 participants in neighbourhood planning areas in Toronto. Statistical analysis found a significant association between the total Walkability Index score and walking for transportation. Street connectivity and residential density did not predict walking time for transportation while land-use mix was a statistically significant predictor in the regression model. For every 1 standard deviation increase in the z-score of land-use mix, there would be 0.246 additional minutes in transportation walking time ($p<0.01$).

1.10.2 Among Canadian older adults

Although many studies were conducted to investigate the associations between neighbourhood walkability and walking/physical activity in Canadian adults, only four studies (16-19) specifically targeted older adults in which three of them (16-18) were conducted in British Columbia. The results were summarised and presented in the Appendix (Table 1.1).

Chudyk et al. (16) found that frequency and duration of walking for transportation (measured by CHAMPS) were associated with the Walk Score. However, the associations between LPA and MVPA, both measured by accelerometer with cut-points proposed by Freedson et al. (147) (100-1951 CPM for LPA; ≥1952 CPM for MVPA), and the Walk Score, were not significant. (16) This could be attributed to the dynamic interaction between an individual and their environment, multiple domains of physical activity such as leisure time, occupational, household and transportation and better proximity to destinations, which led to a shorter distance to destinations and therefore less physical activity was measured. Also, the cut-points may not be accurate enough in reflecting older adults' free-living moderate-intensity activity styles. (106)

In Fleig et al. (18) study, diversity of land use (0.17, $p<0.01$), street connectivity (0.20, $p<0.01$) and access to services (0.12, $p<0.05$) (measured by NEWS) were found to be significantly correlated with total physical activity time (measured by accelerometers) while walking infrastructure, aesthetics, traffic hazards and crime were not associated with total physical activity time ($p>0.05$). Another study that investigated the relationship between self-reported outdoor walking time and the Walk Score among older adults in British Columbia. (17) This study showed a ten-point increase in the Walk Score was associated with a 17 % increase in the odds of meeting physical activity guidelines through walking (OR = 1.17). (17) Participants who lived in a "Walker's paradise" had 3.5 times the odds of meeting guidelines through walking, compared to those who lived in a "car dependent" neighbourhood (OR = 3.57).

Gauvin et al. (19) conducted a five-year longitudinal study in Montreal metropolitan areas. Growth curve analysis showed participants who lived in closer proximity to services and amenities had a greater likelihood of walking. In follow-up, they had a lower likelihood of reporting walking in the fourth year (OR = 0.55) and the fifth year (OR = 0.79), compared to that in the third year. However, the odds of walking did not decrease progressively with time. Instead, fluctuations were observed. These observations may be explained by the adapted mobility framework proposed by Franke et al. (32) As an individual grows older, the determinants of physiological, subjective or context aspects can shift on a sliding scale towards more or less mobile. Mobility is fluid and dynamic. It fluctuates on a daily basis and over the life course.

Based on results from the included studies, it is reasonable to expect that physical activity is associated with land use mix, street connectivity and proximity to services or amenities. However, two studies that were conducted in Vancouver and Portland showed participants who lived in neighbourhoods with high residential density walked more for transportation in both cities. (13, 14) The interaction effect between residential density and country (between Vancouver in Canada and Portland in the US) was significant, suggesting that older adults walked more in Canadian neighbourhoods with higher residential density. Therefore, the relationships between neighbourhood walkability and walking could vary between cities. While Canadian studies mainly focused in British Columbia and Quebec, it is important to inspect how the relationships would change in other cities in Canada.

1.11 Summary

Prolonged sedentary time and physical inactivity among the older adults could be a threat to the public health system, and as a result, the importance of reducing sedentary time and getting adequate physical activity is emphasized. However, many older adults in Canada fail to achieve at least 150 minutes of MVPA per week as suggested. (110) It is therefore crucial to identify and tackle factors that hinder physical activity.

Neighbourhood walkability is a composite measure of the physical environment and reflects an individual's perception of their neighbourhood and the ease of outdoor walking in a neighbourhood. (5-7) Favorable environmental characteristics such as proximity to amenities, aesthetics, and safety may promote physical activities while unfavorable built characteristics may hamper physical activities within a neighbourhood. (8-10) As a result, having a more supportive and walkable neighbourhood environment may help older adults develop regular walking habits. This can be beneficial to their physical and mental health as well as social well-being. (135-137) Moreover, walking in outdoor environments may also reward them with attractive views in nature, such as forests, mountains, seaside, and urban parks, that are also beneficial to mental well-being. (135) Identifying the relationships between neighbourhood walkability and physical activity behavior can help identify older adults' walking time and behaviors, and the relationship between environmental features and walking, so as to promote social cohesion and participation in older adults. (99) Older adults can also be rewarded by knowing the neighbourhood environmental features and arranging healthy outdoor activities in a community. On the other hand, health professionals can arrange outdoor exercises and walking groups according to the neighbourhood environmental features which will ultimately facilitate older adults to expand their mobility beyond their neighbourhood, into the service community, the surrounding area, and the world. (29)

In the last decades, research has emerged to investigate the relationship between neighbourhood walkability and physical activity, as well as outdoor walking. Previous findings (16-19) suggested that physical activity was associated with land use mix, street connectivity and proximity to services or amenities. However, these studies (16-19) were mainly conducted in British Columbia and Quebec. Only two provinces may not be able to represent the variations of urban landscape and population density across the country, which could potentially influence the residents' commute time and modes of travel.(174) Physical activity time, which is measured by accelerometry or self-reported questionnaire, is not specific to outdoor activity. As a result, outdoor walking time may be a better representative of the actual time older adults stay in their neighbourhood specifically. In addition, no study has studied the relationship between neighbourhood walkability and walking among older adults who had difficulty in outdoor walking. How the relationship would change for this group of people remains in question. Therefore, it is crucial to conduct a study that identifies these research gaps and solves the existing problems.

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1.13 Appendix

Table 1.1 Study characteristics in literature review

Initial author, year	Mean age (SD)	Sample size	Locations	Outcome - Walkability (independent variable)	Outcomes - Physical activity (dependent variable)	Main results
Chudyk et al., 2017 (16)	74.3 (6.2)	161	Vancouver, BC	Street Smart Walk Score NEWS-A selected subscale - Aesthetics - Traffic hazards Crime	Accelerometry derived total activity count, number of steps per day, LPA and MVPA	The Walk Score was not significantly associated with total activity count (p=0.546), number of steps per day (p=0.612), LPA (p=0.068) or MVPA (p=0.950).
					Frequency and duration of walking for transportation measured by CHAMPS	The Walk Score was significantly associated with frequency and duration of walking for transportation measured by CHAMPS.
Fleig et al, 2016 (18)	70.3 (7.2)	193	Vancouver, BC	NEWS-CFA full questionnaire	Accelerometry derived LPA and MVPA	Total physical activity time (min/week) was significantly associated with diversity of land use (0.17, p<0.01), street connectivity (0.20, p<0.01) and access to services (0.12, p<0.05).

						Total physical activity time (min/week) was not associated with walking infrastructure and safety, aesthetics, traffic hazards, and crime (p>0.05).
Gauvin et al, 2012 (19)	74.7 (4.1)	521	Montreal, QB	Proximity of services and amenities measured by MEGAPHONE geographic information system	Frequency and duration of physical activity measured by Physical Activity Scale of Seniors	Participants who lived in closer proximity to services and amenities had a greater likelihood of walking. (OR=1.84-3.30)
Winters et al, 2015 (17)	75 (8.3)	1309	Vancouver, Abbotsford-Mission, Kelowna, and Victoria, BC	Street Smart Walk Score	Whether outdoor walking time (min/week) met the standard of having ≥150 min/week outdoor walking measured by Canadian Community Health Survey	A ten-point increase in Walk Score was associated with a 17 % increase in the odds of meeting physical activity guidelines through walking (OR = 1.17). Participants who lived in a “Walker’s paradise” had 3.5 times the odds of meeting the standard of having ≥150 min/week outdoor walking, compared

						to those in a "car dependent" neighbourhood

BC: British Columbia; CHAMPS: Community Healthy Activities Model Program for Seniors survey; MVPA: moderate-to-vigorous physical activity; NEWS-A: Neighborhood Environment Walkability Scale - Abbreviated; QB: Quebec; SWEAT-R: the Senior Walking Environmental Audit Tool – revise; SD: standard deviation

Chapter 2: Problem Statement and Methods

2.1 Purpose

The aim of this study was to study neighbourhood walkability, outdoor walking and moderate-to-vigorous physical activity (MVPA) in older adults with self-reported difficulty in walking outdoors.

2.2 Objectives

The objectives of this study were:

(1) to compare MVPA and outdoor walking time, assessed by one self-reported questionnaire and one objective outcome measure for each variable, in older adults who resided in different cities in Canada

(2) to estimate the associations between outdoor walking time, assessed by one self-reported questionnaire and one objective outcome measure, and neighbourhood walkability among older adults who had difficulty in walking outdoors

(3) to estimate the associations between MVPA time, assessed by one self-reported questionnaire and one objective outcome measure, and neighbourhood walkability among older adults who had difficulty in walking outdoors

2.3 Hypotheses

It was hypothesized that:

(1) there would be significant differences in self-reported and objectively measured MVPA and outdoor walking time gathered from participants across the four cities in Canada.

(2) there would be significant correlations between outdoor walking time and neighbourhood walkability among older adults who resided in different cities and had difficulty in walking outdoors

(3) there would be significant correlations between MVPA time and neighbourhood walkability among older adults who resided in different cities and had difficulty in walking outdoors

2.4 Study Design

This study is a secondary data analysis using cross-sectional baseline data from the GO-OUT study (Getting Older adults OUTdoors), an evaluator-blinded randomized controlled trial. (1)

The GO-OUT study was originally designed to evaluate the efficacy of an outdoor walking program group, in comparison with a weekly reminder group, in promoting outdoor walking activity in older adults who reported having difficulty walking outdoors. The trial was conducted in four cities: Edmonton (Alberta), Winnipeg (Manitoba), Toronto (Ontario), and Montreal (Quebec). Participants were included if they (1) were aged ≥ 65 years; (2) reported having difficulty in walking outdoors; (3) lived independently in the community; (4) were able to walk at least one block (about 50 metres) continuously with or without a walking aid and without supervision; (5) were willing to sign a liability waiver (at three sites) or sent a letter to their physician (at one site) regarding clearance to exercise; (6) scored ≥ 18 on the telephone version of the Mini-mental State Exam; (7) could join an educational workshop and attend at least five weeks of the outdoor walking program; and (8) spoke and understood English. (1) They were excluded if they: (1) reported having at least 150 min per week participation in any types of physical activities; (2) reported having rehabilitation treatment, either physical or occupational therapy, to improve walking; (3) were at high fall risk defined by meeting one or more criteria: ≥2 falls or an acute fall in the last 12 months; having cardiac, respiratory, peripheral vascular or other conditions that would hinder safe and full participation in the interventions; having postural hypotension; resting heart rate <45 or >100 beats per minute; and having severe limitation in visual acuity. (1) Participants were recruited through the local newspapers, seniors' groups, and seniors' centres. Informed written consent was acquired prior to the first evaluation.

A total of 190 participants were recruited and randomized in the GO-OUT study from April to July in 2018 and April to June in 2019, with the final 12-month follow-up evaluation occurring in 2020. The study was conducted in four cities in Canada: Edmonton (n = 51), Winnipeg (n = 53), Toronto (n = 50), and Montreal (n = 36). Prior to randomisation, all participants were given a five-hour educational workshop that took place either in community centres (Montreal and Toronto) or at the university (Edmonton and Winnipeg). The workshop consisted of eight interactive stations covering eight topics: Canadian physical activity guidelines for older adults; goal setting; use of a pedometer; Nordic pole walking; footwear, foot care and proper walking patterns; fall prevention; exercise intensity and safety monitoring; and postural awareness and balance exercises. After that, participants were stratified and then randomly allocated to the outdoor walking program (the experimental group) or the weekly reminders group (the control group). In the outdoor walking group, the ratio of participants to facilitators was planned to be three to one, with a maximum of nine participants per session and three facilitators consisting of a lead facilitator and one to two facilitator assistants. The walking program was designed according to the Patla and Shumway-Cook's framework (2). Depending on the initial walking speed, participants were given different walking distance goals every week. Walking activities were delivered with a progressive increase in walking distance (e.g. from 200 m in the first week to 400 m in the tenth week) and difficulty (e.g. from walking and turning in the first week to carrying a load through a crowd in the tenth week). The walking program was delivered in one or more large parks. Each session was composed of a 10-min warm-up, a distance walk, individualised walking activities, a distance walk, and a 10-min cooldown. Each walking session lasted for one hour, twice a week for ten weeks.

On the other hand, the control group was given weekly reminders by the study coordinators via phone calls. Participants were asked to recall the information and skills taught in the educational workshop. The weekly reminders group also lasted for ten weeks. All participants were assessed in-person at four distinct time points: before the workshop was carried out (baseline evaluation), right after the intervention ended, and 5.5 and 12 months after baseline. For the purpose of our study, only data collected at the baseline evaluation will be used.

2.5 Ethical Approval

This study received the ethical approval from the Health Research Ethics Board of University of Manitoba (HS25237).

2.6 Outcome Measures

2.6.1 Neighbourhood walkability (Independent Variable)

NEWS-CFA was administered in the GO-OUT project to measure neighbourhood walkability. It is composed of 67 items and covers 13 subgroups, including residential density, land use mix, access to services, streets in neighbourhood, places for walking and cycling, neighbourhood surroundings, traffic hazards, neighbourhood safety, lack of parking, lack of cul-de-sacs, hilliness, physical barriers, and social interaction.

The scoring system is based on the CFA results found in two studies. (3, 4) All the subscales are administered in Likert scales. In residential density, items are scored on a five-point scale with "none" receiving one point and "all" receiving five points. It is noteworthy that in residential density, each item carries a different weight. For instance, item 6 - *"How common* *are apartments or condos more than 13 stories in your immediate neighbourhood?"* receives a weight of 75. The total possible score in residential density is 865. In land use mix, six scores are given with "1-5min" scoring 5 points, "6-10min", "11-20min", "21-30min", "31+min" and "don't know" scoring 4, 3, 2, 1 and 1 point respectively. All the other subscales are scored on a four-point Likert scale with "strongly disagree" receiving one point and "strongly agree" receiving four points. Mean scores are calculated for each subscale. It should also be noted that some items (item 3 and 4 in Traffic hazard and item 4 in Crime) are reversed in calculation. The complete NEWS-CFA questionnaire and scoring form can be found at https://drjimsallis.org/measure_news.html. In addition to the subscale score, we also adopt the total NEWS score to identify the combined effects of NEWS subscales in estimating outdoor walking or MVPA time. The total NEWS score is calculated by adding up z-scores that are converted from the subscale scores with conversion so higher total NEWS score represents higher walkability. (5, 6)

Validity and reliability of NEWS are supported by several studies. Significant correlations of weak to moderate strength (r = 0.09-0.36) are found between several NEWS items and different physical environmental variables. (7) Similarly, the perceived environmental scores measured by NEWS are moderately to strongly correlated to the objective rating of the environment (r = 0.38-0.93). (5) Test-retest reliability is also supported by several studies (ICC = 0.40-0.97). (5, 8, 9) Interestingly, built neighbourhood characteristics such as the presence of sidewalks or cul-de-sacs tend to have higher reliability and validity of scores while scores in perceived attributes such as crime seem to have lower validity. (10)

2.6.2 Physical activity and outdoor walking (Dependent Variables)

2.6.2.1 Accelerometry-GPS

Both ActiGraph GT3X+ tri-axial accelerometers (ActiGraph, Pensacola, Florida) and GPS Travel Recorder (BT- Q1000XTA; Qstarz, Taipei, Taiwan) were used in the GO-OUT study. Participants were asked to wear both accelerometers and GPS recorders at the right hip for at least 12 hours a day for eight consecutive days except during sleeping and water-based activity. Then, accelerometry data were processed using ActiLife software version 6.5.4 (LLC, Pensacola, FL). Accelerometry data were used to measure the lifestyle physical activity time (in minutes per week) while Accelerometry and GPS results were time-matched to identify meaningful outdoor walking time (in minutes per week). Although tri-axial accelerometers were used, statistical analysis was based on the data measured in the vertical axis only. With regard to epoch length, older adults were not expected to experience a lot of sudden and rapid speed changes but more continuous physical activity so the estimation of physical activity intensity levels would be quite consistent using a longer epoch length (11), as suggested in previous studies (12-14). Therefore, a 60-s epoch length was adopted. A period of 90 minutes of 0 CPM was used to disregard non-wear time among the participants since it was anticipated that they would have lower physical activity level and prolonged sedentary activities. Furthermore, having at least 10 valid hours (⩾600 minutes) per day was considered to be a valid day; having a minimum of four valid days in a week was deemed as a valid week.

In order to estimate meaningful amounts of physical activity, absolute intensity thresholds were used as a reference. In contrast to Chudyk et al.'s (14) study, cut-points with a lower levels (i.e. 100-760 CPM for light physical activity; ≥761 CPM for MVPA) were adopted. This MVPA cut-point may be better in reflecting the free-living moderate-intensity activity styles (i.e., lifestyle physical activity) among the participants who had self-reported outdoor walking difficulty, as suggested by previous studies (15-17). Furthermore, LFE was also adopted to retain low frequency acceleration. It was shown to improve the accuracy of estimating actual number of steps in individuals with gait speeds at about 1.0 m/s. (17-20) Because of the participant characteristics, adopting LFE was thought to be appropriate in identifying their actual activity behaviors.

Outdoor walking time, on the other hand, was assessed by accelerometry-GPS. In order to identify participants' outdoor walking time, all walking bouts captured by accelerometers were identified. To identify meaningful walking bouts, a cadence of ≥40 steps per minute was taken as the cut-off since it demonstrated high sensitivity (1.00) and specificity (0.97) in differentiating lifestyle physical activity among older adults with self-reported difficulties in walking outdoors, compared to thresholds of ≥30, ≥35, ≥45, ≥50 steps per minute, as well as 760 CPM measured by accelerometers. (17) As a result, start time and end time of walking bouts where ≥40 steps per minute for at least five minutes were recorded. During this period, one minute below threshold was allowed. After determining walking time that was meaningful, participants' geographical positions were inspected by matching latitudes and longitudes of participants' positions captured by the GPS recorder with GIS data found in Google Maps (http://maps.google.com), to determine if the walking occurred outdoors. Daily walking bouts during a day were summed and the average of total walking time across all valid days was used for data analysis.

The inter-instrument reliability of the ActiGraph accelerometer is supported by two studies. (21, 22) However, the correlations between accelerometry derived activity counts and CHAMPS derived energy expenditure are low to moderate among older adults. (23-26) This may be explained by the discrepancy of measurement process between the two measures. Accelerometers cannot measure water-based activities and stationary physical activities, such as strength training and cycling, while the CHAMPS questionnaire is more diversified and able to capture these items. (24, 25) Self-reported questionnaires are also prone to having recall bias since participants may report incorrect physical activity time. (26, 27) This may also contribute to the low to moderate correlations between accelerometry and questionnaires.

2.6.2.2 CHAMPS

CHAMPS was used to capture self-reported MVPA (minutes per week). This outcome measure is more diversified and able to capture items that cannot be captured by accelerometers, such as water-based activities. It should be noteworthy that the correlations between accelerometry derived activity counts and CHAMPS derived energy expenditure are low to moderate only, which may be attributed to differences in measurement properties. (23-26) Although self-reported questionnaires could be influenced by recall bias and response bias (26-28), they are inexpensive, standardised, and easy to carry out. (28) Self-administered questionnaires would be a more appropriate tool to consider when inspecting physical activity and outdoor walking behaviors in a large population or during census.

To calculate self-reported MVPA time, item 7, 9, 14-16, 19, 21, 23-26, 29-33, 36-38, and 40 are extracted. (27) All these activities are suggested to have a MET of ≥3. (27) Six response options are given in the CHAMPS: “less than 1 hour”, “1 - 2.5 hours”, “3 - 4.5 hours”, “5 - 6.5 hours”, “7 - 8.5 hours” and “9 or more hours” per week. Midpoints of the score range of each item are calculated for data analysis (e.g. 0.5 hour for “less than 1 hour” and 1.75 hours for “1 - 2.5 hours”). (27) The scores of the above items are summed up to give MVPA time.

The construct validity of the CHAMPS questionnaire is supported by several studies. (26, 29, 30) Caloric expenditure measured by the CHAMPS questionnaire is correlated with the 6-

minute-walk test, aerobic endurance, agility, dynamics and maximal aerobic capacity, and self-reported health measures. (27-29, 31) CHAMPS derived moderate-to-vigorous caloric expenditure, total caloric expenditure, moderate-to-vigorous intensity duration, and total meaningful activity duration, are significantly correlated with step counts measured by accelerometers. (24, 26) Furthermore, test-retest reliability of the CHAMPS questionnaire is also supported (ICC = 0.55-0.93). (26, 27, 29, 30)

2.6.2.3 CHAMPS-Outdoors

To calculate self-reported outdoor walking time, the five questions in CHAMPS-Outdoors are summed up. These questions correspond to "*How many total hours a week did you walk uphill or hike uphill OUTDOORS (count only uphill part)?*"; "*Walk fast or briskly for exercise OUTDOORS (do not count walking leisurely or uphill)*"; "*Walk OUTDOORS to do errands (such as to/from a store or to take children to school?)*"; and "*Walk OUTDOORS leisurely for exercise or pleasure?*". Additionally, participants are asked to list and score the activity they did if they walked outdoors for any other reasons in a typical week during the past four weeks. Midpoints of the score range of each item are calculated and added for data analysis. Self-reported walking time measured by the CHAMPS-Outdoors questionnaire is moderately correlated with the Accelerometry-GPS outdoor walking time and total steps (Spearman's rho = 0.33 and 0.33, p = 0.011 and 0.011, respectively). (32)

2.6.3 Other Variables

Socio-demographic information, including age, sex, employment status, car use, glasses use, walking aid use, and Charlson Comorbidity Index, was obtained at the baseline evaluation. For employment status, we classified people who had a job as "yes" and those who had retired or did not have a job at the time of evaluation as "no". Car use was assessed by asking participants whether they owned a car and how they get to place that was too far to walk. Participants who reported driving their own cars to get to place that was too far would be classified as "drivers" while those who reported using public transit, adapted transportation such as WheelTrans / Handi-Transit, Taxis, other forms of transportation, or getting picked up by others will be classified as "non-drivers". Furthermore, participants who reported using glasses during walking were classified as "glasses-users" while those who did not use glasses during walking were classified as "non-glasses-users". Participants who reported the use of walking aids on a daily basis were requested to indicate what type of walking aids (a single point cane, a quad cane, a four-wheeled walker or other non-listed walking aids) they used.

Participants who reported using any walking aid daily were categorised as "with walking aids" while those who walked without walking aids were categorised as "without walking aids".

Charlson Comorbidity Index was used to predict mortality from comorbid diseases. (33, 34) It was later revised and adapted to estimate total costs of health care and mortality and thus provide a prognostic value. (35, 36) The score is calculated based on the number of comorbid conditions an individual has. Conditions are weighted according to the severity: mild conditions such as myocardial infarction and chronic pulmonary diseases receive a weight of one; conditions such as hemiplegia and malignancy are weighted to constitute two points; moderate or severe liver diseases are given a weight of three; metastatic solid tumour and HIV are given a weight of six. (35)

2.7 Statistical Analysis

2.7.1 Descriptive Analyses

The statistical package SPSS version 27 (IBM Corp., Armonk, NY) was used to analyse data. Continuous data, including age (years), accelerometry derived MVPA time (min/day), accelerometry-GPS derived outdoor walking time (min in bouts/day), CHAMPS-Outdoors derived outdoor walking time (min/day), CHAMPS derived MVPA (min/day), the NEWS total and subscale scores were expressed with means and standard deviations (SD) to show central tendency and dispersion of data respectively. On the other hand, categorical data, including sex, employment status, car use, glasses use and walking aid use, were expressed with counts and percentages. Charlson Comorbidity Index was expressed with median and 25^{th} and 75^{th} percentiles. Results were stratified by the four cities (Edmonton, Winnipeg, Toronto, and Montreal).

2.7.2 Sample size calculation

Post hoc power analysis was conducted with G*Power 3.1 (https://www.psychologie.hhu.de/arbeitsgruppen/allgemeine-psychologie-und-arbeitspsychologie/gpower.html).(37) The statistical power calculated from significance = 0.05, power = 0.8, sample size = 190 with a correlation of 0.2 drawn from a previous study (13) was 0.87, higher than the expected power of 0.8.

2.7.3 Bivariate analyses

Objective 1: to compare self-reported and objectively measured MVPA and outdoor walking time across four cities in Canada

The first objective was to compare self-reported and objectively measured outdoor walking and MVPA time gathered from participants across the four cities in Canada. We tested whether there were statistically significant mean differences in outdoor walking time across the four cities. Before carrying out parametric tests, three assumptions had to be met. First, the sampling data needed to be normally distributed. Normality was tested by the Shapiro-Wilk test with visual inspection of the P-P plot. (38) If the Shapiro-Wilk test showed a non-significant result ($p>0.05$) with no skewness or kurtosis found in the P-P plot, the data would be regarded as normally distributed. (38) The second assumption was the homogeneity of variance. Homogeneity of variance referred to the variance of one variable being constant at all levels of other variables. (38) If Levene's test was found to be non-significant ($p>0.05$), this assumption of homogeneity of variance was tenable. The last assumption was independence where behaviours of each participant would not affect others' behaviours.

We planned to use one-way analysis of variance (ANOVA) to test mean differences in self-reported outdoor walking and MVPA time across the four cities. Self-reported outdoor walking and MVPA time was added as the outcome variable while cities (four groups) were added as the independent variable. F-statistic was generated by dividing the model mean squares to residual mean squares. A larger F-statistic with p value smaller than alpha value ($p<0.05$) represented a statistically significant difference. If results showed a statistically significant mean difference, pairwise comparisons with Bonferroni correction would be conducted between each of the four groups. Bonferroni correction was done by dividing $\boldsymbol{\alpha} = 0.05$ by number of between-group comparisons (n=6), which gave $\boldsymbol{\alpha} = 0.0083$. A p-value lower than $\boldsymbol{\alpha} = 0.0083$ was identified as being significant. However, Shapiro-Wilk test and Levene's test revealed that the assumptions of normality and homogeneity of variances were both violated. As a result, we used Kruskal-Wallis test to inspect the differences of outdoor walking and MVPA time between the cities. More details will be discussed in chapter 5.

Objective 2: to estimate the associations between outdoor walking time and neighbourhood walkability

The second objective was to estimate the associations between outdoor walking time and neighbourhood walkability. Similar to the assumptions listed above, normality, homogeneity of variance and independence had to be met. Additionally, several more assumptions had to be met to conduct regression analysis. First, scatter plots were used to visually check whether the relationship were linear. (39) The second additional assumption was the absence of multicollinearity between predictor variables. Multicollinearity referred to the associations between predictor variables. The presence of multicollinearity increased the variance of a regression coefficient, as well as the standard error of the regression coefficient. It was examined by the variance inflation factor (VIF). (40) If the VIF was larger than 5, the relationship between two predictors was strong and multicollinearity existed. (40) The third assumption was homoscedasticity where the variance of errors should be constant at each level of the predictor variables. (38) It was inspected by a Zresid vs Zpred plot. Lastly, the predictor variables should not have a zero variance. (38)

We proposed to use multivariate linear regression analysis to inspect the association between neighbourhood environmental characteristics (predictor variable) and either outdoor walking or MVPA time (outcome variable). Multivariate linear regression analysis was performed by adding all the predictors that were significantly associated with the outcome variable into a model. The predictor variables were rejected from the model if the predictors were not associated with the outcome variable after adding into the model.

Model 1 was conducted using NEWS subscale scores as predictor variables. In the first part of model 1, simple linear regression analysis was conducted between outdoor walking time and each subscale. The subscales with highest t-value in **β**-coefficient were retained and added to the regression model ($p<0.05$). In the second part, all other covariates, including age, sex, employment status, car use, glasses use and walking aid use, would be added. In the third part, the cities would coded and added into model 1 as a modulator variable. Model 2 was conducted using NEWS total score as a predictor variable. In the first part of model 2, a crude model was used to investigate the association between the NEWS total score and accelerometry derived outdoor walking time, with no other predictor variables. In the second part, an adjusted model was formulated by adding all other covariates including age, sex, employment status, car use, glasses use and walking aid use. In the third part, the four cities were coded and added into as a modulator variable.

We inspected the assumptions of normality, homogeneity of variances and homoscedasticity of linear regression analysis. However, these assumptions were all violated. As a result, Spearman's rho was used to inspect the correlations between neighbourhood walkability and outdoor walking. More details will be discussed in chapter 5.

Objective 3: to estimate the associations between MVPA time and neighbourhood walkability
The third objective was to estimate the associations between MVPA time and neighbourhood walkability. Similar to the process suggested in objective 2, the assumptions of normality, homogeneity of variances and homoscedasticity of linear regression analysis were tested and did not meet the assumptions. We could not perform the linear regression analysis. Instead, we used Spearman's rho to estimate the associations between MVPA and neighbourhood walkability.

2.8 Summary

The methodology and research design were presented in this chapter. This study used a cross-sectional research design and investigated the relationships between neighbourhood walkability and walking behaviors among older adults who reported difficulty in walking outdoors. This study was also a secondary data analysis utilising data collected in baseline evaluation of the GO-OUT study. The GO-OUT study was conducted in four different cities in Canada and therefore provided an overview of the relationship between neighbourhood walkability and walking behaviors in different locations.

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Chapter 3: Linking methodology and the main research findings

Previous chapters discussed the current evidence on the relationships between neighbourhood walkability and walking behaviors and the proposed methodology and research design of our study. The following chapter is a manuscript that will be submitted to the Journal of Health and Place. Because of the word limitations in a manuscript, parts of the findings and the rationale of the research will not be discussed. A detailed elaboration of all other findings will be provided in Chapter 5 instead.

The authors confirm contribution to the thesis and manuscript as follows: study conception and design: Hong Chan**,** Ruth Barclay, Nancy M. Salbach, Gina Sylvestre, and Sandra C. Webber; data collection: none (this is a secondary data analysis); analysis: Hong Chan; interpretation of results: Hong Chan**,** Ruth Barclay, Nancy M. Salbach, Gina Sylvestre, and Sandra C. Webber; draft manuscript preparation: Hong Chan**;** draft manuscript review and revision: Hong Chan, Ruth Barclay, Nancy M. Salbach, Gina Sylvestre, and Sandra C. Webber. All authors reviewed the results and approved the final version of the thesis and manuscript.

Chapter 4: Outdoor walking and physical activity and their relationship with neighbourhood walkability in older adults with self-reported difficulty in walking outdoors

4.1 Title Page

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Conflict of interest statement: The authors have no conflict of interest to declare.

Funding: This GO-OUT study was funded by Canadian Institutes of Health Research (CIHR). The secondary data analysis received no funding.

Abstract

The study investigated outdoor walking and moderate-to-vigorous physical activity (MVPA) time, and their relationships with neighbourhood walkability in older adults with self-reported difficulty in different cities in Canada. This is a secondary data analysis using results from baseline evaluation in the Getting Older adults OUTdoors (GO-OUT) study. We found (1) significant differences in MVPA time but not outdoor walking time between Edmonton, Winnipeg, Toronto, and Montreal, and (2) significant but weak associations between residential density, land-use access, and street connectivity, assessed by Neighbourhood Environmental Walkability Scale (NEWS), and either outdoor walking time ($r = 0.172$ to 0.233) or MVPA time ($r = -0.235$ to 0.208).

(105 words)

Keywords

Neighborhood walkability; Walking; Physical activity; Older Adults.

Highlights

- We found no between-city differences in outdoor walking time.
- We found between-city differences in MVPA time.
- Land-use mix access was weakly correlated with outdoor walking time.
- Residential density was weakly correlated with MVPA time.
- Total NEWS score was not correlated with physical activity or outdoor walking time.

4.2 Introduction

Neighbourhood walkability has been defined to be the extent to which the built environment in a neighbourhood is pedestrian friendly and easy to walk. (1) Physical and social environmental characteristics, together with personal circumstances and home environments, contribute to an individual's perception of neighbourhood walkability. (2) Ideally, a walkable neighbourhood should consist of tight connections between an individual's home and distinct facilities or amenities (better access and diversity), short routes to reach different destinations (better street connectivity), well-maintained pavements or sidewalks that allow pedestrians to walk safely (better infrastructure), pleasantness of nature and higher residential density which attracts amenities like groceries stores, banks, and convenience stores. For instance, some older adults specifically identify social connections with their friends and neighbours to be an important factor to walk in their neighbourhoods (3-5) while some prefer walking along well-maintained routes, historic buildings or monuments and avoid walking in abandoned streets where no other pedestrians are present. The presence of a large crowd, youngsters, immigrants or the homeless, for example, may discourage some older adults from walking in a neighbourhood. (3, 4) Higher level of walking for transportation was found to be correlated with better physical functioning level among older adults who resided in a more walkable neighbourhood. (6) Understanding the relationship between neighbourhood walkability and walking among older adults may assist with promoting social cohesion and participation in older adults (7), which could in turn expand their mobility beyond their neighbourhood, into the service community and the surrounding areas. (8)

Previous studies showed that residential density, street connectivity, proximity to amenities, land-use mix, public transit, the presence of sidewalks, safety and recreational facilities could influence an adult's outdoor walking behaviors. (9, 10) However, recent research has shown that the relationships between neighbourhood walkability and walking were both region-specific (11, 12) and age-specific (13). Although many studies have been conducted, few focus on older adults in Canada. The studies that did specifically investigate neighbourhood walkability among older adults in Canada were conducted in only two provinces, British Columbia (n = 3) (14-16) or Quebec (n = 1) (17). In the two studies that were conducted in Vancouver, physical activity, measured by accelerometry and Canadian Community Health Survey (Healthy Aging Cycle) respectively, were associated with land use mix, street connectivity and proximity to services or amenities. (14, 16) On the other hand, the frequency and duration of walking for transportation, assessed by the CHAMPS questionnaire, was associated with the Walk Score. (15) It did not find any associations between the Walk Score and accelerometry-derived light physical activity or MVPA using a cut-point of 1952 CPM (18). Growth curve analysis in another study conducted in Montreal showed participants who lived in closer proximity to services and amenities had a greater likelihood of walking. (17) However, only two provinces cannot represent the variations of neighbourhood walkability across the country.

Urban landscape and population density across the country can potentially influence the commute time and modes of travel. (19) For instance, the population density was the highest in Toronto, reaching 3368 persons per square kilometre, while the dwelling density was the highest in Montreal, achieving 1490 dwellings per square kilometre in 2015. (19) Residents in central metropolitan areas, such as Vancouver, Toronto and Montreal were more likely to commute with public transport while those of the neighbouring municipalities were more likely to drive their own vehicles. (19)

Physical activity time, which is measured by accelerometry or self-reported questionnaire, is not specific to outdoor activity since it could be influenced by the amount of indoor physical activity. Therefore, outdoor walking time could be an alternative of measuring the actual time older adults walk in their neighbourhood. In addition, although several studies were conducted on Canadian older adults, none of them has studied this topic among older adults who had difficulty in outdoor walking. How the relationship would change for this population remains in question. Therefore, the aims of this study were (1) to compare outdoor walking and moderate-to-vigorous physical activity time (MVPA) time in participants from Edmonton, Winnipeg, Toronto, and Montreal; (2) to estimate the associations between neighbourhood walkability and outdoor walking, and between neighbourhood walkability and MVPA time in older adults with difficulty in walking outdoors.

4.3 Methods

4.3.1 Study design and sample

This study is a secondary analysis of cross-sectional baseline data from the GO-OUT study (Getting Older adults OUTdoors), an evaluator-blinded randomized controlled trial. (20) The study evaluated the efficacy of an outdoor walking program group, compared to a weekly reminder group, in promoting outdoor walking activity in older adults who reported having difficulty walking outdoors. The trial was conducted in four cities in Canada: Edmonton (Alberta), Winnipeg (Manitoba), Toronto (Ontario), and Montreal (Quebec). Participants were included if they (1) were aged ≥ 65 years; (2) reported having difficulty in walking outdoors; (3) lived independently in the community; (4) were able to walk at least one block (about 50 metres) continuously with or without a walking aid and without supervision; (5) were willing to sign a liability waiver (at three sites) or send a letter to their physician (at one site) regarding clearance to exercise; (6) scored ≥ 18 on the telephone version of the Mini-mental State Exam; (7) could join an educational workshop and attend at least five weeks of the outdoor walking program; and (8) spoke and understood English. (20) They were excluded if they: (1) reported having at least 150 min per week participation in any types of physical activities; (2) reported having rehabilitation treatment, either physical or occupational therapy, to improve walking; (3) were at high fall risk defined by meeting one or more criteria: ≥2 falls or an acute fall in the last 12 months; having cardiac, respiratory, peripheral vascular or other conditions that would hinder safe and full participation in the interventions; having postural hypotension; resting heart rate <45 or >100 beats per minute; and having severe limitation in visual acuity. (20) Participants were recruited through the local newspapers, seniors' groups, and seniors' centres.

A total of 190 participants were recruited and randomized in the GO-OUT study from April to July in 2018 and April to June in 2019, with the final 12-month follow-up evaluation occurring in 2020. The study was conducted in four cities in Canada: Edmonton (n = 51), Winnipeg (n = 53), Toronto (n = 50), and Montreal (n = 36). All participants were given a five-hour educational workshop before random allocation to the outdoor walking program (the experimental group) or the weekly reminders group (the control group). The walking program was designed according to Patla and Shumway-Cook's framework. (21) The control group was given weekly reminders by the study coordinators via phone calls. Both interventions lasted for ten weeks. We received the ethical approval from the Health Research Ethics Board of University of Manitoba (HS25237). For the purpose of this study, only data collected at the baseline evaluation were used in analysis.

4.3.2 Data collection

A table of city characteristics was created. (Table 4.1) City characteristics were drawn from each of the population centres, which was defined as “an area with a population of at least 1,000 and a population density of 400 persons or more per square kilometre” by the Canadian government. (22)

Neighbourhood walkability was assessed by Neighbourhood Environmental Walkability Scale-Confirmatory Factor Analysis (NEWS-CFA), a self-reported outcome measure. (23) It consists of 13 subscales with a total of 67 items. The subscales include residential density, land use mix, access to services, streets in neighbourhood, places for walking and cycling, neighbourhood surroundings, traffic hazards, neighbourhood safety, lack of parking, lack of cul-de-sacs, hilliness, physical barriers, and social interaction. The standard scoring system was developed from confirmatory factor analysis conducted in two studies. (24, 25) All questions are administered on a four-point Likert scales, except residential density and land-use mix diversity, which are administered on a five-point scale. The subscale scores of residential density were calculated by giving a weight of 1 to detached single-family residences, a weight of 12 for townhouses or row houses of 1 to 3 stories, a weight of 10 for apartments or condos 1 to 3 stories, a weight of 25 for apartments or condos 4 to 6 stories, a weight of 50 for apartments or condos 7 to 12 stories and a weight of 75 for apartments or condos more than 13 stories so the maximal and minimal possible scores were 865 and 173 respectively. Mean scores are calculated for the remaining subscales. The maximal achievable and minimal achievable score are 5 and 1 for land use mix-diversity and 4 and 1 for all the other scales. It is noteworthy that some items (item 3 and 4 in traffic hazard and item 4 in crime) are reversed in calculating the subscale scores. The complete NEWS-CFA questionnaire and scoring form can be found at https://drjimsallis.org/measure_news.html. Total NEWS score was not included in the original NEWS questionnaire. Instead, it was suggested in two previous studies. (26, 27) The total NEWS score is calculated by adding up z-scores that are converted from the subscale scores with adjustment so that higher total NEWS score represented higher walkability. (26, 27) The validity and reliability of the original NEWS questionnaire were supported by several studies. Significant correlations of weak to moderate strength ($r = 0.09 - 0.36$) have been reported between several NEWS items and different physical environmental variables in adolescents. (28) Distance measured in the aspects of land-use mix-diversity is negatively associated with higher percentage of corresponding amenities in a neighbourhood (shorter perceived distance to amenities reflects higher percentage of amenities shown in geographic information systems GIS) in adult participants (r = -0.09 to -0.40). (28) Similarly, the NEWS subscale scores are moderately to strongly correlated to ratings of the environment measured by two independent assessors in field visits (r = 0.38-0.93) in adults (aged 18 to 65), although the number of questions in the subscales slightly differs from NEWS-CFA. (26) Test-retest reliability of individual items in the NEWS questionnaire is also supported by previous evidence (ICC = 0.40-0.97). (26, 29, 30)

Outdoor walking time and MVPA time were the outcomes in this study. Each of them was measured with a self-reported questionnaire and an objective measurement tool. Specifically, self-reported MVPA time was administered with the Community Healthy Activities Model Program for Seniors-Outdoors survey (CHAMPS) while objectively measured MVPA time was measured by accelerometers. On the other hand, self-reported outdoor walking time was administered with CHAMPS-Outdoors while objectively measured outdoor walking time was measured by accelerometers and GPS recorders. ActiGraph GT3X+ tri-axial accelerometers (ActiGraph, Pensacola, Florida) and GPS Travel Recorder (BT- Q1000XTA; Qstarz, Taipei, Taiwan) devices were used in the GO-OUT study. Participants were asked to wear both accelerometers and GPS recorders at the right hip for at least 12 hours for eight consecutive days except during sleeping and water-based activity. Then, accelerometry data were processed using ActiLife software version 6.5.4 (LLC, Pensacola, FL). A period of 90 minutes of 0 counts per minute (CPM) was set to disregard non-wear time among the participants. (31) A valid day was determined to be at least 10 valid hours (⩾600 minutes) per day while a minimum of four valid days in a week was deemed a valid week. (31) In order to estimate meaningful amounts of physical activity, cut-points with a lower level (i.e. 100-760 CPM for lifestyle light physical activity; ≥761 CPM for lifestyle MVPA) were adopted. This cut-point may better reflect the free-living moderate-intensity activity styles (i.e., lifestyle physical activity) among the participants who had self-reported outdoor walking difficulty, as suggested (32, 33). Furthermore, the low frequency extension (LFE) analysis algorithm was also adopted to retain low frequency acceleration since it has been shown to improve the accuracy of estimating actual number of steps in individuals with gait speeds ≤1.0 m/s. (34, 35)

Outdoor walking time was assessed by accelerometry-GPS In order to identify participants' outdoor walking time, all walking bouts captured by accelerometers were identified. To identify meaningful walking bouts, a cadence of ≥40 steps per minute was taken as the cut-off since it demonstrated high sensitivity (1.00) and specificity (0.97) in differentiating lifestyle physical activity among older adults with self-reported difficulties in walking outdoors, compared to thresholds of ≥30, ≥35, ≥45, ≥50 steps per minute, as well as 760 CPM measured by accelerometers. (35) Time intervals were recorded when cadence was greater ≥40 steps per minute for at least five minutes. One minute below the threshold was allowed. After meaningful walking time was determined, participants' geographical positions were inspected by matching latitudes and longitudes of participants' positions captured by the GPS recorder with GIS data found in Google Maps (http://maps.google.com), to determine if the walking occurred outdoors. Average daily walking bouts were summed and multiplied by seven to give the total walking time (minutes per week).

Self-reported MVPA (minutes per week) was captured by CHAMPS. Although both CHAMPS and accelerometers attempt to measure similar constructs, the correlations between accelerometry derived activity counts and CHAMPS derived energy expenditure have been shown to be only low to moderate , which may be attributed to differences in measurement properties. (36-38) Nonetheless, self-reported questionnaires are inexpensive, standardised, and easy to carry out (39) and are often a more appropriate tool to consider when inspecting physical activity and outdoor walking behaviors in a large population. Self-reported MVPA time was calculated by adding the duration of activities reported in items 7, 9, 14-16, 19, 21, 23-26, 29-33, 36-38, and 40. These activities are suggested to have a MET of ≥3. (40) For each of the items, six response options are given: "less than 1 hour", "1 - 2.5 hours", "3 - 4.5 hours", "5 - 6.5 hours", "7 - 8.5 hours" and "9 or more hours" per week. Midpoints of the score range of each item were calculated for data analysis (e.g. 0.5 hour for "less than 1 hour" and 1.75 hours for "1 - 2.5 hours"). (40) "9 hours" was used for calculation if participants reported "9 or more hours".

CHAMPS-Outdoors was used to capture self-reported outdoor walking time. (41) It consists of the five questions from the CHAMPS that asked whether the walking occurred outdoors, including "How many total hours a week did you walk uphill or hike uphill OUTDOORS (count only uphill part)?"; "Walk fast or briskly for exercise OUTDOORS (do not count walking leisurely or uphill)"; "Walk OUTDOORS to do errands (such as to/from a store or to take children to school?)"; and "Walk OUTDOORS leisurely for exercise or pleasure?". Additionally, the participants were asked to include any other activity they did if they walked outdoors for any other reasons in a typical week during the past four weeks. Midpoints of the score range of each item were calculated and added for data analysis. Self-reported walking time measured by the CHAMPS-Outdoors questionnaire was moderately correlated with the Accelerometry-GPS outdoor walking time and total steps (Spearman's rho = 0.33 and 0.33, p = 0.011 and 0.011, respectively), in a previous study that used the same data from the GO-OUT study. (41)

Sociodemographic information, including age, sex, employment status, car use, glasses use and walking aid use, and Charlson Comorbidity Index, were obtained at the baseline evaluation. Charlson Comorbidity Index was derived from a weighted score for comorbidity. (42) For instance, mild conditions such as myocardial infarction and chronic pulmonary diseases received a weight of one; conditions such as hemiplegia and malignancy were given two points; moderate or severe liver diseases were given a weight of three; metastatic solid tumour and HIV were given a weight of six. (43)

4.3.3 Analysis

Categorical data were presented with counts and percentage, and medians, lower and upper quartile if necessary. Continuous data were summarized with means and standard deviations (SD). Since outdoor walking time and MVPA time were both highly and positively skewed, they were presented with medians, lower and upper quartiles, as well as minimum and maximum. Results were presented in total and by city.

We planned to use one-way ANOVA to compare the differences of MVPA and outdoor walking time between cities. However, Shapiro-Wilk's test and Levene's test revealed both the assumptions of normality and homogeneity of variances were not fulfilled. Therefore, Kruskal-Wallis test was performed to compare differences between cities in outdoor walking time and MVPA time. Follow-up pairwise comparisons were made with Bonferroni corrections on $\boldsymbol{\alpha} = 0.0083$ level ($\boldsymbol{\alpha} = 0.05$ divided by 6 between-group comparisons) if a positive result was found in the Kruskal-Wallis test.

We attempted to perform linear regression analysis to estimate the associations between outdoor walking time and MVPA with NEWS subscale scores and total scores. However, inversion and log transformations failed to bring the distribution into being normal. The assumptions of homogeneity of variances, and normality were not fulfilled. Additionally, the assumption of homoscedasticity was tested by visually inspecting Zresid vs Zpredi plots (plots of standardized residuals versus standardized predicted values). However, this assumption was also violated. Since the assumptions of linear regression analysis all failed, Spearman's Rho was used to estimate the associations between NEWS scores and variables of MVPA and outdoor walking time respectively. The strength of correlations were inspected according to Prion and Haerling's paper (44), with rho ranging from negligible (0 to 0.20), weak (0.21 to 0.40), moderate (0.41 to 0.60), strong (0.61 to 0.80), and very strong (0.81 to 1.00).

4.4 Results

Characteristics of cities and participants are presented in Table 4.1. The geographical area of the population centres ranged from 343.99 (Winnipeg) to 1,792.99 km^2 (Toronto). (22) Toronto was the densest city, with an average of 3,028 residents residing per 1 km^2. The number of older adults aged above 65 was also the highest in Toronto, reaching a population of 790,515 and constituting 14.56%, while it was the lowest in Winnipeg, reaching a total of 111,850 and constituting 15.71% only. However, the proportion of older adults was the highest in Montreal, reaching 16.46%, and the lowest in Edmonton, constituting 12.44% only. Considering the progressive increase in the proportions of older adults aged over 65 in Canada (from 13.7% in 2006 to 16.9% in 2016) (45), understanding and meeting the needs of older adults becomes increasingly important. Daily average temperatures from April to July are also presented in Table 4.1. (46)

A total of 190 participants between 63 and 94 years of age completed the baseline evaluation of the GO-OUT study. A majority of participants were female (n=139), constituting 73.2% of the total sample. The proportion of unemployed or retired participants was 86-94% across the four cities. Approximately 79.5% of the participants reported driving to travel to destinations that were too far to walk. The use of glasses on a daily basis among the participants was 95%. The proportion of participants who used walking aids was approximately 20.0% in all cities except Toronto in which 46.0% of participants used walking aids.

The NEWS total score and subscale scores are presented in total and by city (Table 4.2). Subscale scores of land-use mix access, street connectivity, infrastructure and safety for walking, aesthetics, lack of cul-de-sacs, and social interaction while walking for each of the cities were approximately three, indicating that these cities, in general, were relatively more walkable in these aspects. Land-use mix diversity for each of the cities scored 2.0 to 2.5 approximately, suggesting the distance to get to the nearby amenities in a neighbourhood was around 20 minutes. On the other hand, subscale scores of traffic hazards, crime, hilliness and physical barriers for each of the cities ranged from 1.5 to 2.5. Since these subscales were reversely scored, these cities were also relatively more walkable in these aspects. The total NEWS score of each of the cities was calculated from all the subscale scores. Kruskal-Wallis test with follow-up pairwise comparisons showed a statistically lower total NEWS score in Montreal, compared to Toronto ($p = 0.004$).

The median of CHAMPS-Outdoors derived outdoor walking time was 105 minutes per week while the median of accelerometry-GPS derived outdoor walking time was 21.5 minutes per week. Kruskal-Wallis tests did not show any between-city differences in outdoor walking time, regardless of being measured by CHAMPS-Outdoors ($p=0.439$) or accelerometry-GPS ($p=0.219$). On the other hand, the median of CHAMPS derived MVPA time was 135.0 minutes per week while the median of accelerometry derived MVPA time was 344.2 minutes per week. Kruskal-Wallis test showed significant between-city differences in MVPA time. The follow-up pairwise comparisons showed a significantly lower self-reported MVPA time in Toronto (median = 75.0 minutes per week), compared to Edmonton (median = 225.0 minutes per week) and Montreal (median = 180.0 minutes per week), as well as objectively measured MVPA time in Toronto (median = 249.8 minutes per week), compared to Edmonton (median = 456.8 minutes per week) and Winnipeg (median = 361.4 minutes per week).

Residential density and street connectivity were significantly but weakly correlated with CHAMPS derived physical activity time ($r = -0.235$ and 0.208 respectively). (Table 4.4) Furthermore, land-use mix – access was significantly but weakly correlated with CHAMPS-Outdoors derived outdoor walking time ($r = 0.233$). On the other hand, the correlations between accelerometry-GPS derived outdoor walking time and variables of land-use mix – diversity and land-use mix – access (r = 0.172 and 0.176 respectively), between land-use mix – access and accelerometry-GPS derived outdoor walking time (r = 0.176) and CHAMPS derived physical activity time (r = 0.185) were significant but negligible. All other subscales were not correlated with outdoor walking or MVPA time among older adults (p>0.05). In addition, our study failed to find any significant correlations between total NEWS score and either outdoor walking or MVPA time.

Power analysis was conducted with G*Power 3.1 (https://www.psychologie.hhu.de/arbeitsgruppen/allgemeine-psychologie-und-arbeitspsychologie/gpower.html).(47) Prior to conducting this study, the statistical power was calculated to be 0.87, with significance = 0.05, power = 0.8, sample size = 190 and a correlation of 0.2 drawn from a previous study. (14) Post-hoc power analysis with significance = 0.05, power = 0.8, sample size = 190 with a correlation of 0.172 to 0.235 (Table 4.4) gave a power of 0.77 to 0.95.

4.5 Discussion

Our study found significant between-city differences in MVPA time but not in outdoor walking time in older adults participants. More than 75% of the participants accumulated at least 150 minutes of MVPA time per week (Table 4.3), as suggested by World Health Organisation. (48) They also had longer objectively measured physical activity time than the findings reported by a recent survey conducted by the Canadian government (103.6 minutes) among older adults aged between 65 and 79. (49) However, a previous systematic review found that the average MVPA time that was calculated with a cut-point of 760 CPM was 381.5 to 721.7 minutes per week among healthy older adults. (50) The discrepancy of the results relative to previous findings could be attributed the inclusion and exclusion criteria of the GO-OUT study. Older adults who were able to walk about 50 metres continuously without supervision and scored ≥ 18 on the telephone version of the Mini-mental State Exam were recruited in the GO-OUT study. This suggests that the participants were physically and mentally sound in the outdoor environment to a certain extent. Also, older adults who were at high fall risk were excluded. However, the participants in the GO-OUT study who had reported having difficulty in walking outdoors, and were not physically active (i.e. having at least 150 minutes of participation in any types of physical activities per week), it is therefore reasonable to see MVPA time found in our study to be situated between previous findings. Nonetheless, it is still important to recognise the low outdoor walking time among the participants and the additional benefits of outdoor walking, such as improving physical health, mental health, and quality of life. (51-53)

The statistical analyses revealed that the lowest self-reported and objectively measured MVPA time was found in Toronto while the self-reported and objectively measured MVPA time was the highest in Edmonton. The lower MVPA time found in Toronto may be attributed to the higher proportion of walking aid use (46%), compared to other groups. Additionally, both comfortable and fast walking speed were higher in Edmonton, compared to any other groups. As a person ages, aerobic capacity declines, which makes walking at a comfortable speed more difficult. (54) Slow walkers generally need to spend more oxygen consumption during walking, so they are more prone to fatigue than fast walkers. (54, 55) Comfortable walking speed below 1 m/s also denotes frailty and is associated with disability and decreased survival rate. (56, 57) Another study (58) established a cut-point of 0.97 and 1.39 m/s, for comfortable and fast walking speed respectively, to be an indicator of attaining 8,000 steps per day or not. Participants in Edmonton achieved relatively higher comfortable and fast walking speeds, compared to the suggested value. It is therefore reasonable to observe higher MVPA time in participants in Edmonton.

Consistent with previous studies (59, 60), self-reported outdoor walking time was consistently greater than objectively measured outdoor walking time in all cities. This finding was anticipated since over-reporting MVPA and under-reporting light physical activity or sedentary activity is common when self-reported questionnaires are administered. (38, 59) On the other hand, self-reported MVPA was consistently lower than objectively measured MVPA in all cities. This finding could be influenced by inadequacy of the items in the CHAMPS questionnaire in measuring MVPA. MVPA was calculated by adding the items 7, 9, 14-16, 19, 21, 23-26, 29-33, 36-38, and 40 since these items indicated an activity level of three metabolic equivalents of tasks (3 METs) or above. (40) However, these items are mainly related to sports, such as aerobic dancing, swimming, rowing, cycling and running, or activities, such as gardening and doing chores. The participants in the GO-OUT study were recruited with the criterion of having reported difficulty in walking outdoors. It is reasonable to infer that they could find it difficult to play sports that involve locomotion if they had difficulty in outdoor walking. Healthy older adults tend to have a lower resting oxygen consumption (2.7 – 3.3 ml/min/kg), as opposed to the more widely used value of 3.5 ml/min/kg. (61-63) As the intensity of physical activity measured in the CHAMPS questionnaire was calculated based on 3.5 ml/min/kg instead of 2.7 – 3.3 ml/min/kg as suggested for older adults, the actual time spent in physical activity above the threshold may have been underestimated. (63) For instance, household activities such as sweeping and vacuuming were measured to be 2.30 to 2.47 METs respectively among healthy older adults, based on 1 MET being equal to 3.5 ml/min/kg. (64) The actual MET of these activities could be higher if 2.7 – 3.3 ml/min/kg was used for calculation. (64) In other words, activities that were regarded below 3 METs based on 3.5 ml/min/kg could be moderate-to-vigorous for older adults who have lower levels of resting oxygen consumption. The actual energy expenditure of these tasks could be even higher among older adults who had self-reported difficulty in mobility. (65) Accelerometry derived MVPA time was measured by accelerometers using a cut-point of 760 CPM. Since this cut-point is designed to capture activities of ≥ 3.0 METs, ranging from sweeping and mopping, gardening, lawn mowing to slow walking (33), it may have been a better tool than the CHAMPS questionnaire to measure MVPA in participants in the GO-OUT study. Additionally, the regular cut-point used in research in adults (1952 CPM) was suggested for differentiating light physical activity and MVPA may not be applicable on older adults (50) since they have a lower resting metabolic rate (2.7 – 2.9 ml/min/kg) (61, 62) and higher energy expenditure during walking (63), compared to adults. Considering the participants in the GO-OUT study had difficulty in outdoor walking, a lower cut-point (i.e. 760 CPM) seems to be more appropriate.

Consistent with a previous study (14), land-use mix, street connectivity, and proximity to services or amenities were significantly but weakly correlated with outdoor walking or physical activity while infrastructure and safety for walking, traffic hazards and crime were not correlated with physical activity or outdoor walking among older adults. However, the results could differ depending on the purpose of travel. (12) For instance, building types, the presence of public spaces, sidewalks and traffic hazards have been associated with walking for transportation but not walking for recreation among older adults. (12) Similar results were also reported in a systematic review. (66) Furthermore, lack of parking at shopping centres was found to be positively correlated with walking for transportation but not walking for leisure. (27) However, outdoor walking measured in the GO-OUT study did not identify walking for transportation. Learning the purposes of outdoor walking may help understand its relationships with neighbourhood walkability.

Our study failed to find any significant correlations between total NEWS score and either outdoor walking or MVPA time. However, the total NEWS score derived from the original NEWS questionnaire was significant in estimating body mass index and the odds of being overweight or obese, in a previous study. (67) In another study, total NEWS score was significantly but weakly correlated with vigorous physical activity (r = 0.23). (68) Nichani et al.'s (27) secondary data analysis also found significant correlations between total NEWS score derived from NEWS-abbreviated and dependent variables of walking for transportation, walking for leisure, and moderate and vigorous physical activity time (measured by the International Physical Activity Questionnaire). The discrepancy of the results could be influenced by the participant characteristics. That study inspected the relationship between neighbourhood walkability and self-reported walking and physical activity time among participants aged between 35 and 69 (mean age = 55). (27) Age could be a determining factor of physical activity time since aerobic capacity declines as one ages. (53) Another explanation could be the complexity of neighbourhood walkability. Neighbourhood walkability is influenced by multiple distinctive components that are difficult to combine into a composite score in a meaningful way. Living in a more walkable area does not always introduce more neighbourhood walking-friendly features. In Philadelphia, for example, as residential density increased, the number of pedestrian-involved crashes increased. (69) In this case, a denser population, which was identified to be an indicator of higher walkability, was associated with traffic hazards, which was considered a walking barrier. The total NEWS score, which combines all subscale scores into one composite score, may not be a good indicator of neighbourhood walkability. Future research should focus on individual aspects of neighbourhood walkability when inspecting its relationship with outdoor walking or physical activity time. Similar constructs could probably be combined to represent a composite score for one aspect of neighbourhood walkability, although more studies are needed to determine which aspects of neighbourhood walkability could be combined.

The baseline evaluations of the GO-OUT study were carried out from May to August. The winter months were not selected because of potential safety problems, such as risks of falling. However, it is noteworthy that seasonality could affect older adults' walking behaviors. For instance, the number of steps per day tends to increase from -2 to 17°C and decrease from 17 to 29℃ between July and February among Japanese older adults. (70) The odds of participating in physical activity was also reported to be lower in winter, compared to other seasons. (71) It was shown that precipitation including both snow and rain could reduce the number of trips from home among older adults, regardless of residing in more walkable neighbourhoods or not. (72)

Several limitations need to be considered to interpret our findings. First, this is a secondary data analysis which utilised the data collected in the GO-OUT study. Methods of measurement and data collection were pre-determined and beyond our control. We were not able to evaluate the potential risk of bias during data collection process, and hence our results could possibly be influenced by data inaccuracy. However, it is noteworthy that the baseline evaluation of the GO-OUT project was standardized and followed the same protocol listed in a previous study. (73) The discrepancies of subject recruitment and measurement across cities could therefore be minimized. Additionally, the participants matched our target group of people (i.e. older adults with difficulty in outdoor walking). Our results could therefore be a representative of this group of population. Our study used the NEWS questionnaire to measure neighbourhood walkability and inspect its relationships with walking behaviors. Although NEWS questionnaire scores demonstrated some evidence of validity and reliability, as discussed above, it was still unable to capture all aspects of neighbourhood walkability. For instance, micro-features, such as transparency, complexity and imageability (1, 74), the presence of benches, noise, smell and other pedestrians (3) could also affect walking behaviors. Traffic congestion, snowy conditions and water puddles during rainy weather could become barriers to outdoor walking. (3) NEWS merely reflects a portion of the external factors of neighbourhood walkability. Other aspects of neighbourhood walkability remained uninspected. Investigations into these aspects that the NEWS questionnaire did not cover may be worthwhile. In addition to neighbourhood walkability, participants' walking behaviors could be influenced by other factors, such as physical health, functioning, confidence, and quality of life. For instance, in another study, adding behavioral control (self-efficacy towards walking) as a mediator increased the strength of the associations between physical activity and variables of land use mix – diversity and street connectivity. (14) Apart from the NEWS questionnaire, the GO-OUT study also implemented other outcome measures, such as 6-minute walk test, the Ambulatory Self-Confidence Questionnaire (ASCQ), Cardiovascular Health Study Frailty Index, Mini Balance Evaluation Systems Test and Rand-36 Measure of Health-related Quality of Life to quantify participants' physical health, functioning, confidence, and quality of life. These could potentially mediate the relationship between neighbourhood walkability and walking behaviors. Future research can inspect the effects of mediating variables on the relationships between neighbourhood walkability and walking behaviors in older adults.

4.6 Conclusion

To the best of our knowledge, this is the first study that identifies the relationships between neighbourhood walkability and walking among Canadian older adults who had difficulty in outdoor walking. We also inspected outdoor walking and MVPA and their relationship with neighbourhood walkability, as opposed to previous studies that mainly focused on MVPA. Our results were generated from older adults who resided in four cities in different provinces in Canada: Edmonton, Winnipeg, Toronto, and Montreal. We found significant between-city differences in MVPA time but not outdoor walking time; and significant but weak associations between neighbourhood characteristics, including residential density, land-use access, and street connectivity, and either outdoor walking or MVPA time in older adults with outdoor walking limitations. Understanding the relationships between neighbourhood walkability and outdoor walking with older adults could help identify the factors that contribute to older adults' walking behaviors, which can in turn expand their mobility beyond their neighbourhood, into the service community and the surrounding area. Older adults can be mindful of the influences of the built environment on walkability when selecting their residential locations. If the neighbourhood environment does not meet their needs of daily walking, traveling to another place for daily physical activity may be considered. Health care practitioners can be aware of the neighbourhood environment and identify facilitators and barriers that could potentially influence older adults' walking habits and hence arrange outdoor exercises and walking groups accordingly. Future research should target the mediating factors between neighbourhood walkability and walking behaviors.

4.7 Acknowledgement

I would like to acknowledge Dr. Rasheda Rabbani and Ms. Yixiu Liu for their support regarding data analysis.

4.8 References

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4.9 Appendix

Table 4.1 City and participant characteristics

	Sample size	All (n=190)	Edmonton (n=51)	Winnipeg (n=53)	Toronto (n=50)	Montreal (n=36)
City characteristics (41)						
Geographical area (km^2)	N.A.	N.A.	572.69	343.99	1792.99	1,293.99
Population	N.A.	N.A.	1,062,643	711,925	5,429,412	3,519,595
Population per 1 km^2	N.A.	N.A.	1855.5	2,069.6	3,028.2	2,719.9
Population above 65 years old	N.A.	N.A.	132,180	111,850	790,515	579,305
Daily average temperature ℃ (42)						
April	N.A.	N.A.	4.7	4.4	7.1	6.4
May	N.A.	N.A.	10.4	11.6	13.1	13.4
June	N.A.	N.A.	14.1	17.0	18.6	18.6
July	N.A.	N.A.	16.4	19.7	21.5	21.2

Participant characteristics	Mean (Standard Deviation) [Minimum-maximum] Median {25th/75th quartile} OR frequency (percentage)					

		OR median{25^{th}/75^{th} quartile}					
Age		190	74.46 (7.12) [63-94] 72.5{69/79}	71.92 (5.90) [64-94] 71{68/75}	73.06 (6.26) [65-86] 71{68/77}	78.42 (7.72) [65-93] 77{72/86}	74.64 (6.92) [63-90] 73{69/80}
Sex	Male (%)	190	51 (26.8%)	16 (31.0%)	16 (30.2%)	9 (18%)	10 (27.8%)
Employment status	Yes (%)	189	16 (8.4%)	4 (7.8%)	4 (7.5%)	7 (14.0%)	1 (2.8%)
Car use	Drivers (%)	189	151 (79.5%)	41 (80.4%)	46 (86.8%)	32 (64.0%)	32 (88.9%)
Glasses use	Glasses-users (%)	190	182 (95.8%)	48 (94.1%)	53 (100.0%)	45 (90.0%)	36 (100.0%)
Walking aid use	With walking aids (%)	190	50 (26.3%)	10 (19.6%)	11 (20.8%)	23 (46.0%)	6 (16.7%)
Walking speed	Comfortable	189	1.07 (0.23) [0.41-1.67] 1.06{0.93/1.22}	1.17 (0.23) [0.59-1.59] 1.17{1.04/1.36}	1.07 (0.23) [0.56-1.67] 1.06{0.96/1.19}	1.00 (0.23) [0.41-1.62] 0.98{0.88/1.16}	1.03 (0.20) [0.61-1.54] 1.04{0.89/1.13}
	Fast	189	1.41 (0.32) [0.63-2.18] 1.43{1.19/1.65}	1.56 (0.31) [0.83-2.18] 1.57{1.41/1.78}	1.40 (0.31) [0.75-2.09] 1.44{1.18/1.60}	1.31 (0.31) [0.63-2.00] 1.31{1.09/1.52}	1.36 (0.27) [0.68-1.90] 1.38{1.19/1.59}
Charlson Comorbidity Index		189	2 {1/3}	2{1/3}	2{1/3}	2{0/3}	1{0/2}

N.A.: not applicable

Table 4.2 NEWS total and subscale scores

NEWS subscale	Sample size	All (n=190)	Edmonton (n=51)	Winnipeg (n=53)	Toronto (n=50)	Montreal (n=36)
Subscale scores [Score range]		Mean (Standard Deviation) [Minimum-maximum] Median {25th/75th quartile}				
A. Residential Density [173 – 865]	190	292 (131) 223{186/397}	258 (112)** 220{177/279}	281 (127)** 221{177/334}	369 (141) 404{205/496}	249 (105)** 198{186/270}
B. Land-use Mix – Diversity [1 - 5]	190	2.47 (0.81) 2.43{1.86/3.14}	2.61 (0.68) 2.64{2.13/3.18}	2.37 (0.77) 2.36{1.73/3.11}	2.54 (0.86) 2.64{1.86/3.19}	2.31 (0.96) 2.09{1.60/3.07}
C. Land-use Mix – Access [1 - 4]	188	2.83 (0.87) 3.00{2.25/3.63}	2.96 (0.85) 3.00{2.25/3.75}	2.85 (0.85) 3.00{2.25/3.38}	2.89 (0.86) 3.00{2.25/3.56}	2.54 (0.91) 2.50{1.75/3.00}
D. Street Connectivity [1 - 4]	188	2.89 (0.75) 3.00{2.33/3.67}	2.76 (0.79) 2.67{2.33/3.33}	3.07 (0.75) 3.00{2.67/3.67}	2.89 (0.78) 3.00{2.33/3.67}	2.81 (0.60) 3.00{2.33/3.00}
E. Infrastructure and Safety for Walking [1 - 4]	188	2.93 (0.60) 3.00{2.60/3.40}	3.09 (0.57)*** 3.15{2.80/3.50}	2.90 (0.67) 3.00{2.40/3.40}	3.00 (0.46) 3.00{2.70/3.40}	2.63 (0.63) 2.60{2.10/3.10}
F. Aesthetics [1 - 4]	187	3.14 (0.57) 3.17{2.67/3.67}	3.09 (0.63) 3.25{2.50/3.67}	3.20 (0.58) 3.17{2.67/3.67}	3.11 (0.51) 3.17{2.83/3.50}	3.14 (0.58) 3.17{2.83/3.54}
G. Traffic Hazards* [1 - 4]	187	2.16 (0.65) 2.17{1.67/2.50}	2.07 (0.62) 2.00{1.63/2.33}	2.28 (0.71) 2.33{1.67/2.75}	2.27 (0.61) 2.17{1.96/2.54}	1.93 (0.56) 2.00{1.46/2.33}

H. Crime*	187	1.71 (0.65)	1.83 (0.64)***	1.77 (0.63)	1.73 (0.71)	1.43 (0.52)
[1 - 4]		1.50{1.25/2.00}	1.75{1.25/2.25}	1.75{1.25/2.00}	1.75{1.00/2.25}	1.25{1.00/1.50}
I. Lack of Parking	187	1.98 (0.99)	2.02 (0.87)***	1.92 (1.00)	2.40 (1.07)	1.41 (0.70)**
[1 - 4]		2.00{1.00/3.00}	2.00{1.00/3.00}	2.00{1.00/3.00}	2.00{1.00/3.00}	1.00{1.00/2.00}
J. Lack of Cul-de-sacs	187	2.84 (1.13)	2.74 (1.12)	2.87 (1.13)	3.16 (1.08)	2.47 (1.16)**
[1 - 4]		3.00{2.00/4.00}	3.00{2.00/4.00}	3.00{2.00/4.00}	4.00{3.00/4.00}	3.00{1.00/3.25}
K. Hilliness*	189	1.57 (0.85)	1.61 (0.94)	1.32 (0.70)**	1.80 (0.88)	1.54 (0.82)
[1 - 4]		1.00{1.00/2.00}	1.00{1.00/2.00}	1.00{1.00/1.00}	2.00{1.00/2.00}	1.00{1.00/2.00}
L. Physical Barriers*	189	1.46 (0.80)	1.51 (0.81)	1.43 (0.89)	1.50 (0.76)	1.37 (0.69)
[1 - 4]		1.00{1.00/2.00}	1.00{1.00/2.00}	1.00{1.00/1.50}	1.00{1.00/2.00}	1.00{1.00/2.00}
M. Social Interaction	189	2.94 (0.92)	3.00 (0.96)	3.09 (0.82)	2.90 (0.91)	2.69 (1.02)
While Walking		3.00{2.00/4.00}	3.00{3.00/4.00}	3.00{3.00/4.00}	3.00{2.00/4.00}	3.00{2.00/3.00}
[1 - 4]						
		Mean (Standard Deviation)				
Total score	187	0.04 (5.17)	0.04 (5.68)	0.30 (5.13)	0.97 (5.46)	-1.76 (3.52)**

*: higher scores in subscale G, H, K, and L denote lower walkability; **: significantly different from Toronto; ***: significantly different from Montreal

Table 4.3 Outdoor walking time and physical activity time

	Sample size	All (n=190)	Edmonton (n=51)	Winnipeg (n=53)	Toronto (n=50)	Montreal (n=36)
		Mean (Standard Deviation) [Minimum-Maximum] Median {$25^{th}/75^{th}$ quartile}				
Outdoor walking time (min/week)						
CHAMPS-Outdoors	188	168.4 (222.4) [0.0-1215.0] 105.0{30.0/210.0}	211.8 (272.7) [0.0-1140.0] 105.0{30.0/228.8}	139.5 (161.0) [0.0-675.0] 105.0{15.0/210.0}	133.5 (182.7) [0.0-1005.0] 105.0{30.0/176.3}	199.7 (265.0) [0.0-1215.0] 105.0{30.0/270.0}
Accelerometer-GPS	176	41.2 (56.8) [0.0-264.3] 21.5{0.0/54.2}	56.6 (64.7) [0.0-203.1] 28.9{0.0/103.0}	32.7 (55.3) [0.0-220.6] 12.3{0.0/34.6}	38.5 (55.5) [0.0-264.3] 23.7{0.0/48.6}	37.4 (48.2) [0.0-191.3] 27.0{0.0/51.8}
Physical activity time (min/week)						
CHAMPS	183	221.0 (303.2) [0.0-2175.0] 135.0{30.0/315.0}	367.8 (451.3)** [0.0-2175.0] 225.0{60.0/495.0}	157.6 (156.8) [0.0-675.0] 105.0{30.0/240.0}	106.8 (136.3) [0.0-570.0] 75.0{0.0/142.5}	278.5 (294.5)** [0.0-1185.0] 180.0{60.0/435.0}
Accelerometer using Lifestyle cutpoints	176	408.0 (267.2) [23.7-1264.4] 344.2{215.1/558.0}	502.4 (318.8)** [105.0-1264.4] 456.8{253.3/621.9}	450.0 (266.0)** [35.9-1048.3] 361.4{264.7/700.9}	283.3 (174.3) [23.7-852.3] 249.8{166.9/398.2}	401.8 (246.9) [28.0-998.4] 448.0{173.3/542.5}

**: significantly different from Toronto

Table 4.4 Correlations between NEWS scores and outdoor walking time and physical activity time

	Outdoor walking time		Physical activity time	
NEWS subscales	CHAMPS-Outdoors	Accelerometry-GPS	CHAMPS	Accelerometry
A: Residential Density	-0.043	0.016	-0.235††	-0.074
B: Land-use Mix – Diversity	0.124	0.172†	0.106	0.113
C: Land-use Mix – Access	0.233††	0.176†	0.185†	0.147
D: Street Connectivity	0.046	0.041	0.208††	0.101
E: Infrastructure and Safety for Walking	-0.003	0.076	0.038	-0.005
F: Aesthetics	0.104	0.065	0.058	0.073
G: Traffic Hazards*	0.001	-0.092	-0.026	-0.067
H: Crime*	0.039	-0.003	0.026	0.039
I: Lack of Parking	0.027	0.025	-0.008	-0.050
J: Lack of Cul-de-sacs	0.002	0.000	-0.011	0.003
K: Hilliness*	-0.073	0.023	-0.111	-0.087
L: Physical Barriers*	-0.102	0.042	-0.036	-0.121
M: Social Interaction While Walking	0.056	-0.107	0.050	-0.043
Total NEWS score	0.123	0.084	0.080	0.133

†: statistically significant on a = 0.05 level; ††: statistically significant on a = 0.01 level; *: higher scores in subscale G, H, K, and L denote lower walkability

Chapter 5: Linking the manuscript and all other findings

The previous chapter was a manuscript and discussed the major findings from our study. Since the number of words in a manuscript are limited, additional findings will be discussed in this chapter.

5.1 NEWS scores

5.1.1 Between-city differences in NEWS total and subscale scores

NEWS subscale and total score were presented in Table 4.2. In addition to the results presented in chapter 4, we inspected the differences of the NEWS subscale scores between the cities. Shapiro-Wilk's test and Levene's test revealed both the assumptions of normality and homogeneity of variances were violated. Therefore, Kruskal-Wallis test was conducted on all subscales in NEWS and total NEWS score to inspect the between-city differences. Pairwise comparisons were made with Bonferroni corrections on $\boldsymbol{\alpha} = 0.0083$ level (by dividing $\boldsymbol{\alpha} = 0.05$ by 6 comparisons made between groups) if a positive result was found in Kruskal-Wallis test.

The NEWS total score and subscale scores are presented in total and by city (Table 4.2). Kruskal-Wallis test with pairwise comparisons showed a significantly higher score in residential density in Toronto compared to other cities. ($p = 0.001$ to 0.008) The mean subscale scores of land-use mix – access, street connectivity, infrastructure and safety for walking, aesthetics and social interaction while walking lied between 2.50 to 3.50. For lack of parking, Montreal only achieved 1.41, which was lower than Edmonton (mean = 2.02) and Toronto (mean = 2.40). A lower score was also found in lack of cul-de-sacs in Montreal (mean = 2.47), compared to Toronto (mean = 3.16). Because of the reversed scoring, higher total score in traffic hazards, crime, hilliness, and physical barriers represented lower walkability. The medians of traffic hazards, crime in all cities lied between 1.50 and 2.50 while the medians of hilliness and physical barriers were mostly 1.00. A reversion in the scores in the four subscales would give medians between 2.50 to 4.00, similar to the scores in other subscales. The total NEWS score was calculated by adding z-scores of all subscales with reversions so that higher total NEWS score denoted higher walkability. Pairwise comparisons following a positive Kruskal-Wallis test showed that the total NEWS scores were higher in Toronto (mean = 0.97) compared to Montreal (mean = -1.76).

5.1.2 Correlations between NEWS subscales

Among the 78 associations made between NEWS subscales, 43 of them were not significant. (Table 5.1). The rest of the associations, however, were mainly weakly correlated ($r = \pm0.21$ to ±0.40). The highest correlation of the subscales came from land-use mix – diversity and land-use mix – access. They were moderately correlated ($r = 0.569$, $p<0.001$). Interestingly, although higher scores denoted higher walkability in some subscales and lower walkability in others, they were not always negatively correlated. For instance, residential density was positively but weakly correlated with traffic hazards ($r=0.255$, $p<0.001$) and crime ($r=0.251$, $p<0.001$). Significantly positive but weak correlations were also found between lack of parking and hilliness ($r=0.248$, $p=0.001$) and between lack of parking and physical barriers ($r=0.220$, $p=0.003$). More details will be discussed in chapter 6.

5.2 Alternative hypothesis 1: results were mixed

The first objective was to compare self-reported and objectively measured outdoor walking and MVPA time gathered from participants across the four cities in Canada. The assumptions of parametric tests were checked before one-way ANOVA was carried out. Shapiro-Wilk test showed that all dependent variables, including CHAMPS derived MVPA time, CHAMPS-Outdoors derived outdoor walking time, accelerometry derived lifestyle MVPA time and accelerometry-GPS derived outdoor walking time, were not normal ($p<0.001$). Visual inspection of histograms also suggested that the variables were not normal (Figure 4.1). In addition, Levene's test showed that only accelerometry-GPS derived outdoor walking time fulfilled the assumption of homogeneity of variance ($p=0.066$) while all other dependent variables failed to fulfill this assumption. Since the assumptions of normality and homogeneity of variance were not fulfilled, one-way ANOVA was dropped and replaced by non-parametric Kruskal-Wallis test. Pairwise comparisons with Bonferroni corrections on $\boldsymbol{\alpha} = 0.0083$ level (dividing $\boldsymbol{\alpha} = 0.05$ by 6 between-city comparisons) were made if Kruskal-Wallis test showed a positive result.

Kruskal-Wallis test showed no significant between-city differences in outdoor walking time, regardless of whether it was CHAMPS-Outdoors derived, or accelerometry-GPS derived (p=0.439 and 0.219 respectively). However, Kruskal-Wallis showed a significant between-city difference in both CHAMPS derived MVPA time (p<0.001) and accelerometry derived lifestyle MVPA (p=0.001). Pairwise comparisons showed significantly higher CHAMPS derived MVPA time in Montreal (p=0.001) and in Edmonton (p<0.001), and significantly higher accelerometry derived MVPA time in Winnipeg (p=0.001) and Edmonton (p<0.001), compared to that in Toronto. No significant results were found between any other groups. (Table 4.3)

5.3 Alternative hypotheses 2 and 3 were rejected

Since the results of the dependent variables were not normal, inversion and log transformations were performed. (Figure 5.2 & 5.3) However, both inversion and log transformations failed to bring the distributions into normal, as indicated by the frequency plots. In order to test the assumptions of homoscedasticity, univariate linear regression analysis was performed to estimate the associations between outdoor walking and physical activity and NEWS subscale scores. R^2 of the predicted models range from to less than 0.001 to 0.041 for CHAMPS derived MVPA time; less than 0.001 to 0.043 for CHAMPS Outdoor derived outdoor walking time; less than 0.001 to 0.023 for accelerometry derived lifestyle MVPA time; and less than 0.001 to 0.028 for accelerometry GPS derived outdoor walking time. This suggested that NEWS subscales had low predictive ability to estimate both physical activity time and outdoor walking time and could only account for 0.1% to 4.3% of the variances in the models. Furthermore, the assumption of homoscedasticity was tested by visually inspecting Zresid vs Zpredi plots (plots of standardized residuals versus standardized predicted values). The plots showed this assumption was also violated. After carrying out the univariate linear regression analysis, NEWS subscales that were found to be significant were added into a single model. Multivariate linear regression analyses were conducted by adding residential density and land-use mix – access for CHAMPS derived MVPA time; adding land-use mix – access for CHAMPS-Outdoors derived outdoor walking time; adding both land-use mix – diversity and land-use mix – access for accelerometry derived lifestyle MVPA time; and adding land-use mix – access and infrastructure and safety for walking for accelerometry-GPS outdoor walking time. However, combining these variables did not result in a higher R^2 in the models while the residuals of the predicted models remained widely distributed. The assumption of multicollinearity was inspected in each of these models. Since VIF was below 5 in all the predicted models, there was no multicollinearity. The above procedures were repeated with total NEWS scores as proposed. Similarly, univariate linear regression analysis revealed R^2 to range from 0.001 to 0.011, meaning that total NEWS scores could only explain 0.1% to 1.1% of the variances in the models. In addition, residuals of the predicted models were largely deviated. Zresid vs Zpredi plots also showed similar findings. Therefore, the assumption of homoscedasticity was also violated.

Considering the assumptions of normality, homogeneity of variances, and homoscedasticity were all violated, linear regression analysis failed to generate an accurate model to estimate the associations between physical activity and outdoor walking time and either NEWS subscale scores or the total NEWS scores, linear regression analysis was therefore dropped. Instead, non-parametric Spearman's Rho was used to estimate the associations between NEWS subscales and the variables of MVPA time and outdoor walking time. The strength of correlations was inspected with respect to Prion and Haerling's paper. (1)

Residential density, land-use access, and street connectivity were significantly but weakly correlated with CHAMPS derived physical activity time (r = -0.235, 0.185 and 0.208 respectively). (Table 4.4) On the other hand, the correlations between accelerometry-GPS derived outdoor walking time and variables of land-use mix – diversity and land-use mix – access were significant but negligible (r = 0.172 and 0.176 respectively). Furthermore, land-use mix – access was significantly but weakly correlated with CHAMPS-Outdoors derived outdoor walking time (r = 0.233). The correlation between land-use mix – access and accelerometry-GPS derived outdoor walking time (r = 0.176) and CHAMPS derived physical activity time (r = 0.185) were both significant but negligible. All other subscales were not correlated with physical activity or outdoor walking among older adults ($p>0.05$). Our study also failed to find any correlations between the total NEWS score and either outdoor walking or MVPA time.

5.4 Summary

All findings were presented in this chapter. The methodology was modified from the proposed one due to the violation of several assumptions of parametric tests. Instead, we used non-parametric tests for our analyses. The next chapter will compare our findings to other literature and discuss the implication of the findings.

5.5 References

1. Prion S, Haerling KA. Making sense of methods and measurement: Spearman-Rho ranked-order correlation coefficient. Clin Simul Nurs. 2014;10(10):535-6.

5.6 Appendix

Table 5.1 Correlations between NEWS subscales

	A	B	C	D	E	F	G*	H*	I	J	K*	L*	M
A	1.000	0.298†	0.184	0.024	0.09	-0.170†	0.255†	0.251†	0.12	0.134	0.111	0.152†	-0.033
B		1.000	0.569†	0.299†	0.231†	0.089	0.039	0.074	0.198†	0.222†	0.117	0.054	0.035
C			1.000	0.393†	0.317†	0.220†	0.024	0.020	0.107	0.060	0.006	-0.119	0.104
D				1.000	0.330†	0.326†	-0.021	-0.019	0.082	0.052	-0.081	-0.106	0.139
E					1.000	0.365†	-0.229†	-0.178†	-0.041	0.105	-0.07	-0.164†	0.156†
F						1.000	-0.302†	-0.313†	-0.058	0.047	-0.091	-0.226†	0.307†
G*							1.000	0.406†	0.182†	0.028	0.260†	0.327†	-0.165†
H*								1.000	0.200†	0.123	0.128	0.370†	-0.115
I									1.000	0.117	0.248†	0.220†	-0.084
J										1.000	0.019	0.080	0.008
K*											1.000	0.541†	0.031
L*												1.000	-0.136
M													1.000

†: statistically significant on a = 0.05 level; *: higher scores in subscale G, H, K, and L denote lower walkability; A: Residential Density; B: Land-use Mix – Diversity; C: Land-use Mix – Access, D: Street Connectivity; E: Infrastructure and Safety for Walking; F: Aesthetics; G: Traffic Hazards; H: Crime; I: Lack of Parking; J: Lack of Cul-de-sacs; K: Hilliness; L: Physical Barriers; M: Social Interaction While Walking

Figure 5.1 Plots of outdoor walking and MVPA time

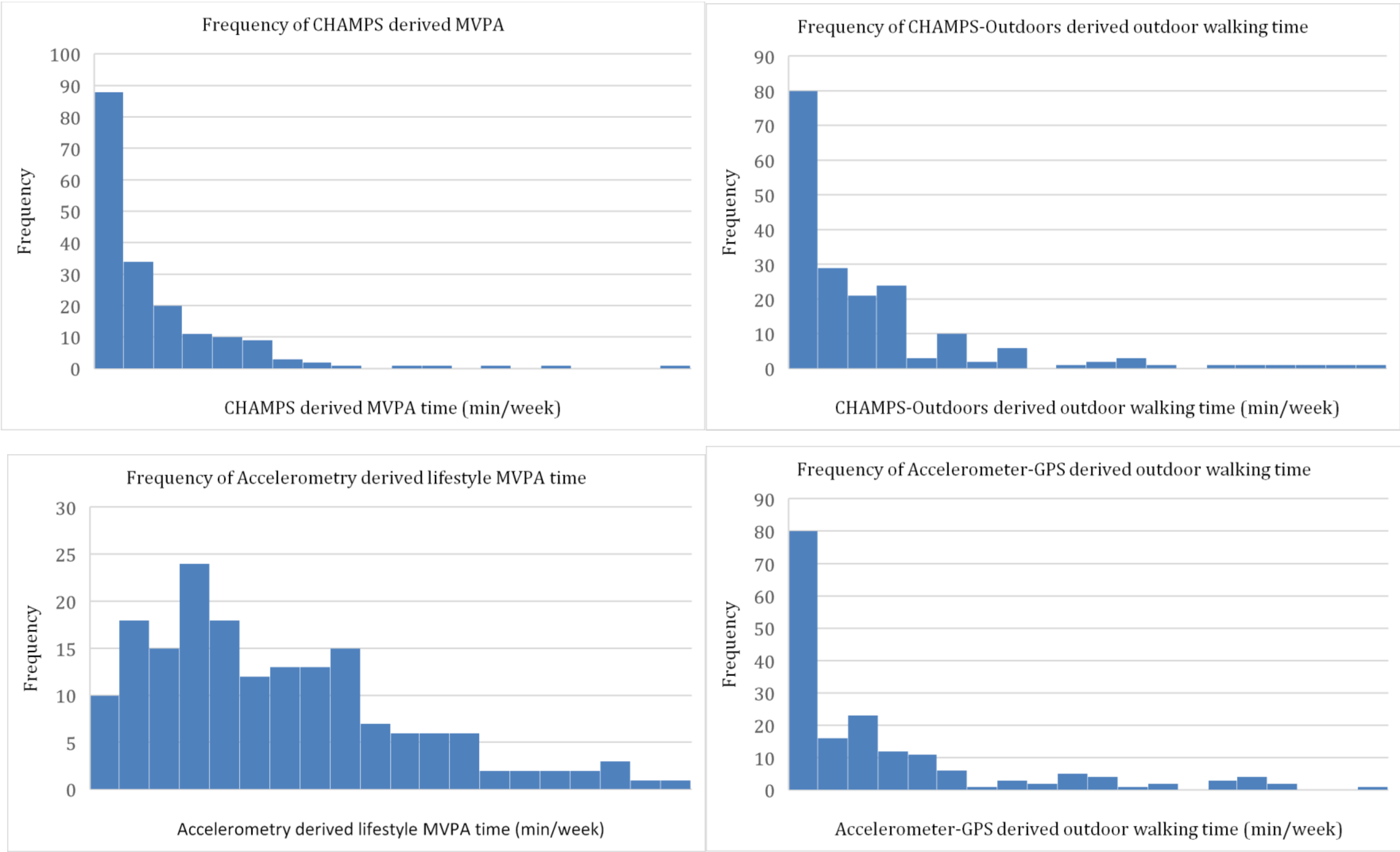


Figure 5.2 Plots of outdoor walking and MVPA time with log transformations

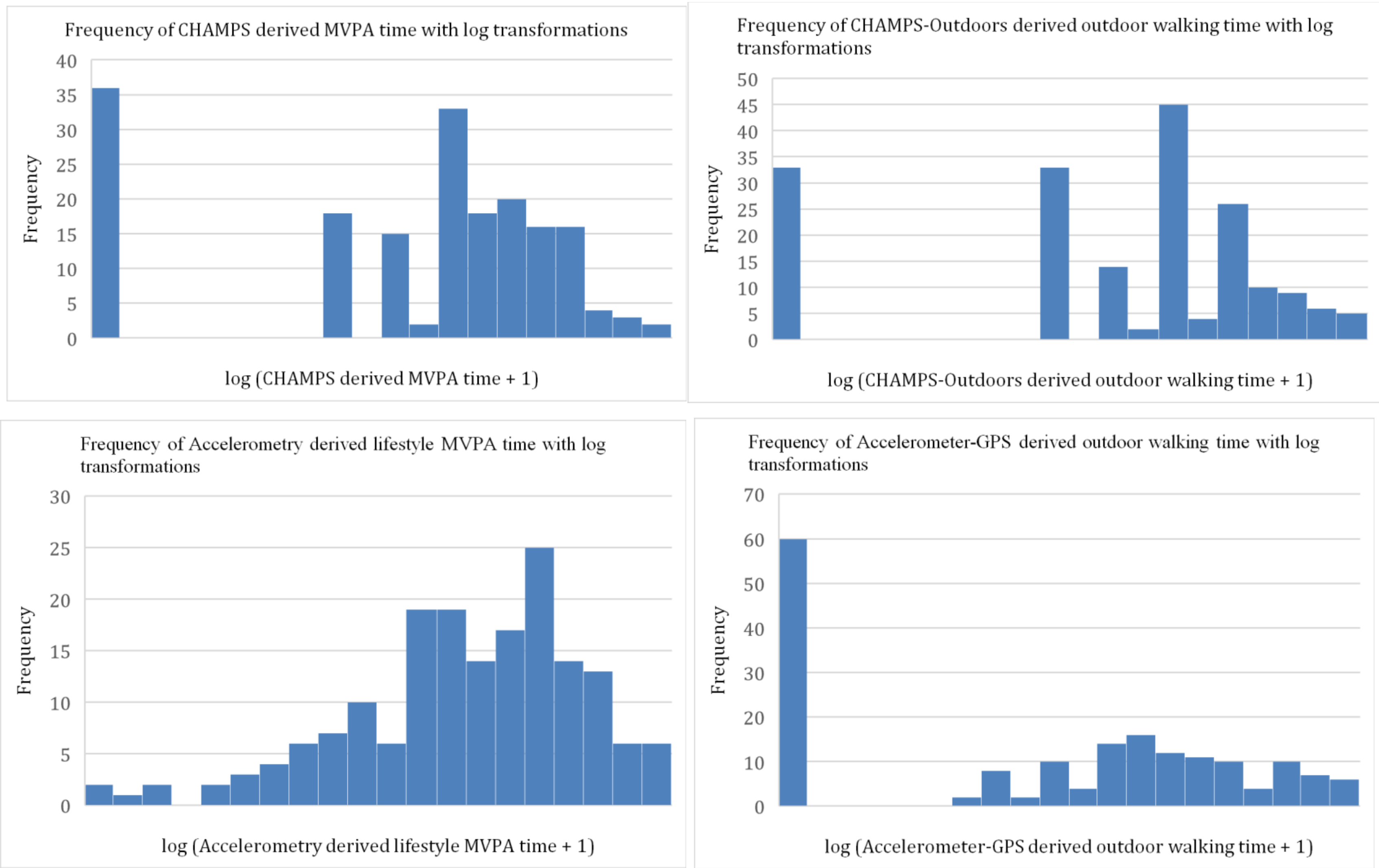
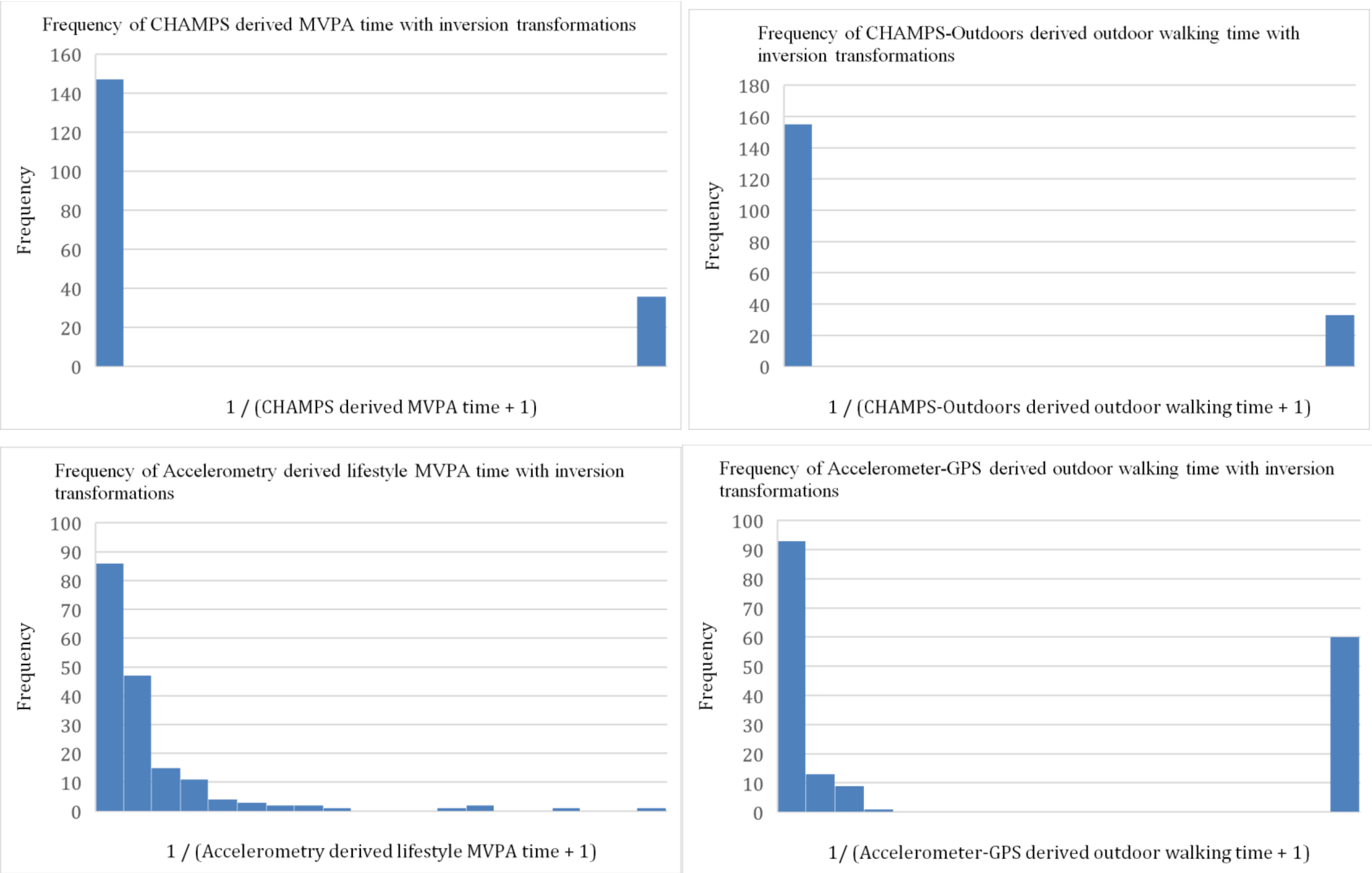


Figure 5.3 Plots of outdoor walking and MVPA time with inversion transformations



Chapter 6: Discussion

6.1 Participant characteristics

The average comfortable and fast walking speed among all participants were 1.07 m/s and 1.41 m/s respectively (Table 4.1). In contrast to our study, an average of 1.30 m/s and 1.71 m/s for comfortable and fast walking speed respectively were reported among independent community walkers who were, on average, 65.8 years of age. (1) Another study found an average of 0.81 m/s and 1.10 m/s for comfortable and fast walking speed respectively among participants who were, on average, 80.4 years of age. (2) A similar study also reported 1.13 to 1.34 m/s among older adults aged between 60 and 79. (3) The walking speed among older adults aged over 80, on the other hand, was between 0.94 and 0.97 m/s. (3) Considering that walking speed was negatively associated with age (4), it is reasonable to find both comfortable and fast walking speed of the participants in our study lied within the observed values of the studies. Similarly, this trend can be found in the participants in different cities. For instance, the average age of participants in Toronto was the highest (78.42 years of age) while their comfortable and fast walking speed were also the lowest (1.00 and 1.31 m/s respectively). Participants in Edmonton, on the other hand, had highest comfortable and fast walking speed (1.17 and 1.56 m/s respectively) but lowest age on average (71.92 years of age).

6.2 Characteristics of the NEWS scores

The correlation between land-use mix – diversity and land-use mix – access was moderate ($r=0.569$, $p<0.001$). The strength of this correlation was the highest among all the correlations made between NEWS subscales. This could be explained by the similar types of questions incorporated in the subscales. For instance, land-use mix – diversity was composed of 23 questions that asked about how long it took to walk to 23 different destinations. Item B1 to B4, B6, B11, and B16 to B18 asked about the duration of traveling to different kinds of stores, ranging from grocery stores to bookstores. These items resembled item C1 and C2 of land-use mix – access that asked respondents how strongly they agreed that stores were located within walking distance from their home. Item B20, on the other hand, resembled item C4 "*It is easy to walk to a transit stop (bus, train) from my home*". The strength of this correlations was also supported by Atkinson et al. ($r = 0.49$) (5) and Sujiyama et al. (the strength was not reported) (6). In addition, hilliness and physical barriers were also moderately correlated (r=0.541, p<0.001). Item K1 "*The streets in my neighborhood are hilly, making my neighborhood difficult to walk in*" resembled item L1 "*There are major barriers to walking in my neighborhood that make it hard to get from place to place (for example, freeways, railway lines, rivers, canyons, hillsides)*" in which both questions addressed hilliness. Because of the similar constructs these subscales addressed, it was reasonable to find a moderate correlation between them. Correlations between other subscales found in our study generally followed the trend shown in a previous study. (7)

Although higher scores denoted higher walkability in some subscales and lower walkability in others, they were not always negatively correlated. We found a positive but weak correlation between residential density and traffic hazards (r=0.255, p<0.001), between residential density and crime (r=0.251, p<0.001), between lack of parking and hilliness (r=0.248, p=0.001) and between lack of parking and physical barriers (r=0.220, p=0.003). Considering the positive correlations between these subscales, we proposed that living in a more walkable area does not always bring more neighbourhood walking-friendly features, it could bring walking barriers instead, such as traffic hazards and insecurity. In Philadelphia, for example, as residential density increased, the number of pedestrian-involved crashes increased. (8) In other words, a denser neighbourhood with higher residential density and proximity of destinations may also introduce other less desirable factors, such as crime, traffic hazards and physical barriers and hence making a neighbourhood less walkable. This may also explain why residential density was negatively correlated with CHAMPS-derived physical activity time (r = -0.235), as opposed to what we expected. Therefore, the total NEWS score, which pools all subscale scores into one composite score, may not be a good indicator of neighbourhood walkability.

6.3 Mediating factors between neighbourhood walkability and outdoor walking/MVPA

In the GO-OUT study, participants were purposefully excluded if they had cardiac, respiratory, peripheral vascular or other conditions that would hinder safe participation in the program. Participants in the GO-OUT study had similar Charlson Comorbidity Index (CCI) across the four cities, with the median value being one to two and the quartiles ranging from zero to three. CCI is an indicator of a person's mortality. (9) The mortality rate of people with CCI greater than three is significantly higher than those with CCI not greater than three. (10)

Since CCI of all participants was not greater than three, their walking behaviors are less likely to be substantially influenced by their pre-existing health conditions.

Our study mainly focused on neighbourhoods in different cities in the GO-OUT study to investigate neighbourhood walkability. However, variations of neighbourhood walkability could be seen between various neighbourhoods in a city. For instance, it was reported that objectively more walkable features in a neighbourhood could alter the perception of self-perceived neighbourhood characteristics in adults more, compared to those who resided in neighbourhoods with less objectively walkable features. (11) Self-reported questionnaires only partly reflect how walkable a neighbourhood is, adding objectively measured tools may provide an alternative perspective of neighbourhood walkability.

6.4 Implications

Neighbourhood walkability reflected an individual's perception of the neighbourhood characteristics and whether a neighbourhood was walking friendly. (12-16) Understanding the relationships between neighbourhood walkability and walking behaviors among older adults could help urban planners develop a more supportive and walkable neighbourhood. This could be beneficial to their physical health, mental health and social well-being (17-19), and social cohesion and participation among older adults. (20) On the other hand, health care practitioners could arrange outdoor exercises and walking groups according to the neighbourhood environmental features, so as to facilitate older adults to expand their mobility beyond their neighbourhood, into the service community, the surrounding area, and eventually the world. (21)

6.5 Conclusion

Our study found significant between-city differences in MVPA time but not outdoor walking time in older adults who resided in Edmonton, Winnipeg, Toronto, and Montreal. We also found significant but weak associations between neighbourhood characteristics, including residential density, land-use access, and street connectivity, and walking behaviors in older adults with outdoor walking limitations. However, we were not able to draw a multivariate model to estimate the associations between outdoor walking time and physical activity time and either total or subscale scores of neighbourhood walkability. Understanding the relationships between neighbourhood walkability and outdoor walking with older adults could help identify the factors that contribute to older adults' walking behaviors, which can in turn expand their mobility beyond home into their neighbourhood and the community. Future research should target the mediating factors between neighbourhood walkability and walking behaviors.

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6.7 Appendix

6.7.1 Ethics approval

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University of Manitoba | Research Ethics and Compliance

HEALTH RESEARCH ETHICS BOARD (HREB)
CERTIFICATE OF FINAL APPROVAL FOR NEW STUDIES
Delegated Review

PRINCIPAL INVESTIGATOR;	**INSTITUTION/DEPARTMENT:**	**ETHICS #:**
Mr. Hong Chan	University of Manitoba/College of Medical Rehabilitation Sciences-Physical Therapy	HS25237 (H2021:386)
APPROVAL DATE: November 10, 2021	**EXPIRY DATE:** <u>November 10, 2022</u>	
STUDENT PRINCIPAL INVESTIGATOR SUPERVISOR (If applicable): Dr. Ruth Barclay		

PROTOCOL NUMBER:	**PROJECT OR PROTOCOL TITLE:**
NA	The relationship between neighbourhood walkability and outdoor walking in older adults with self-reported difficulty in walking outdoors (Linked to H2017:406)
SPONSORING AGENCIES AND/OR COORDINATING GROUPS: N/A	

Submission Date of Investigator Documents:	**HREB Receipt Date of Documents:**
October 26, 2021	October 28, 2021

THE FOLLOWING ARE APPROVED FOR USE:

Document Name	**Version (If applicable)**	**Date**
Protocol:		
Proposal as outlined in the University of Manitoba Bannatyne Campus Research Ethics Board Submission Form for Retrospective Chart or Records Review		October 28, 2021
Consent and Assent Form(s):		
Other:		

CERTIFICATION
The above-named research study/project has been reviewed in a ***delegated manner*** by the University of Manitoba (UM) Health Research Board (HREB) and was found to be acceptable on ethical grounds for research involving human participants. The study/project and documents listed above was granted final approval by the Chair or Acting Chair, UM HREB.

HREB ATTESTATION
The University of Manitoba (UM) Research Board (HREB) is organized and operates according to Health Canada/ICH Good Clinical Practices, Tri-Council Policy Statement 2, and the applicable laws and regulations of Manitoba. In respect to clinical trials, the HREB complies with the membership requirements for Research Ethics Boards defined in Division 5 of the Food and Drug Regulations of Canada and carries out its functions in a manner consistent with Good Clinical Practices.

A unit of the office of the Vice-President (Research and International) https://umanitoba.ca/research/orec/ethics_medicine/index.html

- 1 -

QUALITY ASSURANCE
The University of Manitoba Research Quality Management Office may request to review research documentation from this research study/project to demonstrate compliance with this approved protocol and the University of Manitoba Policy on the Ethics of Research Involving Humans.

CONFLICT OF INTEREST
Any Principal or Co-Investigators of this study who are members of the UMHREB did not participate in the review or voting of this study.

CONDITIONS OF APPROVAL:
1. The study is acceptable on scientific and ethical grounds for the ethics of human use only. ***For logistics of performing the study, approval must be sought from the relevant institution(s).***
2. This research study/project is to be conducted by the local principal investigator listed on this certificate of approval.
3. The principal investigator has the responsibility for any other administrative or regulatory approvals that may pertain to the research study/project, and for ensuring that the authorized research is carried out according to governing law.
4. **This approval is valid until the expiry date noted on this certificate of approval. A Bannatyne Campus Annual Study Status Report** must be submitted to the HREB within 15-30 days of this expiry date.
5. Any changes of the protocol (including recruitment procedures, etc.), informed consent form(s) or documents must be reported to the HREB for consideration in advance of implementation of such changes on the **Bannatyne Campus Research Amendment Form.**
6. Adverse events and unanticipated problems must be reported to the HREB as per Bannatyne Campus Research Boards Standard Operating procedures.
7. The UM HREB must be notified regarding discontinuation or study/project closure on the **Bannatyne Campus Final Study Status Report.**

Sincerely,

[redacted]

John Arnett, PhD. C. Psych.
Chair, Health Research Ethics Board
Bannatyne Campus

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Please quote the above Human Ethics Number on all correspondence.
Inquiries should be directed to the REB Secretary **Telephone:** (204) 789-3255/ **Fax:** (204) 789-3414

6.7.2 NEWS-CFA questionnaire (copied with permission)

(Retrieved from https://drjimsallis.org/Documents/Measures_documents/NEWS_CFA.pdf)

NEWS-CFA: Confirmatory Factor Analysis Scoring for Neighborhood Environment Walkability Scale

We would like to find out more information about the way that you perceive or think about your neighborhood. Please answer the following questions about your neighborhood and yourself.

A. Types of residences in your neighborhood

Please circle the answer that best applies to you and your neighborhood.

1. How common are <u>detached single-family residences</u> in your immediate neighborhood?

1	2	3	4	5
None	A few	Some	Most	All

2. How common are <u>townhouses or row houses of 1-3 stories</u> in your immediate neighborhood?

1	2	3	4	5
None	A few	Some	Most	All

3. How common are <u>apartments or condos 1-3 stories</u> in your immediate neighborhood?

1	2	3	4	5
None	A few	Some	Most	All

4. How common are <u>apartments or condos 4-6 stories</u> in your immediate neighborhood?

1	2	3	4	5
None	A few	Some	Most	All

5. How common are <u>apartments or condos 7-12 stories</u> in your immediate neighborhood?

1	2	3	4	5
None	A few	Some	Most	All

6. How common are <u>apartments or condos more than 13 stories</u> in your immediate neighborhood?

1	2	3	4	5
None	A few	Some	Most	All

1

B. Stores, facilities, and other things in your neighborhood

About how long would it take to get from your home to the __nearest__ businesses or facilities listed below if you __walked__ to them? Please put only __one__ check mark (√) for each business or facility.

	1-5 min	6-10 min	11-20 min	20-30 min	30+ min	don't know
example: gas station	1. ____	2. ____	3. √	4. ____	5. ____	8. ____
1. convenience/small grocery store	1. ____	2. ____	3. ____	4. ____	5. ____	8. ____
2. supermarket	1. ____	2. ____	3. ____	4. ____	5. ____	8. ____
3. hardware store	1. ____	2. ____	3. ____	4. ____	5. ____	8. ____
4. fruit/vegetable market	1. ____	2. ____	3. ____	4. ____	5. ____	8. ____
5. laundry/dry cleaners	1. ____	2. ____	3. ____	4. ____	5. ____	8. ____
6. clothing store	1. ____	2. ____	3. ____	4. ____	5. ____	8. ____
7. post office	1. ____	2. ____	3. ____	4. ____	5. ____	8. ____
8. library	1. ____	2. ____	3. ____	4. ____	5. ____	8. ____
9. elementary school	1. ____	2. ____	3. ____	4. ____	5. ____	8. ____
10. other schools	1. ____	2. ____	3. ____	4. ____	5. ____	8. ____
11. book store	1. ____	2. ____	3. ____	4. ____	5. ____	8. ____
12. fast food restaurant	1. ____	2. ____	3. ____	4. ____	5. ____	8. ____
13. coffee place	1. ____	2. ____	3. ____	4. ____	5. ____	8. ____
14. bank/credit union	1. ____	2. ____	3. ____	4. ____	5. ____	8. ____
15. non-fast food restaurant	1. ____	2. ____	3. ____	4. ____	5. ____	8. ____
16. video store	1. ____	2. ____	3. ____	4. ____	5. ____	8. ____
17. pharmacy/drug store	1. ____	2. ____	3. ____	4. ____	5. ____	8. ____
18. salon/barber shop	1. ____	2. ____	3. ____	4. ____	5. ____	8. ____
19. your job or school [check here _____ if not applicable]	1. ____	2. ____	3. ____	4. ____	5. ____	8. ____

	1-5 min	6-10 min	11-20 min	20-30 min	30+ min	don't know
20. bus or train stop	1. ____	2. ____	3. ____	4. ____	5. ____	8. ____
21. park	1. ____	2. ____	3. ____	4. ____	5. ____	8. ____
22. recreation center	1. ____	2. ____	3. ____	4. ____	5. ____	8. ____
23. gym or fitness facility	1. ____	2. ____	3. ____	4. ____	5. ____	8. ____

C. Access to services

Please circle the answer that best applies to you and your neighborhood. Both local and within walking distance mean within a 10-15 minute walk from your home.

1. I can do most of my shopping at local stores.

1	2	3	4
strongly disagree	somewhat disagree	somewhat agree	strongly agree

2. Stores are within easy walking distance of my home.

1	2	3	4
strongly disagree	somewhat disagree	somewhat agree	strongly agree

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

1	2	3	4
strongly disagree	somewhat disagree	somewhat agree	strongly agree

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

1	2	3	4
strongly disagree	somewhat disagree	somewhat agree	strongly agree

D. Streets in my neighborhood

Please circle the answer that best applies to you and your neighborhood.

1. The distance between intersections in my neighborhood is usually short (100 yards or less; the length of a football field or less).

1	2	3	4
strongly disagree	somewhat disagree	somewhat agree	strongly agree

2. There are many four-way intersections in my neighborhood.

1	2	3	4
strongly disagree	somewhat disagree	somewhat agree	strongly agree

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

1	2	3	4
strongly disagree	somewhat disagree	somewhat agree	strongly agree

H. Places for walking and cycling

Please circle the answer that best applies to you and your neighborhood.

1. There are sidewalks on most of the streets in my neighborhood.

1	2	3	4
strongly disagree	somewhat disagree	somewhat agree	strongly agree

2. The sidewalks in my neighborhood are well maintained (paved, even, and not a lot of cracks).

1	2	3	4
strongly disagree	somewhat disagree	somewhat agree	strongly agree

3. There are bicycle or pedestrian trails in or near my neighborhood that are easy to get to.

1	2	3	4
strongly disagree	somewhat disagree	somewhat agree	strongly agree

4. Sidewalks are separated from the road/traffic in my neighborhood by parked cars.

1	2	3	4
strongly disagree	somewhat disagree	somewhat agree	strongly agree

5. There is a grass/dirt strip that separates the streets from the sidewalks in my neighborhood.

1	2	3	4
strongly disagree	somewhat disagree	somewhat agree	strongly agree

6. It is safe to ride a bike in or near my neighborhood.

1	2	3	4
strongly disagree	somewhat disagree	somewhat agree	strongly agree

7. My neighborhood streets are well lit at night.

1	2	3	4
strongly disagree	somewhat disagree	somewhat agree	strongly agree

8. Walkers and bikers on the streets in my neighborhood can be easily seen by people in their homes.

1	2	3	4
strongly disagree	somewhat disagree	somewhat agree	strongly agree

9. There are crosswalks and pedestrian signals to help walkers cross busy streets in my neighborhood.

1	2	3	4
strongly disagree	somewhat disagree	somewhat agree	strongly agree

10. The crosswalks in my neighborhood help walkers feel safe crossing busy streets.

1	2	3	4
strongly disagree	somewhat disagree	somewhat agree	strongly agree

F. Neighborhood surroundings

Please circle the answer that best applies to you and your neighborhood.

1. There are trees along the streets in my neighborhood.

1	2	3	4
strongly disagree	somewhat disagree	somewhat agree	strongly agree

2. Trees give shade for the sidewalks in my neighborhood.

1	2	3	4
strongly disagree	somewhat disagree	somewhat agree	strongly agree

3. There are many interesting things to look at while walking in my neighborhood.

1	2	3	4
strongly disagree	somewhat disagree	somewhat agree	strongly agree

4. My neighborhood is generally free from litter.

1	2	3	4
strongly disagree	somewhat disagree	somewhat agree	strongly agree

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

1	2	3	4
strongly disagree	somewhat disagree	somewhat agree	strongly agree

6. There are attractive buildings/homes in my neighborhood.

1	2	3	4
strongly disagree	somewhat disagree	somewhat agree	strongly agree

G. Traffic Hazards

Please circle the answer that best applies to you and your neighborhood.

1. There is so much traffic along the street I live on that it makes it difficult or unpleasant to walk in my neighborhood.

1	2	3	4
strongly disagree	somewhat disagree	somewhat agree	strongly agree

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

1	2	3	4
strongly disagree	somewhat disagree	somewhat agree	strongly agree

3. The speed of traffic on the street I live on is usually slow (30 mph or less).

1	2	3	4
strongly disagree	somewhat disagree	somewhat agree	strongly agree

4. The speed of traffic on most <u>nearby</u> streets is usually slow (30 mph or less).

1	2	3	4
strongly disagree	somewhat disagree	somewhat agree	strongly agree

5. Most drivers exceed the posted speed limits while driving in my neighborhood.

1	2	3	4
strongly disagree	somewhat disagree	somewhat agree	strongly agree

6. When walking in my neighborhood there are a lot of exhaust fumes (such as from cars, buses).

1	2	3	4
strongly disagree	somewhat disagree	somewhat agree	strongly agree

H. Neighborhood safety

1. There is a high crime rate in my neighborhood.

1	2	3	4
strongly disagree	somewhat disagree	somewhat agree	strongly agree

2. The crime rate in my neighborhood makes it unsafe to go on walks <u>during the day</u>.

1	2	3	4
strongly disagree	somewhat disagree	somewhat agree	strongly agree

3. The crime rate in my neighborhood makes it unsafe to go on walks <u>at night</u>.

1	2	3	4
strongly disagree	somewhat disagree	somewhat agree	strongly agree

4. My neighborhood is safe enough so that I would let a 10-year-old boy walk around my block alone in the daytime.

1	2	3	4
strongly disagree	somewhat disagree	somewhat agree	strongly agree

I. Lack of Parking

1. Parking is difficult in local shopping areas.

1	2	3	4
strongly disagree	somewhat disagree	somewhat agree	strongly agree

J. Lack of Cul-de-sacs

1. The streets on my neighborhood do not have many cul-de-sacs.

1	2	3	4
strongly disagree	somewhat disagree	somewhat agree	strongly agree

K. Hilliness

1. The streets on my neighborhood are hilly, making my neighborhood difficult to walk in.

1	2	3	4
strongly disagree	somewhat disagree	somewhat agree	strongly agree

L. Physical Barriers

1. There are major barriers to walking in my neighborhood that make it hard to get from place to place (for example, freeways, railway lines, rivers, canyons, hillsides).

1	2	3	4
strongly disagree	somewhat disagree	somewhat agree	strongly agree

N. Social Interaction While Walking

1. I see and speak to other people when I am walking in my neighborhood.

1	2	3	4
strongly disagree	somewhat disagree	somewhat agree	strongly agree

6.7.3 NEWS-CFA scoring form (copied with permission)

(Retrieved from

https://drjimsallis.org/Documents/Measures_documents/NEWS_CFA_scoring.pdf)

NEWS-CFA: Confirmatory Factor Analysis Scoring for Neighborhood Environment Walkability Scale
(Updated: March 15, 2011)

The NEWS is a self-report perceived environment survey originally developed by Saelens et al. (2003), in which *a priori* subscales were created by the authors (the original survey and scoring can be downloaded from http://www.drjamessallis.sdsu.edu/measures.html). Follow-up multi-level confirmatory factor analysis (CFA) was conducted using data from the Neighborhood Quality of Life Study (NQLS) in the U.S. (see Cerin, et al, 2006 and Cerin, et al., 2009). The scoring procedures described here are based on these confirmatory factor analyses. NOTE: the scoring procedures below are applicable if respondents completed the full NEWS. There is an abbreviated version (NEWS-A), which has a similar factor structure to the full version but has fewer items on select subscales (see website noted above for more information on the abbreviated version).

Key differences between original NEWS and NEWS-CFA scales: The residential density and land use mix-diversity subscales were not appropriate for inclusion in the multi-level CFA, so they remain the same. The multi-level CFA tested both individual-level (participant) subscales and blockgroup-level (census unit) subscales (see Cerin et al., 2006 & 2009). However, scoring procedures described below are for the individual-level subscales only.

The CFA-based scoring procedures produce 8 subscales similar to the original NEWS, but also pull out several items to be used as "single-item subscales." Furthermore, two original subscales ("walking/biking facilities" and "traffic/pedestrian safety") are restructured in the CFA-based scoring to be "infrastructure and safety for walking" and "traffic hazards" subscales.

References:

Saelens, B.E., Sallis, J.F., Black, J., Chen, D. (2003). Neighborhood-based differences in physical activity: An environment scale evaluation. *American Journal of Public Health, 93,* 1552-1558).

Cerin, E., Saelens, B.E., Sallis, J.F., & Frank, L.D. (2006). Neighborhood Environment Walkability Scale: Validity and development of a short form. *Medicine and Science in Sports and Exercise, 38,* 1682-1691.

Cerin, E., Conway, T.L., Saelens, B.E., Frank, L.D., and Sallis, J.F. (2009). Cross-validation of the factorial structure of the Neighborhood Environment Walkability Scale (NEWS) and its abbreviated form (NEWS-A). *International Journal of Behavioral Nutrition and Physical Activity*, *6*:32.

NEWS-CFA Scoring: 8 Multi-item Subscales and 5 Single-Item Subscales

Subscale A: Residential density (higher score denoting higher walkability)

A1. How common are detached single-family residences in your immediate neighborhood?
A2. How common are townhouses or row houses of 1-3 stories in your immediate neighborhood?
A3. How common are apartments or condos 1-3 stories in your immediate neighborhood?
A4. How common are apartments or condos 4-6 stories in your immediate neighborhood?
A5. How common are apartments or condos 7-12 stories in your immediate neighborhood?
A6. How common are apartments or condos more than 13 stories in your immediate neighborhood?

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Responses:
None (1) A few (2) Some (3) Most (4) All (5)

Score on subscale: A = A1 + (12 * A2) + (10 * A3) + (25 * A4) + (50 * A5) + (75 * A6)

Subscale B: <u>Land-use mix – diversity</u> (higher score denoting higher walkability)

B1. Convenience/small grocery store
B2. Supermarket
B3. Hardware store
B4. Fruit/vegetable market
B5. Laundry/dry cleaners
B6. Clothing store
B7. Post office
B8. Library
B9. Elementary school
B10. Other schools
B11. Book store
B12. Fast food restaurant
B13. Coffee place
B14. Bank/credit union
B15. Non-fast food restaurant
B16. Video store
B17. Pharmacy/drug store
B18. Salon/barber shop
B19. Your job or school
B20. Bus or trolley stop
B21. Park
B22. Recreation center
B23. Gym or fitness facility

Responses:
1-5 min(5) 6-10 min(4) 11-20 min(3) 21-30 min(2) 31+ min(1) don't know (1)

Note: A 'don't know' response is coded as a "1" because if it is not known whether the facility is within walking distance, the actual walk is likely more than 31 minutes.

Score on subscale: Mean of item responses. B = (B1+ … + B23) / 23

Alternative scoring: For some purposes it may be useful to tally the number of stores, facilities, or types of store/facilities within a 5-, 10-, or 20-minute walk.

Subscale C: <u>Land-use mix – access</u> (higher score denoting higher walkability)

C1. I can do most of my shopping at local stores.
C2. Stores are within easy walking distance.
C3. There are many places to go within walking distance at my home.
C4. It is easy to walk to a transit stop (bus, train) from my home.

Responses:
Strongly disagree (1) Somewhat disagree (2) Somewhat agree (3) Strongly agree (4)

Score on subscale: Mean of item responses. C = (C1 + C2 + C3 + C4) / 4

Subscale D: <u>Street connectivity</u> (higher score denoting higher walkability)

D1. The distance between intersections in my neighborhood is usually short.
D2. There are many four-way intersections in my neighborhood.
D3. There are many alternative routes for getting from place to place in my neighborhood.

Responses:
Strongly disagree (1) Somewhat disagree (2) Somewhat agree (3) Strongly agree (4)

Score on subscale: Mean of item responses. D = (D1 + D2 + D3) / 3

Subscale E: <u>Infrastructure and safety for walking</u> (higher score denoting higher walkability)

E1. There are sidewalks on most of the streets in my neighborhood.
E2. The sidewalks in my neighborhood are well maintained.
E3. There are bicycle or pedestrian trails in or near my neighborhood that are easy to get to
E4. Sidewalks are separated from the road/traffic in my neighborhood by parked cars.
E5. There is a grass/dirt strip that separates the streets from the sidewalks in my neighborhood.
E6. It is safe to ride a bike in or near my neighborhood.
E7. My neighborhood is well lit at night.
E8. Walkers and bikers on the streets in my neighborhood can be easily seen by people in their homes.
E9. There are crosswalks and pedestrian signals to help walkers cross busy streets in my neighborhood.
E10. The crosswalks in my neighborhood help walkers feel safe crossing busy streets

Responses:
Strongly disagree (1) Somewhat disagree (2) Somewhat agree (3) Strongly agree (4)

Score on subscale: Mean of item responses. E = (E1 + E2 + E3 + E4 + E5 + E6 + E7 + E8 + E9 + E10) / 10

Subscale F: <u>Aesthetics</u> (higher score denoting higher walkability)

F1. There are trees along the streets in my neighborhood.
F2. Trees give shade for the sidewalks in my neighborhood.
F3. There are many interesting things to look at while walking in my neighborhood.
F4. My neighborhood is generally free from litter.
F5. There are many attractive natural sights in my neighborhood.
F6. There are attractive buildings/homes in my neighborhood.

Responses:
Strongly disagree (1) Somewhat disagree (2) Somewhat agree (3) Strongly agree (4)

Score on subscale: Mean of item responses. F = (F1 + F2 + F3 + F4 + F5 + F6) / 6

Subscale G: Traffic hazards (higher score denoting lower walkability)

G1. There is so much traffic along the street I live on that it makes it difficult or unpleasant to walk in my neighborhood.
G2. There is so much traffic along nearby streets that it makes it difficult or unpleasant to walk in my neighborhood.
G3. The speed of traffic on the street I live on is usually slow. *{need to reverse-score item}*
G4. The speed of traffic on most nearby streets is usually slow. *{need to reverse-score item}*
G5. Most drivers exceed the posted limits while driving in my neighborhood.
G6. When walking in my neighborhood there are a lot of exhaust fumes

Responses:
Strongly disagree (1) Somewhat disagree (2) Somewhat agree (3) Strongly agree (4)

Score on subscale: Mean of item responses. G = (G1 + G2 + [5-G3] + [5-G4] + G5 + G6) / 6

Subscale H: Crime (higher score denoting lower walkability)

H1. There is a high crime rate in my neighborhood.
H2. The crime rate in my neighborhood makes it unsafe to go on walks during the day.
H3. The crime rate in my neighborhood makes it unsafe to go on walks at night.
H4. My neighborhood is safe enough so that I would let a 10-yr-old boy walk around my block alone in the daytime. *{need to reverse-score item}*

Responses:
Strongly disagree (1) Somewhat disagree (2) Somewhat agree (3) Strongly agree (4)

Score on subscale: Mean of item responses. H = (H1 + H2 + H3 + [5-H4]) / 4

Single-item subscale I: Lack of parking (higher score denoting higher walkability)

I1. Parking is difficult in local shopping areas.

Responses:
Strongly disagree (1) Somewhat disagree (2) Somewhat agree (3) Strongly agree (4)

Score on subscale: Item response. I = I1

Single-item subscale J: Lack of cul-de-sacs (higher score denoting higher walkability)

J1. The streets in my neighborhood do not have many cul-de-sacs.

Responses:
Strongly disagree (1) Somewhat disagree (2) Somewhat agree (3) Strongly agree (4)

Score on subscale: Item response. J = J1

Single-item subscale K: Hilliness (higher score denoting lower walkability)

K1. The streets in my neighborhood are hilly, making my neighborhood difficult to walk in.

Responses:
Strongly disagree (1) Somewhat disagree (2) Somewhat agree (3) Strongly agree (4)

Score on subscale: Item response. K = K1

Single-item subscale L: <u>Physical barriers</u> (higher score denoting lower walkability)

L1. There are major barriers to walking in my neighborhood that make it hard to get from place to place (for example, freeways, railway lines, rivers, canyons, hillsides).

Responses:
Strongly disagree (1) Somewhat disagree (2) Somewhat agree (3) Strongly agree (4)

Score on subscale: Item response. L = L1

Single-item subscale N: <u>Social interaction while walking</u> (higher score denoting higher walkability)

N1. I see and speak to other people when I am walking in my neighborhood.

Responses:
Strongly disagree (1) Somewhat disagree (2) Somewhat agree (3) Strongly agree (4)

Score on subscale: Item response. N= N1

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NOTE: One item in the original NEWS is not recommended for inclusion in either multi-item or single-item subscales due to poor reliability (Cerin et al., 2006 & 2009): "There are walkways in my neighborhood that connect cul-de-sacs to streets, trails, or other cul-de-sacs."