PROJECT F.E.A.L.:
AN INVESTIGATION OF NEIGHBOURHOOD BUILT ENVIRONMENTS AND ACTIVE LIVING IN THE CANADIAN ARMED FORCES

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Abstract

Most Canadian adults do not meet recommended levels of physical activity; this phenomenon has persisted for many years and is associated with health concerns and chronic disease. These trends appear to affect Canadian Armed Forces (CAF) personnel who have heightened mandates around physical activity. CAF operational mandates combined with these trends highlight the importance of addressing divides between expectation and reality. Traditionally the CAF has used approaches targeted to individuals to manage activity levels; however, there have been no studies exploring the relationship between the environment and activity levels among CAF personnel which has the potential to affect far more people. This dissertation examined built environments where CAF personnel live and explored the relationship between the built environment and active living among CAF personnel. There are two studies in this work.

The first study developed a scale with and for the CAF and used this to examine the built environments where CAF personnel live. The results indicated a factor solution and demonstrated good-to-strong psychometric properties. Among the environments, it highlighted areas of strength and potential areas of improvement. These findings contribute to a better understanding of the built environments where CAF personnel live.

The second study used data from several sources at individual and neighbourhood levels to conduct a hierarchical linear model analysis to explore the relationship between the built environment and physical activity among CAF personnel. The findings revealed information about the different relationships between active living (measured by physical activity level) of CAF personnel and individual and neighbourhood characteristics.

The findings in this dissertation provide novel evidence about the relationship of the built environment and active living among CAF personnel. The aim of this research was to provide evidence and information to decisionmakers that serves to meaningfully contribute to the pursuit of the overall health and wellbeing of CAF members. The findings provided meaningful information to help guide and inform Canadian Forces Morale and Welfare Services (CFMWS) policy, programming, and resource decisions that affect CAF personnel.

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Statement of Co-Authorship

The dissertation includes two studies with contributions from my supervisor and colleagues. As the first author of these studies, I conducted and led the literature reviews, led data collection and organization, conducted data analyses, performed interpretations, and drafted and edited the manuscripts. Michael Dignam appears as the third author on the first study and the second author on the second study. He contributed to the literature review for both studies, participated in data organization and initial analyses in the second study, and helped lead the development of map figures for both studies. Michael Yee is listed as the second author on the first study and the third author on the second study. He helped conduct the literature reviews for both studies and contributed to structuring, organizing, and editing both manuscripts. Dr. Michael Sawada is listed as the fourth author on the first study. He contributed to the overall study structure, helped organize and streamline the neighbourhood audit areas for data collection with ArcGIS and Apple iPads, and provided valuable feedback. Dr. Veronika Huta is listed as the fourth author in the second study. She contributed to the initial study design and power analyses for the study. She also provided guidance on hierarchical linear modelling, organization, and interpretations. Hugo Crites is listed as the fifth author on the second study as he helped in the acquisition and implementation of census data and the development of map figures for both studies. Dr. Kristjansson appears as the last author on both studies for her contributions providing guidance on the design, structure, analyses as well as editing several versions of the papers. All authors reviewed the drafts of these studies.

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Chapter 1: General Introduction

General Introduction

The majority of Canadian adults do not meet recommended levels of physical activity and recent studies indicate that these low activity levels have been stable for the past decade (Colley et al., 2011, 2019). Longstanding findings show that decreased activity levels are associated with many health concerns, illness, and disease (Gilmour, 2007; Warburton et al., 2006). These trends appear to affect even Canadian Armed Forces (CAF) military personnel. In the CAF, “all sailors, soldiers, airmen, and airwomen [are expected to be] deployable at any time and therefore must be healthy and physically fit to be successful in all missions and operations” (Franz, 2015, p. 6). However, the Health and Lifestyle Information Survey – a “quadrennial population-based survey that provides a snapshot of the current health status of Canadian Armed Forces personnel”– noted decreases in activity levels between 2004 and 2009 activity before slight improvements in self-reported physical activity in 2014 (Born et al., 2009; Thériault et al., 2016, p. iii). Worrying increases in sedentary behavior and obesity rates among active personnel were also highlighted (Thériault et al., 2016).

CAF operational mandates combined with findings from the Health and Lifestyle Information Survey demonstrate a need to rethink how researchers address divides between expectation and reality. The CAF has traditionally used interventions targeted at the individual- or unit-level, such as annual fitness test training. Individual-level prevention or intervention is beneficial for the individuals being targeted (e.g., overweight and/or sedentary individuals), but is less likely to influence change at the population level. However, there is substantial research that suggests that population-based interventions and preventive measures may prove to be more successful and sustainable at affecting meaningful change (Rose et al., 2008; Sallis et al., 2006). One of the most common approaches relates to the settings, or environment, in which active living and physical activity occur. Rather than targeting individuals or units, population-based interventions can impact a community's environment. A systematic review by Reis et al. (2016) identified environmental and urban planning as key factors in improving and maintaining activity levels on a macrosystem and global level. Moreover, a strong and growing body of evidence shows that the built environment shares significant relationships with active living which can facilitate and support positive health outcomes (e.g., Frank, Iroz-Elardo, et al., 2019; Joseph et al., 2006; Kärmeniemi et al., 2018; Sallis et al., 2020; Thompson Coon et al., 2011).

There is a dearth of research that examines the impact of the built environment on active living and physical activity among military personnel and, to the best of our knowledge, none among the Canadian military. For example, Malkawi et al. (2018) completed a systematic review and identified several beneficial interventions for weight and fitness management among military personnel. However, all the interventions appeared targeted towards individuals or local groups rather than population-based approaches. Within this context, Malkawi et al. (2018) also identified a need for more studies involving non-U.S. or European militaries. The aim and purpose of this dissertation is to contribute to this gap in literature through (1) the examination of built environments where CAF personnel live and (2) explore the relationship between the built environment and active living among Canadian military personnel. The purpose of this introductory chapter is to provide an overview of active living, the built environment, and the theoretical framework to conceptualize these approaches.

Active Living

Active living is defined as "a way of life that integrates physical activity into daily routines" and is an overarching concept that includes several types of activity (Sallis et al., 2006;

Sallis, Linton, et al., 2005, p. 1). This dissertation acknowledges active living and physical activity under the same umbrella, as active living is a more inclusive and contemporary conceptualization of current lifestyles and types of activities (Sallis et al., 2006). As a result, both active living and physical activity may be used at times. Active living is typically conceptualized into four categories: active recreation, active transport, household activity, and occupational activity (Sallis et al., 2006). The approach to measuring active living also informs the terminology which will be explored in a later section. The evolution from exercise and physical activity to active living is accompanied by a timeline of interventions promoting physical activity from a small, individual scope to approaches scaled for populations.

Overview

Sallis et al. (2005) provide an excellent summary of the road to active living in which they describe its evolution. They note that in the 1960s research examined the impact of physical activity on different biological outcomes. In the 1970s, studies began to explore physical activity and fitness in relation to physical and psychological health outcomes. In the 1980s, more research took place to bolster the evidence and outcomes to support the benefits of an active lifestyle. This continued research eventually led to the recognition that physical health is a public health priority in the 1990s (e.g., Sallis, Linton, et al., 2005; U.S. Department of Health and Human Services, 1996).

More recently in the 2000s, the physical activity research horizon has broadened to include a greater range of activities with more focus on overarching factors, such as environmental and policy factors, that contribute to higher prevalence of inactive lifestyles. As a result, this broadened focus has led to new research collaborations with different disciplines to further expand and develop the understanding of factors contributing to inactivity. Active living research has had contributions from many domains, including public health, behavioral science, urban planning, transportation, leisure studies, recreation studies, public policy, political science, and economics (Sallis et al., 2006). For example, early public health and behavioural science research on behavioural change found that individual interventions (e.g., improving physical activity) had moderate impacts on long-term changes at the population level, but found promising results when reviewing environmental and policy changes (Sallis et al., 2006). This early public health research on active living were the early signifiers for the positive effects of the environment and policy. Subsequent research over the years has continued to build more evidence highlighting the importance of factors that have population level impacts (e.g., Barnett et al., 2017; Sallis et al., 2020).

As active living research expanded its perspective to include population level considerations and impacts, it followed that its transdisciplinary nature would be seen in the postulated outcomes. For example, a nice sidewalk or walking path can contribute to beneficial outcomes across several domains (Sallis et al., 2006). Similarly, effects were postulated by Sallis et al. (2006) at the neighbourhood level: neighbourhoods designed to be safe, attractive, and considerate of cyclists could help to improve overall active living and physical activity as well as have a host of other potential health, infrastructure, medical, and transportation benefits. An onslaught of subsequent research from the 2000s, 2010s, and more recently has supported active living research and fueled its growth (e.g., Barnett et al., 2017; de Vet et al., 2011; Frank et al., 2006; Sallis et al., 2020; Wasfi, Dasgupta, Orpana, et al., 2016b; Zhu et al., 2020). A key value of active living research is that it can make meaningful contributions to long-term and population-based increases in physical activity that bring with them numerous health benefits (Sallis et al., 2006).

Although there is growing evidence for environmental and policy impacts on population health, individual level interventions are commonly used in programming. While beneficial to some, individual interventions are less likely to take root and produce meaningful change at a population level (Rose et al., 2008; Sallis et al., 2006). This highlights the continued need for population-based research and interventions to address activity levels amongst the general population and in specific populations.

Population & Health Implications

> Amongst the general population, the World Health Organization (WHO) recommends: adults between 18 and 64 years old should do at least 150 – 300 minutes of moderate-intensity aerobic physical activity; or at least 75–150 minutes of vigorous intensity aerobic physical activity; or an equivalent combination […] throughout the week, for substantial health benefits (2020, p. 2).

However, it has been known for quite some time that "most adults in industrialized countries do not meet [these] physical activity guidelines" (Allen & Morey, 2010; Sallis et al., 1998, p. 1). Even if these guidelines are not met, light intensity activity can still provide some health benefits (World Health Organization, 2020). Closer to home, these findings hold true in Canada. Eighty-five percent of Canadian adults do not meet recommended levels of physical activity and recent studies indicate these activity levels have been stable for the past decade (Colley et al., 2011, 2019). Whether light, moderate, or vigorous activity, active living in general has many health implications. For example, in adults, physical activity is associated with a lower risk of cardiovascular disease, cancer, hypertension, diabetes, overweight and obesity, and overall mortality; it is also associated with improved mental health (e.g., reduced symptoms of depression and anxiety, and better quality of life), cognitive health, and sleep (Aars et al., 2019; Katzmarzyk & Janssen, 2004; Martins & Lopes, 2013; Warburton et al., 2006; World Health Organization, 2020). In fact, there is strong evidence that any level and intensity of activity is associated with most of the health benefits mentioned above (World Health Organization, 2020).

Moreover, for the first time, the World Health Organization in 2020 provided recommendations about the association between sedentary behaviour and health outcomes. They defined sedentary behaviour "as time spent sitting or lying with low energy expenditure, while awake, in the context of occupational, educational, home and community settings, and transportation" (2020, p. 38). They found that "higher amounts of sedentary behaviours are associated with poor health outcomes [including] all-cause mortality, cardiovascular disease mortality and cancer mortality and incidence of cardiovascular disease, cancer, and type-2 diabetes" (World Health Organization, 2020, p. 3). Importantly, there is moderately strong evidence that more physical activity (particularly higher intensity) can mitigate adverse health outcomes connected to sedentary behaviour (World Health Organization, 2020).

Considered within current global contexts, the importance of these findings have come into sharper focus. Over the past two years, the COVID-19 pandemic and accompanying restrictions (i.e., lockdowns and public health measures) have adversely impacted physical activity and led to increased sedentary behaviours (Stockwell et al., 2021). For example, lockdowns have eliminated many potential opportunities for activities that were part of daily life such as active transportation (e.g., walking or biking to a destination), occupational activities, and leisure activities (e.g., recreational sports) (Stockwell et al., 2021). The complementary aspect of decreased opportunities for physical activity points to an increased potential for sedentary behaviour. For example, writing this dissertation from home instead of walking to the university eliminates 40 minutes of total walking time per day (or 200 minutes per week) that is replaced by more writing time. Although productive, it is also an increase in sedentary time and reduction in physical activity.

While the above example is anecdotal it is indeed supported by research. A recent systematic review by Stockwell et al. (2021) found that physical activity declined, and sedentary behaviours increased during COVID-19 lockdowns. These changes occurred “regardless of subpopulation or the methodology used” (Stockwell et al., 2021, p. 3). Specifically, they noted physical activity during lockdowns decreased compared with pre-lockdown in healthy adults and children, and individuals with medical conditions (except eating disorders). These findings were largely consistent with a systematic review of Italian studies by Zaccagni et al. (2021). This is notable because Italy had some of the strictest lockdown measures. Specifically, they found that most studies highlighted a significant reduction physical activity compared to pre-lockdown in the general population and in individuals with chronic conditions (e.g., metabolic, cardiovascular, and neurodegenerative diseases). However, they reported increases in physical activity in two of 23 studies which they attributed to highly physically active people sustaining a lifestyle that allows them to maintain their activity, even in challenging situations such as lockdown (Zaccagni et al., 2021). COVID-19 and its global impact demonstrate the importance of physical activity across many areas including health (e.g., physical, functional), mental health (e.g., anxiety, depression), and in the prevention and treatment of medical conditions (e.g., metabolic, cardiovascular, and neurodegenerative) (Stockwell et al., 2021; Zaccagni et al., 2021;

Wolf et al., 2021; Warburton & Breton, 2017). The pandemic also provides heightened impetus for the importance of population-based approaches to support active living and physical activity.

There are also certain subpopulations from which physical activity is a mandate or job requirement. This includes first responders such as firefighters and police officers. These professions have physical demands not typically found in occupations among the general population. However, the trends regarding physical activity and related health outcomes observed in the general population continue to hold true despite these physical activity requirements (e.g., Leischik et al., 2015; Malkawi et al., 2018; Yu et al., 2015).

Another prominent occupation with well known physical activity requirements is the military. However, military mandates are also not immune to trends seen in first responders and in the general population. Researchers found that there was a rising trend in obesity observed in the U.S. military that mirrored the general population (Tanofsky-Kraff et al., 2013). At one point in 2012, 49.3% of active-duty military personnel in the U.S. were overweight (Veterans Affairs, 2014). A systematic review that was echoed by a more recent review found that obesity in the military was connected to factors including sex, age, and rank, among other factors (Malkawi et al., 2018; Sanderson et al., 2011). Specifically, obesity was found in men over the age of 35 with lower ranks and who were married. These findings are important because they provide additional evidence of the worrying trends regarding increasing obesity rates in professions where there is an added importance of physical activity. A particularly unique aspect of military service in most (if not all countries) is that personnel "must pass physical fitness tests every 6–12 months, with adverse career consequences for those who fail to meet standards" (Littman et al., 2013, p. 784).

These trends are also true among the Canadian military. The Health and Lifestyle Information Survey – a "quadrennial population-based survey that provides a snapshot of the current health status of Canadian Armed Forces personnel" (Thériault et al., 2016, p. iii) – reported a decrease in overall activity levels among CAF personnel since 2008 with slight improvements leading up to 2014. Particularly, they highlighted worrying trends of increasing sedentary behavior and obesity rates among active personnel. Sedentary time increased 3.24 hours per week since 2008-2009, and 6.35 hours/week since 2004 (Thériault et al., 2016). Much like the American and European militaries, annual fitness tests in the CAF appeared to have also done little to reverse or stem this tide. This area of research is particularly important because these mandates help to "ensure that military personnel are capable of handling the physical demand in the military environment and reducing the risks of injuries in addition to maintaining proper military appearance" (Malkawi et al., 2018, p. 2). There also appears to be a solid literature base regarding physical activity and its implications among first responders and in certain areas this applies to military, but there is still significant room for growth. For example, a systematic review by Malkawi et al. (2018) called for more research about physical activity and active living that focuses on militaries outside of the U.S. and Europe. They also identified a need for more research on interventions to improve physical activity to clarify its effect. Additionally, research by Littman et al., (2013) about military veterans aligned with the above findings and called for improving interventions to encourage physical activity and reduce sedentary time.

While the above examples focus on obesity and align with concerning trends noted in The Health and Lifestyle Information Survey from the CAF, the benefits of physical activity are much broader. One of the main reasons researchers have called for improving interventions to encourage physical activity are its numerous benefits and implications. A systematic review of systematic reviews by Warburton and Bredin (2017, p. 544) on the health benefits of physical activity highlighted overwhelming evidence “that regular physical activity is associated with reduced risk for all-cause mortality and many chronic medical conditions.” In addition to reducing risk to manage and improve health, physical activity also contributes to well-being and quality of life (Hyde et al., 2013; Marquez et al., 2020). For instance, Hyde et al. (2013) noted that physical activity indirectly enhances life satisfaction in older age and is related to positive affect. Similarly, Marquez et al. (2020) reported that adults and older adults showed positive relationships between physical activity, quality of life, and well-being. Considered together, these studies show that the benefits of physical activity not only reduce health risks but can contribute to positive and helpful outcomes that impact our lives.

Warburton and Bredin (2017) also noted that the benefits of physical activity are not contained to moderate or vigorous activity. In fact, they indicated that the greatest relative benefits and reductions of health risks occur at lower amounts of physical activity (Warburton & Bredin, 2017). For example, moving from inactive to active or engaging in light physical activity. This points to the importance of active living which encapsulates all types of activity. The benefits of physical activity extend across a wide domain of activity. Since concerning trends regarding physical activity and related health outcomes seen in the general population appear to hold true in professions with physical activity requirements (i.e., the military), it is feasible to assume that so might the benefits of active living.

Individual vs. Population Level

These findings about physical activity trends, sedentary time, and health outcomes among military personnel along with calls for improvements to interventions shines a light on the types of interventions currently in use by militaries. In 2018, Malkawi et al. conducted a systematic review of the literature on interventions among active military personnel focusing on physical activity, weight management, and diet. The findings regarding physical activity are of particular interest and at a broader conceptual level all types of interventions reveal important information. Interventions included promotion of physical activity, healthy diets (e.g., food and equipment/kitchen-based), motivational interviewing, mindfulness meditation, goal setting and self-monitoring, counselling (e.g., telephone, in-person, email, online lessons), and a combination of the aforementioned interventions. Weight management interventions, which included physical activity interventions, used many of those mentioned above. The greatest number of effective studies tended to use individualized or combined individualized weight management interventions. Regarding physical activity specific interventions, the moderate-to-strong rated studies primarily used self-monitoring strategies, such as exercise diaries, and calorimeters. Interestingly, the review could not draw any conclusions about the effectiveness of physical activity interventions because of a lack of evidence from moderate-to-strong rated studies.

The findings from the Malkawi et al. (2018) review contain rich information at different levels. However, when observed from a broad and conceptual perspective of all interventions, and in particular the physical activity interventions, a consistent theme emerges: these interventions (e.g., one-on-one counselling, self-monitoring, calorimeters, diet and kitchen interventions, online lessons) are focused on individual levels. This is consistent with annual or semi-annual fitness tests commonly seen in the military. Individual-level prevention and intervention can be beneficial for the targeted individuals, but its potential reach among broader populations is limited (Rose et al., 2008). This also fits within the context of research on militaries from other countries and regions such as the United States and Europe (e.g., Malkawi et al., 2018; Sanderson et al., 2011; Tanofsky-Kraff et al., 2013). And from an even broader perspective, research from the World Health Organization indicates that most people in industrialized countries do not engage in enough physical activity and active living (World Health Organization, 2020); in Canada, that number is 85% (Colley et al., 2019).

Given the vast evidence on a global scale, within Canada, and within the CAF operational mandates it is important to address this divide. While individual-level interventions are beneficial to some and very common, research also suggests population-based approaches and preventative measures may prove to be more successful and sustainable at affecting meaningful change (Rose et al., 2008; Sallis et al., 2006). Population-based approaches can affect meaningful change because the focus is on altering the conditions that lead to the distribution of risk in a population (Frohlich, 2014; Rose et al., 2008). These types of interventions attempt to change contextual conditions of risk to change the distribution of risk in populations. For example, changing contextual conditions may include targeting policy, socio-cultural factors (e.g., norms), and/or environmental factors (Ahern et al., 2008; Frohlich, 2014). These ideas and examples have led to numerous areas of study, including community and neighbourhood level exposures among populations (Ahern et al., 2008). This particular focus has included studying active living within the context of communities and neighbourhoods.

Assessing Active Living

There are several different approaches to assessing active living. Activity is typically assessed using energy expenditure (EE) and/or physical activity measurements. Physical activity is defined as any bodily movement that results in EE and thus, energy is used as a result of physical activity (Hills et al., 2014). In other words, physical activity is behavior that results in an increase of EE above resting levels. The resting level often referred to a resting metabolic rate or basal metabolic rate and provides an important behavioural context and anchor. When physical activity and EE are expressed relative to resting values it is commonly expressed as physical activity level or metabolic equivalent of task (MET). Physical activity level is expressed as total energy expenditure divided by resting energy expenditure. Typical values in free-living (e.g., active living) adults typically range from 1.40 to approximately 2.40 (Hills et al., 2014). Regarding METs, one unit is equal to oxygen consumption at rest. The increasing intensity of activities relative to resting levels is then used to describe the intensities of different physical activities. The most common use of METs has been to categorize physical activity intensity. Moderate-to-vigorous physical activity is defined as > 3 METs, moderate physical activity (only) as 3–6 METs and vigorous physical activity as > 6 METs (Hills et al., 2014). To determine physical activity level or METs, there are two overarching methods used to assess physical activity and energy expenditure data: subjective and objective methods.

Subjective, or self-report, measures are indirect approaches to assessing physical activity and involve participants recording their own activities (Ridgers & Fairclough, 2011). These measures can include activity diaries, interviews, and are derived from items within physical activity questionnaires. Some of the most common include items from activity questionnaires and activity diaries. Physical activity diaries can provide detailed information regarding activity types and patterns (Hills et al., 2014). Physical activity questionnaires typically include detailed accounts of physical activity such as frequency and duration of activities over extended periods of time, typically 24 hours to seven days (Corder et al., 2008; Hills et al., 2014). There are several advantages and disadvantages to subjective assessment methods. Subjective methods have several strengths including low cost, ease of administration, being more amenable to large sample sizes, and requires minimal participant resources (Fuller et al., 2008). The primary limitations of subjective approaches are the potential accuracy of the information included. For example, recall challenges, performance bias, semantics, and available activity choices on the questionnaire can all influence the data collected. Another limitation is that subjective approaches essentially quantify the perception of physical activity as opposed to direct physical activity itself (Venditti et al., 2014).

Objective measures directly assess physical activity and energy expenditure. These include the doubly labelled water technique, calorimetry, heart rate monitoring, motion sensors (e.g., pedometers, accelerometers), and combined methods. The doubly labelled water (DLW) technique is generally recognized as the gold standard approach to assessing total EE (Dowd et al., 2018; Hills et al., 2014). DLW involves the identification and tracking of isotopes in participants' urine samples using isotope ratio mass spectrometry (IRMS) in a procedure to calculate energy expenditure. However, DLW only provides a daily average of activity over the data collection period. It does not take into account the duration or intensity of physical activity.

Calorimetry is another highly regarded assessment approach (Robertson et al., 2015). There are two types of calorimetry: direct and indirect. Direct calorimetry involves assessing EE through measuring heat production directly. Indirect calorimetry is the measurement of a substitute of heat production (e.g., oxygen consumption or carbon dioxide production) and tends to be more commonly used (Hills et al., 2014). To conduct calorimetric measures, some approaches require whole-room metabolic chambers, which is quite resource intensive. Both calorimetry and DLW approaches can be cost prohibitive, invasive, and are not feasible for population-based research (Dowd et al., 2018; Melanson et al., 1996; Robertson et al., 2015).

Heart rate monitors are used to determine energy expenditure based on the assumed linear relationship between heart rate and oxygen consumption (Hills et al., 2014). In a comparison study, Fuller et al. (2008) found that heart rate monitoring provided the closest approximation of energy expenditure to the gold standard method of DLW. Hills et al. (2014) reported that heart rate monitors are popular, convenient, relatively inexpensive, non-invasive, and versatile. Additionally, Robertson et al. (2015) indicated that they are more cost effective than DLW and calorimetry and are more accurate than activity diaries (self-report) and accelerometers alone. Limitations in the use of heart rate measures include capturing the changes in different activities, however these can be managed by integrating individual resting heart rates to differentiate between rest and activity (Hills et al., 2014).

Motion sensors have become increasing popular and accessible. Pedometers and accelerometers are two of the most common types of motion sensors. Pedometers measure steps taken during walking and running activities (Hills et al., 2014). Cut-points have been investigated to estimate alignment with EE. These motion sensors are inexpensive, easy to use and accessible, and can contribute to physical activity motivation. However, there are important limitations to the use of pedometers. Both Hills et al. (2014) and Robertson et al. (2015) reported several studies which questioned the accuracy of pedometers. For example, the impact of individual differences in height and leg length, stride, and slow speed accuracy. Accelerometers are wearable devices and motion sensors that identify accelerations due to body movement (Migueles et a., 2017). They can detect the rate of change in velocity over a given time (often a three dimensional time-series of accelerations) and can provide objective assessments of physical activity and sedentary time (Rastogi et al., 2020; Migueles et a., 2017). From this, variables such as the frequency, intensity, and duration of an activity can be determined (Ridgers & Fairclough, 2011). Hills et al. (2014) reported that several studies have indicated accelerometers are objective, practical, non-invasive, accurate, and reliable. Due to the rapid development of accelerometers and analyses there are also constant advancement. These advances have allowed researchers to use accelerometer data to develop improved methods, accessible analysis tools, and new summary variables (Rastogi et al., 2020). The downside to this progress is that there does not appear to be a consensus about what approaches to use (Migueles et al., 2017).

Combined approaches are generally recommended because there is no one method that is without limitations (Hills et al., 2014). The use of multiple measures allows for improved management of potential limitations and building on complementary strengths. Similarly, there is a risk of compounding limitations if the weakness of measures overlaps. Therefore, careful consideration of strengths and weakness of different measures is highly important. One example of a combined measure is the use of a heart rate monitor and an accelerometer. Heart rate monitors and accelerometers are practical, accurate, non-invasive, convenient, versatile, and relatively inexpensive. Potential limitations are accounted for by multiple and complementary sources of data. Hills et al. reported that several studies indicated that heart rate monitoring and accelerometry provides a “potentially powerful approach to quantifying [energy expenditure]” (2014, p. 8).

Overall, objective measures of active living and physical activity have less variability in their methods than subjective approaches (Dowd et al., 2018; Littman et al., 2013). A systematic review of reviews by Dowd et al. (2018) recommended using objective measures that align with the specific behaviours of interest. In this dissertation, specifically study 2, energy expenditure was calculated by determining physical activity levels using data collected with combined devices - a heart rate monitor, accelerometer, and GPS (FirstBeat Bodyguard), and a body composition measure (InBody 520). This data was provided as secondary data from a previous study at Canadian Forces Morale and Welfare Services (CFMWS). By examining the strengths and weaknesses of the different approaches, potential resources, and larger sample size, the rationale for using this approach can be determined.

Built Environment

The physical environment is a broad term that encompasses the built environment and natural environment. Broadly defined the built environment comprises "all buildings, spaces, and objects that are created or modified by people; this includes homes, schools, workplaces, parks and recreation areas, greenways, transportation systems, and vehicles" (Sallis, 2009, p. 2). It has been similarly defined as "the physical space of the environment which is human-made or modifiable and where people live and carry out their daily activities" (Bonaccorsi et al., 2020, p. 2). This may include several environmental features such as buildings (e.g., homes, schools, workplaces), open spaces (e.g., parks, recreation areas), and infrastructures (e.g., transportation systems) (Bonaccorsi et al., 2020). The natural environment refers to places where aspects of the environment may impact human behaviour such as open spaces, forests, climate, weather, vegetation, and topography (Sallis, 2009). In some cases, components of the natural environment may overlap with the built environment. For example, the decision, selection, and placement of trees, hedges, or other types of vegetation while natural features, are conducted as part of the design process for the built environment and therefore can be assumed to be part of both. This dissertation focuses on the built environment and acknowledges the role and contribution of the natural environment.

People experience the effects of the built environment every day - whether at work, at home, or participating in leisurely or recreational activities (Clifton et al., 2008). It has been strongly associated with effects on human experiences of physical activity, crime, mood and mental health, and social interaction, and physical health among others (e.g., Barnett et al., 2017; G. W. Evans, 2003; Frank et al., 2006; Leyden, 2003; Sallis et al., 2020; Sampson et al., 1997). For example, areas of high residential density and physical disorder can negatively affect mental health and supportive relationships (G. W. Evans, 2003). On the other hand, features of the built environment can also contribute to enhancing neighbourhood social environments (Jun & Hur, 2015; Owens, 1993). For example, the built environment can facilitate opportunities to engage and connect with others and foster social inclusion in your area via walking, meeting, or gathering (Jun & Hur, 2015). An important factor that is worth exploring further is the relationship between the built environment and active living.

Built Environment and Active Living

Research has shown a strong relationship between built environment and active living, however, there are some mixed findings. Sallis et al. (2020), as part of the international physical activity and environment network (IPEN) analyzed data from studies in 12 countries on five different continents. A systematic review by Barnett et al. (2017) examined studies that included data from 22 different countries. Both studies demonstrated the important role that the built environment can play and its influences on physical activity and implications for health outcomes (Barnett et al., 2017; Sallis et al., 2020). These cross-continental findings also show that the built environment plays an important role across countries, cultures, and different populations. From a theoretical perspective, this is important because the built environment can be a consistent superordinate factor. Exposure to built environments can influence populations over long periods and built environment design has been connected to many important behavioural and health outcomes (Dannenberg et al., 2011; Sallis et al., 2018).

A systematic review on walkability and active transportation found that residents who live in neighbourhoods with more walkable areas reported 30 more minutes of walking per week and an increase in total physical activity (Frank et al., 2006). This review has been bolstered by more current research which also noted increases in walking, cycling, and active transport related to the built environment (e.g., Kärmeniemi et al., 2018; Méline et al., 2017). This is echoed by numerous studies demonstrating a relationship that individuals who move to more walkable neighbourhood environments see increases in their physical activity (e.g., Li et al., 2005; Saelens & Handy, 2008; Wasfi, Dasgupta, Orpana, et al., 2016b; Zhu et al., 2020). Research has also shown that those who live in neighbourhood environments with high levels of objectively recorded disorder, such as litter and unwanted graffiti, appear to have 50% lower odds of being physically active (Ellaway et al., 2005).

In addition to this evidence base, there is also research that has had mixed findings, both significant and non-significant, when examining the relationship between the built environment and active living (Nordbø et al., 2020; Rodríguez et al., 2005). In studies where the built environment did not initially appear related to active living, researchers highlighted that there may be a connection between the built environment and the intensity of physical activity in these findings (Rodriguez et al., 2005). Therefore, the perspective taken when exploring these relationships may play an important role. A systematic review also observed mixed findings in this area (Nordbø et al., 2020). Researchers posited that the same built environment features may influence people in different ways depending on individual characteristics such as age. It is plausible this may also extend to a host of other characteristics as well. These individual characteristics may then play a role in or contribute to non-significant results.

Canadian Contexts. Closer to home in Canada, research findings align with studies from different countries. For example, a quasi-experimental evaluation conducted in Vancouver, British Columbia demonstrated that the increased physical activity effects of retrofitting an urban greenway for bicyclists could be felt even beyond 300m of the greenway intervention which showed improved physical activity and reduced sedentary behaviour (Frank, Hong, et al., 2019). Two longitudinal studies by Wasfi et al. (2016a; 2016b) examined the influence of the built environment on walkability in one's neighbourhood and found that moving to areas with environments that facilitated walkability led to increases in utilitarian walking and was connected to BMI. For example, men in more walkable neighbourhoods had lower BMI while the opposite was true for less walkable areas with higher BMI. Farkas et al. (2019) conducted a systematic review that examined the relationship between objective measures of the built environment and physical activity. This was the first review that examined Canadian contexts and found that while this is an emerging area in Canada, there appears to be a relationship between the built environment and physical activity behaviours. Christie et al. (2020) performed a systematic review on the associations between the built environment and physical activity among adults with low socioeconomic status (SES). They found that objectively assessed features of the built environment (e.g., street connectivity, greenness, density of destinations, and walkability) were positively associated with physical activity in adults with low SES. This echoes conclusions from other Western countries which provides additional context and weight in these findings.

Within Canada, a few studies have begun to examine the influences of the built environment on different features of populations. For example, Christie et al. (2020) reviewed relationships between the built environment and physical activity in people with low SES. However, generally, there is a dearth of such research. This is certainly true in Canada and to a lesser extent in other countries. One such area where this is particularly true is the military. There is some research from the United States (e.g., Nicosia & Datar, 2018; Tarlov et al., 2019) that examined the role of the built environment in physical activity among adolescents in military families and veterans. A longitudinal study by Nicosia & Datar (2018) found that increases in opportunities for physical activity in the built environment were significantly related to increases in total and vigorous physical activity among adolescents in military families. Tarlov et al. (2019) found that among military veterans, neighbourhood walkability was more beneficial for men aged 30-49 and 50-64, and women aged 20-29 and 30-49. Most (if not all) attempts to address this in the military tend to focus on individual approaches (Malkawi et al., 2018; Thériault et al., 2016). Therefore, by looking at broader higher-level factors, such as the built environment, there is an opportunity to have the built environment help facilitate improvements in physical activity and related health outcomes among military personnel in Canada. More generally, there is also a call for research to address lack of studies involving militaries other than the United States and Europe (Malkawi et al., 2018). From a built environment perspective, the dearth of research relevant to the military presents an exciting opportunity to address a gap in the literature and contribute novel information to those serving our country.

Neighbourhood Built Environments

While there are many different areas of the built environment, most research that examines the connection between the built environment and active living has focused on neighbourhood residential areas (Jansen et al., 2016). In fact, Jansen et al. (2018) reported that people spend a large amount of their time – approximately 60% (McInerney et al., 2016) – in their residential neighbourhood. Neighbourhoods can be defined as "the geographical area […] around the residence of a family [or similar dwelling], delimited by physical characteristics of the environment" (Bonaccorsi et al., 2020, p. 2). In the context of active living and physical activity, this provides a helpful foundation and offers practical and real-world applicability to guide the understanding of the role and influence of neighbourhood built environments.

Generally speaking, there are two approaches to neighbourhood definition: subjective and objective. Subjective or perceived definitions typically describe a neighbourhood that is a 10-to-20-minute walk from a home or even village or community boundaries (Barnett et al., 2017). Objective neighbourhood built environment definitions may include the use of census areas, postal codes, or other administrative tools (Barnett et al., 2017). They also commonly include buffers which delineate neighbourhood areas (e.g., ≤ 250m, 300m, 400-500m, 800-1000m, >1000m), and variable or unfixed buffers. One of the most used approaches is using an approximately 800-1000m area around a participant's home postal code which typically equates to a 10 to 20-minute walk (Hillsdon et al., 2015; Troped et al., 2010). This alignment of one of the most used objective delineations with the most used subjective determinations, according to a systematic review by Barnett et al. (2017), suggests a strong overlap between objective and subjective approaches. Another commonly used practice involves the use of multiple buffers. For example, Hurvitz et al. (2014) used home (< 125m), near (125-1666m), and away (>1666m) designations to determine the relative impact of different built environments. The use of multiple buffers provides an opportunity for additional information and range beyond one delineation which provides greater detail.

The problem or trouble with these approaches lies in the potential variability of neighbourhood built environments. The most common conceptualizations of this variability are urban, rural, or mixed neighbourhoods (Barnett et al., 2017). These neighbourhood definitions are most commonly applicable in urban settings where a 10-to-20-minute walk or 800-1000 m buffer range can provide much information. However, in rural areas these definitions may be less useful. For example, Hillsdon et al. (2015) reported that the distances at which the built environment impacted physical activity was more local or concentrated in urban settings but was greater in further away areas such as rural areas, towns, and those on the urban fringe (e.g., suburbs). In essence, the 800 to 1000m is likely not the most representative range in a rural environment. These discrepancies between different types of settings speaks to a need to address variations in neighbourhood definitions. Definitions of neighbourhood areas by distance-based cut-offs are less likely to depict the extent of built environment influences on physical activity (Hillsdon et al., 2015). As a result, the most appropriate range(s) may vary depending on the study aims and characteristics. One way to approach this is to draw on local knowledge and expertise to inform neighbourhood definition. This approach could begin to reflect more accurately the realities of the types of neighbourhoods being studied. Moreover, a hybrid model of drawing on local expertise while still retaining the use of buffers, for example, may also present an approach that draws on existing literature while beginning to account for different types of neighbourhood built environments.

Further accounting for different types of neighbourhood built environments, additional information at the neighbourhood level may also serve to provide added perspectives. Two such variables are population density and neighbourhood income (a proxy for socioeconomic status). Population density may offer helpful perspectives that can begin to address potential neighbourhood variability and conceptualizations (e.g., urban, rural, or mixed neighbourhoods; Barnett et al., 2017). It is also helpful because of differences found in the built environment and activity levels of people among different population densities (G. C. Liu et al., 2007). For example, several studies have observed that higher density areas (e.g., urban) have more amenities and developed infrastructures that may contribute to increased activity levels (Forsyth et al., 2007; Josey & Moore, 2018; Rodríguez et al., 2005). Studies have also noted different activity levels between rural versus urban settings connected to neighbourhood environments (e.g., presence of sidewalks, streetlights) (G. C. Liu et al., 2007; Wilcox et al., 2000). Likewise, neighbourhood income (i.e., a proxy for SES), could also serve as a helpful source of information shedding light on neighbourhood level characteristics at play. Research has established that neighbourhood socioeconomic status can influence activity levels, after controlling for individual socioeconomic status (R. E. Lee et al., 2007). Moreover, the income of a neighbourhood may offer insight into the environment and types of activity likely to occur. For example, physical activity in lower income (SES) neighbourhoods may be accrued through active transportation (R. E. Lee et al., 2007; Xiao et al., 2019).

These additional neighbourhood level sources of information, along with the built environment contribute a stronger context from which to understand neighbourhood environments and their influence more fully. Additionally, research has also shown that more detailed neighbourhood environment characteristics are related to active living. For example, Rodriguez et al., (2005) and Troped et al., (2010) described evidence showing that attributes of built environments around homes are positively related to physical activity. Hurvitz et al., (2014) indicated a sizeable amount of time was spent in moderate-to-vigorous physical activity (MVPA) in areas near the home (e.g., 833 to 1666m). Total time increased when adding the time spent active in the home area (<125m). MVPA typically occurred beyond the immediate vicinity (i.e., >125m) of the home, and "disproportionately at locations within walking distance of homes" (Hurvitz et al., 2014, p. 185). As a result, they deduced that research focusing on neighbourhood built environments appear to be appropriately targeting environments that support active living.

Similar findings were also noted when including light physical activity (LPA) with MVPA. Jansen et al. (2018) found significant "associations between objective neighbourhood characteristics and neighbourhood-based LPA and MVPA" (p. 4) which aligns with overall active living. These findings held true even when adjusted for individual factors including attitudes about physical activity. Jansen et al. (2018) described that this helps to account for selection bias when choosing a neighbourhood and may point to a causal mechanism underlying these associations. A systematic review by Barnett et al. (2017) and an analysis of several primary studies by Sallis et al., (2020) also highlighted strong associations and relationships between neighbourhood built environments and physical activity among different populations and countries, further strengthening this evidence base.

Collectively, this body of literature contributes to the case that the neighbourhood built environments, and the general neighbourhood environment, can be linked to an active lifestyle. These promising results also suggest that neighbourhood built environments, across a large scale, could make a helpful contribution to population-level physical activity and health. Several researchers also noted that these associations are meaningfully related to health outcomes (e.g., Hurvitz & Moudon, 2012; Jansen et al., 2018; Sallis et al., 2018, 2020). To better understand how neighbourhood built environment changes can influence active living and subsequently health outcomes, it is helpful to take a broad perspective to understand potential structures and mechanisms. First, as noted in several examples in this section characteristics of the built environment play an important role. In a review of the value of green space Lee et al. (2015) highlighted research on environment characteristics that influence its use, including availability, accessibility, quality, features, attractiveness, and security. While these characteristics refer to green space in Lee et al. (2015), they also appear in research focusing on several areas of the built environment such as those involving sidewalks and cycling infrastructure among many other features (e.g., Barnett et al., 2017; Castillo et al., 2019; Suminski et al., 2008; Sallis et al., 2006). For example, Suminski et al. (2008) noted the importance of access, opportunity, proximity, attractiveness, and safety (security) when examining sidewalks in relation to physical activity. Similar characteristics were also described by Castillo et al. (2019) when expanding bicycle infrastructure. Overall, these characteristics point to attributes that can be targeted in the built environment to guide and inform potential changes to active living.

Second, Lee et al., (2015) also highlights an important distinction between characteristics of the built environment (i.e., green space) and the outcomes such as health benefits from physical activity. Lee et al. (2015) described this distinction as functionality pointing to the activity that occurs in these spaces. In short, they indicated the characteristics influence the functionality which influences the health benefits. In the case of active living, it could be translated as the characteristics of the environment influencing the use of the environment for activities and exercises that lead to health benefits. For the purpose of this dissertation, the importance of this distinction is that it provides further understanding of the mechanisms underlying potential built environment changes to increase active living. Building on the use of environments, Barnett et al. (2017) noted that almost all physical activity in their review was related to active transport or leisure-time (recreational) activity. These findings indicate types of active living pointing to their usage and purpose which helps elucidate the “behavioural pathways through which the built [environment] impacts” physical activity (Barnett et al., 2017, p. 19). This additional consideration helps to highlight functionality by providing a suggestion of the types of activities that occur when an environment is used. These characteristics and functions highlight the underlying mechanisms and their relationship with one another. Importantly, they provide helpful targets and structures to understand potential mechanisms of action that can inform, and guide potential built environment interventions to increase active living.

Built Environment Assessments

Given the aims of this dissertation, this section will focus on built environment assessments connected to active living and physical activity. There are two general approaches to assessing the built environment: subjective and objective. Subjective measures tend to place emphasis on individuals’ perceptions and experiences of their environments and attributes as well as superordinate influences such as culture and beliefs (Barnett et al., 2017; E. Lee & Dean, 2018). These measures often take the form of self-report questionnaires. As a result, assessments of different locations may contribute to different findings based on measurement instead of actual differences in the built environment. However, these experiences and perceptions can play an important role in one’s engagement with the environment in potentially determining the impact of the built environment. A systematic review by Rhodes et al. (2020) outlines the direct and indirect relationship between physical activity and the built environment that aligns with the role of subjective measures, particularly perceptual measures. In short, they describe that individual-level perceptions can function as a mediator between the built environment and physical activity through social cognition (e.g., perceptions). Although there are different pathways in this model (e.g., direct and indirect), this pathway has important implications for built environment research. For example, Lee and Dean (2018) indicated that perceptions of environment walkability are important motivators for engaging in physical activity behaviours. Overall, subjective measures have several advantages including participant accessibility, ease of use, minimal time commitment, and can be relatively low cost. Importantly, they provide insight into an individual's relationship(s) with the built environment in which they live, work, and play. However, this also highlights potential drawbacks including subjective interpretations, rater error, and experiential and cultural bias (Barnett et al., 2017).

Objective measures assess the built environment separately from people and their actions (E. Lee & Dean, 2018; Sallis, 2009; Sallis et al., 2006). These measures can come in different forms; most commonly direct observations, geographic information systems (GIS), and combinations of observations and GIS. First, there are several types of observations including block observations (e.g., Gauvin et al., 2005), random sampling observations (e.g., Howell et al., 2020; Lafontaine et al., 2017), and virtual assessments (e.g., Steinmetz-Wood et al., 2019). Each approach presents its own advantages and disadvantages. Block observations can provide rich and detailed data and information about a built environment. However, they can require significant temporal, financial, and training investment and commitment. For example, Gauvin et al. (2005) used eight raters over one to five months, five days per week. The resources of a given project will largely indicate feasibility. Random or stratified random sampling observations can provide representative data that retains the richness of in-person audits and improves data collection efficiency and capability (Lafontaine et al., 2017). However, it can be based on data that could be outdated and not reflective of current environments (Howell et al., 2020). Like block observations, a significant training investment is likely. Virtual assessments offer improved efficiency and accessibility for data collection in addition to time and cost benefits (Steinmetz-Wood et al., 2019). Machine learning also presents significant opportunities for assessments (L. Liu et al., 2017). However, virtual assessments do not incorporate sensory inputs, such as noise, soundscapes, and scent (Badland et al., 2010; Ben-Joseph et al., 2013; Steinmetz-Wood et al., 2019) and virtual images can change suddenly and unpredictably which leads to time discrepancies and could bias results (Lafontaine et al., 2017).

Second, GIS is “a framework for gathering, managing, and analyzing data” (*What Is GIS?*, n.d.). It integrates many different types of data, analyzes spatial location, and visualizes layers of information using maps. From this, it can reveal “deeper insights into data, such as patterns, relationships, and situations” (*What Is GIS?*, n.d.). GIS can also sample participants, define areas, and organize data, among many other features (Brownson et al., 2009). These systems offer valuable tools, incredible flexibility, and scope for conducting objective measurements. GIS approaches also play an important role in population-level studies that assess the impact of the built environment on health because it can provide analysis over vast areas (Brownson et al., 2009; Nordbø et al., 2018). Potential drawbacks to this approach include potential cost, training, and expertise required to proficiently use GIS.

Third, the combination of GIS and direct observations has enhanced data collection capabilities as well as bolstered its the ease and efficiency (Sallis, 2009). Moreover, GIS software applications and mobile technology advancements have led to increased flexibility and applied field usage. For example, the ability to integrate an observational questionnaire as a GIS feature layer for field use (e.g., Lafontaine et al., 2017). Overall, objective measures have several advantages including type of data as well as benefits to data collection. Additionally, when used in complement with each other, objective and subjective measures can provide rich and detailed information about the built environment (E. Lee & Dean, 2018). In fact, Sallis et al. (2020) reported that assessing built environments, whether by objective measures or self-report measures, produced similar associations with physical activity and health indicators such as weight. A systematic review and meta-analysis by Barnett et al. (2017) noted a very similar split of objective environment (48%) and perceived environment measures (52%). Overall, these findings suggest both types of measures can undoubtedly provide valuable sources of information. However, a recent systematic review noted objective measures were more consistent with the built environment than perceived (self-reported) measures (Christie et al., 2020). Considered together, these review outcomes may point to the notion that both objective and subjective measures are valuable; however, the degree to which they are valuable may depend on the research project objectives, goals, and theoretical framework.

Theoretical Frameworks

Theoretical frameworks facilitate the design and interpretation of research. They delineate key assumptions, define and structure pertinent variables, create hypotheses, and allow for generalization. Theoretical frameworks are superordinate to individual theories and therefore a single framework may contain many theories that share key similarities (Rocco & Plakhotnik, 2009). The following sections detail the major theoretical frameworks of changing active living and physical activity behaviours (Rhodes et al., 2019). Like most sub-fields within psychology, physical activity research is susceptible to the broader research trends within the discipline. Therefore, the following sections will detail a brief history of each framework and a short discussion of some of their strengths and weaknesses before identifying and examining the best approach for this dissertation.

Social Cognitive

The social cognitive framework emerged from a growing sentiment to move beyond the dogma of behaviourism to a cognitive paradigm that considered social learning and motivational processes (Atkinson, 1957; Kerlinger, 1973; Locke, 1968). It assumes that individuals form expectations about potential behavioural outcomes and then act based on the expected value of said expectations. The nature of these expectations depends on the individual social cognitive theory, but generally is concerned with either the prospective outcome of a behaviour or one's ability to complete it (Rhodes, 2017). The social cognitive paradigm was the first framework applied to physical activity (Rosenstock, 1974) and remains a dominant approach today. Its most popular theory, the theory of planned behaviour (Ajzen, 1991), alone has been applied to physical activity in over 100 studies (Downs & Hausenblas, 2005; Hagger et al., 2002; McEachan et al., 2011). In addition to its primacy within the literature, its popularity can likely be attributed to its intuitive premise and the observed correlations between physical activity and many of the framework's variables, like intention and self-efficacy (Bauman et al., 2012; Rhodes et al., 2017, 2019). However, the social cognitive framework is not without its faults. Within the last couple decades substantial criticism has been levied its way and researchers, as a result, have begun to move towards other frameworks. While this shift is prevalent across many sub-disciplines within psychology, there is a growing list of contradictory findings specific to the field of physical activity (Rhodes et al., 2019). These include the small and transient effects of social cognitive interventions on physical activity, the discrepancy between population physical activity levels and population knowledge of its benefits, and the efficacy of rival frameworks (Conn et al., 2011; Hillsdon et al., 2005; Martin et al., 2000; O'Donovan & Shave, 2007; Rebar et al., 2016; Rhodes & de Bruijn, 2013; Sallis et al., 2016). In short, despite the social cognitive framework's popularity its many limitations have begun to loosen its grip on the physical activity discipline.

Humanistic

Like early social cognitive theorists, the humanistic framework emerged from a growing desire to move beyond behaviourism. Humanistic theorists argued that human behaviour derived not from mere stimuli responses but instead from an individual's innate desire to develop and grow, a process often called self-actualisation (Goldstein, 1995; Maslow, 1943; Rogers, 1995). Self-determination theory is the most common humanistic theory applied to physical activity. It is comprised of five mini theories that examine the effect of various factors (e.g., individual differences, the environment, goal type, and the innate tendencies and needs of individuals) on human motivation (Deci & Ryan, 2000, 2004). Self-determination theory research has seen substantial growth within the field of physical activity. For example, a systematic review identified 66 studies that utilized the framework, with 53 of the included articles having been published within 5 years of the review (Teixeira et al., 2012). This boom in popularity can likely be attributed to recent empirical support and the cost effectiveness of potential interventions. Key framework variables, like feelings of autonomy, competence, and intrinsic motivation, have demonstrated positive correlations with physical activity in a variety of samples and settings.

While the majority of studies within the literature utilize non-experimental research designs, similar positive outcomes have been observed within the few present experimental studies, (Fortier et al., 2007; Silva et al., 2010; Teixeira et al., 2012). Research has even shown positive results of group-level interventions when training group exercise leaders (Cheon et al., 2012; Ntoumanis et al., 2017). While recent research has highlighted possible theoretical shortcomings (e.g., Sheldon, 2011; Sheldon et al., 2001; Sheldon & Lyubomirsky, 2012; Sylvester et al., 2016), given its growth and the mounting criticism surrounding the social cognitive framework, the humanistic framework seems poised to become the dominant individual level framework within the discipline.

Dual Process

The dual process framework has a long history. While its ultimate origins likely stem from William James, the modern incarnation of the framework can be traced to judgement and decision-making research in the 1970s and 1980s (e.g., J. S. B. Evans, 1989; Wason & Evans, 1974). Since then, the framework has grown substantially in popularity (Barbey & Sloman, 2007; J. S. B. Evans, 2007; J. S. B. Evans & Over, 2013; Kahneman, 2013; Sloman, 1996; K. Stanovich, 2011; K. E. Stanovich & West, 1997) and has been applied to a variety of subdisciplines from learning (e.g., Dienes & Perner, 1999; Reber, 1996; Sun et al., 2005) to social cognition (e.g., Chaiken & Trope, 1999; Epstein, 1994; Kruglanski & Orehek, 2007; Smith & DeCoster, 2000). At their most basic, dual process theories categorize individual level determinants of behaviour as either implicit (i.e., automatic) or explicit (i.e., controlled) (Rebar et al., 2016; Williams & Evans, 2014). While individual theories differ on how these systems are exactly defined and interact, most adopt a default-interventionist perspective whereby individuals are thought to act in line with their non-conscious (implicit) determinants unless sufficient conscious (explicit) resources are mobilized against them (J. St. B. T. Evans & Stanovich, 2013; Strack & Deutsch, 2004). The dual process framework is arguably the least popular of the four major frameworks with a recent 2016 systematic review, identifying only 52 studies (regardless of theory) applying the framework to physical activity (Rebar et al., 2016). Its relative unpopularity is likely linked to its lack of novelty and plethora of methodological issues. Studies applying the paradigm often use variables from other frameworks, most notably the social cognitive framework, when defining explicit determinants of behaviour (Rebar et al., 2016). This suggests that the only truly novel contribution the framework offers is its use of implicit measures which are commonly conceptualised as either habits or automatic evaluations (Rebar et al., 2016; Williams & Evans, 2014). Aggregate work has shown that both measures exhibit positive correlations with physical activity, though only the former are above minuscule levels (Chevance et al., 2019; Gardner et al., 2011; Rebar et al., 2016). Nonetheless, the inclusion of implicit determinants helps explain the link between past and present physical activity that previous frameworks could not account for. Despite this it is unclear if the dual process framework represents an improvement of other individual level frameworks. Recent research has questioned the existence of two qualitatively different cognitive states preferring a continuum instead (Melnikoff & Bargh, 2018) and criticized the validity of commonly used implicit measures; specifically, the two-choice timed tasks (e.g., De Houwer et al., 2009; Fiedler et al., 2006) and self-report questionnaires. It remains to be seen if future studies will rectify these issues and increase the framework's popularity within the discipline.

Socioecological

Though its roots can be traced to earlier theorists, most notably Lewin (1951) and Barker (1968), contemporary socioecological research largely stems from Bronfenbrenner's (1979) seminal work. The theory's premise of interacting with environmental spheres of influence spanning from the individual to the level of local and federal policy remains practically unchanged within modern applications of the framework (McLeroy et al., 1988; Stokols, 1992). Unlike other major frameworks, the socioecological model is completely compatible with any individual-level approaches to physical activity, as it primarily focuses on individuals within a larger environmental context (Sallis et al., 2015; Sniehotta et al., 2017). Similarly, despite the framework not exclusively endorsing environmental explanations for physical activity, the dearth of other macro-level frameworks within the discipline has made the social ecological model almost synonymous with them. This theoretical gap is likely one of the major explanations for the socioecological model's growing popularity. Mimicking a trend found in public health more generally, research applying the socioecological framework to physical activity has increased dramatically with over 30% of all physical activity studies featuring at least one environmental variable in the early 2000s (Rhodes & Nasuti, 2011). These and other studies demonstrate a link between physical activity and environmental variables. However, comparing the effect sizes of individual and environmental level factors suggest that the latter play a smaller role (approx. β = 0.05 to 0.30) than the former (approx. β = 0.20 to 0.50) (Giles-Corti & Donovan, 2002; McCormack et al., 2013; McNeill et al., 2006; Rhodes et al., 2006, 2018; Sallis, Saelens, et al., 2005). These findings by no means refute the socioecological model but highlight a potential concern. However, even a small effect at the environmental level can have the ability to affect many people. Overall, given the lack of other macro-level frameworks, its growing popularity, and its complementary nature with individual-level approaches, the socioecological model is positioned to remain a dominant framework for years to come. The socioecological model provides a broad understanding to physical activity and active living that allows for the possibility of larger scale approaches and interventions by organizations, governments, or other entities.

Theoretical Fit

All these frameworks outline important contributions; however, their value differs depending on the research objectives. Considering the aims and goals of this dissertation to explore the relationship between the built environment and active living there is one framework that best meets the needs of these studies and situates them within appropriate contexts: the socioecological framework. From a socioecological perspective, active living and physical activity "is shaped by complex and dynamic interrelations between individual, social, and environmental factors" (Barnett et al., 2017, p. 2; Sallis et al., 2006; Stokols, 1992). This framework highlights this dissertation's approach and novel contributions to the CAF. Furthermore, CFMWS (e.g., Directorate of Fitness) has used the socioecological model since 2015 to frame its activities and initiatives, including their physical performance strategy (Canadian Forces Morale and Welfare Services, 2018).

The CAF has traditionally employed individual-level approaches and findings from the Health and Lifestyle Information Survey have noted some concerning trends amongst their personnel (Born et al., 2009; Franz, 2015; Thériault et al., 2016). The potential consequences of these trends on the health and performance of CAF personnel warrant research attention. Seminal work by Rose (2008) suggests that preventative measures (or interventions) that focus on individuals, may offer benefits to those individuals, but have less of an impact among the total population. This sentiment is echoed by Sallis et al. who state, “any expectation that programs with moderate and temporary effect that reach small numbers of people will create population-wide increases in physical activity is unreasonable” (2006, p. 299). Research suggests population-based approaches may prove to be more successful at affecting meaningful change for more people (Rose et al., 2008; Sallis et al., 2006). This can be attributed to population approaches attempting to change the contextual conditions of risk (i.e., policy, social norms, environments) to change the distribution of risk in populations (Ahern et al., 2008; Frohlich, 2014; Rose et al., 2008). This provides an alternative approach to typical methods used in the CAF and is well supported by a socioecological framework. From a population perspective, the built environment is a common and consistent element of environments. By examining the built environment it also offers significant public health value because people are regularly exposed to it (Barnett et al., 2017). Applied to the military, this can facilitate a more comprehensive understanding of the relationship of built environment and active living among CAF personnel.

Sallis et al., (2006) provided an ecological model of active living that provides additional context that is highly relevant to the current project. This model provides a framework that assumes that environmental changes can lead to individual changes, such as improving active living and physical activity levels. It highlights and conceptualizes active living within a socioecological approach that is congruent with Bronfenbrenner’s framework. As a result, it continues to be highly compatible with individual-level approaches. This compatibility speaks to the previously mentioned popularity and the potential for future research that contextualizes factors from a holistic and multi-level perspective (Devís-Devís et al., 2015; Krenn et al., 2011; Sallis, 2009).

Sallis et al. (2006) outline the different levels of the model, including intrapersonal, perceived environment, behavioral, behavioral settings, and policy environment. The intrapersonal level involves personal factors including family situation, biological, psychological, and demographic characteristics. Perceived environment focuses on one's perception of their environment rather than objective measures of the environment. These include factors such as perceived safety, accessibility, convenience, crime, and comfort. The behaviour level incorporates the four domains of active living. It consists of active living: active recreation, active transport, occupational activities, household activities (Sallis et al., 2006). The behaviour settings level corresponds to the types of active living and includes environments such as neighbourhoods, recreational, home, school, workplace, and information during transport (e.g., safety signage). In other words, it is the physical context of the place where the behaviour is done (Sallis, 2009). Finally, the policy environment includes several different components such as, zoning codes, development regulations, transport investment and regulations, public recreation policies, park policies, and school zone regulations, among others (Sallis et al., 2006). The natural environment, information environment, and social cultural environment are also noted. Please see Appendix A for this model.

This dissertation focuses on the behaviour and behaviour setting levels of this model. Regarding behaviours (e.g., active living), the active recreation and active transport domains most strongly align with the aim of this research. Residential neighbourhood built environments are the area of focus at the behavioural settings level. This dissertation is composed of two studies. From a theoretical framework perspective, Study 1 focuses on the behavioural settings level; specifically, residential neighbourhoods where CAF personnel live. Study 2 explores the relationship between the behaviour and behaviour setting levels via CAF personnel.

Gaps in the Literature

Considered together these areas outline gaps in the literature. First, there has been a growth in built environment research since 2000 (Sallis, 2009). This also applies to Canada to some extent and is notable by recent research from Frank et al. (2019), Wasfi et al., (2016a; 2016b), Farkas et al. (2019), Christie et al. (2020), and others. However, research from other countries is not always relevant in Canada because of differences in various factors including economic and social policy, SES and poverty distribution, population density, and cars per capita (Christie et al., 2020; Oreopoulos, 2008; Pucher & Buehler, 2006). As a result, there is still considerable room to grow and information to glean about the built environment in Canadian contexts. This is particularly true in relationship to specific populations in Canada, such as CAF personnel. Research from other countries, notably the United States, has explored the role of the built environment on physical activity to varying degrees with military family members, personnel, and/or veterans (e.g., Datar et al., 2015; Nicosia & Datar, 2018; Tarlov et al., 2019). However, based on the literature review and consultations with CAF team members in health promotion and human performance, there have been no Canadian studies that examine the relationship between the built environment and active living among CAF personnel.

Research focusing on the built environment and active living among Canadian military personnel addresses additional gaps and calls to action in the literature. First, a systematic review by Malkawi et al. (2018) identified a need for research that focuses on non-American and non-European militaries. Second, there is a need for alternatives to individual-level approaches that are common among policy and programming that aim to improve concerning health trends and related health outcomes (e.g., Malkawi et al., 2018; Thériault et al., 2016). The built environment potentially provides an alternative approach from a population-based perspective with strong research backing to meaningfully address and contribute to this need (Rose et al., 2008; Sallis et al., 2006).

Objectives & Hypotheses

The overarching objectives of this dissertation are to explore the built environments where CAF personnel live and assess the relationship between the built environment and overall physical activity, also known as active living. The dissertation strove to contribute novel evidence about and for the CAF while also addressing gaps in the literature involving military research, Canadian built environment studies, and different approaches to address physical activity levels in the military.

It was guided by the following research questions: First, is the built environment where CAF personnel live related to their physical activity levels? Second, if so, what features of the built environment appear to be related to active living? We hypothesized that the built environment may be related the physical activity levels of CAF personnel. If there is a relationship, we further hypothesized that it would be because of built environment features such as environmental supports, appeal, and opportunities for physical activity.

Two studies were conducted to investigate and address these research objectives. The first study (chapter two) assesses the built environment where CAF personnel live across Canada using an initial version of a built environment assessment tool developed with and for the CAF. The second study (chapter three) examines the relationship between the built environment where CAF personnel live and their physical activity levels.

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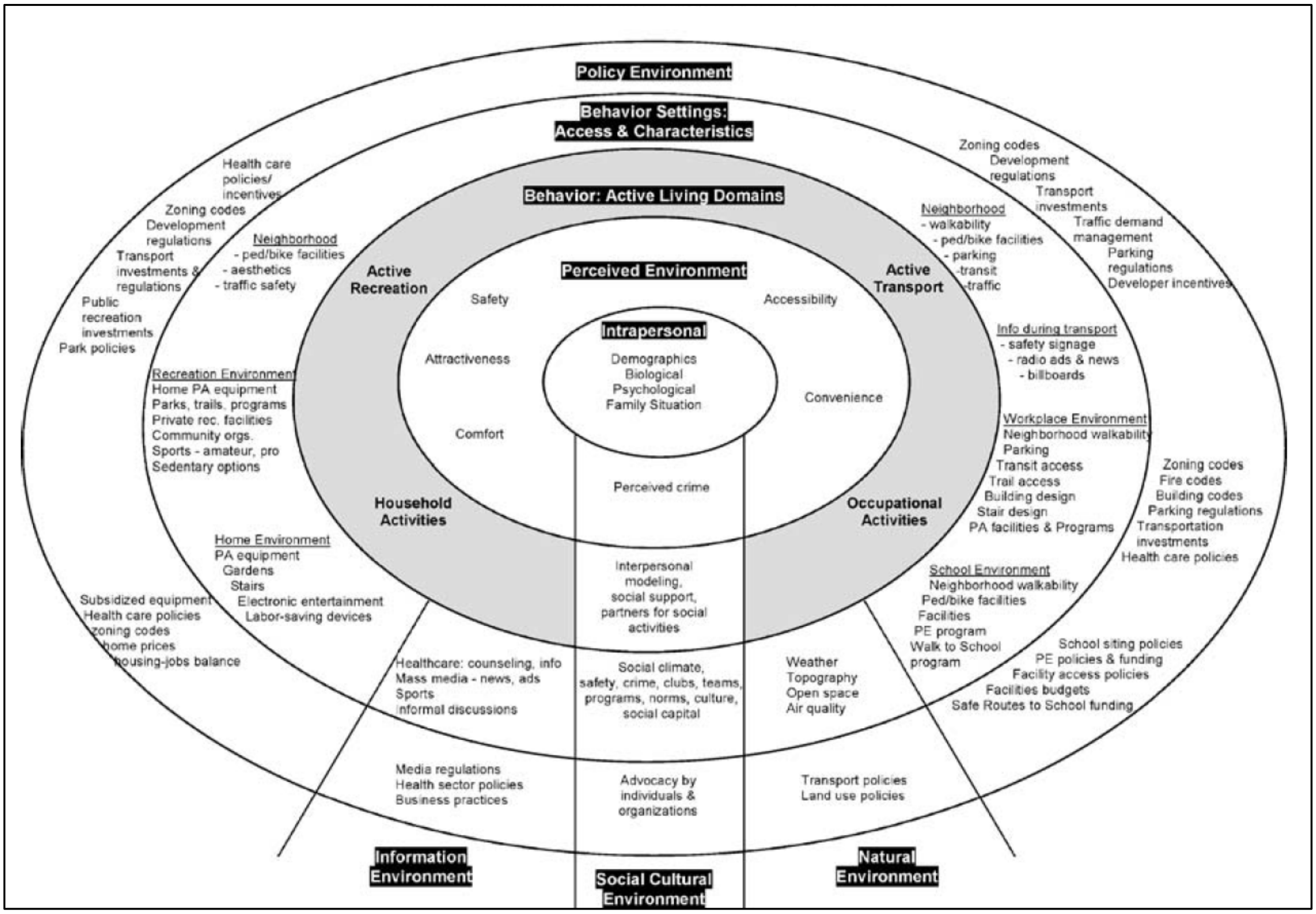
Appendix A

Ecological Model of Four Domains of Active Living



Note. A detailed overview of Sallis et al. (2006) ecological model of active living.

Please Note

The following two chapters (Chapter 2: Study 1 and Chapter 3: Study 2) are intended as publications.

Therefore, there will be some repetition in the content and materials covered in these chapters.

Chapter 2 Study 1:

Examining the Neighbourhood Built Environments of Canadian Armed Forces Personnel

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Abstract

The built environment has been shown to be related to active living and has the potential to affect many people. However, to properly explore this relationship among Canadian Armed Forces (CAF) personnel, it is important to first examine the built environment where CAF personnel live. Study 1 had two objectives. The first was to develop an observational built environment scale with and for the CAF. Second, we aimed to assess the built environments where CAF personnel live using that scale. Using a collaborative approach with the CAF the Forces Environments for Active Living (FEAL) scale was developed. Analyses found a three-factor solution: active living infrastructure, neighbourhood streetscape, and aesthetics. These three factors had good-to-strong psychometric properties. Field use highlighted features of the neighbourhood built environments including active living infrastructure representing an area for improvement while neighbourhood streetscape and aesthetics were generally areas of strength. The findings of this study aligned with the literature and provided insights about the environments where CAF personnel tend to live.

Introduction

Canadian Armed Forces (CAF) personnel “[are expected to be] deployable at any time and therefore must be healthy and physically fit to be successful in all missions and operations” (Franz, 2015, p. 6). However, the Health and Lifestyle Information Survey reported concerning decreases in overall activity levels between 2004-2009 among certain CAF populations, with slight improvements leading up to 2014 (Thériault et al., 2016). Specifically, sedentary behavior among active personnel (especially those who were young and male) increased by 6.35 hours/week. Decreased physical activity is associated with obesity (Gilmour, 2007; Warburton et al., 2006) and a risk factor for several illnesses including cardiovascular disease, cancer, diabetes, hypertension, osteoporosis, and depression (Colley et al., 2019; Maffetone & Laursen, 2020; Tremblay et al., 2010). The Health and Lifestyle Information Survey highlights increasing rates of sedentary behaviors, pointing to a need to consider alternative approaches to support active living and facilitate its benefits in the CAF.

This study is the first part of a larger project; the overarching objective of this project was to assess the relationship between the neighbourhood built environment and active living where CAF personnel live across seven bases in Canada. A review of the literature did not reveal any built environment assessments designed with and for the military. Therefore, in collaboration with the CAF, we developed our own such assessment. This paper describes the development of the Forces Environments for Active Living (FEAL) scale and its results from field use.

The Built Environment

The built environment is defined as “the physical space of the environment which is human-made or modifiable and where people live and carry out their daily activities” and includes neighbourhoods, workplaces, park areas, schools, and transportation systems (Bonaccorsi et al., 2020, p. 2; Jansen et al., 2016; Leyden, 2003). It has been associated with physical activity, crime, mood, and social interaction, among others (e.g., Barnett et al., 2017; Evans, 2003; Frank et al., 2006; Leyden, 2003; Sallis et al., 2020; Sampson et al., 1997). This study is built upon the premise that by understanding and contributing to improvements to the built environment where CAF personnel live, active living may increase and potentially lead to improvements in overall activity and associated indicators (i.e., obesity and sedentary time).

The Built Environment and Active Living

While there have been numerous studies exploring the relationship between the built environment and active living among different populations (Frank et al., 2006; Sallis et al., 2020; Wasfi et al., 2016) there has been less focus on this among military personnel. This is important because there are certain subpopulations (e.g., military, first responders) in which physical activity is required which differentiates them from other populations. Therefore, the built environment can be an added level or source of support. A handful of studies appear to have assessed the relationship of the built environment to active living in military populations. A longitudinal study found that increases in opportunities for physical activity in the built environment were significantly related to increases in total and vigorous physical activity among adolescents in military families (Nicosia & Datar, 2018). Similarly, research found that association between neighbourhood walkability and BMI among military veterans was more beneficial for men aged 30-49 and 50-64, and women aged 20-29 and 30-49 (Tarlov et al., 2019). Both studies were conducted in the United States, pointing to a need for more research involving militaries from other countries (Malkawi et al., 2018).

Assessing the Built Environment

Much like previous research, this study utilizes objective (i.e., direct observational) measures designed to assess the built environment. While subjective (i.e., self-report) measures emphasize individuals' perceptions and experiences of their environments (Lee & Dean, 2018), objective measures assess the built environment separately from people and their actions (Sallis, 2009; Sallis et al., 2006). Theoretically, the complementary use of both provides the richest information, but this is not always feasible in population-based data collection. In the current study, a direct observation approach was selected. This approach facilitates the collection of reliable, detailed environmental and spatial feature information (Frank et al., 2019). It also mitigates the loss of potential data that may occur through not being present in a location (e.g., noise, sound, scent, details) as may be the case in virtual assessments. The combination of direct observations with GIS and mobile technology has enhanced data collection capabilities as well as bolstered its the ease and efficiency making it more feasible for researchers to employ (Sallis, 2009; Lafontaine et al., 2017. This approach also provides a solid foundation for the integration of health-related data to evaluate the impact of environmental attributes. Additionally, logistical support from military Health Promotion Delivery partners also provided an opportunity directly observe locations that aligned with the study objectives and resources.

Goals

This study is part of a larger project on the built environment and active living of military personnel. In response to a paucity of appropriate measures, we developed a scale to evaluate the built environment potential for active living on and around military bases: the Forces Environments for Active Living (FEAL) scale.

This paper reports on the development of the FEAL scale. It was developed in collaboration with the Canadian Forces Morale and Welfare Services (CFMWS) Health Promotion team who facilitated data collection both on- and off-base where military personnel live. To the best of our knowledge, this is the first study of its kind in which CAF personnel were involved in the development and initial implementation of a measure designed to assess and evaluate the built environment from a Canadian military perspective. First, the development, content validation, inter-rater reliability, factor analysis, and internal consistency of the scale will be described and reported. Second, the outcomes from built environment audits will be shared.

Methods

The FEAL scale is a 20-item observational measure for use by trained raters. Each item is scored using a five-point Likert scale. An accompanying codebook was developed to guide and train raters (Appendix A).

In this study, seven CAF base locations that included all three branches of the military (Army, Navy, and Air Force) were selected across Canada for assessment. These locations were selected based on Project HR-BASE. Project HR-BASE a study from the Directorate of Fitness at CFMWS that aimed to assess the efficacy of the CAF Fitness Strategy by assessing physical activity, sleep duration, and quality of recovery and fatigue. The seven base locations were selected in Project HR-BASE because of their command (e.g., branch representativeness) and operational (versus training) orientation. These locations were then used in the current study because of logistical considerations given the use of secondary data in Study Two (see Chapter 3).

Scale Development

Stage one comprised a review of measures for items to include in the new scale. This process was conducted by the principal investigator with input from collaborators in academia and the military with knowledge in measurement, psychometrics, population health, and active living. There were three main collaborators from the military (two primary and one occasional) and two main collaborators from academia at this stage. Potential items for the scale were selected based on general accessibility of the scale (e.g., available and accessible to use), fit with proposed sampling approach (i.e., direct observation), psychometric properties (e.g., strong reliability and validity), and potential relevancy and applicability to the CAF (e.g., meaningful to where CAF personnel tend to live). A list of 49 items from four different scales was generated.

The four scales used to generate items were the Ottawa Neighbourhood Study Aesthetics scale and Walkability scales, the Rural Active Living Assessment tool, and the Neighbourhood Active Living Potential scale (Gauvin et al., 2005; Ottawa Neighbourhood Study 2011a; Ottawa Neighbourhood Study 2011b; Hartley et al., 2009). These scales (and items) were accessible and included accompanying resource documents. The four scales also reported good-to-strong psychometric properties (Gauvin et al., 2005; Lafontaine et al., 2017; Ottawa Neighbourhood Study 2011a; Yousefian et al., 2010).

Content Validation

In Stage Two, the 49 items were compiled and used in a content validation questionnaire to gain input from experts in the field. Experts were defined as someone who conducts research in the area of the built environment and health. Experts were asked to rate the relevance of each item on a five-point Likert rating scale (0 to 5) that also included a "don't know" option (Appendix B). A space for written feedback was provided but not required. The content validation questionnaire was sent to 19 experts comprised of representatives from academia in Canada and the United States, the government (e.g., public health, epidemiology), and the military (commanding officers of the Army, Navy, and Air Force).

We received feedback from 11 experts for a 58% response rate. One response was excluded due to incorrect form completion, bringing the total number of usable responses to 10. Respondents comprised researchers working at Health Canada (3), the Canadian Armed Forces (2), and in academia in Canada and the U.S. (5).

In Stage Three, a cut-off of 3.02 (1 standard deviation above the mean) out of a possible 5 was used to identify items for retention. Instances of written feedback were also taken into consideration. For example, items in which concept or content overlap was identified, or when items were noted as important, but potentially beyond the scope of the current study. Based on this, nineteen items were removed. This left a total of 30 items from the initial 49, creating an initial version of the scale. Appendix C provides an overview of the initial pool of items along with their rating score and an indicator of the feedback and comments from the 10 expert responses.

Phase One: Preliminary Testing

Preliminary testing of the scale was conducted during July and August 2018 at a former CAF base in Ottawa, Ontario. Locations were randomly selected to represent data collection points on and around the base. Four neighbourhood areas were selected along with three residential neighbourhood areas in a different location. Audit points 100m in diameter known as "buffer zones" were randomly selected based on residential housing and street data available via Statistics Canada. A total of six audit locations were used per neighbourhood. The principal investigator and the CFWMS Health Promotion Delivery Manager were the primary raters involved in testing.

Modifications and improvements were made to items (e.g., wording, descriptions) based on rater feedback and psychometric evidence. Intra-class correlation coefficients (ICC) were used to assess interrater reliability (Hallgren, 2012).

Phase Two: Field Study

For each of the seven military bases, ten custom neighbourhoods where CAF personnel were most likely to live were defined and selected by a local committee. Most neighbourhoods were off base, while one or two at each location were on base. The local committees included a Health Promotion manager, a Canadian Forces Housing Agency (CFHA) representative, and a local real estate agent who works with military personnel This approach mitigates risk by drawing on an averaged knowledge base rather than relying on one person. Five audit points, 100m in diameter, within each of the neighbourhoods were randomly generated using residential housing and street data packages available from Statistics Canada using the ArcGIS online website and software (*ArcGIS Online*, 2021; *ArcGIS Pro*, 2020). Prior research has found this overall approach to be representative of a neighbourhood area when compared to block-face observations (e.g., Lafontaine et al., 2017). This approach was important because it maintains the richness of in-person audits while keeping temporal and financial resources minimal, which was valuable in the current project. Additionally, the use of Apple iPads and GIS Kit Pro app by

GARAFA contributed to temporal efficiency of data collection (Kennedy et al., 2014; Ploeger et al., 2016). Only two raters were required for this study. The same two raters described above were able to visit 10 neighbourhoods at each of the seven locations across Canada within the available resources.

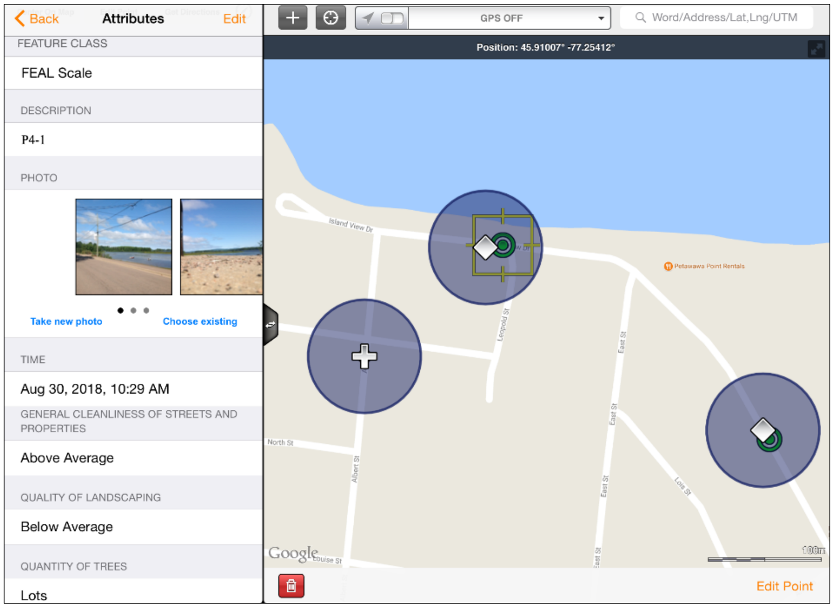
Built environment audits involved the following locations: CFB Trenton (Air Force), CFB North Bay (Air Force), CFB Comox (Air Force), CFB Petawawa (Army), CFB Kingston (Army), CFB Gagetown (Army), and CFB Esquimalt (Navy). Data collection was completed between August 20 and September 21, 2018. Appendix D provides an image of audit locations (inset map) and neighbourhood examples at CFB Esquimalt.

Materials

We used Apple iPad 2 + cellular device for data collection because it contains a hardware-based GPS receiver required to record positions of field audit points without needing an internet connection. We also used GIS Kit Pro by GARAFA software for mobile mapping and data collection. The GIS Kit application is a mobile Geographic Information System (GIS) software that combines data management with a mapping engine. It was able to cache Google Maps and satellite imagery along with its GPS navigator. The FEAL scale itself was entered into the GIS Kit application as a feature class (Figure 1).

Figure 1

Screenshot of the FEAL Scale in GIS Kit Application



Note. This figure provides an example of the FEAL scale in the GIS Kit application on the Apple iPad device. To the centre and right, it shows a map image with the audit location centroid (white squares) within the 100m buffer zones (navy blue). The buffer zones represented the boundaries within which raters would audit. The "+" sign within a buffer zone represents an extra audit point that was added as backup. The green target symbol represents the FEAL scale feature class point from that location. Once it is placed, it opened the FEAL scale in the GIS Kit as seen on the left of the figure. This figure shows the description, the ability to take photos, the time and date, and scale items and response options (e.g., above average was a selected response).

Data Analysis

Interrater Reliability

There were two raters that completed each audit point at the same timepoint. Therefore, interrater reliability (IRR) was assessed using a two-way, mixed, consistency, average-measures intraclass correlation coefficient (ICC; (Hallgren, 2012; McGraw & Wong, 1996)). These ICCs were calculated using IBM SPSS Statistics (Version 27).

Neighbourhood Scores

Neighbourhood scores were determined by calculating the average of the two raters' scores for each of the five buffer zone scores in each neighbourhood; then, they were averaged across the five buffer zones (see Figure 1 for buffer zone example). Notably, there were no instances of missing data for the same location between both raters.

Factor Analyses & Internal Consistency

A factor analysis was conducted followed by internal consistency calculations. The factor analysis was completed on the average of the two raters' scores; there were 350 data points, once averaged between the two raters. Three factors were retained from the factor analysis which are referred to as subscales for clarity and consistency with scoring approaches (see below). Please see results section, specifically the factor analysis subsection, for more information.

Built Environment Scores

Using what DiStefano (2009) termed as a non-refined method (e.g., straightforward), we calculated a composite score using the means of each of the three subscales determined from the factor analysis. This approach facilitates comparisons across factors when there are a different number of items in each factor (DiStefano et al., 2009). We aimed to select a scoring method that would be easily replicable and practical to use for those who may not have the training or access to calculate advanced (i.e., refined) scoring methods. A composite score can be more intuitive to interpret for community partners and stakeholders outside of academia.

Overall scores across all bases were similarly calculated using composite score. Scores were also examined between on- and off-base neighbourhoods. These results will be used to examine the relationship between the built environment and active living among CAF personnel.

Results

Interrater Reliability

Preliminary Testing

Intraclass correlation coefficients (ICC) were calculated for each of 30 items across the two raters. ICCs of r = 0.75-1.00 are considered excellent, r = 0.60-0.74 are considered good, r = 0.40-0.59 are considered fair, and scores < 0.40 are considered poor (Hallgren, 2012). We found that 25 items scored in the excellent range and two scored in the good range. One item, intersection safety, was removed due to the small number of intersections. Two additional items concerning accessibility of walking surfaces and adaptations for people with disabilities, were removed for conceptual and practical purposes. Specifically, that following consultations the raters acknowledged that two able-bodied raters with limited training in this area were not the best fit to assess this domain.

Table 1

Reliability of 27 Items from the Preliminary Study

Items	**Intraclass Correlation Coefficient (ICC):**
Gen. Cleanliness of Streets and Properties	0.87
Landscaping	0.93
Quantity Of Trees	0.95
Quality Of Trees	0.69
Sidewalks	0.97
Sidewalk Buffer	0.95
Road Condition	0.83
Defined Street Shoulder	0.96
Upkeep Of Homes	0.93
Pedestrian Safety	0.73
Proximity To Traffic	0.88
Amount Of Street Lights	0.77

Bike Lanes	1.00
Number of People Walking	0.94
Public Amenities	1.00
Variety of Destinations	0.93
Visual Interest	0.75
Transportation System Connections	1.00
Abandoned Buildings	1.00
Unsanctioned Graffiti	1.00
Absence of Visible Substance Use	0.83
Noise Level	0.77
Amount Of Traffic	0.93
Physical Barriers to Walkability	1.00
Topography	0.76
Absence of Threat of Traffic to Cyclists	1.00
Absence of Threat of Traffic to Pedestrians	0.98

Note. 0.75-1.00 = Excellent; 0.60-0.74 = Good; 0.40-0.59 = Fair; < .40 = Poor; (Hallgren, 2012)

Field Study

Intraclass correlation coefficients (ICC) were calculated for each of the 27 items between the two raters from the field study. Results indicated that the ICC for 18 items was excellent, five items were good, two items were fair, and two items were poor. The two items that scored < α = 0.40 were removed from the scale, bringing the total number of items to 25. See Table 1 for the reliability figures.

Table 2

Reliability of 25 Items from the Field Study

Items	Intraclass Correlation Coefficient (ICC):
Amount Of Traffic	0.97
Sidewalk Buffers	0.96
Sidewalks	0.96
Unsanctioned Graffiti	0.94
Number of People Walking	0.93

Public Amenities	0.91
Amount Of Street Lights	0.90
Quantity Of Trees	0.89
Variety of Destinations	0.89
Proximity To Traffic	0.87
Absence of Threat of Traffic to Pedestrians	0.85
Transportation System Connections	0.84
Topography (flatness)	0.81
Landscaping	0.80
Upkeep Of Homes	0.79
Bike Lanes	0.78
Gen. Cleanliness of Streets and Properties	0.76
Absence of Visible Substance Use	0.74
Quality Of Trees	0.73
Defined Street Shoulder	0.68
Road Condition	0.68
Pedestrian Safety	0.68
Noise Level	0.63
Visual Interest	0.46
Absence of Threat of Traffic to Cyclists	0.41

Note. 0.75-1.00 = Excellent; 0.60-0.74 = Good; 0.40-0.59 = Fair; < .40 = Poor; (Hallgren, 2012)

Factor Analysis

Eight items were found to be non-normal when checking the assumption of normality. Five items were transformed using square root transformations and three were removed after the transformations (e.g., square root and logarithmic) did not resolve non-normality. This brought the total number of scale items to 22 items. After an initial analysis, two items with loadings < 0.30 were eliminated, bringing the total to 20 items. One item, topography, that had a score which was close to 0.30 was retained due to relevance.

An unweighted least squares analysis was conducted on 20 items with orthogonal rotation (varimax). The Kaiser-Meyer-Olkin (KMO) measure verified the sampling adequacy for the analysis, KMO = 0.776 ("good"; Hutcheson & Sofroniou, 1999). All KMO values for individual items were above the acceptable limit of 0.5 with the majority (17/20) greater than or equal to 0.67. Bartlett's test of sphericity (X^2 (190) = 1069.74, p < .000), indicated that correlations between items were adequately large to run the analysis. An initial analysis was run to determine factor retention using the scree plot (see Appendix E) and Velicer's minimum average partial analysis to determine the number of factors (Howard, 2016; O'Connor, 2000). Both methods indicated three components which explained 60.79% of the variance explained. Table 2 shows the factor loadings after rotation along with the percentage of variance explained and Cronbach's alpha. The items that load on the same components suggest that factor one represents active living infrastructure, factor two: neighbourhood streetscape, and factor three: aesthetics.

Internal Consistency of Factors

The first and third factors, active living infrastructure and aesthetics, both have high internal consistency reliabilities, Cronbach's α = > 0.80 (α = 0.88 and α = 0.80, respectively). The second factor, neighbourhood streetscape, had a lower but still acceptable Cronbach's α of 0.71.

Table 3

Final Summary of Scores of Subscale Factor Loadings, % of Variance Explained, and Internal Consistency

Items (Factor Loadings)	Subscale 1: Active Living Infrastructure	Subscale 2: Neighbourhood Streetscape	Subscale 3: Aesthetics
Sidewalks	**0.89**	-0.31	0.18
Transportation System Connections	**0.87**	-0.14	0.04
Sidewalk Buffers	**0.86**	-0.38	0.12
Proximity to Traffic	**0.84**	-0.42	0.16
Absence of Threat of Traffic to Pedestrians	**0.84**	-0.37	0.13
Public Amenities	**0.54**	0.20	0.19

Variety of Destinations	**0.53**	0.13	-0.04
Defined Street Shoulder	**0.50**	0.04	0.09
Pedestrian Safety	**0.47**	-0.63	-0.02
Absence of Threat of Traffic to Cyclists	**0.38**	0.32	-0.09
Road Condition	**0.36**	-0.02	0.33
Number of People Walking	**0.34**	-0.11	-0.21
Quantity of Trees	-0.12	**0.88**	0.08
Quality of Trees	-0.13	**0.78**	0.17
Visual Interest	-0.04	**0.49**	0.39
Topography (flatness)	-0.01	**0.29**	0.23
Upkeep of Homes	0.12	0.17	**0.87**
General Cleanliness of Streets and Properties	0.09	0.11	**0.79**
Landscaping	0.27	0.26	**0.74**
Absence of Visible Substance Use	-0.10	-0.34	**0.44**
% of Variance Explained	31.93	18.71	10.16
α	0.88	0.71	0.80

Note. Bolded figures indicate factor loadings above the 0.30 cut-off. % of variance explained and internal consistency (α) headings provide additional information for the subscale loadings.

Built Environment Scores

Across all neighbourhoods, the scores were approximately normally distributed. For all scores, higher was considered better or more favourable. Subscale 1, active living infrastructure, had a mean score of 1.75 out of 5 and a SD of 0.35. Subscale 2, neighbourhood streetscape, had a mean score of 4.05 out of 5 and a SD of 0.30. Subscale 3, aesthetics, had a mean score of 3.59 out of 5 and a SD of 0.29. For additional context, Appendix F shows the means and standard deviations of each item on the FEAL scale. Off-base residential neighbourhood scores represent 84% (or 59) of the neighbourhood scores while on-base residential neighbourhood scores represent 16% (or 11). Additional analyses of on and off base group differences (e.g., ANOVA) found no difference between groups for Subscale 1[$F(1,68) = 1.09$, $p = 0.300$] but indicated a significant difference between groups on Subscale 2 [$F(1, 68) = 4.80$, $p = 0.032$] and Subscale 3

[$F(1, 68) = 4.12$, $p = 0.046$]. However, the large difference between the number of on and off base neighbourhoods suggests these differences should be interpreted cautiously.

Discussion

In collaboration with the CAF, we developed an initial version of the FEAL scale for use in CAF contexts and reported on its findings in the built environment. Guided by the socioecological model, this study operates within the ecological model of active living (Sallis et al., 2006) and incorporates a tenet of participatory action research, which suggests that "those being researched should be involved in the process actively" (Baum et al., 2006, p. 854). The CAF continues to be active collaborators in the applications of this measure.

The results of the factor analysis indicate a three-factor solution: (Subscale 1) active living infrastructure, (Subscale 2) neighbourhood streetscape, and (Subscale 3) aesthetics. A meta-analysis and systematic review identified important environmental attributes connected to active living, including infrastructure and streetscapes (Barnett et al., 2017). Similarly, a recent international study and review highlighted the importance of pedestrian-friendly infrastructure and safety, traffic safety, aesthetics, and destinations, among several others (Bonaccorsi et al., 2020; Sallis et al., 2020). In the following section, we describe each factor and relate it to the extant literature.

Subscale 1: Active Living Infrastructure

This factor refers to both the physical built environment and neighbourhood safety. Thematically, this factor describes the degree to which infrastructure such as public amenities and destinations that support active living is present (Moran et al., 2014; Van Cauwenberg et al., 2016). Factors such as road condition, street shoulder, or sidewalk buffers are included here and can either facilitate or hinder physical activity. Explicit (e.g., traffic) and implied safety (e.g., space) also play key roles in the infrastructure supporting and facilitating active living. For example, proximity to traffic may affect the likelihood of using sidewalks, roads, or street shoulders for physical activity. These components substantiate previous work that has highlighted the connection between pedestrian-friendly infrastructure and active living (Barnett et al., 2017; Bonaccorsi et al., 2020).

Results from field testing identified largely unsatisfactory scores for this subscale, suggesting room for improvement. Analyses indicated no differences between on and off base scores on this subscale. The item assessing road conditions was the highest scoring item in this subscale (i.e., 3.7 out of 5). Cyclist-related built environment infrastructure across all audited neighbourhoods was virtually non-existent; this presents a clear way to improve and provide opportunities to facilitate active living. Similarly, sidewalks and street shoulders, while present in some areas, are absent or minimal in others, potentially contributing to fewer opportunities and willingness to engage in active living. Together these items echo the overall findings that infrastructure that encourages and facilitates active living would likely benefit from improvement across all locations in this study.

Subscale 2: Neighbourhood Streetscape

This factor comprises the quantity and quality of trees, visual interest, and topography. Overall, trees loaded strongly on this factor. Generally, research on exposure to greenspace, such as trees, has found a host of physical and mental benefits (Kardan et al., 2015), most notably in reduction in sedentary leisure time and promotion of physical activity (Humpel et al., 2002;

Kaczynski & Henderson, 2007; Storgaard et al., 2013). Visual interest and topography may also play a similar role. Indeed, researchers posit that more interesting scenery and environments may increase the likelihood of physical activity (King et al., 2000).

Field testing indicated relatively high neighbourhood streetscape scores (i.e., 4.05 on average), suggesting that neighbourhood areas where CAF personnel live are likely to have street-level features that support active living. On average, neighbourhood scores were slightly higher in off-base residential neighbourhoods than on-base (i.e., 4.08 and 3.88 out of 5 respectively); this appeared mostly attributable to the amount and quality of trees. Visual interest and topography are largely the same across neighbourhoods. Overall, military personnel tend to live in neighbourhoods that are visually interesting and have level surfaces, contributing to the likelihood of active living (King et al., 2000; Nguyen et al., 2013).

Subscale 3: Aesthetics

This factor refers to items assessing upkeep of homes, cleanliness of streets and properties, quality of landscaping, and absence of visible substance use. Neighbourhood aesthetics, among other components, have been identified as an important predictor of active living (Cerin et al., 2006; Moran et al., 2014).

Our field study indicated high aesthetics scores, indicating that on- and off-base residential neighbourhoods had appealing and attractive environmental features. Off-base scores were slightly higher in most but not all cases but should be interpreted with caution given the smaller sample size for on-base neighbourhoods. These neighbourhoods and their homes and properties are generally clean and well maintained and have little to no signs of disorder.

Notably, on-base neighbourhood landscaping scores suggest an area of improvement for these neighbourhoods. Overall, this aligns with previous research findings that aesthetically pleasing features can play an important role in facilitating active living (Barnett et al., 2017; Cerin et al., 2006; King et al., 2000; Sallis et al., 2020).

Strengths and Limitations

This study is the first of its kind in which a measure of built environment features was developed in collaboration with, and for use by, the CAF. By involving the community it is intended to help, the FEAL scale is better equipped to implement meaningful change and adapt to the needs of its participants. Further, by working alongside community partners and researchers, it increases the likelihood of its acceptance and impact. The FEAL is easily administered, is targeted to the communities it serves including all branches of the military, and demonstrates robust psychometric properties and themes that align with previous research.

The findings from this study should also be considered and interpreted within the context of certain limitations. First, it is important to acknowledge that these findings are interpreted through the lens of active living. This is important because decisions made about the built environment in real-world settings typically involve multiple perspectives with different objectives. Planners, developers, and stakeholders make decisions regarding the built environment for a variety of reasons (e.g., organizational policy, zoning, bylaws) and typically not from one perspective. Second, the on-base sample size is smaller compared to off-base; however, this is reflective of the reality of where CAF personnel live. Third, data collection occurred in August and September 2018, making it plausible to generalize these findings to the spring, summer, and fall seasons, but they are likely less generalizable for the winter. The development of winter active living measures (e.g., NEWS-North; Takacs, 2017) speaks to the unique challenges and circumstances presented during the winter. In this study, weather was controlled and accounted for as much as possible by scheduling data collection across the same times and within a relatively short timeframe. The role of weather in active living in different seasons has been identified as an area for future research (Li et al., 2005). Lastly, another area for future research would be to have an established scale evaluate the same locations to compare against the FEAL scale. This would enable the scale to be further strengthened and allow for continued improvement.

Conclusion

This study put forth an initial version of a built environment scale developed in collaboration with the CAF. The findings indicate that active living infrastructure can be improved across all locations to support active living, while neighbourhood streetscape and aesthetics factors are generally areas of strength with certain areas of growth. It is important to note that some of these deficiencies (e.g., cycling infrastructure) are present in most Canadian cities and towns.

From an active living perspective, these results suggest that neighbourhoods where CAF personnel live are not ideally built to support or encourage active lifestyles. By identifying deficient features of the built environment, we provide a wealth of information. The use of the FEAL can help inform policy decisions at various levels, as it is positioned to support meaningful change among CAF communities. Within the CAF, there is opportunity and jurisdiction to implement recommendations in on-base residential neighbourhoods. Furthermore, because a large proportion of these neighbourhoods are off-base, military stakeholders in municipal partnerships may hold significant weight when identifying strengths and weaknesses to community partners.

Overall, the development of the FEAL contributes to important foundational literature on the built environment, contributing to the groundwork for future studies intended to explore and improve military communities at the built environment level. It also provides the preliminary work to explore the actual impact that the built environment has on active living among military personnel.

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Appendix A

Forces Environments for Active Living (FEAL) Codebook

Variable	Scale				
Weather	Take a Photo using the iPad.				
Sidewalks	**Extremely poor**	**Below average**	**Average**	**Above average**	**Excellent**
	x No sidewalk, or very narrow, cracked sidewalk that is too close to traffic to be safe.	x Narrow, cracked, or uneven sidewalks that are in need of repair.	x Level, uncracked sidewalks that are consistent and relatively wide.	x Very wide, well kept sidewalks (pedestrian bridge) or newly laid sidewalks.	x Aesthetically pleasing sidewalks made of brick or stone with nice patterns. Very wide.
Transportation System Connections •Bicycle parking at public transport •Number of routes and stops of public transportation •Vehicle parking accessible to walking routes •Opportunities to take bicycles on public transit •Park and ride stops attached to public transit	**None (no connections)** x No connections or opportunities for connection of different modes of transportation.	**Few** x Few connections or opportunities (mainly 1 type) for different modes of transport or activity.	**Some** x Some connections, opportunities, and options for different modes of transportation (e.g., biking, driving).	**Many** x Many connections and opportunities, routes for different modes of transportation (e.g., walking, biking, driving).	**Lots (of Connections)** x Lots of connections, opportunities, and options (e.g., parking and bike racks at a subway or LRT station).
Sidewalk Buffers	**Extremely poor** x None or deteriorating buffer separating the sidewalk from the road.	**Below average** x Sidewalk buffer is present but, a small space separating sidewalk from the road.	**Average** x A moderate (or average) size space separating the sidewalk from the road.	**Above average** x Large space separating the sidewalk from the road.	**Excellent** x Large space with other barriers to separate road from sidewalk.
Proximity to Traffic	**Very Close** x No sidewalk, and against a wall. Very difficult to separate self from traffic.	**Close** x No sidewalk, but grass to walk on if necessary.	**Moderate** x Sidewalk.	**Far** x Sidewalk and barrier separating traffic from pedestrians.	**Very Far** x Very large sidewalk far from traffic. (Ex: Sparks St. in Ottawa).

Absence of Threat of Traffic to Pedestrians **[reverse score]**	**None (no threats)** x Removed/away from traffic. No threat.	**Few** x Pedestrians separate from traffic with use of space, barriers and/or buffers. Relevant signage or traffic signals may also be present.	**Some** x A defined area (sidewalk) with some separation from traffic and signage, but no barriers.	**Many** x Defined area (sidewalk) with no buffer or barrier from traffic, no signage for pedestrians.	**Lots (Very Threatening)** x No defined area for pedestrians, no barriers, or buffers. Dangerously close to traffic.
Public Amenities e.g., garbage cans, water fountains, pay phones, public lavatories, public benches, recycling centers, etc.	**None** x None.	**Few** x 1-2 public amenities.	**Some** x 3-4 public amenities.	**Many** x 5-6 public amenities.	**Lots** x 7+ public amenities.
Variety of Destinations	**None (homogenous)** x No destinations.	**Few** x Fairly homogenous, few potential destinations (e.g., residential only).	**Some** x Some destinations (e.g., residential/neighbourhood area with nearby park(s).	**Many** x Many potential destinations (e.g., residential, commercial).	**Lots** x Lots of potential destinations (e.g., commercial, small business, residential, parks).
Defined Street Shoulder	**Extremely poor** x Little to no shoulder separating traffic lines from the edge of the road.	**Below average** x Small separation separating traffic lines from the edge of the road.	**Average** x Moderate separation of traffic lines from the edge of the road. Well defined.	**Above average** x Good separation of traffic lines from the edge of the road. Clearly defined.	**Excellent** x Excellent separation with ample space. Very clearly defined.
Absence of Threat of Traffic to Cyclists **[reverse score]**	**None (no threats)** x Away/Removed from traffic.	**Few** x Separate from traffic with a barrier, buffer, and signage.	**Some** x Defined area for cyclists with some barriers, buffers, or signage from traffic.	**Many** x Defined area for cyclists amongst traffic with no buffer or barrier from traffic.	**Lots (Very Threatening)** x No defined areas for cyclists, no barriers, buffers, or signage. Integrated amongst traffic.
Pedestrian Safety	**Extremely poor** x No sidewalk or separation, no crosswalks. Difficult visibility.	**Below average** x Possible walking areas, no crossing lights or barriers, little-to-no signage/demarcations.	**Average** x Sidewalks present, well-defined crosswalks with stop sign or pedestrian lights present and functioning.	**Above average** x Pedestrian crossing signs present, push buttons for lights to change, speed bumps may be present.	**Excellent** x Pedestrians completely separated with wide, well-lit, level pathways.

Road Condition	**Extremely poor** x No road, or unmaintained dirt road.	**Below average** x Gravel road or uneven road with a lot of potholes. Road needs work.	**Average** x Road is fairly even, but not recently paved or painted.	**Above average** x Road has no pot holes, well painted lines, is fairly wide.	**Excellent** x Road is recently paved and painted, very smooth and wide.
Number of People Walking	**None** x 0 pedestrians.	**Few** x 1-4 pedestrians.	**Some** x 5-9 pedestrians.	**Many** x 10-19 pedestrians.	**Lots** x 20+ pedestrians.
Quantity of Trees	**None** x No trees present.	**Few** x Approximately one tree per 2-3 houses.	**Some** x Approximately one tree per house.	**Many** x More than one tree planted at most houses.	**Lots** x 3+ trees per house (or a forest).
Quality of Trees	**Extremely poor** x Dead or dying trees.	**Below average** x Brown leaves, not well taken care of, at risk of dying.	**Average** x Green leaves, may be sparse. Alive and growing. Bark may be peeling.	**Above average** x Tree is very healthy and foliage is pretty dense.	**Excellent** x Very lush trees, healthy bark, may have animal homes in them.
Visual Interest	**Extremely Poor** x No distinguishing architecture, uninteresting, very little (if any) spaces.	**Below Average** x Mostly similar architecture, buildings, and few (if any) spaces. Not very interesting.	**Average** x Some interesting architecture, differences in buildings and spaces.	**Above Average** x Good variety of architecture, mostly different buildings, space for use. Quite interesting.	**Excellent** x Variety of architecture, different buildings, and walk and green spaces. Very interesting.
Topography (flatness) **[reverse score]**	**Level** x Flat (Able to see very far down the street.)	**Fairly level** x Slight slant and/or small bump in the road.	**Moderate** x Moderate slant and/or moderate bump in the road.	**Steep** x Steep hill.	**Very steep** x Very steep hill that is difficult to walk up and down.

Upkeep of Homes (i.e., soffits, downspouts, eaves troughs, siding, windows, roofs, etc.)	**Extremely poor** x Clearly not well tended to, falling apart or rotting. Siding or shingles peeling off.	**Below average** x Patched things up but have not fixed them. Home looks old and falling apart, but safe to live in.	**Average** x Well tended to, nothing falling apart. Not new, but not too old. Not fancy or expensive looking.	**Above average** x In very good condition. Aesthetically pleasing house with extra ammenities such as garage doors,or fancy windows.	**Excellent** x Excellent condition, looks new. Very aesthetically pleasing with lots of extra ammenities.
General Cleanliness of Streets and Properties	**Extremely poor** x A lot of litter and garbage present, possibly smells bad. Street looks neglected.	**Below average** x Plenty of litter or garbage, does not smell though.	**Average** x Seems relatively well taken care of by the residents. Still some noticeable litter.	**Above average** x Clean, very little litter and garbage.	**Excellent** x No litter, extremely clean and well taken care of.
Landscaping	**Extremely poor** x No landscaping, dead grass, dirt paths, fences falling apart. No houses on street are well landscaped.	**Below average** x Grass is browning, but there is some effort put in (eg. a tree or deck). 10% of houses can be well landscaped.	**Average** x Green grass, some trees or gardens, driveway is well tended to. 11-50% of houses are well landscaped.	**Above average** x Nice aesthetics of lawn, good gardens, or nice driveway. Landscaping has lots of effort put in and is well kept up. 51-75% of houses are well landscaped.	**Excellent** x Landscaping is clearly done by a professional and very well maintained. Very nice aesthetics. 76-100% are very well landscaped.
Absence of Visible Substance Use **[reverse score]**	**None** x No evidence of substance abuse.	**Few** x 1-2 indicators of mild abuse; ie. bottles or cigarettes.	**Some** x 3-4 indicators of mild abuse Or 1-2 indicators of more serious abuse, ie. pills, pill bottle.	**Many** x 5+ indicators of mild abuse, i.e., there are bottles all over; Or 3-4 indicators of serious abuse, i.e. pills, drugs, pipes, needles.	**Lots** x 5+ indicators of serious abuse.

Note. Appendix A shows the Forces Environments for Active Living (FEAL) codebook that was developed to help guide and train the raters. The images associated with each rating (“x”) were removed in this document. Please contact the author if you would like additional information about the item images.

Appendix B

Content Validation Questionnaire Document

<u>*Email Text:*</u>

[*Insert title and name*],

I hope this email finds you well. My name is Sean Lafontaine. I am a doctoral student of Dr. Elizabeth Kristjansson at the University of Ottawa. We are working with Dr. Michael Spivock on an exciting new project that focuses on the built environment, active living, and the Canadian military.

I am writing to ask your help with the content validation of the Forces Environment for Active Living scale (FEAL). The FEAL is an observational checklist that will evaluate the active living potential of the built environment on Canadian Armed Forces bases and in nearby neighbourhoods. It will evaluate walkability, aesthetics, disorder, and other aspects of active living potential using selected items from established measures. The items included in the checklist are derived from the Neighbourhood Active Living Potential (NALP) scale, the Ottawa Neighbourhood Study (ONS) Walkability and Aesthetics scales, and the Rural Active Living Assessment tool (RALA). This project is part of my dissertation under the supervision of Dr. Elizabeth Kristjansson in the School of Psychology.

Before the FEAL can be used, we need to evaluate its content validity. The current checklist is quite thorough and at the moment too long for the purpose of this study. The objective of this request is to determine the most relevant items for inclusion in the FEAL by removing those items that are redundant or unnecessary.

We would like to ask you to assess the FEAL by completing the attached checklist. This should take about 15 minutes of your time. Any information will be kept confidential and will not be used to identify you. We are aiming to have responses returned over the next few weeks.

Sincerely,

Sean Lafontaine, Elizabeth Kristjansson, and Michael Spivock

<u>Content Validation Questionnaire</u>

For each of the following items and headings, please rank their perceived importance out of 5 by circling, bolding, or highlighting your choice. Following each item or heading is an area for comment where you may add your comments pertaining to this item or your reasoning for its score.

For future reference, once the items are determined images will be selected that correspond to each of the item ratings in order to facilitate understanding and inter-rater agreement. For a brief example, please see Appendix A. This procedure has been successfully used with the Ottawa Neighbourhood Study Walkability and Aesthetics scales. Once finalized, the scale will be administered using an Apple iPad. Specifically, raters will use the GIS Kit Pro software application allowing raters to collect and store the built environment data digitally. Any questions you may have can be directed to Dr. Elizabeth Kristjansson or Sean Lafontaine.

Please rate the following items and section headings in terms of their importance.

Not at all important	**Not very important**	**Somewhat Important**	**Important**	**Very Important**	**Don't Know**
1	2	3	4	5	DK

<u>Related to Pedestrian Interests</u> 1 2 3 4 5 DK

Comments:

1. **(N) Inclusive of Pedestrians** 1 2 3 4 5 DK

Comments:

2. **(A)Quality of Sidewalks** 1 2 3 4 5 DK

Comments:

3. **(A)Pedestrian Safety** (e.g., lights, signs, sidewalks, etc.) 1 2 3 4 5 DK

Comments:

4. **(N)Street Network Limits Pedestrian Needs** (e.g., no/small sidewalks) 1 2 3 4 5 DK

Comments:

5. **(W)Amount of traffic** 1 2 3 4 5 DK

Comments:

6. **(W)Proximity to traffic** 1 2 3 4 5 DK

Comments:

7. **(W)Amount of street light** 1 2 3 4 5 DK

Comments:

8. **(W)Level of pedestrian friendly infrastructure** 1 2 3 4 5 DK

Comments:

9. **(W)Amount of people walking (related to social)** 1 2 3 4 5 DK

Comments:

10. **(N) Accessibility of path/sidewalk/walking surface for people** 1 2 3 4 5 DK

	with disabilities						
Comments:							
11.	**(N) Are the crossing signals and other signs adapted for people with disabilities**	1	2	3	4	5	DK
Comments:							
12.	**(N) Are the surroundings adapted for people with disabilities**	1	2	3	4	5	DK
Comments:							
13.	**(A)Quality of parked cars**	1	2	3	4	5	DK
Comments:							
14.	**(N) Number of Destinations**	1	2	3	4	5	DK
Comments:							
	Features of the Built/Physical Environment	1	2	3	4	5	DK
Comments:							
15.	**(R) Sidewalk Buffers**	1	2	3	4	5	DK
Comments:							
16.	**(R) Defined Street Shoulder**	1	2	3	4	5	DK
Comments:							
17.	**(N) Variety of Destinations**	1	2	3	4	5	DK
Comments:							
18.	**(N) Street Network Addresses Cyclists Needs**	1	2	3	4	5	DK
Comments:							
19.	**(N) Transportation System Connections**	1	2	3	4	5	DK
Comments:							
20.	**(N) Environmental Stimulus**	1	2	3	4	5	DK
Comments:							
21.	**Visual Interest**	1	2	3	4	5	DK
Comments:							
22.	**(A) General cleanliness of streets and properties**	1	2	3	4	5	DK
Comments:							
23.	**(A) Quality of landscaping**	1	2	3	4	5	DK
Comments:							
24.	**(A) Quantity of trees**	1	2	3	4	5	DK
Comments:							
25.	**(A) Quality of trees**	1	2	3	4	5	DK
Comments:							

26.	**(A) Upkeep of homes (*and buildings*)**	1	2	3	4	5	DK
Comments:							
27.	**(A) House spacing**	1	2	3	4	5	DK
Comments:							
28.	**(A) Quality of fences**	1	2	3	4	5	DK
Comments:							
29.	**(A) Quality of lawns (*Greenspace*)**	1	2	3	4	5	DK
Comments:							
30.	**(A) Quality of road condition**	1	2	3	4	5	DK
Comments:							
31.	**(A) Abandoned buildings**	1	2	3	4	5	DK
Comments:							
32.	**(A) Vacant/undeveloped land**	1	2	3	4	5	DK
Comments:							
33.	**(W) Amount of mixed environmental attributes**	1	2	3	4	5	DK
Comments:							
34.	**(W) Topography (flatness of street – how easy or challenging it is to walk and how far you can see down the street)**	1	2	3	4	5	DK
Comments:							
35.	**(W) General colours of the Environment (buildings only – no trees and plants)**	1	2	3	4	5	DK
Comments:							
36.	**(W) Barriers to walkability**	1	2	3	4	5	DK
Comments:							
37.	**(W) Aesthetics of walking path**	1	2	3	4	5	DK
Comments:							
38.	**(W) Presence and Quality of bike lanes**	1	2	3	4	5	DK
Comments:							
39.	**(W) Public amenities (e.g., garbage cans, water fountains, pay phones, public lavatories, recycling centers)**	1	2	3	4	5	DK
Comments:							
40.	**(W)Thematic consistency of block face**	1	2	3	4	5	DK
Comments:							

41. (W)Amount of street furniture	1	2	3	4	5	DK
Comments:						
<u>Addresses or Highlights Safety Concerns</u>	1	2	3	4	5	DK
Comments:						
42. (W)Intersection safety	1	2	3	4	5	DK
Comments:						
43. (N) Perception of Safety From Crime	1	2	3	4	5	DK
Comments:						
44. (N) Threat of Traffic to Pedestrians	1	2	3	4	5	DK
Comments:						
45. (N) Threat of Traffic to Cyclists	1	2	3	4	5	DK
Comments:						
46. (W)Hiding places	1	2	3	4	5	DK
Comments:						
<u>Physical Disorder</u>	1	2	3	4	5	DK
Comments:						
47. (A) Graffiti	1	2	3	4	5	DK
Comments:						
48. (A) Substance abuse	1	2	3	4	5	DK
Comments:						
49. (A&W) Noise level	1	2	3	4	5	DK
Comments:						

Legend

(N): Neighbourhood Active Living Potential Items (Gauvin et al., 2005)

(A): ONS Aesthetics Scale Items (Lafontaine et al., 2017; Ottawa Neighbourhood Study, 2011a)

(W): ONS Walkability Scale Items (Ottawa Neighbourhood Study, 2011b)

(R): Rural Active Living Assessment Tool Items (Hartley et al., 2009)

Note. This is an example of the content validation questionnaire that was provided to experts to elicit their feedback.

Appendix C

Content Validity Summary

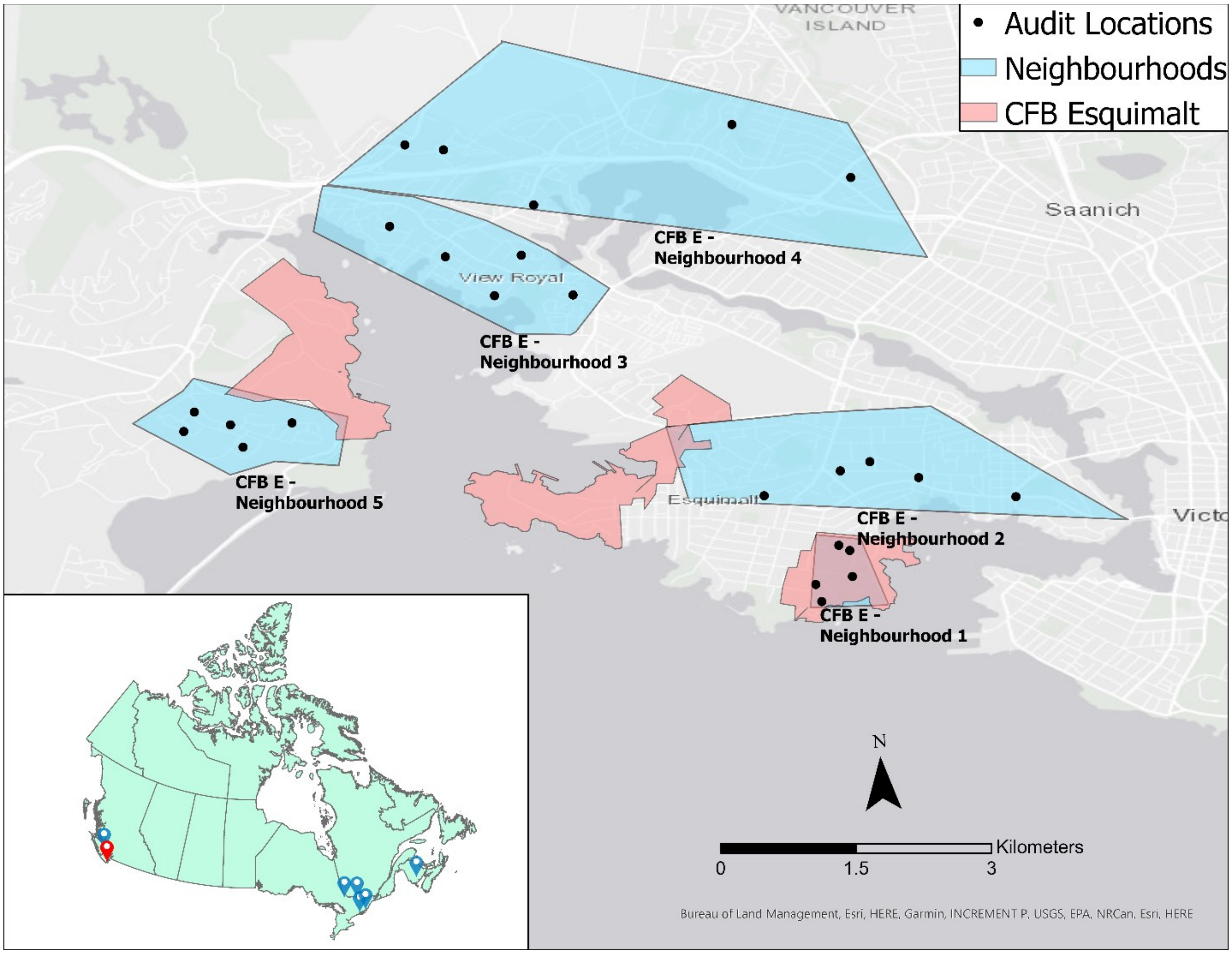
Items	Mean Rating	Feedback/ Comments
Transportation System Connections	4.44	+/-
Quality of bike lanes	4.30	+
Intersection safety	4.22	+/-
Pedestrian safety	4.20	+
Variety of destinations	4.20	+
Crossing signals and signs adapted for PWD	4.20	-
Quantity of trees	4.11	+
Abandoned buildings	4.10	+/-
General cleanliness of streets and properties	4.10	+
Sidewalks	4.10	+
Accessibility of walking surface for PWD	4.10	-
Upkeep of homes	4.00	+
Public amenities	3.90	+
Absence of Threat of Traffic to Pedestrians	3.90	+/-
Defined street shoulder	3.81	+
Overall noise level	3.80	+/-
Landscaping	3.78	+
Proximity to traffic	3.70	+
Absence of Threat of Traffic to Cyclists	3.70	+/-
Absence of Visible Substance Use	3.67	+
Number of people walking	3.60	+/-
Road Condition	3.60	+
Sidewalk buffers	3.56	+/-
Topography (flatness)	3.50	+
Visual Interest	3.50	+/-
Physical Barriers to walkability	3.43	+/-
Amount of streetlights	3.40	+/-
Amount of traffic	3.40	+
Quality of trees	3.22	+/-
Unsanctioned Graffiti	3.22	+/-
Items Removed		
Number of Destinations	4.60	+/-
Perception of Safety from Crime	4.00	-
Street Network Limits Pedestrian Needs	4.00	-

Street Network Addresses Cyclists Needs	3.90	-
Amount of mixed environmental attributes	3.67	-
Aesthetics of walking path	3.63	-
Are the surroundings adapted for PWD?	3.63	-
Level of pedestrian friendly infrastructure	3.63	-
Vacant/undeveloped land	3.50	-
Amount of Street Furniture	3.38	-
Inclusive of Pedestrians	3.00	-
Quality of lawns	3.00	-
General colours of the Environment	2.90	-
Environmental Stimulus	2.83	-
House spacing	2.75	-
Thematic consistency of block face	2.63	-
Quality of fences	2.44	-
Quality of parked cars	2.43	-
Hiding places	2.33	-

Note. This table provides an overview of the content validation feedback from the experts surveyed. It shows the initial 30 items retained as well as the 19 that were removed. For each item, it lists its mean rating score and indicates the nature of the comments and feedback. Considered together the mean ratings and feedback provided helpful context to help determine their fit within the study.

Appendix D

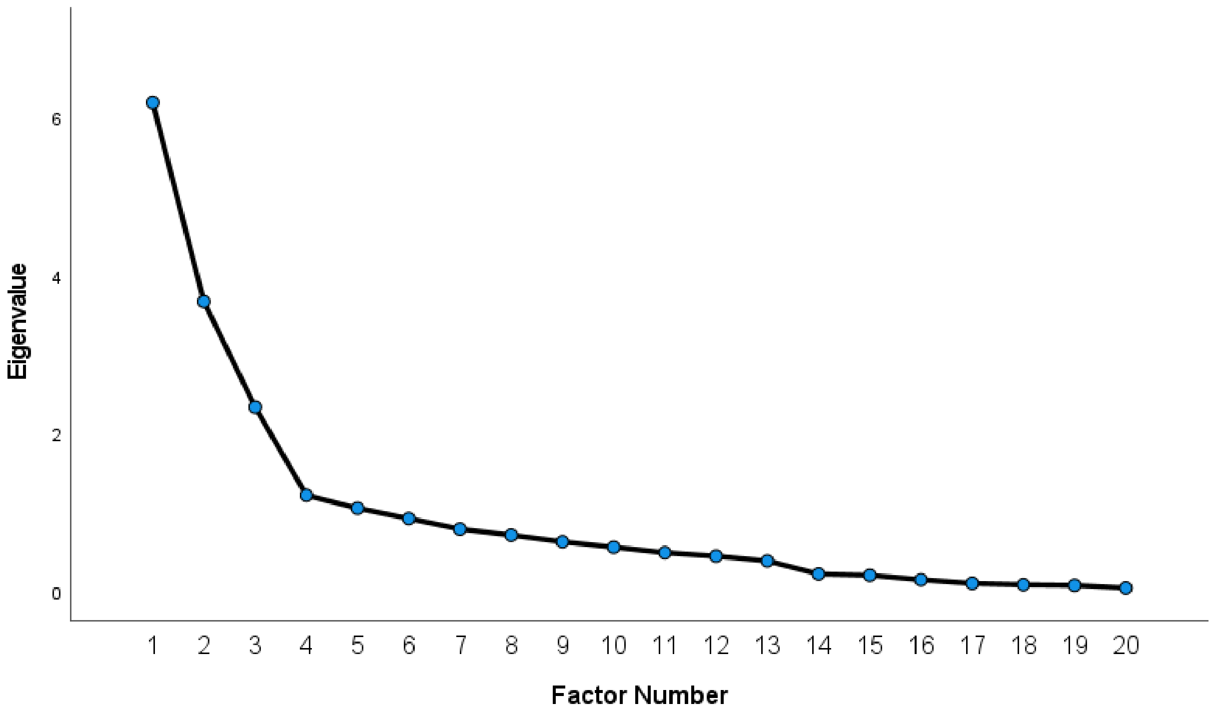
Neighbourhood and Audit Location Example



Note. The inset map shows all the locations in the study (blue markers) with CFB Esquimalt highlighted (red marker) to indicate the location of the example neighbourhoods shown. The main image shows five examples of neighbourhood areas (transparent blue) in Victoria, BC where CFB Esquimalt is located (red). Within each of the neighbourhood areas, the black circles represent the audit locations.

Appendix E

Scree Plot Use in Factor Retention Process



*Note***.** This image displays the scree plot used in the factor retention decision-making process. The inflection or "elbow" is located at the fourth factor indicating three factors for retention is appropriate.

Appendix F

FEAL Scale Items Means & Standard Deviations

Items	N	Mean	Std. Deviation
General Cleanliness of Streets & Properties	70	3.69	0.38
Landscaping	70	3.20	0.47
Quantity of Trees	70	4.19	0.69
Quality of Trees	70	4.21	0.42
Sidewalks	70	1.41	1.05
Sidewalk Buffers	70	1.31	1.06
Road Condition	70	3.24	0.32
Defined Street Shoulder	70	1.48	0.35
Pedestrian Safety	70	2.01	0.34
Proximity to Traffic	70	2.44	0.36
Variety of Destinations	70	2.16	0.21
Visual Interest	70	3.29	0.30
Transportation System Connections	70	1.45	0.39
Absence of Substance Use	70	4.29	0.24
Absence of Threat of Traffic to Pedestrians	70	1.76	0.68
Upkeep of Homes	70	3.21	0.36
Number of People Walking	70	1.42	0.36
Public Amenities	70	1.27	0.26
Topography (flatness)	70	4.51	0.37
Absence of Threat of Traffic to Cyclists	70	1.04	0.10

Note. This table displays the means and standard deviations of each of the items in the FEAL scale across all the neighbourhoods surveyed (n = 70).

Chapter 3 Study 2:

Exploring the Relationship Between the Built Environment and Active Living Among Canadian Armed Forces Personnel

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Abstract

Since the turn of the century there has been a growing interest in the built environment in relation to active living. However, there has been no research examining the relationship between these areas and Canadian Armed Forces (CAF) personnel. Study 2 investigated the relationship between neighbourhood environments and activity levels of CAF personnel. A two-level hierarchical linear model analysis was conducted using several sources of data, including the study 1 data, the 2016 Canadian census, and CAF personnel physical activity and demographic data. The final sample included 335 participants and 62 neighbourhoods from seven different CAF locations. Overall, the built environment did not have a significant relationship with active living among CAF personnel. However, the broader context of these findings provided valuable information. They highlighted that among CAF personnel physical activity levels decreased with increasing age, rank, and population density. The literature supported these findings and provided additional explanations and context for the results. This study provided novel evidence about the relationship between the environment and active living among CAF personnel.

Introduction

Active Living

Active living is a vital component in reducing and managing disease, chronic illness, building strength, and managing physical and mental health (de Souto Barreto, 2014; Katzmarzyk & Janssen, 2004; Pimlott, 2010; Powell et al., 2011; Statistics Canada, 2013; Stranavska et al., 2020; Warburton et al., 2006). To reflect the understanding and practice of current lifestyles, the act of defining active living has shifted from assessments of physical activity to a more contemporary approach of an active lifestyle (Sallis, 2006). It encompasses several domains including exercise, physical activity, recreational activities, household and occupational activities, and active transportation. It also contains contributions from public health, behavioral science, leisure and recreation studies, economics, public policy, transportation, and urban planning (Sallis et al., 2005). This paper acknowledges that active living and physical activity are under the same umbrella (Sallis et al., 2006). As a result, both active living and physical activity may be used at times.

Assessing Active Living

There are many approaches to assess active living. Subjective measures of active living include activity diaries, interviews, and have been derived from items within physical activity questionnaires. While these measures are useful in some contexts, they are limited in their ability to accurately capture information. Subjective measures rely largely on self-report, they are subject to performance bias, response bias, recall bias, and semantics, as respondents report on their own perceptions of activity (Venditti et al., 2014).

Objective measures, on the other hand, assess physical activity directly. The doubly-labeled water technique and calorimetry are considered the traditional objective gold standards for measuring total energy expenditure, but they are extremely resource-intensive and are not suitable for population-based samples (Dowd et al., 2018; Melanson et al., 1996; Robertson et al., 2015). Heart rate monitors have been shown to provide the closest approximation of total energy expenditure to the doubly-labeled water technique but are limited in detecting changes in between activities (Fuller et al., 2008). Other measures, such as accelerometers, are relatively inexpensive and can provide accurate assessments of physical activity, sedentary time, and related variables (Rastogi et al., 2020; Migueles et a., 2017).

Since no one method is without its limitations, a combination of objective approaches is generally recommended (Hills et al., 2014). The current study aligned with this recommendation and used secondary data which was collected from a combined approach. Secondary active living data was collected from a heart rate monitor and accelerometer device along with a body composition analysis tool. These specific devices and their outputs are further discussed in the methods section.

Built Environment

A growing proportion of active living research has focused on the role of the built environment. The built environment can be simply defined as "the [aspects] of the environment which is human-made or modifiable and where people live and carry out their daily activities", such as neighbourhoods, workplaces, parks, city centres, schools, and even transportation systems (Bonaccorsi et al., 2020, p. 2; Jansen et al., 2016). As such, it is naturally scaffolded by the socioecological model, which considers human behavior and development as a function of a complex system of interdependencies between individuals, groups, communities, social institutions, and environments (Bronfenbrenner, 1979; Devís-Devís et al., 2015; Lawson, 1992; Stokols, 1992). The framework developed by Sallis et al. (2006), posits that environmental changes can lead to individual changes. This approach conceptualizes the components of active living which include intrapersonal, behavioral, behavioral settings, perceived environment, and policy environment components.

A well-designed environment with walkable and supportive infrastructure, greenspace, and minimal litter and graffiti has been related to increased odds of being physically active (Ellaway et al., 2005; Foster et al., 2011; Frank et al., 2006; Hunter et al., 2015). Most research in this space has focused on neighbourhood residential areas where people spend the majority (e.g., ~60%) of their time (Jansen et al., 2016; McInerney et al., 2016). Additionally, neighbourhood environments can also vary depending on factors such as neighbourhood income (a proxy for socioeconomic status) and population density. Population density offers a helpful perspective that begin to address potential neighbourhood variability (e.g., urban, rural, or mixed) where there are differences in the built environment and activity levels of people among different population densities (Barnett et al., 2017; Liu et al., 2007). Likewise, neighbourhood income/SES could also serve as a source of information shedding light on potential factors influencing activity levels (Lee et al., 2007). Research has established that neighbourhood socioeconomic status can influence activity levels, after controlling for individual socioeconomic status (Lee et al., 2007). Functionally speaking, these two variables also fit with the current study regarding availability and customizability at the neighbourhood level. While the main focus of this study is the built environment, additional neighbourhood level factors help to enrich and further strengthen our understanding. The built environment has been examined in relation to several contexts and populations, however, there is a dearth of such studies in relation to the Canadian Armed Forces (CAF).

Military Context

The CAF is a demanding physical occupation that is distinct from other public servant professions and are thus held to a higher fitness standard (Yu et al., 2015). CAF guidelines call for one hour of physical activity five times per week – double that of the general population (Thériault et al., 2016; World Health Organization, 2020). The Health and Lifestyle information Survey, a report on military health and welfare, noted concerning trends regarding decreasing physical activity among certain populations and increasing sedentary time and obesity rates (Thériault et al., 2016).

The military has traditionally relied on the individual level approaches and perspectives which have been met with moderate outcomes (Born et al., 2009; Franz, 2015; Thériault et al., 2016). Researchers have noted that holistic and multi-level approaches are just as, if not more, important than interventions targeted at the individual level (e.g., Devís-Devís et al., 2015; Krenn et al., 2011; Rose et al., 2008; Sallis, 2009).

Aim

Therefore, the aim of the current study is to explore the influence of the built environment on activity levels of CAF personnel guided by the socioecological model. It examines neighbourhood-level data including built environment, population density, and neighbourhood-level income data in combination with individual level data about age, rank, and active living. In doing so, this study seeks to understand the relationship of the built environment and active living among CAF personnel and provide information that guides and informs policy and resource decision-making.

Methods

This study uses data from the built environments audit (chapter 2), the 2016 Canadian census, and physical activity measures of CAF personnel to explore the relationship between the built environment and active living among CAF personnel. Secondary active living data was provided and collected as part of project HR-BASE by Health Promotion Delivery and the Directorate of Fitness at Canadian Forces Morale and Welfare Services (CFMWS).

Research Design

This study employed a cross-sectional multi-level design using secondary data, data from Study 1 (Chapter 2) as well as the 2016 Canadian census. The secondary data is from Project HR-BASE, a previous study from the Directorate of Fitness at CFMWS. Project HR-BASE assessed the efficacy of the CAF Fitness strategy by assessing physical activity, sleep, and quality of recovery and fatigue, among other related factors.

Participants

Participants were recruited as part of Project HR-BASE. Access to participant information was provided as secondary data. Participants were recruited in Project HR-BASE by location (see locations section) and receipt of a letter of invitation. The principal investigator and Base/Wing Unit Training Officers distributed letters to targeted personnel through their chains of command. Recruitment letters were targeted according to stratification specifications (i.e., age and gender specifications representative of the CAF). Pregnant women, individuals with a pacemaker, personnel who were unable to return the device upon completion, and civilians employed by the CAF were excluded from participation in Project HR-BASE. Demographic information was self-reported by participants and active living related data was captured by measurement devices described below. For the current study, participant information such as base location, age, rank, gender, and active living related information (i.e., energy expenditure, session total time, basal metabolic rate, etc.) were provided to the principal investigator.

Locations

Like the participants, the seven CAF base locations were selected from across Canada from Project HR-BASE. The locations were CFB Trenton (Air Force), CFB North Bay (Air Force), CFB Comox (Air Force), CFB Petawawa (Army), CFB Kingston (Army), CFB Gagetown (Army), and CFB Esquimalt (Navy). The seven base locations were selected in Project HR-BASE because of their command (e.g., branch representativeness) and operational (versus training) orientation which was part of participant recruitment process described above. These locations were used in a previous study (Chapter 2, Study 1) that developed and used a built environment assessment scale. 10 neighbourhoods at each location were examined to evaluate neighbourhood built environments. These built environment scores will be used in the current study. Additionally, these locations align with the locations of the participants which is key for the study design and analyses.

Analyses

This study uses two-level hierarchical linear model (HLM) design to analyze the data. HLM identifies the relationship between independent and dependent variables within the same group (level 1) and then between groups (level 2) (Woltman et al., 2012; Zhao et al., 2020). This approach resulted in a design with CAF personnel at Level 1 and neighbourhood environments at Level 2.

Initial power analyses identified a feasible target of 60 neighbourhoods, providing a significant increase in power over the minimum 40 to 50 neighbourhoods. Missing data only occurred in the rank data at one base location and was addressed using median imputation. Data was screened and transformations were performed when necessary. Screening occurred by checking the univariate residuals and multivariate residuals. Univariate residuals were examined through screening of intercepts and of slopes (i.e., outliers and non-normality), and screening of homogeneity of variance of intercepts and of slopes across categories. Multivariate residuals were examined through screening of relationships of intercepts and of slopes with quantitative upper-level IVs (i.e., outliers, non-normality, non-linearity, and heteroscedasticity). Extreme outliers (z-score > 3) were removed from Level 2 and remaining outliers (z-score > 2.58) were transformed via Winsorizing.

Outcome Measures

Active living was assessed using secondary data from the FirstBeat Bodyguard 2 and the InBody 520. The FirstBeat Bodyguard 2 is a wearable composite device consisting of a heart rate monitor and accelerometer. The InBody 520 machine assesses several body measures including fat, muscle, weight, water retention, and most importantly for this study, a calculation of resting energy expenditure captured as the basal metabolic rate (“InBody Composition Analyzer,” n.d.). The use of these combined measures allowed for accurate assessments of active living. Additionally, heart rate monitors and accelerometers are practical, accurate, non-invasive, convenient, versatile, and relatively inexpensive (Hills et al., 2014; Robertson et al., 2015;

Migueles et al., 2017). The limitations of heart rate monitors (e.g., changes in activities) can be managed by integrating resting heart rate.

CAF personnel were instructed to wear the FirstBeat Bodyguard 2 device for at least 6 days, including at least one weekend day. This period of data collection reflects the gold standard (Hills et al., 2014), and considers the functional limitations of the device's battery life. Participants were required to remove the FirstBeat device prior to showering or water activities. The FirstBeat device and software uses the heart rate data and information about respiration rate and VO2 derived from the data to estimate energy expenditure (FirstBeat Technologies, 2007; Robertson et al., 2015). Studies have found that the use of heart rate variability data was appropriate for determining energy expenditure across day-to-day activities (i.e., active living), all while being practical, low-cost, and convenient to participants (Garet et al., 2005; Robertson et al., 2015). Using the outputs from these measures, active living was calculated as the physical activity level (PAL) ratio: *PAL = total energy expenditure (TEE) / basal metabolic rate (BMR).* PAL has previously been used in population research making it a good fit for this study (Hills et al., 2014).

Level One: CAF Personnel Independent Variables

Age and rank were used as the individual level variables in this study. Rank provides important occupational context and has been associated with changes in physical activity, sedentary behaviors, and indices of health behaviors such as obesity (Martins & Lopes, 2013; Sanderson et al., 2011; Thériault et al., 2016). Age also provides important contextual information and can influence physical activity over the lifespan (Colley et al., 2019; Westerterp, 2018).

Level Two: Neighbourhood Level Independent Variables

Neighbourhood level variables were assessed through the collection of built environment scores, neighbourhood income, and neighbourhood population density (i.e., dissemination area population/km^2 averaged across the dissemination areas included in custom neighbourhood area). Built environment scores were calculated in a previous study using the FEAL scale, which demonstrated an overall internal consistency of $\alpha = 0.78$ (see chapter 1). Average neighbourhood income was used as a proxy for neighbourhood SES and population density represented the concentration of people in a neighbourhood area. The custom neighbourhoods did not directly overlap with census geographic units. To address this, dissemination area population density and neighbourhood income variables were rasterized (50 metres) to calculate means (zonal statistics) across the polygons of the custom neighbourhoods. This approach provided a cost and time effective approach compared to a custom tabulation which is significantly more cost and time intensive. See Appendix A for additional details.

Assigning Participants & Neighbourhoods

Fifteen of the 446 participants lacked PAL data and were removed from the study. Of the remaining participants only 255 lived within neighbourhoods outlined by the local stakeholders and only 29 of the included 59 neighbourhoods met the recommended threshold of participants (four) indicated by the K+2 rule in which K represents the number of observations at the individual level (Huta, 2014). Therefore, to increase statistical power, we devised an allocation method that increased both the number of included participants and the number of neighbourhoods meeting the recommended threshold while balancing ecological validity (i.e., only including participants in neighbourhoods they likely interact with). First, we included any participants found within roughly 3.2km of any audit location. This number was derived by calculating the largest distance between a participant found within a neighbourhood and their closest audit location. This increased the number of included participants to 346, but still left only 29 neighbourhoods meeting the recommended participant threshold. To rectify this, we created a computer program (see Appendix B) that reassigned participants belonging to neighbourhoods that exceeded the participant threshold (four) if another neighbourhood below the threshold was within the minimum distance (3.2km). Reassignment occurred iteratively starting with the smallest reassignment distance and continued until no other participants met the outlined criteria. Appendix C provides an example of this process. This process increased the number of neighbourhoods which satisfied the K+2 rule from 29 to 40. We included these and additional neighbourhoods that were close to the threshold since the majority of neighbourhoods met this threshold.

To assess any evidence of sampling bias, a logistic regression was performed which correctly classified 80.1% of cases ($p < .05$) yet explained only 13.3% (Nagelkerke R^2) of the variance in inclusion status. Both Age ($\beta = .956$, 95% CI) and PAL ($\beta = .315$, 95% CI) were significant predictors ($p < .001$) of inclusion status. Lastly, four neighbourhoods were identified as extreme outliers (z-score > 3) and were removed (please see the analyses section above for more detail on screening procedures). Therefore, a total of 62 neighbourhoods and 335 participants were included in the final analysis.

Results

Participant Characteristics

We included a total of 335 participants ($\bar{x}$ = 47.86 per base) which comprised of 243 (72.54%) males and 92 (27.46%) females. Ages ranged from 23 to 64 years old ($\bar{x}$ = 39.54, σ = 9.66). Participants' rank ranged from junior non-commissioned members to senior officers. Rank was operationalized by assigning numerical values to the participants' ranks (1-14). The mean and median rank among participants was a high-ranking junior non-commissioned member. Physical activity level scores (dependent variables) ranged from 0.87 to 2.50 ($\bar{x}$ = 1.64, σ = 0.31). Gender was not included as a variable due to power and sampling requirements. This would have called for minimum requirements across each neighbourhood which would not have been feasible with this dataset.

Neighbourhood Characteristics

A total of 62 customized neighbourhoods from seven locations were included from CAF locations across British Columbia, Ontario, and New Brunswick. All variables were approximately normally distributed. Neighbourhood income ranged from \$54,013 to \$111,907 ($\bar{x}$ = \$75,624, σ = \$11,703). Population density ranged from 8.28 to 2969.29 people/km^2 ($\bar{x}$ = 980.39, σ = 755.42). Overall built environment scores ranged from 1.22 to 4.65 ($\bar{x}$ = 3.13) on a scale of 1 to 5.

HLM Analysis

We performed hierarchical linear modeling using the software HLM8 (Raudenbush et al., 2019). There were 2 levels in the hierarchy, with Level 1 units representing participants (CAF personnel) and Level 2 units representing neighbourhood characteristics. There were on average

5.40 Level 1 observations per Level 2 group and 62 groups at Level 2. The DV was physical activity level (PAL). The Level 1 IVs were age and rank. The Level 2 IVs were built environment score, population density, and neighbourhood income and we tested their main effects on the DV. Level 1 IVs Age and Rank were group mean centered to maximize the accuracy of the analyses with the Level 1 IVs. It also allows for the study of the effects of Level 1 IVs independently from the effects of Level 2 IVs. The Level 2 IVs were grand mean centered. Because the DV was quantitative and normally distributed, we performed regular Hierarchical Linear Modeling (HLM).

A preliminary analysis in the model with only the DV showed that the intercept did not vary, although it was close to marginal significance, across Level 2 units (χ^2 = 72.91, p = 0.14). A preliminary analysis with the DV and the Level 1 IVs in the model showed that the Level 1 intercept varied marginally (χ^2 = 43.94, p = 0.096) while the slopes did not vary significantly across Level 2 units (Age: χ^2 = 35.63, p = 0.345; Rank: χ^2 = 24.31, p >0.500). These marginal intercept results provide some justification for adding the Level 2 IVs to predict the intercept. However, the smaller sample size at Level 2 and the fact this is a preliminary study to develop stronger understanding provides theoretical justification thereby strengthening the rationale for proceeding with HLM. Thus, we required an analysis like HLM, which accounts for the nested nature of the data.

An initial run of the model included all error terms, but examination of coefficient reliabilities, coefficient inter-correlations, and number of iterations suggested a need to simplify the model. Specifically, low reliability and a high number of iterations led us to remove the error terms for Level 1 IVs, Age and Rank, to simplify the model.

Table 1 displays the coefficient for each effect, along with its standard error, and p-values. The coefficient β_{00} showed that the grand mean score on the DV was 1.64. The coefficients $\beta_{01}, \beta_{02}, \beta_{03}$ showed both significant and non-significant results. β_{01} (Overall Built Environment Score) and β_{03} (Neighbourhood Income) were non-significant, while β_{02} (Population Density) has a significant negative relationship with the DV. The coefficient β_{10} showed a significant negative relationship between the DV and the Level 1 IV Age. The coefficient β_{20} showed a marginally significant negative relationship between the DV and the Level 1 IV Rank. Appendix D shows the full model equation.

Table 1

HLM Analysis Output

Fixed Effect	Coefficient	Standard error	p-value
For Intercept, β_0			
Intercept, β_{00}	1.637471	0.015376	<0.001*
Overall BE Sores, β_{01}	-0.031128	0.028093	0.272
Population Density, β_{02}	-0.000053	0.000022	0.020*
Neighbourhood Income, β_{03}	-0.000001	0.000002	0.414
For Age Slope, β_1			
Intercept, β_{10}	-0.006796	0.001797	<0.001*
For Rank Slope, β_2			
Intercept, β_{20}	-0.011195	0.005932	0.060**

Note. INTRCPT2 represents the intercept of the respective variable (DV and Level 1 IVs); Overall BE Scores represents overall built environment score.

*p < .05 (significant); **p > .05 and < .10 (marginal)

Supplemental Analysis

For exploratory purposes, it may also be helpful to look into additional built environment analyses so that additional information and context may be gleaned.

ON vs. OFF Base Analysis. Looking specifically at the built environment additional context can be found by exploring whether the presence of a neighbourhood on or off base influenced the PAL of CAF personnel. Table 2 shows with on vs. off base as variable at Level 2. It displays the coefficient for each effect, along with its standard error, and p-value. Of particular interest, the coefficient β_{01} showed a non-significant result with the DV.

Table 2

On vs. Off Base Analysis

Fixed Effect	Coefficient	Standard error	p-value
For Intercept, β_0			
Intercept, β_{00}	1.641092	0.020342	<0.001
On vs. Off Base, β_{01}	-0.010456	0.038521	0.787

Note. INTRCPT2 represents the intercept of the respective variables (DV and Level 1 IVs); On vs. Off Base represents the Level 2 variable examining the influence of on vs. off base neighbourhoods.

Subscale-by-Subscale Analysis. Although the built environment was not related to PAL as indicated in the previous analysis, for exploratory purposes it may be worthwhile to examine the built environments scores on a subscale-by-subscale basis. Table 3 shows the individual subscales that makes up the overall built environment score and displays the coefficient for each effect, along with its standard error, and p-values. The coefficients for each subscale (β_{01}, β_{02}, β_{03}) showed both significant and non-significant results. β_{01} (active living infrastructure) and β_{03} (aesthetics) were non-significant, while β_{02} (neighbourhood streetscape) has a significant negative relationship with the DV.

Table 3

Subscale-by-Subscale Analysis

Fixed Effect	Coefficient	Standard error	p-value
For INTRCPT, β_0			
Active Living Infrastructure, β_{01}	-0.031059	0.058081	0.595
Neighbourhood Streetscape, β_{02}	-0.133203	0.060274	0.031*
Aesthetics, β_{03}	0.032202	0.067640	0.636

Note. Active Living Infrastructure represents Subscale 1; Neighbourhood Streetscape represents Subscale 2; Aesthetics represents Subscale 3. Please note that this table is composed of individual subscale-by-subscale analyses.

* $p < .05$

Item-by-Item Analysis. For additional exploratory purposes, it may also be worthwhile to investigate the built environment scores further by examining the FEAL scale items. with an item-by-item approach. Table 4 shows the output from an item-by-item approach. It displays the coefficient for each effect, along with its standard error, and p-values. The coefficients for each item ($\beta_{01,}$ β_{02}, β_{03}) showed both significant and marginally significant results. β_{01} (transportation system connections) had a significant negative relationship with the dependent variable. β_{02} (absence of visible substance use) had a marginally significant positive relationship with the dependent variable. Lastly, β_{03} (quantity of trees) had marginally significant negative relationships with the dependent variable.

Table 4

Item-by-Item Analysis

Fixed Effect	Coefficient	Standard error	p-value
For INTRCPT, β_0			
Transportation System Connections, β_{01}	-0.089835	0.0343	0.011*
Absence of Visible Substance Use, β_{02}	0.121061	0.06393	0.063**
Quantity of Trees, β_{03}	-0.048442	-1.902	0.062**

Note. * $p < .05$ (significant); ** $p > .05$ and $<.10$ (marginally significant). Please note that this table is composed of individual item-by-item analyses.

Discussion

The intersection of active living and the built environment has gained significant traction since the turn of the century (Sallis et al., 2006). Most of the available research has focused on general populations (Barnett et al., 2017; de Vet et al., 2011; Sallis et al., 2020), and little has been done to examine this interaction among military personnel (e.g., Malkawi et al., 2018). Moreover, no studies exist that explore the impact of the built environment on Canadian military personnel. This study provides findings that begin to address this gap.

The following paragraphs detail the results of the study and their fit within the current literature. In response to our research question, our results suggest that at the neighbourhood level, the built environment was not significantly related to the PAL of CAF personnel. The main results may be attributed to differences in population characteristics (e.g., military vs. civilian populations), expectations (e.g., CAF physical activity guidelines), and opportunities for activity (e.g., work time for physical activity) and thus may contribute to these findings (Nordbø et al., 2020; Statistics Canada, 2019; Thériault et al., 2016). Previous research on the role of the built environment related to active living while supportive has also been mixed (e.g., Nordbø et al., 2020; Rodríguez et al., 2005). For example, aspects of the built environment may influence people differently depending on personal characteristics such as age (Nordbø et al., 2020).

There was also no significant impact of neighbourhood income on PAL. Past research has shown that physical activity in lower-income neighbourhoods might be accrued through active transportation (i.e., public transit, biking, walking) (Lee et al., 2007; Xiao et al., 2019), while there may be less need for these methods in higher-income neighbourhoods. Given that the average income of all neighbourhoods in this study is $75,624, there is a higher income range and there may be a smaller need for active transportation, thereby reducing or eliminating potential physical activity.

The results showed that population density had a significant negative impact on PAL. Previous studies have noted that physical activity is associated with denser areas (Rodríguez et al., 2005, 2006), which is commonly attributed to infrastructure (Audirac, 1999; Burchell et al., 1998). However, research has also revealed that density may impact specific activities such as purposeful walking (Forsyth et al., 2007) rather than measures of overall activity. This finding could be the result of possible town/city-effect effects or self-selection of more active participants into less dense areas. While an additional check (i.e., ANOVA between PAL and town) indicated no significant difference between locations and physical activity levels [$F(6,55) = 1.73$, $p = 0.131$], it did indicate that more variation (mean square = 0.053 vs. 0.031) may be explained at the group or town-level. This may be due to the certain properties of the city or even the base itself. Although pursuing city effects was beyond the scope and power of this study, it highlights a valuable area for future research.

At the individual level, PAL was found to decrease with increasing age and rank. These outcomes align with physical activity trends in the general population that tend to accompany aging (Spittaels et al., 2012; Westerterp, 2018) and higher rank in the military (Martins & Lopes, 2013; Thériault et al., 2016). The findings showing a connection between rank and physical activity may be due increases in complementary behaviours such as sedentary time in higher ranking members (e.g., Thériault et al., 2016). Furthermore, the occupational nature of higher ranks in the military can often feature increased responsibilities, management, and administrative duties compared to lower ranks. As a result, simply less time may be available for physical activity.

Three supplemental analyses regarding on and off base neighbourhood locations, a subscale-by-subscale analysis, and an item-by-item analysis provided additional information. First, whether the neighbourhood location was on or off base did not influence the PALs (or other IVs) of CAF personnel suggesting overall consistency between locations and aligns with the main analysis findings. However, these exploratory results should be interpreted with caution given the low number of on base locations compared to off base. Second, the results of the subscales were somewhat consistent with the overall built environment score. Specifically, active living infrastructure and aesthetics subscales were non-significant. However, the neighbourhood streetscape subscale had a significant negative relationship to PAL suggesting that among CAF personnel the higher the streetscape score the less active military personnel may be. However, this runs somewhat contrary to literature which has noted that the make up of the streetscape subscale, such as trees, topography, and visual interest have had positive associations with physical activity (e.g., Kardan et al., 2015; King et al., 2000; Nguyen et al., 2013). The second supplemental analysis hints that aspects of the built environment may play a role in activity levels among CAF personnel, but perhaps in different ways or intensities than was examined here (see limitations section). The third supplemental analysis points to specific characteristics of the built environment that may play a role in activity levels of CAF personnel. First, that there were only three significant or marginally significant items (meaning the majority were not) generally aligns with the overall and subscale findings. However, focusing on the three items (transportation system connections, absence of visible substance use, and quantity of trees), they generally align with key built environment components related to active living identified in reviews (e.g., Barnett et al., 2017; Sallis et al., 2020) and studies of specific features. Further research with this population is undoubtedly warranted.

Overall, this study contributes important conceptual understandings regarding the impact of neighbourhood residential built environment features on the PAL of CAF personnel. Although neighbourhood built environment does not appear to be significantly related to PAL in this study, the broader context of these results and an exploration of individual and neighbourhood level variables in the HLM model provide foundational knowledge to this growing area of study involving the military and lend support for the necessity of future research.

Limitations & Future Directions

The results of this study should be interpreted within the context of certain limitations. First, the sufficient but smaller sized sample may have contributed to insufficient power to detect certain significant results. Second, this study considers overall physical activity levels rather than discrete categories such as light physical activity (LPA) or moderate-to-vigorous physical activity (MVPA). It is possible that neighbourhood built environment features are sensitive to some types of physical activity but not others, but given the nature of the secondary data, this analysis was not possible. The inverse may also be true with certain built environment features sensitive to physical activity over others. This provides a strong area for future research. Similarly, we ideally would have only assessed physical activity when the person was outside in their neighbourhood. However, given that data was secondary data and research indicates the majority of time is spent in neighbourhood areas (Jansen et al., 2018; McInerney et al., 2016), along with the use of military personnel participants, we believe that this was sufficiently managed. Third, the use of census tract data with custom neighbourhoods led to an averaging of this data across neighbourhoods; however, this data was extracted and averaged at a granular level with ArcGIS using pixels and DAs which accounts for potential differences in the neighbourhood areas and allows for more accurate representations. Additionally, the use of a sensitivity analyses could also contribute supplementary information. Lastly, participant activity data was collected in the summer months which could have influence participant's activity levels compared with other seasons (e.g., too hot, too cold). However, summer data collection for both the built environment and PAL allowed for consistency of season across all locations. Nevertheless, this study reveals important information and contributions about the relationship of neighbourhood residential built environments to the activity levels of CAF personnel.

Implications

This study may inform decision-making and policy surrounding necessary resources and programming meaningful to military personnel. Results suggest that an increased focus could be placed on individuals and/or built environments within CAF jurisdiction to support physical activity. Similarly, targeted resources for older and higher-ranking personnel may be beneficial to maintain PAL across the spectrum. Extended more broadly, the CAF could also take the lead in areas directly within their jurisdiction to provide more meaningful outcomes.

Conclusion

In conclusion, this study found that the neighbourhood built environment was not related to the PAL of CAF personnel, but that individual factors such as age and rank, as well as certain neighbourhood level features such as population density, were influential. Investing in individual level programs while considering select built environment characteristics may prove to be a worthwhile use of resources. Ultimately, this project contributes evidence to help shape and develop the intersection of built environment and active living while informing policy and resource allocation among the CAF's departments and programs.

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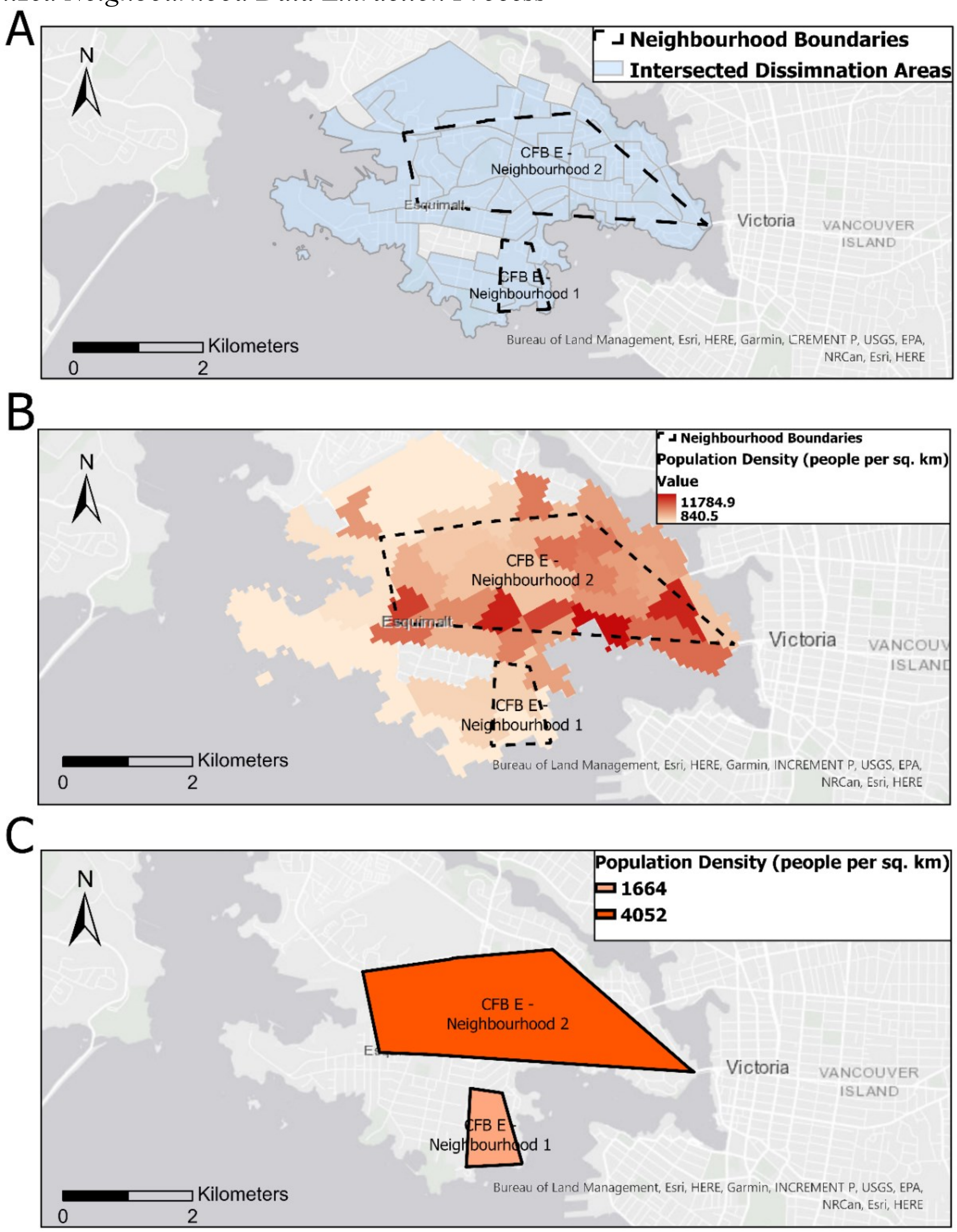
Appendix A

Customized Neighbourhood Data Extraction Process



Note. Appendix A shows the customized neighbourhood data extraction process using population density in this example**.** Figure A (top) shows the dissemination areas (blue) and the overlap with the two example neighbourhood areas (dotted lines). Figure B (middle) displays the population density colour ramp of the dissemination areas in and around the neighbourhoods which are represented by the dotted lines. Figure C (bottom) shows the output from the use of zonal statistics presenting the mean population density for that neighbourhood.

Appendix B

Participant Neighbourhood Reassignment Code for MATLAB

***Final Project File**

```
lear;
clc;
%Lines 73 + 74 hardcode the distance and group membership values

%Select Files to be used
%Note that they should be in the current folder
%The reference location file refers to the Neighbourhood sampling locations
%The Point CSV file refers to the participant location file
[filename1, mypath1] = uigetfile ('*csv', 'Pick your reference location CSV file');
[filename2, mypath2] = uigetfile ('*csv', 'Pick your point CSV file');

%Convert CSV into various variables for clarity
ref = readtable(filename1);
point= readtable(filename2);

ref_lat = ref(:, 2);
ref_lat = ref_lat{:,:};

ref_lon = ref(:, 3);
ref_lon = ref_lon{:,:};

ref_name = ref(:, 1);
ref_name = ref_name{:,:};

point_lat = point(:, 2);
point_lat = point_lat{:,:};

point_lon = point(:, 3);
point_lon = point_lon{:,:};

point_name = point(:, 1);
point_name = point_name{:,:};

%Create axis for clarity and to visualize the matrices that will be usedvert_axis = point{:,1};
horz_axis = ref{:,1};
horz_axis = horz_axis';

%Create Data Matrix with distance values
length = size(point_name,1);
```

```
width = size(ref_name,1);
distance_values = NaN(length, width);


%Calculate Distances between each point and every sampling location
for i = 1:length;
   for j = 1:width;
      lat1 = ref_lat(j);
      lon1 = ref_lon(j);
      lat2 = point_lat(i);
      lon2 = point_lon(i);
      distance = Haversine(lat1,lon1,lat2,lon2);
      distance_values(i,j) = distance;
   end;
end;

distance_short = NaN(length,width/5);

%Save only lowest value between each point and each sampling location of every neighberhood
for i = 1:length;
   for j = 1:width/5;
      data = distance_values(i,1+((j-1).*5):j*5);
      data = sort(data);
      distance_short(i,j) = data(1);
   end;
end;

%New Horz axis for clarity
horz_axis2 = ref{:,1};
horz_axis2 = horz_axis2(1:5:end);
horz_axis2 = erase(horz_axis2,"-1");
horz_axis2 = horz_axis2';

distance = 3.25;
group_size = 5;

%Compute rank data for each participant within distance_short
data = NaN(1,width/5);
part_rank = NaN(length,width/5);
for i = 1:length;
      data = distance_short(i,:);
      [x,data2] = sort(data,'ascend');
      for j = 1:width/5
         part_rank(i,j) = find(data2==j);
      end
```

```
end

%Assign group membership if less than specified distance and first ranked
group_memb = string.empty(length,0);
for i = 1:length;
    for j = 1:width/5;
        if distance_short(i,j) < distance && part_rank(i,j) == 1
            group_memb{i,1} = horz_axis2{1,j};
        else
        end;
    end;
end;


data_values = NaN(length,width/5);
data = NaN(1,width/5);

%Datavalues only includes distances under the distance limit and therefore can be reassigned
for i = 1:length
    for j = 1:width/5
        if distance_short(i,j) <= group_size
            data_values(i,j) = distance_short(i,j);
        else
        end
    end
end

%Remove participants points that have more duplicates than the group size
%because they will never be able to be reassigned
to_delete = double.empty();
count = double.empty();
dup_count = double.empty();

%Calculate number of duplicates for each participant location
for i = 1:length
    lat = point_lat (i,1);
    lon = point_lon (i,1);
    count = 0;
    for j = 1:length
        if lat == point_lat(j,1) && lon == point_lon(j,1)
            count = count + 1;
        else
        end
    end
    dup_count(i,1) = count;
```

```
end

%Remove those in excess of group size from data_values
for i = 1:length
    if dup_count(i,1) > group_size
        data_values(i, :) = NaN(1,width/5);
    else
    end
end

%Remove closest values from data_values as they're already assigned to
%these neighbourhoods
for i = 1:length
    for j = 1: width/5
        if part_rank(i,j) == 1
            data_values(i,j) = NaN;
        else
        end
    end
end


%Run reassigner until no more reassignment can be done
counting = 0;
part_to_move = 1;
while part_to_move > 0
    [groups_update,data_update,part_to_move] =
Reassigner(group_size,group_memb,data_values,horz_axis2);
    data_values = data_update;
    group_memb = groups_update;
if part_to_move == 0
    break
end
end

%create csv
filename = sprintf('group_memb_%d.csv',distance);
writematrix(group_memb,filename);
```

*--

***Haversine**

```
function [distance] = Haversine(lat1,lon1,lat2,lon2)
%point1 and point2 are the two points you wish to find the distance between
%points are required to be in decimal degrees
```

```
%the output distance is in kilometers
    dlat = radians(lat2-lat1);
    dlon = radians(lon2-lon1);
    lat1 = radians(lat1);
    lat2 = radians(lat2);
    a = (sin(dlat./2)).^2 + cos(lat1) .* cos(lat2) .* (sin(dlon./2)).^2;
    distance = (2 .* asin(sqrt(a))) .* 6371;

function rad = radians(degree)
% decimal degrees to radians
    rad = degree .* pi / 180;
end;
end
```

*--

***Re-assigner**

```
function [groups_update,data_update,part_to_move] =
Reassigner(group_size,group_memb,data_values,xaxis)
%recompute variables
width = size(data_values,2);
length = size(data_values,1);

%Count number of participants in each Neighberhood
group_memb_count = group_memb;
group_memb_count = group_memb_count(~cellfun('isempty',group_memb_count));
[C,ia,ic] = unique(group_memb_count);
mydata_counts = accumarray(ic,1);

%Isolate which nieghberhoods have over the group size limit
big_groups = string.empty();
for i=1:size(mydata_counts,1)
    if mydata_counts(i,1) > group_size
        big_groups(end+1) = convertCharsToStrings(C(i,1));
    else
    end
end

%Calcualte the number of possible neighbourhood each point can possible
%belong to
part_group_count = double.empty(length,0);
for i = 1:size(data_values,1)
    data = data_values(i,:);
    data2 = rmmissing(data);
    count = size(data2,2);
```

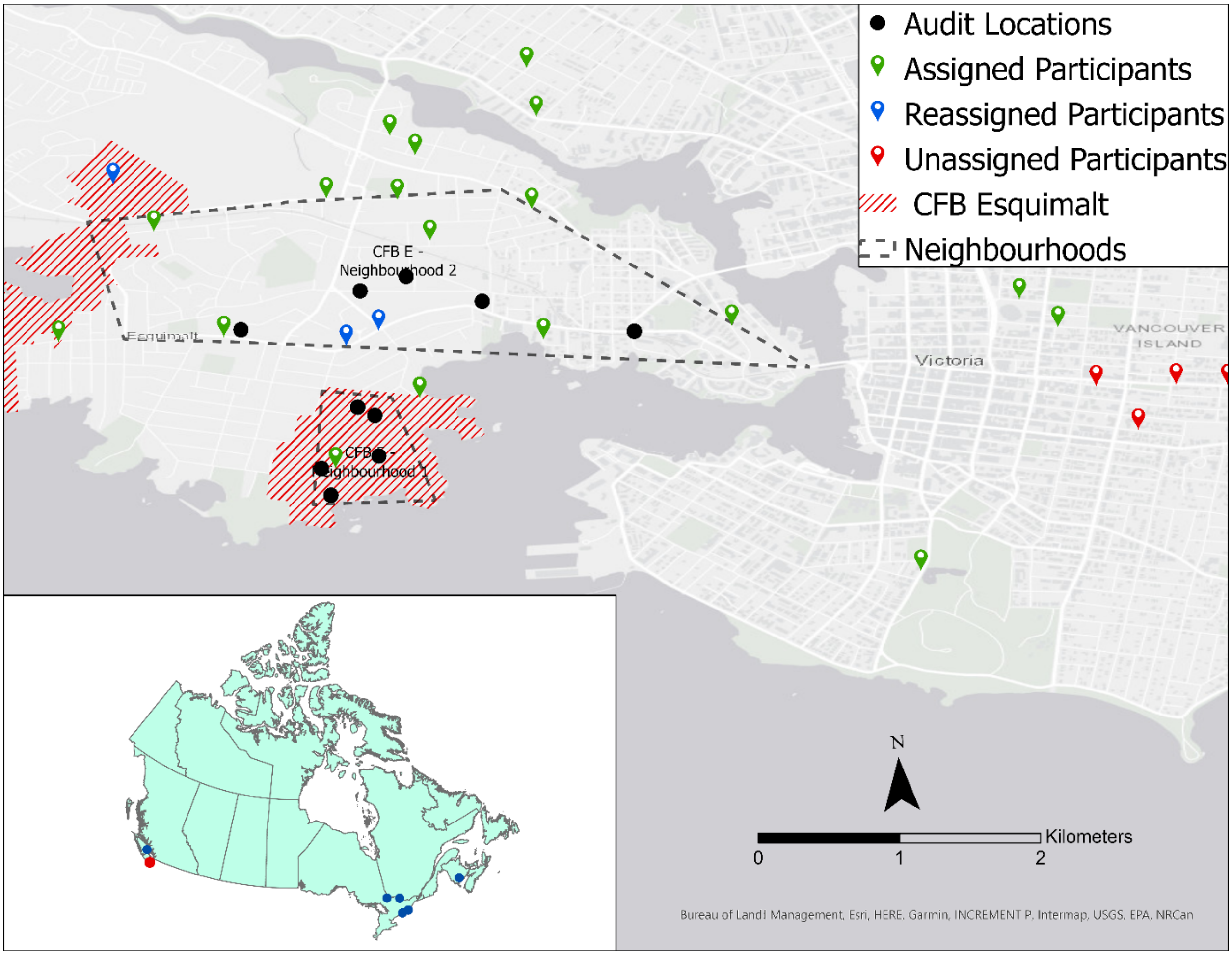
```
    part_group_count(i,1) = count;
end


% Erase neighbourhoods from data_values with more than or equal to group
% size number so that no points attempt to be reassigned into them
to_delete = double.empty();
group_memb = erase(group_memb,"[]");

for i = 1:length
    data = convertCharsToStrings(group_memb(i,1));
    if isempty(data) == 0
        if ismember(data,big_groups) == 1
            [~,col] = ismember(data,xaxis) ;
            to_delete(1,end+1) = col;
        else
        end
     else
     end
end

to_delete = unique(to_delete);
to_delete = sort(to_delete,'descend');

for i = 1:size(to_delete,2)
    data_values(:, to_delete(1,i)) = NaN(length,1);
end

%Exclude participants (delete them from data_values) that are not members of neighbourrhoods
which are over the
%group size limit
for i = 1:length
    if ismember(group_memb(i,1),big_groups) == 0
        data_values(i,:) = NaN(1,width);
    else
    end

end

%Among remaining distance values find the lowest value
data_values(data_values==0) = NaN;
min_neigh_value = min(data_values);
min_value = min(min_neigh_value);
if min_value ~= NaN
    [min_val_row, min_val_col] = find(data_values==min_value);
```

```
else
end

%Find number of participants within Neighberhood that is being potentially
%having participants reassigned into
for i = 1:width
   neigh_count(i,1) = sum(group_memb(:) == xaxis(1,i));
end

%Reassign + remove participant from data_value so they don't move again
part_to_move = size(min_val_row,1);
%If there are possible values to reassign do the middle, always do nothing
if min_val_col ~= NaN
   %If there is only 1 participant to move reassign and remove it
   if part_to_move == 1
      group_memb(min_val_row,1) = xaxis(1,min_val_col);
      groups_update = group_memb;
      data_values(min_val_row,:) = NaN(1,width);
      data_update = data_values;
   elseif part_to_move + neigh_count(min_val_col(end,1),1) > group_size
      %If number of participants + number of participants within proposed
      %neighbourhood is greater than the group size limit than just
      %remove it
      for i = 1:part_to_move
         data_values(data_values==min_value) = NaN;
         data_update = data_values;
         groups_update = group_memb;
      end
   else
      for i = 1:part_to_move
         %if they don't meet the above characteritics then reassign and
         %remove all values
         group_memb(min_val_row(i),1) = xaxis(1,min_val_col(i));
         groups_update = group_memb;
         data_values(min_val_row(i),:) = NaN(1,width);
         data_update = data_values;
      end
   end
else
   data_update = data_values;
   groups_update = group_memb;
end
end
```

Note. Appendix B shows the code that was used in MATLAB (*MATLAB*, 2020) to reassign participants belonging to neighbourhoods that exceeded the participant threshold (four) if another neighbourhood below the threshold was within the minimum distance (3.2km).

Appendix C

Neighbourhood Boundaries and Participant Assignment



Note. The inset map shows all the locations in the study (blue circles) with CFB Esquimalt highlighted (red circle) to indicate the location of the example neighbourhoods shown. The main image shows two examples of neighbourhood areas (black dotted lines) in Victoria, BC where CFB Esquimalt is located (red hatching). It visualizes information for participants that are assigned to a neighbourhood area (green marker), participants that are unassigned (red marker), and participants that were reassigned (blue marker). The black circles represent the audit locations.

Appendix D

Summary of the HLM Equation

Level-1 Model

$PAL_{ij} = \beta_{0j} + \beta_{1j}*(AGE_{ij}) + \beta_{2j}*(RANK\_IND_{ij}) + r_{ij}$

Level-2 Model

$\beta_{0j} = \gamma_{00} + \gamma_{01}*(OVRBE\_SC_{j}) + \gamma_{02}*(WPOP\_DEN_{j}) + \gamma_{03}*(NHBD\_INC_{j}) + u_{0j}$
$\beta_{1j} = \gamma_{10} + \gamma_{11}*(OVRBE\_SC_{j}) + \gamma_{12}*(WPOP\_DEN_{j}) + \gamma_{13}*(NHBD\_INC_{j})$
$\beta_{2j} = \gamma_{20} + \gamma_{21}*(OVRBE\_SC_{j}) + \gamma_{22}*(WPOP\_DEN_{j}) + \gamma_{23}*(NHBD\_INC_{j})$

Mixed Model

$PAL_{ij} = \gamma_{00} + \gamma_{01}*OVRBE\_SC_{j} + \gamma_{02}*WPOP\_DEN_{j} + \gamma_{03}*NHBD\_INC_{j}$
$+ \gamma_{10}*AGE_{ij} + \gamma_{11}*OVRBE\_SC_{j}*AGE_{ij} + \gamma_{12}*WPOP\_DEN_{j}*AGE_{ij} + \gamma_{13}*NHBD\_INC_{j}*AGE_{ij}$
$+ \gamma_{20}*RANK\_IND_{ij} + \gamma_{21}*OVRBE\_SC_{j}*RANK\_IND_{ij} + \gamma_{22}*WPOP\_DEN_{j}*RANK\_IND_{ij} + \gamma_{23}*N$
$HBD\_INC_{j}*RANK\_IND_{ij}$
$+ u_{0j} + r_{ij}$

*Note***.** HLM equations shown as a Level 1 and Level 2 model as well as a mixed model version of the equation. OVRBE_SC represents overall built environment score; WPOP_DEN represents population density; and NHBD_INC represents neighbourhood income.

Chapter 4: General Discussion

General Discussion

Since the turn of the century, the relationship of the built environment to active living has been the focus of a growing body of literature (Sallis et al., 2006, 2020). While there is a substantial amount of literature exploring the relationship between the built environment and active living among many populations and groups within those populations, there has been relatively little research exploring these areas among military personnel (e.g., Nicosia & Datar, 2018; Tarlov et al., 2019). This is mirrored within Canadian contexts; there is a growing body of literature among different populations, but none involving the Canadian Armed Forces (CAF; Christie et al., 2020; Farkas et al., 2019; Frank et al., 2019; Wasfi et al., 2016). Researching the built environment and active living among Canadian military personnel represents a unique opportunity because of the occupational demands and physical activity requirements inherent to CAF personnel (Franz, 2015; Thériault et al., 2016).

Summary of Objectives and Findings

The dissertation aimed to evaluate the built environment where CAF personnel live and explore the relationship of these built environments to active living among CAF personnel. This project involved two studies to investigate these objectives.

Study 1 had two objectives. The first was to develop a measurement scale with and for the CAF. Second, we aimed to assess the built environments where CAF personnel live using that scale. In collaboration with CFMWS and Health Promotion, the Forces Environments for Active Living (FEAL) scale was developed. Using the FEAL scale, two trained raters evaluated built environment neighbourhoods where CAF personnel live across seven CAF base locations across Canada.

The analyses for study 1 indicated a three-factor solution: active living infrastructure, neighbourhood streetscape, and aesthetics. These three factors had good-to-strong psychometric properties. The use of the FEAL scale highlighted features of the neighbourhood built environments that military personnel lived and worked in. Notably, the average active living infrastructure score was low, suggesting that it can be improved across all locations. On the other hand, neighbourhood streetscape and aesthetics and are generally areas of strength, although there are certain areas that could be improved.

Study 2 investigated the relationship of the neighbourhood built environment to the activity levels of CAF personnel. Using secondary data provided by Canadian Forces Morale and Welfare Services as well as built environment scores and census data, hierarchical linear modelling was conducted. This data included several variables with age and rank at the individual level (level 1) and built environment score, population density, and average neighbourhood income at the neighbourhood level (level 2). The findings indicated that the built environment did not have a significant relationship with active living. However, the broader context of the results also provided valuable information highlighting that among CAF personnel physical activity levels decreased with age, rank, and population density.

Situating the Findings

Study 1

The following section will provide a brief overview of the findings from Study 1 and situate these outcomes within the context of the literature. In Study 1, the specifically identified factors, align with existing literature exploring the built environment and active living. Active living infrastructure, neighbourhood streetscape, and aesthetics along with their sub-themes align with findings from meta-analyses, reviews, and international studies which have also noted and identified these themes. A systematic review and meta-analysis by Barnett et al. (2017) identified environmental attributes connected to physical activity and active living, including infrastructure (e.g., sidewalks, streets), streetscapes, and safety. Similarly, an international study Sallis et al. (2020) identified important factors surrounding pedestrian infrastructure (e.g., sidewalks), aesthetics, and safety among others. A review by Bonaccorsi et al. (2020) also highlighted key areas including pedestrian-friendly infrastructure and safety, traffic safety, aesthetics, destinations, and greenery (i.e., trees). Lastly, an even broader review of physical function (which included physical activity) noted similar findings to the above reviews (Rachele et al., 2019).

Looking more specifically at each of the factors, the items in these also fit with the literature. Active living infrastructure and its components regarding the physical structure and design, safety, amenities, and their roles are noted in several studies (e.g., Barnett et al., 2017; Bonaccorsi et al., 2020; Kärmeniemi et al., 2018; Moran et al., 2014; Rachele et al., 2019; Van Cauwenberg et al., 2016). For instance, the presence or absence of a sidewalk implies several themes including safety (implicit and explicit) and active living support and promotion. Going for a walk on a road with vehicles driving by is less enticing than on a sidewalk separated from traffic. This view is supported by research that provides evidence that infrastructure such as sidewalks play an important role in physical activity and should be considered health resources (e.g., Barnett et al., 2017; Sallis et al., 2020). Likewise, neighbourhood streetscape includes themes such as greenspace (i.e., trees), visual interest, and topography that have been the subject of research that highlights their importance and their association with physical activity (e.g., Humpel et al., 2002; Kaczynski & Henderson, 2007; Kardan et al., 2015; King et al., 2000;

Nguyen et al., 2013; Storgaard et al., 2013). For example, greenspace, and specifically trees, have been found to have numerous health benefits including improvements to physical and mental health (Kaczynski & Henderson, 2007; Kardan et al., 2015; Storgaard et al., 2013). In fact, one study stated that "having 11 more trees in a city block, on average, decreases cardio-metabolic conditions in ways comparable to an increase in annual personal income of $20,000 […] or being 1.4 years younger" (Kardan et al., 2015, p. 1). Lastly, aesthetics highlights "the importance of clean and attractive neighbourhoods […] in facilitating physical activity" (Barnett et al., 2017, p. 18; Moran et al., 2014). Cerin et al. (2006) identified neighbourhood aesthetics, among other neighbourhood features, as an important predictor of physical activity. Likewise, research has also noted similar associations between aesthetics and physical activity across a range of populations and neighbourhoods (Foster et al., 2011; Humpel et al., 2002; King et al., 2000). For example, people were found to be more likely to walk and otherwise physically active in attractive and appealing neighbourhoods (Foster et al., 2011; Owen et al., 2004; Pikora et al., 2006; Sugiyama et al., 2009). Moreover, in areas (e.g., neighbourhoods) with poor aesthetic environments, people were 40% less likely to exercise (Ball et al., 2001).

Overall, the identification of these factors and their alignment with the literature suggests that the FEAL scale findings highlight relevant areas of focus. While the FEAL themes are similar to existing themes in non-military related research, the development process ensures that it not only has a strong research foundation but is also meaningful to the CAF. From a military perspective, it also indicates that the built environments where CAF personnel live align with those in the general population. Broadly speaking, this could also suggest that the FEAL may also be relevant for use in non-military populations. However, continued testing and use is recommended.

These FEAL scale also provided insight on the built environments where CAF personnel tend to live. Across all locations, active living infrastructure scores were low and represented an area for improvement. For example, cyclist safety from traffic, street shoulders, and sidewalks, were clear areas for improvement. In fact, cyclist-related infrastructure across all neighbourhoods was virtually non-existent and presents a distinct area for improvement. On the other hand, neighbourhood streetscapes and aesthetics scored well which suggests that CAF personnel tended to live in appealing and attractive neighbourhoods with active living supportive streetscape features. For example, the amount and quality of trees appeared to have an impactful role in neighbourhood areas. For more details about these results please refer to Study 1.

Study 2

Study 1 findings were incorporated in Study 2. The following section will provide a brief overview of the findings and situate them within the context of the research landscape; a particular focus will be placed on the built environment. The findings from Study 2 showed that physical activity levels (PAL) decreased as age, rank, and population density increased. It also revealed that at the neighbourhood level, the built environment and neighbourhood income did not appear to be related to PAL. These findings generally align with the literature but also feature some differences.

Regarding age, our findings suggest that as CAF personnel age increases there is a reduction in physical activity. The reduction of physical activity with age aligns with trends in the general population which also sees individuals become less active as they get older (Spittaels et al., 2012; Westerterp, 2018). In terms of rank, these findings suggest that as CAF personnel move up in rank, they experience a decrease in physical activity. This aligns with some research showing a connection between rank and physical activity and complementary behaviours such as increases in sedentary time in higher ranking members (Martins & Lopes, 2013; Thériault et al., 2016). These findings also point to the occupational nature of higher ranks in the military which often feature increased responsibilities, management, and administrative duties compared to lower ranks. For example, a senior officer will likely be involved in daily meetings, planning, and strategizing. As a result, it is plausible there may be less dedicated time available for physical activity due to the nature of their work tasks.

With respect to population density, the findings suggest that CAF personnel tend to be less physically active when living in neighbourhoods with higher concentrations of people. These findings appear to align with the research which is somewhat mixed. Previous studies have noted that physical activity tends to be associated with higher population density (Josey & Moore, 2018; Rodríguez et al., 2005, 2006). However, it has also been found that density may be connected to specific activities (e.g., purposeful walking), but is generally not associated with total or overall activity (Forsyth et al., 2007). Given the type of activity used in this study, these findings appear to agree with the mixed aspects of the literature while presenting a meaningful outcome for CAF personnel. Study 2 (chapter 3) provides additional information about population density. There was no relationship of neighbourhood income to PAL. Past research has shown physical activity in lower-income neighbourhoods might be accrued through active transportation (i.e., public transit, biking, walking), while there may be less of a need for these methods in higher-income neighbourhoods (Lee et al., 2007; Xiao et al., 2019). Given that the average income of all neighbourhoods in this study is $75,624, there may be less of a need for active transportation, thereby reducing or eliminating potential physical activity.

Built Environment Findings

The Study 2 findings indicated that the built environment did not have a significant influence on the physical activity levels of CAF personnel. The supplemental analysis looking specifically at the built environment provided additional information. The exploration of on versus off base scores aligned with the main analysis. The exploratory look at subscale-by-subscale and item-by-item influences somewhat aligned with the previous findings, but still provided notable and slightly different findings that warrants continued research. The main results and supplemental analyses fit within the existing literature which has found mixed results (Barnett et al., 2017; Kärmeniemi et al., 2018; Nordbø et al., 2020; Rodríguez et al., 2005; Sallis et al., 2020). Previous research provides additional context for when the built environment does not appear to be related to physical activity. For instance, Rodríguez et al. (2005) noted mixed results and postulated that the type of physical activity measured may impact its relationship with the built environment. In Study 2, a measure of overall physical activity was used in the calculation to determine physical activity levels. According to Rodriguez et al. (2005) it is plausible that different types of physical activity such as light, moderate, or vigorous rather than a total physical activity measure may have led to different outcomes. For example, an international study by Sallis et al., (2020) noted significant associations and measured different types of physical activity (e.g., leisurely activity, MVPA). With this suggestion in mind, it may more be accurate to state that the built environment does not have a significant relationship with the total PAL of CAF personnel.

A second perspective was provided in a study by Nordbø et al. (2020) who posited that the same built environment features might influence people in different ways depending on factors such as age. Expanded further, it is also plausible that factors such an individual's occupational characteristics (e.g., rank, responsibilities, expectations) could also contribute to how the built environment may be experienced. Applied to this dissertation, this could contribute to a potential explanation as to how the built environment does not appear to be related to the activity levels of CAF personnel when other research has indicated they are related (e.g., Bonaccorsi et al., 2020; Humpel et al., 2002; Kärmeniemi et al., 2018; Sallis et al., 2020). This suggests that all other things being equal (e.g., the built environment), individual characteristics can play an important role in the findings observed in the literature. Thus, our findings are likely to be most meaningful considered within the context of the CAF.

The literature also suggests a mechanism which could explain why in some cases the built environment does not appear related to physical activity. A systematic review by Rhodes et al. (2020) consolidates this explanation. They identified a mediational framework which highlighted a connected and accessible built environment for physical activity to facilitate engagement in active behaviours. Specifically, they believe that the self-efficacy and perceived behavioural control over accessibility and convenience of the built environment is connected to physical activity. Simplified, these findings suggest that an individual's perception of the built environment plays an important role. For example, if a neighbourhood built environment has barriers to physical activity it may make a person less likely to be active. Considered within the findings of this dissertation, this mechanism provides a plausible perspective. For example, even though the neighbourhood built environments where CAF personnel live received good scores on streetscape and aesthetic factors, the low scores on active living infrastructure (study 1) could be perceived as a barrier to activity. For instance, the absence of sidewalks and closeness to traffic in some areas may present logistical and safety challenges and could be perceived as having poor accessibility and convenience. As a result, CAF personnel may not engage in physical activity in their neighbourhoods and when assessed it would likely indicate no significant relationship between the built environment and their physical activity (study 2).

Although there was no relationship between the neighbourhood built environment and physical activity levels among CAF personnel, these results in and of themselves are meaningful. First, these findings highlight the need for further research about the built environment and military contexts. The built environment can be a powerful influence at a population level (Rose et al., 2008; Sallis et al., 2006) and further research could serve to highlight these potential areas. This is particularly meaningful for the CAF because they are in a unique situation where they have the authority to potentially shape the neighbourhood built environments that fall under their jurisdiction. This means that there is more potentially freedom to implement desired changes than may be typically seen at the municipal or community level where there are multiple public stakeholders and perspectives. This may be of particular interest at CAF base locations and communities which suspect city/community level influences. Second, considered together the built environment findings from Study 1 and Study 2 can inform policy, programming, and resources at the organizational level (e.g., CFMWS). Considering this, the outcomes of both studies could guide planning, programming, and policy to support physical activity interventions. For example, since the built environment does not appear to impact physical activity among CAF personnel (study 2), but there are clear areas of improvement at the neighbourhood built environment level such as those surrounding active living infrastructure (study 1), resources can be appropriately allotted. Third, considering both sides of the literature (e.g., significant and non-significant findings) these findings point to the value of investigating different types of physical activity with the built environment in the context of CAF personnel. It would build off the research presented in this dissertation and provide additional clarity to inform CAF population wide programming.

Theoretical Framework Interpretations

It is also helpful to interpret the findings from this dissertation in the context of the theoretical framework. As outlined in chapter 1, this dissertation is guided by the ecological model of active living put forward by Sallis et al. (2006) which, in turn, is based on the socioecological framework (Bronfenbrenner, 1979). By placing the studies from this dissertation within this framework, it provides a platform to strengthen understanding from the conceptual to concrete levels. In this framework, Study 1 is situated at the behavioural settings level; specifically, residential neighbourhoods where CAF personnel live. Study 2 is situated primarily at the behaviour level where it explored and examined the relationship between the behaviour setting and the behaviour level with the involvement of other levels.

Regarding study 1, the built environment score results address the neighbourhood behaviour settings in which the built environment audits took place. They outlined the strengths and weaknesses of these settings and indicated areas of improvement. These findings also lay the foundation for the next study where additional levels are involved. However, the development process that occurred in study 1 also played a role at another level. The involvement of CFMWS (e.g., Health Promotion) personnel in the development of the FEAL scale, outlining neighbourhoods, and the data collection process also contributes to the policy environment level of this framework. While not formally analyzing this level, the involvement and contribution of those involved supports this aspect of the framework. Key decision-makers and policy and program developers were involved in this project and its objectives. For example, space was made for the integration of these results into upcoming strategic plans and each location will be provided with a separate local summary of their results to potentially inform local policy and decisions. Overall, the main objective of Study 1 operates at the behaviour settings level. However, the collaborative process through which this is achieved also provides support and contribution at the policy level.

Study 2 operates at multiple levels of this framework: the behaviour setting, behaviour, and intrapersonal (or individual) levels with a particular focus on the former two levels. Specifically, the dependent variable (DV) physical activity level (PAL) is representative of the behavioural level. The Level 1 independent variables (IV) of age and rank are representative of the intrapersonal level. The Level 2 IVs of built environment scores, population density, and neighbourhood income are representative of characteristics of the behavioural setting level. Interpreted from this theoretical framework perspective, certain aspects of these levels of the model interact with each while others do not. Concerning the primary interest of this study, the built environment, the behaviour setting level does not appear related to the individual behaviour level. However, if we expand the focus of this interpretation, we see the relationship to the behaviour setting is mixed. The behaviour setting of population density does appear to be related to behaviour, while neighbourhood income does not. This supports the link to the literature that the relationship between behaviour settings and behaviours is mixed (e.g., Barnett et al., 2017; Ferdinand et al., 2012; Nordbø et al., 2020; Rodríguez et al., 2005; Sallis et al., 2020). Expanding this interpretation further, the intrapersonal (individual) level does have an impact at the behaviour level (physical activity). This is similarly consistent with general population and military findings including individual factors such as age and rank (e.g., Martins & Lopes, 2013; Spittaels et al., 2012; Thériault et al., 2016; Westerterp, 2018).

From a general perspective, this theoretical framework also points to a potential area of future research: the perceived environment. Specifically, it will be important to investigate CAF personnel and their perception of their environments. Under the umbrella of the perceived environment, the ecological model of active living outlines areas such as safety, attractiveness, comfort, perceived crime, accessibility, and convenience (Sallis et al., 2006). The latter two areas were mentioned by Rhodes et al. (2020) as potentially playing a mediating role in the relationship between the built environment and active living. Systematic reviews have noted that while the perceived environment can play an important (although sometimes modest) role in relation to physical activity (Duncan et al., 2005; Orstad et al., 2017) it can also be less consistent than objective environment measures (Christie et al., 2020).

The potential interconnection of perceived and objective measures of the environment also warrants further research (Orstad et al., 2017). This dissertation, the theoretical framework, and existing reviews provide a roadmap for continued research (e.g., Christie et al., 2020; Duncan et al., 2005; Orstad et al., 2017; Rhodes et al., 2020; Sallis et al., 2006). Overall, the theoretical framework interpretation of these findings highlights that the socioecological model contains dynamic relationships between individuals and the environment (Nordbø et al., 2020).

Implications

There is an absence of research evaluating the relationship between built environment and active living among CAF personnel. In addressing this gap in the literature, this dissertation also contributes to research needs including expanded military research (e.g., Malkawi et al., 2018), strengthening Canadian built environment research (e.g., Christie et al., 2020; Oreopoulos, 2008), and exploring alternative approaches to managing active living in the military. These findings also provide a framework for continued research in this area of study supporting a more focused scope of research moving forward. These results also have implications for practice and policy within the CAF, particularly for CFMWS.

The findings from this project present several opportunities to inform policy and practice. Considered broadly, the collaborative process of this project fostered involvement and integration of the scale development, results, and feedback. For example, results will be incorporated into reports and strategic plans at CFMWS. These findings may be used to inform various types of policy and programming decisions. For example, they can contribute to targeted policies regarding active living among certain CAF personnel. Further to this point, it can also inform policy and resources regarding external community partnerships. Lastly, this project also provides an approach to evaluate and provide meaningful information about other CAF neighbourhood built environments in the future.

Limitations & Strengths

The previous chapters addressed specific limitations of each study; however, there are some general limitations in this dissertation that should be noted. First, the neighbourhoods and participants in this dissertation represent a Canadian sample. While beneficial for Canadian research contexts, it may limit generalizability to other countries and regions. Second, although beneficial, the use of secondary participant data meant the data was already collected from participants; this led to some unexpected bureaucratic obstacles (e.g., duration of data transfer). Third, the CAF locations were based on a previous CFMWS study meaning the selection of bases/towns for this study was not truly random. However, this approach allowed each branch of the military to be represented and enabled the findings to be generalized across the CAF.

This dissertation also contains several strengths that are worth highlighting. First, this project involved a collaborative process with the CAF throughout which also aligns with participatory action research (Baum et al., 2006). Additionally, working alongside collaborators increases the likelihood of its acceptance and impact, which has been noted by its incorporation in local CAF bases' strategic planning for the upcoming year. Second, while the use of secondary data had limitations in terms of the type of data collected, it also afforded the opportunity to work with CAF personnel participants. This is an opportunity that may have otherwise been highly challenging, if not unfeasible within the constraints of a dissertation. Third, this dissertation addresses and contributes to research needs from different perspectives including Canadian built environment research and military research (e.g., Christie et al., 2020; Malkawi et al., 2018; Oreopoulos, 2008). Fourth, the neighbourhood built environments used throughout the dissertation were selected independently of the secondary data (e.g., participants) which helps ensure the accuracy of the neighbourhood locations irrespective of participant influence. Finally, the neighbourhood built environments are from locations across Canada increasing the generalizability to CAF personnel across the country.

Future Directions

Since this was the first study of its kind examining the relationship between the built environment and active living among CAF personnel there are several directions for future research. Regarding the FEAL scale, continued testing, refinement, and monitoring of psychometric properties is an area ripe for continued study. Future investigations with increased sample sizes are also recommended. At the neighbourhood level, this may look like increased sampling of on-base residential neighbourhoods separately or in addition to total neighbourhoods assessed. At the individual level, this would entail sampling larger numbers of CAF personnel participants who live in these areas. A variation of this might see CAF populations compared to civilian populations for differences in physical activity and relationships to the built environment. Overall, by increasing sample sizes at one or both levels, it's plausible that it may increase the sensitivity to which additional results are detected. If multilevel modelling is pursued in future studies, these increased sample sizes would strengthen the power and facilitate greater flexibility with variables.

Further, the dependent variable of physical activity level (PAL) also represents an area with several future research directions. The use of total physical activity in calculating PAL provided valuable information; however, examining nuanced versions of active living may offer additional insight. For example, examining different types of physical activity: light, moderate, and/or vigorous physical activity in relation to the built environment may prove meaningful. From a conceptual perspective, incorporating theoretical framework interpretations is another direction for future research (Sallis et al., 2006). For example, investigating participants' environmental perceptions, especially towards convenience and accessibility (e.g., Rhodes et al., 2020) might also contribute valuable information. Similarly, exploring the impact of the CAF and CFMWS policy environment on behaviour settings or behaviour levels could present interesting and meaningful information from an additional perspective.

Conclusion

The aim of this research is to provide evidence to decisionmakers that serves to meaningfully contribute to the pursuit of the overall health and wellbeing of CAF members. To that end, the findings from this dissertation provided evidence about the relationship of the built environment and active living among CAF personnel. While the built environment was not related to the physical activity of CAF personnel, the project shed light on impactful factors such as age, rank, and population density. In doing so, this dissertation also provided a scale and information about neighbourhood built environments meaningful to CAF members. The collaborative process used throughout the dissertation contributed to important findings and the CAF involvement through this project. Overall, these findings provide meaningful information to help guide and inform CFMWS policy, programming, and resource decisions that affect CAF personnel.

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