# Successful Aging into the 21st Century: The Social and Built Environment as Facilitators or Barriers for Individuals Aging with Disability

by

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# DEDICATION

This dissertation is dedicated to my family, including my parents Muhammad and Anjum, and my siblings, Hamaeel and Haseeb. They have always been supportive of my academic endeavors and encouraged me to challenge myself and strive to achieve my goals. Completing a dissertation during a global pandemic was a challenging feat, but the support of my family made the process possible. From them I have learned the meaning of persistence and hard work as well as the values of learning and always staying true to oneself. I am grateful for the sacrifices my parents have made that afforded the opportunities I have had today. Words cannot describe how grateful I am to have such a solid support group that provides unconditional love and validation. I hope that they are proud of the work I have completed and the person I have become through this process. I also thank my friends who have supported me while I work on this dissertation. Your willingness to engage with my work has challenged my thinking along this journey. I have valued your friendship immensely.

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# ABSTRACT

Up to 21% of Americans are *aging with a disability* acquired at birth or within the first 4-5 decades of life. Their disability trajectory and life course experiences make them a distinct group of older adults with a disability. They have higher risk of age-related chronic diseases and secondary conditions stemming from their disability, and face barriers to navigating their communities. Their limited mobility means they may be more reliant on their environments to facilitate good health. However, little is known about the role of the environment in successful aging for this population.

This dissertation addressed this gap by examining the relationship between features of the environment and quality of care and health outcomes for individuals aging with a physical disability. The cohort was identified using claims data from a national private health insurance database and linked to neighborhood data from the National Neighborhood Data Archive (NaNDA).

The first Aim examined specific features of the built environment pertinent to this population, and their association with incident cardiometabolic disease. Residence in neighborhoods with a high density of recreational establishments, parks, broadband internet connections, and transit stops was associated with lower risk of any cardiometabolic disease. Neighborhoods with a high density of “health promoting” resources were protective for cardiometabolic health but no significant findings were observed for “health harming” establishments. Density of healthcare establishments was not independently associated with cardiometabolic health, suggesting that other factors such as quality of care experiences, not the presence of healthcare establishments per se, may be important to consider.

The second Aim of this dissertation characterized quality of care, measured using Bice-Boxerman continuity of care (COC) index, and identified the associated individual and community-level factors. This population had low COC scores, indicative of more fragmented care, and saw a variety of provider specialties. Those with high COC had a greater proportion of visits concentrated amongst two specialties (Family & Internal Medicine). Living in less affluent communities, and having less access to transit, broadband internet and health care providers (e.g., Medical Specialists) was associated with more concentrated care patterns. Residence in neighborhoods with fewer healthcare establishments was associated with lower odds of continuous care. Environments that facilitate access to many health care providers afford readily available opportunities to seek care from different sources to meet health preferences and needs; though it may lead to more fragmented care patterns. Examination of health outcomes is required to better understand the effect of these care patterns.

Aim three examined the association between COC and diagnosis of chronic health conditions and receipt of preventive screening. After adjusting for individual and community-level confounders, high continuity was associated with lower odds of pain diagnosis and receipt of preventive screening. Effects were more salient in younger adults (<40 years).

In concert, these dissertation Aims highlight the role of the neighborhood environment in understanding quality of care patterns and health outcomes for individuals aging with a physical disability. Neighborhood-level interventions should focus on investment in health-promoting resources. Innovative policies that consider factors outside the healthcare system are required to avert fragmented care in this population, with important implications for supporting appropriate screening and early disease detection for younger adults aging with disability. This work has the potential to support neighborhood designs, policies and programs that facilitate the ability of this population to age successfully in place.

# CHAPTER I:

# Introduction and Aims

## 1.0 Overview

There are approximately 53 million Americans living with a physical, sensory, intellectual, independent living or self-care disability (Okoro, et al. 2018; Meade, Mahmoudi and Lee 2015; He, Larsen and U.S. Census Bureau 2014). Therefore, individuals with disabilities represent a large proportion of the United States population. The number of individuals with a disability is projected to increase due to population aging trends and a rise in potentially disabling chronic conditions (e.g., stroke) (World Health Organization 2011). However, a growing number of individuals are aging with a disability acquired earlier in life. The life course experiences of those aging with a disability developed at birth, in childhood or during mid-life ("aging with disability") are distinct from those who develop a disability as a result of the aging process ("aging into disability") (Clarke and Latham 2014; Vergrugge, Latham and Clarke 2017). This makes the cohort with early-acquired disabilities a unique population among older, disabled adults. The increased longevity for those with early-onset disabilities highlights the need to better understand the factors that support healthy aging.

In the gerontology literature, paradigms of successful aging emphasize avoidance of disease and disability, as well as the role of the individual in maintaining physical and cognitive function (Rowe and Kahn 1997). These traditional paradigms have garnered some criticism for not adequately capturing what successful aging means to older adults, including some limitations that may apply specifically for individuals aging with a disability (Martinson and Berridge 2015). Successful aging with disabilities emphasizes resilience/adaptation, social connectedness, and health (in particular, prevention of secondary health conditions and access to healthcare) (Molton and Yorkston 2017). However, individuals with disability also experience unmet healthcare needs and restricted access to medical care (Campbell and Putnam 2017; Campbell, Sheets and Strong 1999).

Individuals with disability have a higher burden of chronic health conditions and lower prevalence of most routine preventive screenings (Centers for Disease Control 2020(a); Centers for Disease Control 2020(b); American Association on Health and Disability 2011). For example, data from the National Household Interview Survey (NHIS) noted that amongst women 50-74 years of age, 75% of them without disabilities reported receiving a mammogram in the last two years, compared to only 61% with a disability (Centers for Disease Control (b) 2020). Similar findings have also been observed for receipt of Pap tests (81% among women without disabilities compared to 66% for women with a mobility disability) (Steele, et al. 2017). Despite a greater burden of high cholesterol and blood pressure, individuals with disabilities are less likely to receive screenings for these conditions (American Association on Health and Disability 2011). Adults with disabilities are three times more likely to have heart disease, stroke, diabetes or cancer, compared to their counterparts without disability (Centers for Disease Control 2020(a)).

The burden of chronic disease is more pronounced for adults with disability who do not get sufficient aerobic exercise (Centers for Disease Control 2018). However, 50% of individuals with disability get no aerobic physical activity, compared to 25% amongst individuals without disability (Centers for Disease Control 2018). Specifically, amongst those disabilities acquired in early life, data from the 2006-2012 National Household Interview Survey (NHIS) highlighted that they had higher odds of developing heart disease (adjusted odds ratios (aOR) 2.57, 95% confidence intervals (CI): 2.33, 3.66), diabetes (aOR 2.57, 95% CI: 2.10, 3.15) and hypertension (aOR 2.18, 95% CI: 1.94, 2.45) net of sociodemographic characteristics (Dixon-Ibarra and Horner-Johnson 2014). Similar findings have been observed for adults with cerebral palsy (CP) and spina bifida (SB) compared to their counterparts without these conditions using private health insurance data for any cardiometabolic disease (Hazard ratio [HR] 1.52, 95% CI: 1.47,1.57), psychological morbidity (HR 1.60, 95% CI: 155-1.65) and fractures (Odds Ratio [OR] 2.5, 95% CI: 2.2, 2.7) (Whitney, et al. 2019; Peterson, et al. 2021; Peterson, et al. 2020).

In addition to barriers in healthcare access, they also report inadequacies within the healthcare system (e.g., lack of providers who are knowledgeable about their disability), making quality of care measures such as continuity of care (COC) paramount to study (McColl, Jarzynowska and Shortt 2010). In the general population, barriers in the social and built environment have been shown to pose challenges in accessing social and health resources and services, and are related to the development of adverse health conditions (Centers for Disease Control 2018) (Centers for Disease Control (b) 2020) (Rural Health Information Hub n.d.). However, there exists a paucity of evidence examining how environmental factors can support successful aging outcomes for individuals aging with disabilities acquired in early or mid-life.

Adults aging with disability may be more reliant on local environments that facilitate their full participation in society and engagement in health-promoting behaviors. Therefore, studying the features of the social and built environment that facilitate positive health outcomes for those aging with disability is critical. However, as most studies focus on the psychosocial characteristics of this population, there is a noticeable gap in the literature examining their interface with socio-environmental factors. The overall aim of this dissertation is to elucidate the features of the built and social neighborhood environment that may influence quality of healthcare, and health outcomes for those aging with disability.

In its totality, Chapter 1 of this dissertation provides an overview of the literature on the population aging with disability and conceptual models that integrate understanding of disability, access to care, health outcomes and the role of the neighborhood environment. It identifies gaps in our understanding of the role of the environment in shaping health for those aging with disability. The Chapter begins by describing how demographic changes have influenced observed trends in disability (Section 1.1). The Chapter notes the distinction between a population aging *with* disability and one aging *into* disability (Section 1.2), limitations in our current understanding of successful aging for a population aging with disability, and discussions about what aging successfully with a disability would entail (Section 1.3). Subsequently, the Model of Healthcare Disparities and Disability (MHDD) is discussed as a model which aims to reconcile the disparate frameworks for understanding disability and access to care, while highlighting the role of the social and built environment (Section 1.4). I then discuss some important data sources that can be leveraged to study the role of the environment in healthcare access and health outcomes for individuals aging with disability (Section 1.5). The chapter concludes by noting how information on the role of the social and built environment and its association with health outcomes and quality of care amongst those aging with disability is lacking. The case is made for the importance of the environment for a population aging with disability and how that informs the dissertation aims and the conceptual model guiding this work (Section 1.6).

## 1.1 Demography of Aging and Disability

In the United States, 50.9 million people (15.6% of the population) are 65 years of age or older (United States Census Bureau 2018). This represents a growth of 34% since 2007 (United States Census Bureau 2018). In the coming years, this segment of the population is expected to grow further, such that in the next three decades, ~23% of the population will be within this age bracket (United States Census Bureau 2018). The change in the aging population structure has been partially driven by medical, scientific and public health advancements. These include, but are not limited to, new therapies and treatments for cardiovascular disease, and sanitation programs to mitigate infectious diseases (Crimmins 2015; United Nations Department of Economic and Social Affairs 2017).

Population aging is consequential for trends in disability. The prevalence of physical, sensory, intellectual or self-care disability in the United States ranges from 13-25% (Okoro, et al. 2018; Meade, Mahmoudi and Lee 2015). However, the prevalence in adults 65 years of age or older is >35% (He, Larsen and U.S. Census Bureau 2014; Kraus, Lauer and Coleman 2018). Ambulatory disabilities (impairments in movement such as walking or climbing stairs), account for the greatest proportion of all disabilities (Okoro, et al. 2018; Kraus, Lauer and Coleman 2018; Administration for Community Living 2018). The World Health Organization (WHO) projects that the number of people with disabilities will continue to grow due to trends in population aging and the increase in potentially disabling chronic health conditions (e.g., diabetes and cardiovascular disease) (World Health Organization 2011).

The cumulative effects of entering old age with a disability that was developed in mid-life or earlier is *distinct* from the experience of developing a disability in later life. In the disability and gerontology literature these represent two distinct populations of older adults, one aging *with* disability and another aging *into* a disability.

## 1.2 Aging *with* Disability vs. Aging *into* Disability

The population aging *with* disability encompasses those living with a disability acquired at birth, in childhood or during mid-life (typically in the first 4-5 decades of life) (Campbell and Putnam 2017) (Vergrugge, Latham and Clarke 2017). Terms such as early-onset, long-term or long-standing disability are often used interchangeably to describe the process of aging with a disability. This population includes individuals with physical (e.g., Spina bifida [SB], cerebral palsy [CP], neuromuscular disorders, post-polio, spinal cord injury [SCI], traumatic brain injury and multiple sclerosis [MS]), intellectual (e.g., Down syndrome), sensory (e.g., Hearing impairment) and developmental (e.g., Epilepsy) disabilities (Campbell and Putnam 2017). It is estimated that 9-21% of the population is living with these long-term disabilities, representing a substantive sub-set of the entire American population with a disability (Kraus, Lauer and Coleman 2018; Vergrugge, Latham and Clarke 2017; Verbrugge and Yang 2002; Katz and DeRose 2010; LaPlante 2014; Schiller, et al. 2012). The large variability in prevalence estimates is attributed to the manner in which disability is defined and measured, and incomplete data resulting from the omission of questions related to age of onset of disability and/or the duration of disability (Campbell and Putnam 2017; LaPlante 2014; Putnam, et al. 2016). This is in contrast to the group aging *into* disability that becomes disabled late in life, typically as a result of the aging process, chronic health conditions or an injury (Molton and Yorkston 2017).

The increased longevity amongst individuals aging with disability can be attributed to medical advancements promoting early survivorship, technological innovations, policies and programs at the state and federal level, and improved disease control (Molton and Yorkston 2017; Campbell and Putnam 2017; Campbell, Sheets and Strong 1999; LaPlante 2014; Krause and Coker 2006; Lin, et al. 2012). This has contributed to an increase in the number of individuals aging with a disability. Their causes of death also mirror those observed in the general population (Janicki, et al. 1999).

Individuals aging with disability are more likely to be female, Black or Hispanic, tend to spend fewer years married, and more time living alone (Clarke and Latham 2014; Kraus, Lauer and Coleman 2018; Vergrugge, Latham and Clarke 2017; Zarb and Oliver 1993; DeVivo and Richards 1996). They are also exposed to the adverse effects of lower educational attainment and higher unemployment rates for longer periods of their lives (Clarke and Latham 2014). Clarke and Latham (2014) utilized over 30 years of data from the Panel Study of Income Dynamics (PSID) to study the life course health and socioeconomic profiles of Americans aging with a disability (Clarke and Latham 2014). Disability was defined according to repeated measures of work limitations in prime working years. The study noted the following significant findings, comparing individuals aging with a disability to their counterparts with late onset disability or no disability: 1) attainment of a college degree was lower (13.8% vs 22.2%), 2) fewer individuals were employed throughout the life course, and 3) they had persistently lower household income, which was most pronounced in mid-life (Clarke and Latham 2014). These factors have implications for economic savings, retirement, and health among those who develop disabilities earlier in life.

Given their disability trajectories and life course experiences, individuals aging with disability represent a distinct subset of older adults with disability. As the number of adults aging with disability grows, there is increasing interest in understanding how to support successful aging in this population. Understanding the factors that contribute to healthy and positive aging for this group is becoming an increasingly important area of research.

## 1.3 Successful Aging with a Disability

An aging population and increasing longevity has placed greater focus on promoting health in old age and in aging "successfully" (Molton and Yorkston 2017). Rowe and Kahn (1997) have proposed the most commonly cited model of successful aging. It describes successful aging as being comprised of three elements: 1) avoidance of disease and disability, 2) maintenance of cognitive and physical function, and 3) social engagement (Rowe and Kahn 1997) (Appendix A, Figure A.1). Lack of disability or disease makes it easier to maintain physical and mental functioning, which can make engagement in daily activities possible (Rowe and Kahn 1997). Research using the Health and Retirement Study (HRS) reported the prevalence of aging successfully to range from 3.3 to 33.5% depending on how these broad criteria were operationalized (McLaughlin, Jette and Connell 2012).

Despite the popularity of this model, there are some limitations discussed in the literature, especially as it pertains to persons aging with disability (Martinson and Berridge 2015). First, it has been suggested that there should be a greater discussion of subjective measures of aging and well-being. This may, in part, explain the discrepancies between individuals' self-reports of whether they are aging successfully compared to the Rowe and Kahn (1997) model (Phelan, et al. 2004; Strawbridge, Wallhagen and Cohen 2002). Secondly, the model places emphasis on the individual to maintain physical and mental functioning with age. It has been argued that this might shift responsibility away from the state to provide supports for older adults and individuals with disability (Martinson and Berridge 2015). There is also limited discussion about the importance of social and community supports that can facilitate successful aging (Minkler and Fadem 2002). Additionally, placing the responsibility for successful aging on the individual precludes consideration of the role of contextual factors in this process (Minkler and Fadem 2002). For example, someone may want to access preventive health services but barriers within their environment such as lack of public transportation may preclude them from doing so. Thus, greater attention should be paid to the role of contextual factors in successful aging paradigms and how positive health outcomes may be achieved for individuals aging with disability. Lastly, the model argues for the avoidance of disease and disability, suggesting that those aging with disability are not aging successfully (Minkler and Fadem 2002). According to the model, this is because they have an early-onset disability and navigate the life course managing the condition.

However, work by Molton and Yorkston (2017) and Krause and Coker (2006) provide evidence that individuals aging with disability can age successfully (Molton and Yorkston 2017; Krause and Coker 2006). Qualitative work on successful aging with disability has emphasized the role of resilience/adaptation, social and physical supports, and physical health (Molton and Yorkston 2017). Therefore, there is a need to further study what successful aging outcomes look like in individuals with early-onset disability and the role of contextual factors in this process.

### 1.4 Conceptual Models of Disability, Access to Healthcare and Health Outcomes and Disability

Historically, models of disability, healthcare disparities and access to care have existed in silos. The International Classification of Functioning, Disability and Health (ICF) is the most prominent model of disability worldwide. In the ICF, functioning is classified at the level of the body or body part (impairments), the person (activity limitations; disability) and the person situated within society (participation restrictions) (World Health Organization n.d.). It makes mention of relevant personal and environmental factors which can modify the progression of the disablement process from impairment to activity limitations and participation restriction (Appendix A, Figure A.2) (World Health Organization n.d.). However, the ICF is limited in its conceptualization of person-level factors and their interaction with environmental characteristics (Meade, Mahmoudi and Lee 2015). The Aday and Anderson (1974) model of healthcare access, which conceptualizes usage of health services as being determined by the dynamics between predisposing (e.g., age), enabling (e.g., access to health insurance) and need (e.g., diseases burden) factors, is limited in its inclusion of contextual factors that can affect access to care (Appendix A, Figure A.3) (Aday and Andersen 1974; Meade, Mahmoudi and Lee 2015). Instead, the emphasis is on need and individual characteristics that influence healthcare use (Meade, Mahmoudi and Lee 2015). This may not be adequate for understanding the interventions needed for vulnerable populations such as those with disability (Meade, Mahmoudi and Lee 2015).

A more recent model proposed by Meade, Mahmoudi and Lee (2015) aimed to integrate the ICF and the Aday and Anderson models of healthcare access and address the aforementioned limitations of these models. By doing so, it aimed to provide a more complete understanding of the role of how individual and contextual factors impact access to care and health outcomes for those with disability (Meade, Mahmoudi and Lee 2015). The Model of Healthcare Disparities and Disability (MHDD) conceptualizes how personal (e.g., race/ethnicity or insurance status) and environmental factors, including features of the social and built environment (e.g., policies, transportation and health systems), influence healthcare access and quality of care. This, in turn, may modify the extent to which an individual is able to manage their impairment and health (Figure I.1) (Meade, Mahmoudi and Lee 2015). The model recognizes the role of an individual's environment for health and healthcare access and identifies several modifiable individual and environmental factors that can improve healthcare access, quality of care and health outcomes for those with disabilities. Research and public health programs have demonstrated that personal and environmental factors need to be considered in tandem to achieve better health outcomes (Meade, Mahmoudi and Lee 2015). However, quantitative research testing this model, in particular the role of the environment and individual characteristics on quality of care and outcomes in those aging with disability, is lacking.

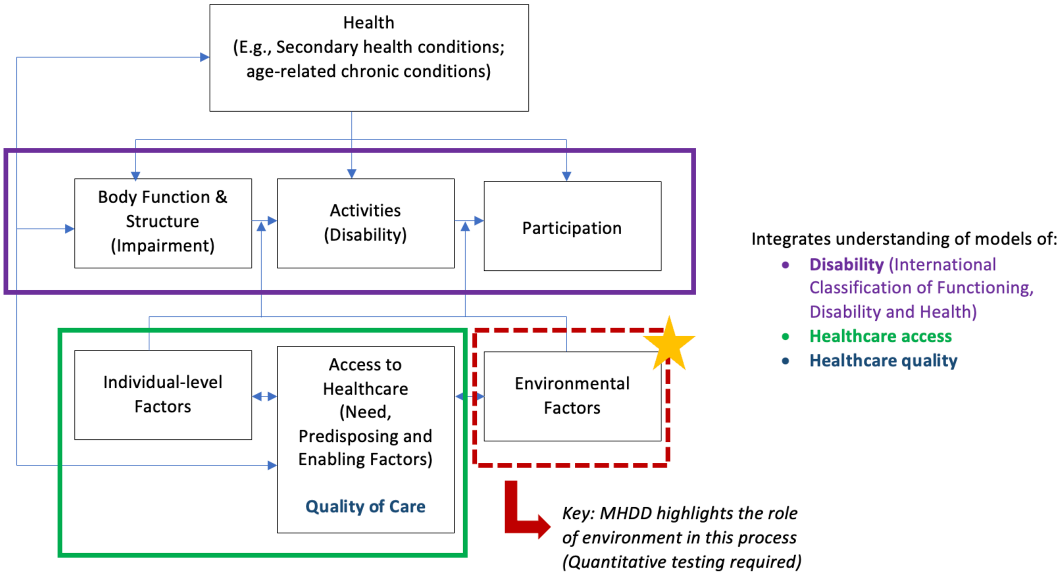


Figure I.1 Meade, Mahmoudi and Lee's (2015) Model of Healthcare Disparities and Disability (MHDD) (Adapted from: Meade, Mahmoudi and Lee 2015)

## 1.5 Data Sources Informing Understanding of the Neighborhood Environment, Healthcare Access and Chronic Disease Amongst Individuals Aging with Disability

Examining the relationship between disability as a risk factor for late life health has important implications for disease prevention. However, the majority of studies to date have been cross-sectional, making the temporal relationship between disability and subsequent health difficult to assert (Dixon-Ibarra and Horner-Johnson 2014). When studying this question amongst those aging with disability, there is the added challenge of ascertaining when the disability occurred and the duration of their disability, all of which are integral to establishing whether an individual is aging *with* disability or aging *into* disability. This information is available in some survey data such as the National Household Interview Survey (NHIS), where information on disability type and age of onset are available (Dixon-Ibarra and Horner-Johnson 2014). Findings for these data sources have made important contributions to our understanding of the experiences of the population aging with disability, including disease burden compared to those without disability (Dixon-Ibarra and Horner-Johnson 2014). However, the cross-sectional nature of this data source prevents us from fully understanding the aging process with disability, including the timing and onset of health problems. Examining these relationships in cohort studies could facilitate a more detailed examination of the temporal relationship between disability and health, including the role of environmental and personal factors. Medical claims data affords a unique opportunity to address this information gap by enabling the creation of cohorts with identified disabling conditions (e.g., physical, intellectual, vision, hearing) and following them longitudinally for incident health events.

Linkage to additional data sources also presents opportunities for a richer understanding of the factors that influence health for individuals aging with disability.

*Use of health administrative claims data for research:*

A plethora of clinical data is collected as part of ongoing patient care, formal surveys or clinical trial programs. These data include, but are not limited to, Electronic Health Records (EHR), patient/disease registries, health surveys (e.g., National Household Interview Survey [NHIS], National Health and Nutrition Examination Survey [NHANES]) and health claims data (University of Washington 2021).

Claims data are collected as part of routine healthcare encounters between a patient and their health care provider (University of Washington 2021; National Rural Health Resource Center n.d.). It is generated from billable interactions (insurance claims) between a patient and the healthcare system (e.g., visit to physician's office, receipt of a diagnostic procedure or filled prescription), with a record being generated for each encounter at the patient-encounter level (National Rural Health Resource Center n.d.; Cadarette and Wong 2015). The primary purpose of these data is for the service provider (health care provider and/or facility) to be reimbursed for the services they rendered (University of Washington 2021; National Rural Health Resource Center n.d.). Therefore, these data contain detailed information related to diagnoses, procedures and cost. More specifically, claims data contain enrolment information for individuals on the insurance plan (e.g., demographics, plan details), data on inpatient and outpatient visits (e.g., diagnosis codes, cost, procedure codes, types of service provided), and pharmacy prescriptions filled (e.g., dosage, drug type) (University of Washington 2021; Rural

Health Information Hub n.d.). There exist both government/public (e.g., Medicare, Medicaid) and private insurance (e.g., United HealthCare) companies. Use of claims data for research is its *secondary* purpose.

### *Optum® Clinformatics® Data Mart:*

A widely-used health claims database is Optum® Clinformatics® Data Mart, which was the data source used in this dissertation. Optum® Clinformatics® Data Mart is a health administrative claims database containing de-identified information for members (aged 0-90 years of age) of a single private insurance payer (Eden Prairie, MN, USA) (Optum 2014; Optum 2017; Mahmoudi and Kamdar 2020). Data is available from 2001-2019 (Mahmoudi and Kamdar 2020). It is a large, longitudinal claims dataset in the United States and contains information on >80 million unique individuals with pharmacy and medical insurance coverage. Each person is assigned a unique identifier, which allows for longitudinal follow-up even when there is a lapse in coverage (no longer enrolled in this private insurance plan) or a change in the specific details of their plan (Optum 2014).

The basic socio-demographic information for Optum® Clinformatics® Data Mart beneficiaries include patient age, sex, race, net worth, education and residential geographic identifiers (Optum 2014). The most granular level of geographic information available for a given beneficiary on the plan is their 5-digit residential ZIP code. It is important to note that when a plan enrollee's ZIP code is provided to data users, information on individual-level race, net worth and education is not included in order to protect patient privacy.

### Using claims data to identify a cohort of individuals with a diagnosis of physically disabling condition:

Data from Optum® Clinformatics® Data Mart was used to identify individuals aging with a physical disability (Optum's de-identified Clinformatics Data Mart Database, Eden Prairie, MN). All individuals 18 years of age and older at the time of their enrolment (2007-2018) with the qualifying physically disabling conditions were eligible for this study. International Classification of Diseases, 9th revision, Clinical Modification (ICD-9-CM) codes were used to identify individuals who had at least one of the following physically disabling conditions: 1) Cerebral palsy [CP], 2) Spina bifida [SB], 3) Multiple sclerosis [MS], and 4) Plegia (paralysis). CP (a condition in which abnormal brain development or damage to a developing brain results in an inability to control muscles), and SB (damage to the spine and nerves stemming from a failure of the neural tube to close properly *in utero*) are both considered congenital conditions (present at birth) (Centers for Disease Control and Prevention 2019(a); Centers for Disease Control and Prevention 2019(b)). Conversely, MS (a nervous system disease in which neural networks are slowed down or blocked between the brain and body), and Plegias (loss of muscle function) are considered acquired conditions (occurring sometime after birth) (National Institute of Neurological Disorders and Stroke 2019). The diagnostic codes used to identify these conditions were selected based on their use in previous claims-based studies and are detailed in Appendix B (Table B.1) (Whitney, et al. 2019; Goodin, et al. 2014). Inpatient and outpatient claims were searched for at least one of the qualifying codes in any diagnostic field (e.g., main diagnosis or secondary diagnosis) when an individual was at least 18 years of age.

All individuals included in the final study cohort had *at least* four years of continuous enrolment on this plan. Continuous enrolment means that the person did not have a lapse in coverage on this specific private payer plan for the duration of the observed period. Continuous enrolment periods are required to ensure that diagnoses and encounters within the healthcare system during that time can be captured in their entirety and this information is not missed due to the beneficiary switching to another insurance plan. The enrolment period in the current study was selected based on preliminary work examining sample size and characteristics of cohorts with differing continuous enrolment windows. The aim was to find a balance between sample size (the longer the continuous enrolment requirement, the smaller the sample size, as fewer people meet the criteria) and a sufficient follow-up time from entry into the study cohort to examine incidence of chronic health conditions. Individuals with disability are known to have a higher burden of disease and experience accelerated aging, which means an adequate number of outcome events is plausible to observe in a shorter follow-up window (Campbell and Putnam 2017).

Since CP and SB are congenital conditions, it was assumed that adults would have had the condition at the time they began enrolment. Thus, for individuals with a diagnostic code for CP/SB at any time in claims data, the qualifying code was not necessarily the first occurrence of a diagnostic code in the record but rather the latest of when they turned 18, the year 2007 or when they were first enrolled in the policy. Furthermore, one year proceeding the qualifying condition flag within the four-year enrolment was used as the “look-back” period in which to identify comorbidity history and prevalent chronic conditions. A look-back period is required for analysis pertaining to incident outcomes. It represents a span of time over which an individual's records are scanned for diagnostic codes related to the outcome condition of interest, representing a history of the disease (prevalent condition). Individuals that do have a diagnostic code for the outcome condition during this time were excluded in any analysis aimed at computing risk of disease (incidence). Determination of incident disease can be challenging in claims data. Decisions about how long the duration of time in which to look for prevalent conditions can be based on disease management guidelines (e.g., how often individuals should be seeing their health care provider for medical assessments) and the frequency with which the population of interest is likely to contact the healthcare system for their medical needs. A one-year look-back period was selected for the current work owing to persons with disability being frequent users of the healthcare system (Kennedy, Wood and Frieden 2017). The subsequent years were used to assess for outcomes. In the case of MS and Plegia, I used the first occurrence of the diagnostic code during the study period. The one-year preceding the qualifying diagnostic code was used to assess for comorbidities and prevalent chronic conditions and to ensure the disability diagnosis was indeed incident. The following years were used for outcomes ascertainment. Individuals with MS or Plegia were only included if they had their diagnosis of the physically disabling condition by the age of 50, to be consistent with traditional definitions of aging with disability cited in the literature (Campbell and Putnam 2017) (Vergrugge, Latham and Clarke 2017).

*Strengths and limitations of using health administrative claims data for research:*

Utilizing health administrative claims data for research purposes presents with notable advantages. First, it captures information from all encounters within the healthcare system, making it good for measures of healthcare utilization (Wilson and Bock 2012). Measures of access to care can also be derived from this information. In addition, it provides information on what happens during a medical encounter through procedure codes, the reasons for visits to inpatient or outpatient facilities through diagnostic codes, and the medications that were filled by individuals (Wilson and Bock 2012; ResDAC 2018). Survey data is often subject to self-selection and/or non-response biases. In the case of health administrative claims databases, complete information is generally available for all fields for those enrolled in the health plan. The completeness of information stems from the primary purpose of claims data, which is for physicians to be reimbursed for services provided. Therefore, both the insurer and the physician are incentivized to obtain and maintain as complete information as possible on individuals enrolled in the plan. National health claims data also affords large, population-based study samples (Wilson and Bock 2012; ResDAC 2018). This is particularly important for having adequate power to study less common health conditions.

There are, however, limitations to the use of health administrative claims data for research purposes. Information on diagnoses and encounters are not available for out-of-pocket costs or services used outside of the plan. In addition, data for a person are only available when they access the healthcare system. This systematically excludes information on individuals who are not users of the healthcare system (e.g., choose not to seek healthcare services, those who lack access or when a person's health conditions are well managed and they do not require frequent visits to their care provider). While use of claims data does contain information on diagnosed conditions, some diseases may be undiagnosed (e.g., pre-diabetes which often presents without symptoms) and their prevalence in these data may be artificially lower (ResDAC 2018). Furthermore, this data source makes it challenging to ascertain how long an individual has had the condition and to distinguish between whether a disease is incident or prevalent (ResDAC 2018). Determining this information requires ascertaining if a person has a history of the condition. There are several reasons why a diagnostic code may not be present in claims data despite an individual having a particular condition. First, a person may have had the condition for an unknown duration before visiting the clinician to obtain a diagnosis. Secondly, for well-managed conditions, individuals may not make frequent visits to their clinicians (irrespective of clinical recommendations). Therefore, depending on the time period that is examined or available in claims data for condition ascertainment, there may not be a diagnostic code for a condition despite the individual having the disease. This is made particularly challenging if individuals switch from one health insurance plan to another over time, in which case their previous medical information may not be available for research use. Therefore, previous diagnoses may be missed if they have not been coded during a doctor’s visit in the subsequent health insurance plan. This could potentially result in misclassifying conditions as being incident.

As it pertains specifically to the use of claims data for studying a population aging with disability, having a diagnosis of a health condition (congenital or acquired) does not necessarily equate to having a disability as defined by the ICF model. This is because individuals with a potentially disabling condition may not experience limitations in activities, work or ability to participate in society. Assuming conducive neighborhood environments result in better health outcomes for individuals aging with disability (protective), and misclassification of the study population results in the inclusion of individuals who experience no limitations in activities, then findings obtained in this work could be an over-estimation of the true association. This is because it is likely that a healthier population is selected, which is more likely to be exposed to better environmental conditions and less likely to have disease. This would make good neighborhood environments appear more protective than they truly are.

Lastly, there is also limited information in claims data on the social determinants of health, subjective patient experiences and physiological measures (e.g., blood pressure and weight) (ResDAC 2018). In order to obtain information on these measures, claims data needs to be supplemented with additional data sources such as HER or survey data. In Optum® Clinformatics® Data Mart, geographic identifiers can be used to supplement information available for individuals by including data on the environments in which plan members reside. While information on individual-level income, education, region, and race are available in claims data, including for the beneficiaries in Optum® Clinformatics® Data Mart, neighborhood features, immigration status, occupation, policies/programs, culture, perspectives and lifestyle factors are lacking (Cadarette and Wong 2015).

### *National Neighborhood Data Archive (NaNDA):*

As noted earlier, health administrative claims data lack information on the breadth of social determinants of health often required to answer important public health questions, and this includes information on the neighborhood environment. To overcome this limitation, these data can be supplemented with additional data sources to examine the relationship between the neighborhood environment and health outcomes in claims data (Cadarette and Wong 2015). This means that claims data can be used to address a broader range of population health and epidemiological questions. One example of such a dataset is the National Neighborhood Data Archive (NaNDA).

NaNDA is a publicly available data archive that contains contextual measures for locations across the United States from 1980-2020 (Social Environment and Health n.d.). The measures are all theoretically derived and can be used to study a multitude of social, clinical, psychological and aging outcomes. The variables are available at various spatial scales (e.g., Census tract, ZIP code) and can be linked to existing survey, cohort, EHR or claims data using these geographic identifiers (i.e., having the Census tract of individuals in your study cohort can enable you to include information on walkability or recreational centers in their Census tract by linking to NaNDA) (Social Environment and Health n.d.).

### Linking a cohort of individuals aging with physical disability to information on their neighborhood environment:

The smallest spatial scale available in Optum® Clinformatics® Data Mart is the 5-digit ZIP code associated with a members' residential addresses. I used ZIP code as a proxy for an individual's neighborhood as that was the smallest geographic boundary available. ZIP codes are designated by the United States Postal Service and used to identify postal delivery routes (United States Census Bureau 2020). Therefore, they do not represent a confined spatial area. Data in the NaNDA repository capture neighborhood context at the ZIP Code Tabulation Area (ZCTA) level. ZCTAs are generated by the United States Census Bureau and are generalized representations of ZIP codes (United States Census Bureau 2020). Methods used to create ZCTAs are detailed elsewhere. Briefly, the Census Bureau generated a list of all ZIP codes in a given Census Block with the most frequently occurring ZIP code assigned as the preliminary ZCTA (United States Census Bureau 2015). This was then aggregated by code to create larger areas (United States Census Bureau 2015). As a result, ZIP codes do not constitute a perfect match to ZCTAs. Therefore, a ZIP to ZCTA crosswalk file provided by the United States Census Bureau was used to link the ZIP codes of individuals in the cohort to their corresponding ZCTA, which enabled linkage with their neighborhood characteristics from NaNDA.

### 1.6 Gaps in our Understanding of the Role of the Neighborhood Environment in Successful Aging for Individuals Aging with Disability

In the general population, there is an established body of literature identifying neighborhood-level factors associated with participation and health. Prior research in older adults has identified neighborhood environments to be modestly associated with health for older adults (Clarke and George 2005; Yen, Michael and Perdue 2009). In a synthesis of the literature, neighborhood-level socio-economic status was noted to be amongst the strongest and consistent risk factors, with higher deprivation associated with worse health (Yen, Michael and Perdue 2009). Accessible neighborhoods were associated with more walking, whilst the presence of physical activity resources were found to be associated with more exercise (Michael, et al. 2006; Berke, et al. 2007; Booth, et al.

2000). Community safety was also noted to be important to consider since fear of crime may prevent people from seeking out services and resources even if the built environment is conducive and accessible (Pruchno, Wilson-Genderson and Cartwright 2012). Previous work has identified icy and snowy surfaces as barriers to outdoor mobility (Clarke, Hirsch, et al. 2017). Poor quality of the physical residential environment, low political engagement, high unemployment, and lower access to private transportation are some of the factors which have been associated with worse self-rated health in previous work (Cummins, et al. 2005; Mathis, Rooks and Kruger 2015).  Older adults residing in neighborhoods that lacked health supportive services (e.g., pharmacies, grocery stores and recreational facilities) and also had a high density of liquor stores, pawn shops and fast-food outlets, had higher odds of fair/poor self-rated health (Spring 2018). Specific features of the environment have also been found to be independently associated with risk of diabetes, namely grocery stores, physical activity resources and neighborhood socio-economic status (Christine, et al. 2015).

There have been a limited number of studies that have examined the role of the neighborhood in facilitating participation in physical activity and accessing healthcare amongst individuals with disabilities, more broadly. Neighborhoods that had adequate handicap parking had higher odds of engagement in social and work activities (White, et al. 2010). Qualitative and quantitative studies have also identified severable notable barriers for engaging in aerobic exercise including getting to programs and places which offer opportunities for physical activity, finding health professionals who can provide physical activity options that match one’s abilities, accessibility of facilities and programs, and adverse weather conditions (Rimmer, et al. 2004; Centers for Disease

Control and Prevention 2020). Qualitative work has also identified outdoor built environments as barriers and facilitators to activity among mid-life and older adults with mobility disabilities (Rosenberg, et al. 2013). Lack of curb ramps or improperly maintained ramps (e.g., slippery), inadequate parking (lack of handicap parking space, parking too far from entrance) and lighting, extreme weather conditions (e.g., snow, ice, heat), challenging street crossings, lack of sidewalks, traffic, unsafe environments and few places to rest (e.g., shelters or benches) were all found to be barriers to participation (Rosenberg, et al. 2013). Additional contextual challenges for individuals with disability in obtaining screening include lacking transportation to clinics (Steele, et al. 2017; Centers for Disease Control 2018).

Despite this, to my knowledge, there has been no large-scale study to date which has examined the relationships between features of the environment, metrics of health quality and development of chronic health conditions amongst individuals aging with physical disability. Adults aging with disability may be more reliant on supportive environments for their full participation in society and engagement in health-promoting behaviors. Consequently, identifying the features of the neighborhood environment that facilitate positive health outcomes for those aging with disability is critical. However, most studies focus on the psychosocial characteristics of this population, and there is a noticeable gap in the literature examining their interface with socio-environmental factors.

Therefore, the overall aim of this dissertation was to elucidate how features of the neighborhood environment may influence quality of healthcare, and health outcomes for those aging with a physical disability. To address this goal, I used a cohort of individuals with a diagnosis of physically disabling conditions, both congenital (CP and SB) and acquired (MS and Plegia) obtained from Optum© Clinformatics© Data Mart. Individuals were linked to contextual data on their neighborhood environment from NaNDA based on geographic identifiers and all information on health outcomes and care quality was obtained from Optum©.

Specifically, this dissertation addressed the following three Aims:

**Aim 1:** Investigate the relationship between features of the neighborhood environment and incident cardiometabolic disease amongst individuals aging with a physical disability.

- <u>Sub-aim 1a:</u> Investigate the relationships between specific features of the built neighborhood environment where people aging with physical disability reside, and development of incident cardiometabolic conditions.
    - *Hypothesis 1a:* Individuals residing in a neighborhood with a high density of healthcare facilities, transit stops, recreational establishments, parks or broadband internet connections would have lower incidence of cardiometabolic disease compared to those who reside in communities with lower density of these resources.
- <u>Sub-aim 1b:</u> Create a composite measure describing the “health promoting” and “health harming” features of the neighborhood environment and examine the association between these composite measures and incident cardiometabolic disease.
    - *Hypothesis 1b:* Individuals aging with a physical disability who reside in areas with high density of health promoting resources (compared to low

density) would have a lower risk of cardiometabolic disease, net of individual-level characteristics and neighborhood socioeconomic status. Conversely, residing in neighborhoods with a higher density of health harming infrastructure (versus lower density) would be associated with significantly higher risk of cardiometabolic diseases, adjusted for additional factors.

**Aim 2:** Characterize care continuity in a population aging with physical disabilities and identify the individual and contextual factors associated with continuous care.

- Sub-aim 2a: Describe continuity of care (COC) across cohorts of adults aging with different physically disabling conditions using the Bice-Boxerman COC score.
    - *Hypothesis 2a:* Individuals with CP/SB, MS and Plegia would have low COC scores compared to other complex care populations. Individuals with low COC scores would see a variety of different healthcare specialties compared to those with high COC where visits would be concentrated amongst fewer different provider specialties.
- Sub-aim 2b: Examine the relationship between individual-level demographic and clinical factors, features of the built environment and spatial accessibility of health care providers, and COC in individuals aging with physical disability.
    - *Hypothesis 2b:* Individual-level factors independently associated with high COC would include older age, male gender and fewer co-morbid conditions. Community-level factors associated with high continuity would include higher density of healthcare resources, broadband internet

and spatial accessibility of health care providers, net of individual-level characteristics.

**Aim 3:** Examine the relationship between COC and health outcomes and receipt of preventive screenings amongst individuals aging with physical disabilities, adjusting for important individual and neighborhood-level variables.

- <u>Sub-aim 3a:</u> Assess the association between high COC and the occurrence of secondary health conditions and the receipt of preventive screenings.
    - *Hypothesis 3a:* Individuals with high continuity would have lower incidence of hypertension and lower odds of pain and mood diagnoses, adjusted for individual-level demographic characteristics and neighborhood-level socioeconomic status and healthcare resources. Additionally, high continuity would be associated with more appropriate screening.
- <u>Sub-aim 3b:</u> Examine whether the relationship between COC and secondary health conditions or receipt of preventive screening differs amongst younger and older adults aging with a physical disability.

    *Hypothesis 3b:* The association between COC and secondary health conditions and preventive screening would be stronger for younger adults compared to older adults due to benefits of care continuity for earlier diagnosis at younger ages.

*Conceptual framework:*

The overall framework for this dissertation is depicted in Figure I.2 and includes the relationships between structural/environmental factors, health care processes, and objective measures of health for individuals aging with a physical disability. As depicted in Figure I.2, Aim 1 of this dissertation examined the relationship between features of the neighborhood environment and their association with incident cardiometabolic disease. Aim 2 described quality of care for adults aging with physical disability, in particular, care continuity (operationalized by the Bice-Boxerman COC score) and assessed the associated individual- and- community-level factors. Finally in Aim 3, I further explored the relationship between the health care process measure and health outcomes by examining the relationship between COC and secondary health conditions and receipt of routine preventive screening amongst individuals aging with physical disabilities, accounting for important individual and neighborhood-level factors.

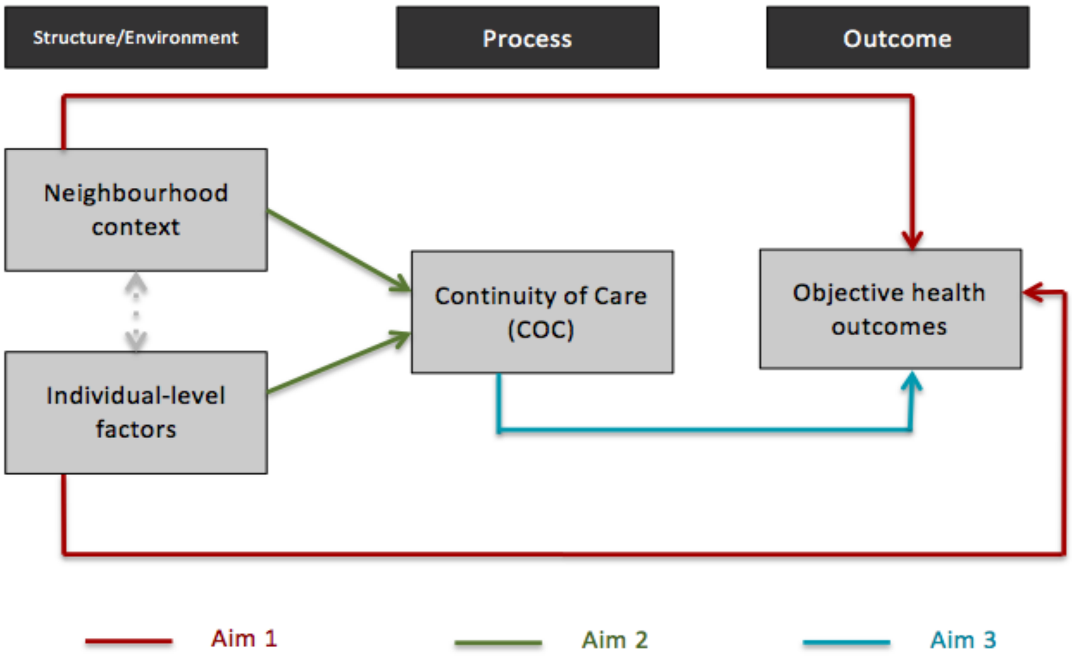


Figure I.2 Conceptual framework depicting the relationship between Aims 1, 2 and 3

# CHAPTER II:

## Identifying Features of the Neighborhood Environment Associated with Incident Cardiometabolic Disease Amongst Individuals Aging with a Physical Disability

### 2.0 Introduction

There is increasing understanding that both individual and environmental factors should be considered in the development of effective public health interventions. The role of the environment has been increasingly integrated into models of disability including the International Classification of Functioning, Disability and Health (ICF). The ICF conceptualizes how individual and environmental factors play a role in the disablement process (World Health Organization n.d.). Additionally, the Model of Healthcare Disparities and Disability (MHDD) provides a framework for conceptualizing how a mismatch between personal and environmental factors may result in reduced healthcare quality and access, which may lead to reduced functioning, activity and participation among people with impairments, and development of chronic health conditions (Meade, Mahmoudi and Lee 2015). While there is some empirical evidence for the role of the environment in the disablement process in later life, little is known about how the environment affects the health of those aging with a physical disability developed at birth, or in early and mid-life. This group represents a distinct population from those who develop their disability later in life due to the aging process. In Aim 1 of this dissertation, I addressed this gap by examining whether the neighborhood environment was important for successful aging outcomes in individuals aging with a physical disability, and identified the features of the neighborhood environment, both “health promoting” and “health harming,” that are particularly important for health in this population. In order to address this research question, I undertook a secondary analysis linking data from Optum® Clinformatics® Data Mart to contextual data from the National Neighborhood Data Archive (NaNDA). Findings have the potential to inform understanding of features that are important for supporting successful health outcomes for individuals aging with disability. This can have implications for design of communities that support health and public health policies for this vulnerable population.

## 2.1 Background

*Chronic disease and health among persons aging with a disability:*

Individuals with disabilities have high rates of premature mortality, preventable chronic conditions, activity limitations and mental health disorders (Campbell and Putnam 2017; Lennox and Kerr 1997; Turk , et al. 2001). For example, data from the Netherlands reported that individuals with a disability (defined as restrictions in activities of daily living [ADL] and mobility challenges) had a 10-year shorter life expectancy compared to those without a disability, based on life expectancy calculations at age 55 (Majer, et al. 2011). Furthermore, men and women with a disability had a 62% (HR 1.62; 95% CI: 1.15, 2.30) and 87% (HR 1.87; 95% CI: 1.32, 2.64) higher risk of mortality, respectively (Majer, et al. 2011). Data from the Centers for Disease Control and Prevention (CDC) highlights that working-age individuals with a disability were at increased risk of heart disease, stroke, diabetes and cancer compared to their counterparts without a disability (Centers for Disease Control 2018). Individuals aging *with* a disability acquired at birth or within the first 4-5 decades of life can develop similar chronic and preventable conditions that affect adults without disabilities, or those who develop a disability as a result of the aging process (Campbell and Putnam 2017; Verbrugge and Yang 2002; Vergrugge, Latham and Clarke 2017). This can be attributed to the aging process, the long-term effects of exposure to environmental hazards, and cumulative effects of poor health behaviors (Campbell and Putnam 2017). These are termed age-related chronic conditions. Additionally, they are at increased risk of developing secondary health conditions (Campbell, Sheets and Strong 1999; Altman and Bernstein 2008). These are defined as physical or mental health conditions that originate either directly, or indirectly, from a disabling condition (e.g., shoulder pain in wheelchair users due to physical overuse, compensatory injuries, fatigue) that affect the rest of the aging process (Campbell and Putnam 2017; Jensen, et al. 2013; Smith, Molton and Jensen 2016). Secondary conditions can be distinct, but also overlap with age-related chronic conditions. There is evidence indicating that adults aging with disability exhibit signs of accelerated aging (Campbell and Putnam 2017). Despite sparse data at the population level, clinical and survey research indicates that the aforementioned higher rates of adverse health conditions experienced by people with disabilities acquired in early or mid-life occur 20–25 years sooner compared to those without disabilities (Field and Jette 2007). This premature aging would mean that they are likely to enter mid- to-late life with more comorbid chronic conditions and secondary health problems than the general population.

### *Cardiometabolic disease in individuals aging with disability:*

As noted earlier, individuals aging with a disability experience accelerated aging and are at increased risk for developing chronic health conditions (Campbell and Putnam 2017). One group of adverse conditions for which they are at elevated risk is cardiometabolic disease. Cardiometabolic disease comprises a cluster of conditions that include cardiovascular illnesses (e.g., heart attack, stroke), diabetes and non-alcoholic fatty liver disease (Tufts University 2019).

Research has found that individuals with a diagnosis of a spinal cord injury (SCI) had a 67% higher 4-year risk of any cardiometabolic disease (HR 1.67; 95% CI: 1.58, 1.76) compared to their counterparts without SCI (Peterson, et al. 2021). Similar findings have been observed for incidence of specific cardiometabolic conditions including type 2 diabetes mellitus (T2DM) (15.9% for those with SCI compared to 9.2% for those without) and hypercholesterolemia (25.5% versus 16.9%) and hypertension (43.7% versus 24.8%) (Peterson, et al. 2021). Amongst privately insured adults with cerebral palsy (CP) and spina bifida (SB), which are both congenital conditions (occur at birth), the prevalence of any cardiometabolic disease was 43%, compared to 31% for controls without CP or SB (Peterson, Lin, et al. 2021). Furthermore, they were found to have a higher disease burden. Approximately 22% of individuals with CP or SB had two or more cardiometabolic conditions, compared to 15% amongst their counterparts without these conditions (Peterson, Lin, et al. 2021). These findings were supported by subsequent work examining incident disease in a cohort with CP or SB. They reported a 52% higher risk of any cardiometabolic disease (hazard ratio [HR] 1.52; 95% confidence intervals [CI]: 1.47, 1.57) (Peterson, et al. 2020). Statistically significant associations were also observed for T2DM (45% higher risk), hypercholesterolemia (20% higher risk) and hypertension (46% higher risk) in fully adjusted models (Peterson, et al. 2020). Similarly, individuals with multiple sclerosis (MS), an acquired physically disabling condition, were found to be at elevated risk of a variety of cardiometabolic conditions. For example, they had a 28% higher risk of acute coronary syndrome, and 59% higher incidence of cerebrovascular disease compared to those without an MS diagnosis (Palladino, et al. 2020).

### *Established risk factors for development of cardiometabolic diseases:*

There is a large body of literature examining the biological, physiological and lifestyle factors associated with development of cardiovascular disease. Established biological risk factors include age and gender (Mozaffarian, Wilson and Kannel 2008). Examples of well-established lifestyle risk factors associated with elevated risk include poor dietary habits, inadequate physical activity, and adiposity (Mozaffarian, Wilson and Kannel 2008; Anand, et al. 2015; Lachman, et al. 2018). These risk factors are strongly associated with an individual's blood pressure measurements and cholesterol levels, as well as a diagnosis of cardiovascular disease. For example, reducing trans-fat consumption in one's diet has been associated with a reduction in cardiovascular risk (Mozaffarian, Katan, et al. 2006). At the population-level, improving lifestyle risk factors is important for primary (mitigate disease occurrence amongst those without a history of cardiovascular disease) and secondary prevention (prevent recurring cardiovascular disease amongst those with a history of disease) of cardiovascular disease (de Lorgeril, et al. 1999; Mozaffarian, Wilson and Kannel 2008).

Individuals with a disability are known to have worse cardiovascular risk factor profiles. Children and adults with mobility and intellectual disabilities have a higher prevalence of obesity compared to their counterparts without these conditions (Bandini, et al. 2005; Chen, et al. 2010; Ellis, et al. 2006). Cigarette smoking is also significantly higher amongst adults with a disability, with 27.8% of adults with a disability being current smokers compared to 13.4% without a disability (Centers for Disease Control and Prevention 2019). Almost 50% of adults with a disability get no leisure time aerobic physical activity (Centers for Disease Control and Prevention n.d.). Findings in this population regarding low levels of physical activity were also in line with data from National Health and Nutrition Examination survey [NHANES] (2003-2006) which was used to examine physical activity patterns across age and physical functioning status. The study concluded that based on total activity counts, those who were classified as having high-level of mobility functioning were 30% more active than those with a disability (Steeves, et al. 2019). The authors noted that significant differences in activity levels between the groups indicated that the ability to walk without special equipment, and to engage in activities of daily living (e.g., walking around the house from room to room, standing from a chair, and bathing) without difficulty is a major determinant of older adults' levels of physical activity (Steeves, et al. 2019).

### *Overview of the role of environment in participation and healthy lifestyles in the general population:*

In the general population, several direct and indirect mechanisms have been proposed to explain the complex processes through which individual and neighborhood factors can influence health and health inequalities (Clarke, Morenoff, et al. 2013; Diez Roux and Mair 2010). These neighborhood features include availability of health-promoting resources (e.g., green space, recreational facilities), exposure to air pollution and adverse weather conditions (e.g., rain or snow), social cohesion, information exchange, reinforcement of health behaviors, and biological implications of living in stressful conditions (e.g., stress induced by residing in areas with high levels of crime) (Clarke, Morenoff, et al. 2013). Work by Diez Roux and Mair (2010) summarized how the neighborhood physical, social and built environment could contribute to disparities in health outcomes (Figure II.3).

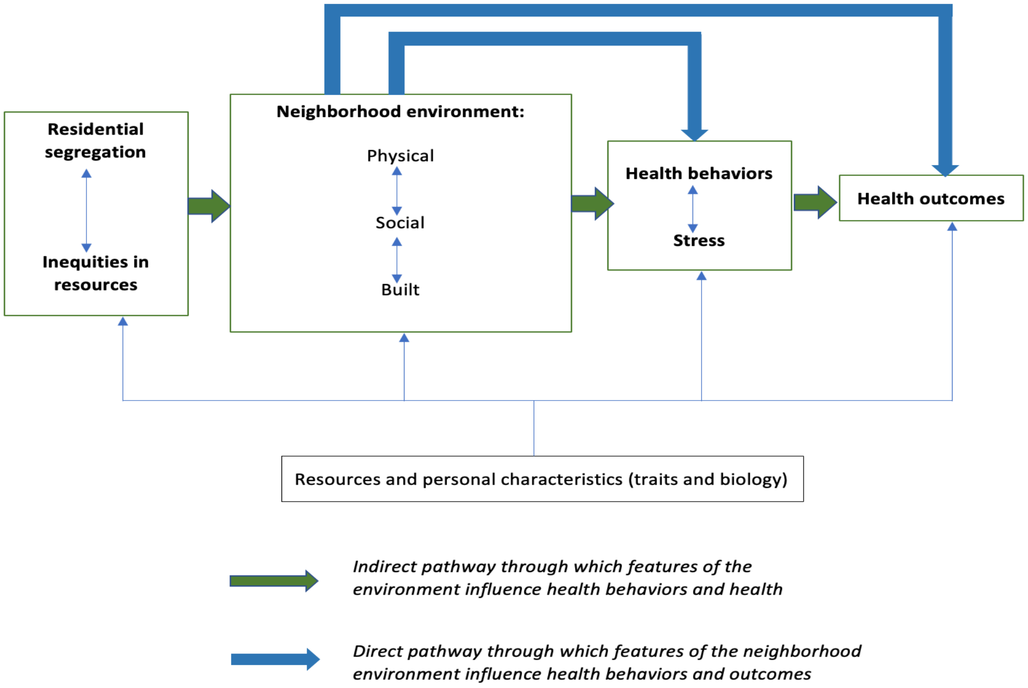


Figure II.3 Schematic of Diez Roux and Mair's (2010) conceptualization of how neighborhood environments influence health (Adapted from: Diez Roux and Mair 2010)

In their conceptual model, the authors state that broader structural inequities and residential segregation are mutually reinforcing such that residential segregation may exacerbate inequities in neighborhood resources that in turn contribute to segregation (Diez Roux and Mair 2010). These broader, upstream factors can also contribute to characteristics of the physical, built and social environment and availability of resources within one's neighborhood. Features of the built environment such as parks, that serve as meeting hubs for the community, can influence social interactions within the neighborhood that may in turn shape advocacy on the part of individuals residing in neighborhoods for improved resources. Availability of neighborhood resources can affect processes at the individual-level such as behaviors (e.g., ability to access healthy foods in neighborhoods considered food desserts) and stress (e.g., high levels of neighborhood crime may introduce stress amongst individuals residing in and being exposed to these environments) (Diez Roux and Mair 2010). This ultimately shapes health, in particular health inequities amongst certain groups.

Availability of healthcare facilities and development of heart disease is a concrete example of how the neighborhood environment may indirectly influence health outcomes. Policies within the healthcare system incentivize specialists to practice in certain neighborhoods (e.g., high income areas due to discretionary spending power amongst those residents (structural policies)) (Khan, et al. 2018; Jiang and Begun 2002). This may contribute to disparities in availability of, and access to health care providers and facilities in some neighborhoods (aspect of the built neighborhood environment). Lower neighborhood investment may also preclude individuals in these neighborhoods from advocating for more healthcare access due to less leverage and information networks. This may in turn make it more difficult to get routine preventive services such as cholesterol screening, wellness visits and diabetes testing (behavioral factors). Stresses, competing priorities and less well-connected networks of individuals in these neighborhoods may partially reinforce this (stresses). Ultimately this could contribute to development of heart disease due to delayed identification of risk factors and treatment (health outcomes).

Prior research in older adults has identified some barriers that can exist through non-supportive environments such as inaccessible buildings and sidewalks (e.g., lack of curb cuts and ramps), and recreational facilities and public transportation systems which are not appropriately equipped and conducive to individuals with mobility problems

(Clarke and George 2005; Rimmer, et al. 2004; Yen, Michael and Perdue 2009). These are some of the environmental factors that can enhance independence and social participation among those with disabilities. Individuals residing in neighborhoods that had adequate accessible parking had higher odds of engagement in social and work activities (White, et al. 2010). Community safety is also important to consider since fear of crime may prevent people from seeking out services and resources even if the built environment is conducive and accessible (Pruchno, Wilson-Genderson and Cartwright 2012). Climate and temperature are also related to health and independence in people with mobility limitations. For example, previous work has identified icy and snowy surfaces as barriers to outdoor mobility (Pruchno, Wilson-Genderson and Cartwright 2012).

Features of the social and built environment in which an individual resides are also associated with various health behaviors and outcomes. For example, light traffic, the presence of sidewalks, and safety from crime are associated with more physical activity (Casagrande, et al. 2009; Rosenberg, et al. 2013). Poor quality of the physical residential environment, low political engagement, high unemployment, lower access to private transportation, and commercial decline are some of the factors which have been associated with worse self-rated health in previous work (Cummins, et al. 2005; Spring 2018; Mathis, Rooks and Kruger 2015). Research has also noted an interaction between environmental features and individual-level factors in influencing health outcomes. For example, data from Los Angeles, California found that individuals with chronic conditions reported significantly worse self-rated health when they also lived in socially deprived census tracts than among those in a more advantaged area (Brown, Ang and

Pebley 2007). Furthermore, older adults may be more inclined to avoid challenging aspects of their environment. For example, inclement weather and heavy traffic volume were found to be impediments to going outside and walking for older adults with mobility challenges (Shumway-Cook, et al. 2003; Rosso, Auchincloss and Michael 2011; Clarke and George 2005). Amongst aging adults, exposure to high levels of precipitation was associated with faster rates of cognitive decline (Finlay, et al. 2020). It was hypothesized that precipitation may contribute to social isolation and lack of physical activity, precluding engagement in activities thought to be cognitively stimulating and protective against cognitive decline (Finlay, et al. 2020). This highlights the role of the neighborhood in independence and activity of older adults.

Neighborhood characteristics such as availability of healthy food stores and walkability have been found to be associated with increased fruit and vegetable consumption, lower body mass index (BMI) and higher levels of physical activity. For example, data from the Atherosclerosis Risk in Communities (ARIC) study noted that amongst Black and White participants, fruit and vegetable consumption increased for each supermarket in the census tract (e.g., Black: Relative Risk [RR] 1.32, 95% CI: 1.08, 1.60) (Morland, Wing and Diez Roux 2002). A systematic review examining neighborhood features correlated with physical activity in youth and adolescents noted that objective measures of walkability, traffic speed/volume, access to recreational sites, land-use mix and residence density were associated with physical activity (Ding, et al. 2011). Similar findings were observed amongst older adults in St. Louis (Missouri) and Savannah (Georgia) where greater perceived access to recreational facilities and objective attractiveness of these facilities was associated with more engagement in recreation activities (Hoehner, et al. 2005). This was summarized in a review describing how built environment attributes are associated with physical activity and obesity (Sallis, et al. 2012). Population density, close proximity to more resources, and transportation facilities (e.g., bicycle paths) were associated with active transportation (e.g., engaging in cycling) and increased levels of physical activity. Findings in regards to obesity were mixed. Some cross-sectional studies found walkable neighborhoods to be protective against risk of being overweight and obese, whilst others did not or did not in longitudinal studies (Sallis, et al. 2012).

A recent body of work has aimed to understand the barriers to accessing healthcare and have identified the physical environment, transportation and provider knowledge as being important. Residents of disadvantaged neighborhoods were significantly less likely to have a usual source of care, more likely to report unmet care needs, and less likely to adhere to United States Preventive Task Force guidelines (Kirby and Kaneda 2005). Physician and healthcare facilities are not distributed at random and quality healthcare tends to be located in neighborhoods with a greater abundance of resources (Khan, et al. 2018; Jiang and Begun 2002). The density and location of healthcare facilities is associated with access and use (Law, et al. 2005; Li, et al. 2003; Wheeler, et al. 2014; Khan, et al. 2018). Residing in a neighborhood which has a high proportion of non-residential land use, a large number of federally qualified health centers, and where more people rely on public transit, was predictive of a greater likelihood of a lapse in care (Ryvicker and Russell 2018; Goins, et al. 2005; Zullig, et al. 2012; Allerton and Emerson 2012).

Features of the physical environment may also directly influence health outcomes, bypassing the role of behavior. In older adults from the Reasons for Geographic and Racial Differences in Stroke (REGARDS) cohort, short-term exposure to region-specific cold and extreme cold temperatures was associated with worse performance on cognitive tests in regions that experienced traditionally warmer temperatures (Khan, Finlay, et al. 2021). Though not formally tested, it was hypothesized that an inability to concentrate and physiological reactions to extreme temperature could contribute to observed findings. On the other hand, inability to leverage adaptative mechanisms such as heating and insulation, which are scarce in these traditionally warm regions, could also indirectly explain findings (Khan, Finlay, et al. 2021).

### *Neighborhood environment and cardiovascular disease in the general population:*

In the general population, there are several features of the neighborhood found to be associated with a variety of cardiometabolic conditions. One of the most studied and robust neighborhood-level risk factors is socioeconomic status. Data from Sweden found that low neighborhood-level socioeconomic status, defined by education and income (proportion of people in lowest national income quartile) was associated with higher incidence of coronary heart disease, adjusted for individual-level characteristics (Sundquist, et al. 2004). Similar findings were observed in a study in the United States using data from Atherosclerosis Risk in Communities (ARIC). A composite socioeconomic measure comprised of information about neighborhood wealth, income, education and occupation noted that residing in more disadvantaged neighborhoods was associated with increased incidence of coronary heart disease (Diez Roux, Merkin, et al. 2001).

Data from the Multi-Ethnic Study of Atherosclerosis (MESA) examined the association between neighborhood-level measures of favorable food stores and physical activity resources, in addition to self-reported walking/physical activity environment, safety, and social cohesion on cardiovascular health (Unger, et al. 2014). Greater availability of food stores with healthy options (e.g., supermarkets) and physical activity resources in one's neighborhood, better walking/physical activity environment, and neighborhood socioeconomic status were associated with higher odds of having an ideal cardiovascular score (Unger, et al. 2014). Other work has also examined the association between neighborhood-level healthy food (e.g., grocery stores), physical activity (e.g., commercial recreational facilities) and social (e.g., safety and cohesion) environments with incident T2DM (Christine, et al. 2015). Cumulative exposure to more healthy food and recreational facilities was associated with lower incidence of T2DM, independent of individual-level factors (Christine, et al. 2015). Work has also been done examining the role of the food, physical activity and social environment for hypertension (Kaiser, et al. 2016). Significant findings were observed only for survey-based measures of the healthy food environment. A one standard-deviation improvement in the food environment was associated with a 10% lower risk of hypertension (HR 0.90, 95% CI: 0.83, 0.97) (Kaiser, et al. 2016).

### *Role of neighborhood environment for physical activity in individuals with a disability:*

Socio-ecological models describe how health behavior can be influenced at the level of the individual, society, institutions, community, environment, and policies. As a result, interventions are thought to be most effective when they change the person's behavior, in addition to the social and built environment, and broader policies (Sallis, et al. 2012; Rural Health Information Hub (b) n.d.). Motivating a person to change in an environment that poses many barriers is not expected to be very effective (Sallis, et al. 2012). This may be particularly true for individuals with physical disability who are more reliant on their neighborhood environment owing to limited mobility. While the literature has not examined the relationship between features of the neighborhood environment on cardiovascular outcomes for those aging with physical disabilities, there is work examining how these features influence participation and physical activity in individuals with disabilities more broadly.

Qualitative focus groups conducted in individuals with disabilities across ten regions in the United States noted that built and natural environmental barriers to engaging in physical activity included inaccessible environments such as lack of curb cuts, lack of clear access routes, facility doorways being too narrow, and inaccessible parking spaces or ramps (Rimmer, et al. 2004). Amongst mid-life and older adults with mobility disabilities, key features of the built environment important for engaging in physical activity included curb ramp availability and their condition, aesthetics of facilities, presence of places to rest and shelter on the street, safety and traffic (Rosenberg, et al. 2013). Empirical data supports these findings with cross-sectional analysis of data collected from chronically disabled adults (with SCI) residing in the community. They noted that living in communities with large amounts of open space was associated with likelihood of reporting physical, occupational and social participation (Botticello, Rohrbach and Cobbold 2014).

While there is increasing realization that contextual and community-level factors can influence health outcomes for the general population, evidence is scant as it pertains to the role of the neighborhood for individuals aging with physical disability. Effects of the built and social environment may be especially important to study within this population aging with disability, as they may be more reliant on conducive environments to engage in health promoting behaviors and to fully participate in society. Most studies involving individuals aging with disability have focused on physical and psychosocial characteristics of the population but few have addressed their interface with socio-environmental factors.

Relationships characterized in the general population cannot necessarily be applied to adults aging with physical disability. Proximity to resources may not confer the same benefits for this population. Furthermore, different features of the physical environment may be more or less salient owing to accessibility concerns as it pertains to reaching these facilities, the layout of these spaces and the specific health needs of this population (Rimmer, et al. 2004). Furthermore, it remains unclear which specific features of the neighborhood environment are associated with increased or decreased risk of cardiovascular disease, including the combined presence of features classified as health promoting and harming in a neighborhood. Therefore, an examination of the features of the neighborhood that facilitate good cardiovascular health in adults aging with disability is warranted.

Therefore, this Aim examined whether features of the neighborhood environment are associated with the development of incident cardiometabolic disease for individuals aging with a physical disability. I hypothesized that individuals aging with a physical disability residing in neighborhoods with a higher availability of broadband internet connections, transit stops, healthcare facilities and recreational establishments would have a lower risk of cardiometabolic disease. Understanding which features of the neighborhood environment are most important for mitigating cardiovascular morbidity for adults aging with physical disability has implications for developing neighborhood-level interventions to support positive health outcomes for this growing population. Findings from this work have the potential to inform how environments can be optimized to promote full participation and improve the health of individuals with physical disabilities as they age.

## 2.2 Methods

*Data source:*

For this work, I leveraged data from Optum® Clinformatics® Data Mart (OptumInsight, Eden Prairie, MN). Optum® Clinformatics® Data Mart is a national, private, health insurance database. It includes de-identified health claims information of more than 80 million individuals who are commercially insured through a single private-payer in the United States (Optum 2017; Mahmoudi and Kamdar 2020). Optum® Clinformatics® Data Mart captures information for emergency department, outpatient, inpatient, and pharmacy claims for enrollees (Optum 2014). Plan enrollees are assigned a unique identification number that enables longitudinal follow-up including in the case where there are lapses in their coverage or the terms of their coverage change.

*Study sample:*

Individuals 18 years of age or older at the time of their enrolment in Optum® Clinformatics® Data Mart (2007 to 2018) were eligible for this study. I utilized International Classification of Diseases, 9th edition, Clinical Modification (ICD-9-CM) codes to identify individuals who had a diagnosis code of at least one of the following physically disabling conditions: 1) CP, 2) SB, 3) MS, or 4) Plegia, during the enrolment period (Appendix B, Table B.1). I excluded a small number of individuals who had both CP and SB, owing to lack of clinical feasibility (likely data error).

All individuals retained in the study had at least four years of continuous enrolment within the study period to ensure stable membership on the plan, and to allow for adequate follow-up for chronic health conditions. One year within this enrolment period was used as the “look-back” window to assess for prevalent disease, co-morbidity burden and in the case of acquired conditions (MS and Plegia), ascertain that they are incident disabilities (no code for the condition in the one-year period). The remaining enrolment period was used as follow-up time to assess for outcomes. For acquired conditions (MS and Plegia), this one-year look-back window was in the year preceding the diagnostic code for the disabling condition. For individuals with congenital conditions (CP or SB) this was in the year following the diagnosis code for the physically disabling condition. This is because persons with CP and SB are born with these conditions, so there is no need to assess for incidence, thereby maximizing sample size. The date of diagnosis that met the inclusion criteria was assigned as the "index date" for analysis (Appendix B, Figure B.4).

Given the aim of this work was to identify individuals aging *with* a physical disability, I only included those who were ≤50 years of age at the time of their qualifying diagnosis code within the enrolment period for the acquired conditions (MS and Plegia). This conforms to traditional conceptualizations of aging with disability, in which the condition is usually acquired within the first 4-5 decades of life (Verbrugge and Yang 2002). A study flow schematic can be found in Appendix B, Figure B.5.

*Cardiometabolic outcomes:*

As noted earlier, cardiometabolic disease represents a group of conditions that include cardiovascular disease (e.g., heart attack), diabetes and non-alcoholic fatty liver disease (Tufts University 2019). In the present work, I included a composite of *any* cardiometabolic disease, which consisted of the following conditions: 1) cardiac dysrhythmias, 2) heart failure, 3) peripheral and visceral atherosclerosis, 4) non-alcoholic liver disease, 5) chronic kidney disease, 6) T2DM, 7) hypercholesterolemia, and 8) hypertension. Medically diagnosed conditions were identified in Optum® Clinformatics® Data Mart based on the presence of a single ICD-9-CM or ICD-10-CM code during the follow-up period (Appendix C, Table C.2). A binary indicator was created for presence of the outcome over the follow-up period. I also examined specific cardiometabolic conditions, namely incident hypertension, hyperlipidemia, and T2DM. Features of the neighborhood may be differentially important to consider across these outcomes. Additionally, understanding the specific features of the environment that are important for individual outcomes can facilitate the development of more targeted population-based programs or policies aimed at addressing these specific conditions. I selected these conditions *a priori* based on hypothesized role of the environment in their development in the general population (Christine, et al. 2015; Kaiser, et al. 2016). The primary outcome was time, in days, to incidence of any cardiometabolic disease, hypertension, hyperlipidemia and T2DM, following index date.

*Primary exposure – neighborhood environment:*

Measures of the neighborhood environment were obtained from the National Neighborhood Data Archive (NaNDA) (https://www.openicpsr.org/openicpsr/nanda). NaNDA is a publicly available data archive containing contextual measures for locations across the United States at various spatial scales (Social Environment and Health n.d.). The variables are derived from different data sources and can be readily linked to the study cohort using geographic identifiers.

I used an individual's residential ZIP code as a proxy for their neighborhood, which represented the most granular level of geographic information available for individuals in the Optum® Clinformatics® Data Mart. I had access to all ZIP codes for an individual in the cohort over the study period, enabling me to capture any residential moves reported across the observation period and update their neighborhood exposures accordingly. ZIP codes are designated by the United States Postal Service and used to identify postal delivery routes (United States Census Bureau 2015; United States Census Bureau 2020). Data in the NaNDA repository capture neighborhood context at the ZIP Code Tabulation Area (ZCTA) level. ZCTAs are generated by the United States Census

Bureau and are generalized representations of ZIP codes (United States Census Bureau 2015; United States Census Bureau 2020). ZIP codes do not constitute a perfect match to ZCTAs. Therefore, I used a crosswalk to link the ZIP codes of individuals in the cohort with their neighborhood characteristics in NaNDA.

I focused on specific features of the neighborhood environment that were hypothesized to influence: 1) mobility and independence (e.g., transportation), 2) ability to engage in physical activity (e.g., parks, recreational facilities), and 3) availability of, and access to, health-promoting (e.g., availability of healthy food establishments, and broadband internet) and healthcare (e.g., density of ambulatory care facilities) resources. These are thought to directly or indirectly influence health for individuals aging with a physical disability. Similarly, availability of transportation, and measures of high resource neighborhoods (e.g., neighborhood affluence) may influence access to these resources.

In NaNDA, data on healthcare services (including ambulatory care centers, hospitals and residential/skilled nursing facilities; hereafter referred to as "healthcare services"), fast food restaurants, recreational establishments (including recreational facilities, golf courses/country clubs, bowling alleys; hereafter referred to as "recreational establishments"), grocery stores (including supermarkets and warehouses or supercenters; hereafter referred to as "grocery stores") and liquor, tobacco and convenience stores were identified from the National Establishment Time-Series (NETS) dataset, on an annual basis, within each ZCTA (Khan, et al. 2020; Finlay, Li, et al. 2020(a); Finlay, Li, et al. 2020 (b); Esposito, et al. 2020; Finlay, Mao, et al. 2020 (c)). The NETS dataset provides information on businesses, non-profit, government establishments and sole proprietors

(Walls 2015). Establishments were identified using North American Industry Classification System (NAICS) codes (Appendix C, Table C.3). I computed the density (number of establishments per ZCTA population) for each of these features of the built environment.

Data on the number of public transit stops in NaNDA were derived from the National Transit Map (NTM), published by the Bureau of Transportation Statistics (Melendez, et al. 2020). NTM is a nationwide catalogue of transit service in the United States obtained from publicly available information (Bureau of Transportation Statistics 2018). Data is reported voluntarily to the NTM from one of the regional transit agencies choosing to participate. Density of transit stops, defined as the number of stops per population, was computed.

The metric of broadband internet availability in NaNDA was based on information obtained from the American Community Survey (ACS) (Li, et al. 2020). In the ACS, there is data on internet subscriptions in households. I divided the number of household broadband internet connections by population size.

Data on American parks (publicly owned local, state and national parks, certain school parks and privately owned parks that are publicly accessible) in NaNDA were available from ParkServe™ (Li, Melendez, et al. 2020). ParkServe™ is a database of parks in 14,000 communities in the U.S. compiled by the Trust for Public Land (The Trust for Public Land 2016). Information is based on Geographic Information System (GIS) data obtained directly from local communities, publicly accessible websites and satellite imagery. Similar to before, I created a measure for the density of parks in a ZCTA (number of parks per capita).

I operationalized the density of neighborhood variables as tertiles, consistent with previous studies (Spring 2018). Prior research has found that environmental effects on health are generally nonlinear and often emerge in the most disadvantaged living conditions (Do, Wang and Elliot 2013; Krause 1996). Examining the mean and median density of the different neighborhood characteristics examined in this study, overall and within tertiles, suggested a non-linear relationship (Appendix C, Table C.4). Therefore, incremental changes in density of these neighborhood characteristics are unlikely to be equivalent, and will also be less meaningful. Creation of tertiles enabled me to compare health of those living in the least resourced category to the other categories.

I also created a composite of health-supportive and harming features. For health-supportive resources I summed the number of services that could support healthy food choices (grocery stores, supermarkets, warehouse clubs), physical activity (parks, fitness/recreational facilities, golf courses, bowling alleys), and healthcare services (hospitals, ambulatory care centers, pharmacies and residential care/skilled nursing facilities), as well as the number of broadband internet connections and public transit stops. This was divided by the population size of the ZCTA to create my measure of "health promoting infrastructure." Summing the number of fast-food outlets, and convenience, liquor and tobacco stores in a given ZCTA was used to create the numerator for the density of health-harming features of the neighborhood. This was then divided by the population size to create the density measure hereafter referred to as "health harming infrastructure." The standardized Cronbach alpha was computed to assess internal consistency of the variables included in the composite measure of health promoting and harming features (UCLA Statistical Consulting Group n.d.). The Cronbach alpha values were 0.83 and 0.82 for health promoting and harming features, respectively, representing good internal consistency.

Considering health promoting and harming infrastructure in the same model is important because neighborhoods are complex and individuals interact with both types of features in their surroundings. For example, if an individual resides within a neighborhood with very low density of health promoting resources (e.g., grocery stores) but a plethora of convenience stores or fast-food restaurants (health harming), convenience stores and fast-food restaurants may be more likely to influence their dietary choices/patterns due to availability and access. This is something that would be more challenging to discern based on examining just the individual components/features of the neighborhood. Furthermore, neighborhoods with varying amounts of these health promoting and harming features may be distinct from one another (e.g., in terms of culture or norms) and that can only be commented on when neighborhoods are more fully characterized by considering both the promoting and harming features.

However, examining the effects of particular features of a neighborhood, when included in a regression model with other neighborhood-level variables can be complicated by the fact that many of these characteristics are highly correlated with one another (Diez Roux 2001). This creates challenges to partitioning the effects of these characteristics on health outcomes. Given that the measures of health promoting and health harming infrastructure were highly correlated (correlation = 0.70), I was unable to simultaneously place them in a regression model (to compute independent and joint effects) to examine how the presence of both health promoting and health harming features of the environment work in tandem to influence development of cardiometabolic disease. This is because from a statistical perspective, multi-collinearity introduces imprecision and causes estimates to become unstable. Therefore, I used a typology to examine how the specific features of the neighborhood, both health promoting and harming, work in tandem to impact participation and health and to more accurately reflect the ways in which individuals interact with their neighborhoods (navigate both health promoting and harming features). This is likely to afford a more complete picture and understanding of neighborhood environments. I conducted a literature review of existing typologies and adapted one published by Spring (2018) previously used to study the effects of the neighborhood-built environment on self-rated health in older adults (Spring 2018). Briefly, it is a five-category typology created from the density of services that constitute service-dense and commercial decline in a respondent's ZCTA (Spring 2018). In the current study, I adapted this typology to be relevant to individuals aging with disability. For example, I included additional features of the neighborhood environment thought to be important for preventing cardiovascular disease in this population, namely parks (for recreation), public transit (for facilitating access to resources), and broadband internet access (for supporting telehealth and access to health information).

Consistent with previous studies, I first categorized the ZCTA-level density of health-promoting and health-harming infrastructure into quartiles (Spring 2018). Informed by the work of Spring (2018), the intersection of these quartiles were used to construct the following *mutually exclusive* categories to which each ZCTA was assigned: 1) high density of *both* health-supportive and health-harming (service-dense), 2) low density of *both* health-supportive and health-harming, 3) high density of health-supportive services; low density of health-harming, 4) low density of health-supportive;

high density of health-harming, and 5) average density of health-supportive and health-harming (Appendix C, Figure C.6).

Residential neighborhood information was computed on an annual basis such that changes over time could be captured whenever neighborhood resources changed, or a participant moved to an area constituting a new ZCTA.

*Covariates:*

Individual-level covariates included age (continuous), sex (male or female), and Elixhauser comorbidity index (ECI) (continuous). The ECI identifies comorbidities in administrative claims records using ICD-9-CM diagnostic codes, and is included as a measure of comorbidity burden at the time of index diagnosis for disability. I created a modified version of the index containing only 22 conditions by removing conditions that could be correlated with the outcome of cardiometabolic morbidity (Appendix C, Table C.5). The index is predictive of hospital resource use and in-hospital mortality. Furthermore, it is a better predictor of mortality than other comorbidity measures such as the Charlson Index, in a variety of patient populations (Menendez, et al. 2014; Chu, Ng and Wu 2010; Chang, et al. 2016).

I included measures of neighborhood socioeconomic disadvantage and affluence to capture the broader context of resources and investment at the neighborhood-level that are relevant for health. Distinct from socioeconomic disadvantage, affluent neighborhoods are characterized by a greater density of highly educated adults in professional occupations that are likely to attract a set of institutions (e.g., places to exercise) that foster norms conducive to good health (Browning and Cagney 2003). I used measures of disadvantage and affluence available in NaNDA that are derived from sociodemographic indicators from the United States Decennial census and ACS (Melendez, Clarke, et al. 2020). In NaNDA, neighborhood disadvantage is an average of five census indicators: 1) proportion of female headed families with children, 2) proportion of households with public assistance income or food stamps, 3) proportion of families with income below the federal poverty level, and 4) proportion of population 16+ who are unemployed, and 5) proportion of non-Hispanic Black individuals (Melendez, Clarke, et al. 2020). Affluence is the average of three indicators: 1) proportion of households with income greater than $75,000, 2) proportion of population aged 16+ years who are employed in professional or managerial occupations, and 3) proportion of adults with Bachelor's Degree or higher (Melendez, Clarke, et al. 2020). The values ranged from 0 to 1. I also included a measure of population density to account for the greater density of services in more populated neighborhoods.

### *Statistical analysis:*

I used a retrospective cohort study design. Frequencies and means were used to describe the study sample.

Cox proportional hazard models were used to model the time to each of the incident cardiometabolic outcomes. I ran a series of survival models in order to compute the adjusted hazard of cardiometabolic disease, hyperlipidemia, hypertension and T2DM. For each outcome, individuals with prevalent disease were excluded from the model. I capped the follow-up period to three years to ensure equal follow-up. Individuals were considered at-risk until the diagnosis of interest or right censored due to end of follow-up, whichever occurred first.

Contextual variables and the typology were modelled as time-varying to capture the movement of individuals in-and- out of different types of neighborhoods and to account for the changes in characteristics of neighborhoods. All regression models were adjusted for individual-level covariates and neighborhood (ZCTA)-level affluence, disadvantage and population density. I estimated separate Cox Proportional Hazards regression models for each of the outcomes and reported the hazard ratios (HR) and corresponding 95% confidence intervals (CI). I used cluster-robust standard errors to account for the clustering of individuals within ZCTAs.

Statistical significance was assessed at $p<0.05$ and all tests were two-sided. Analyses were conducted in SAS version 9.4 (SAS Institute, Cary, North Carolina).

I began by running a series of regression models, each capturing a different aspect of the neighborhood environment. This was aimed at ascertaining specific features of the neighborhood environment that may be associated with any cardiometabolic disease, hypertension, T2DM and hyperlipidemia. Examining each outcome separately allowed me to assess whether particular features were more important for some health outcomes than others.

In model 1, I focused on healthcare resources (e.g., ambulatory care facilities, hospitals, pharmacies and residential/skilled nursing facilities). In model 2, I added density of broadband internet connections and transit stops to model 1. Broadband internet represents another mode through which individuals aging with a physical disability can access healthcare (e.g., telemedicine) and persons with physical disabilities may be more reliant on transit to navigate their environments and access healthcare facilities (Wilcock, et al. 2019; Rosenbloom 2007). Model 3 captured the food and recreation environment. Therefore, in this model, I included density of grocery stores as well as recreational establishments and parks (as it represents another venue for persons aging with a disability to engage in recreational activities). Model 4 examined the composite created for health promoting features and in the final model (model 5), I examined the composite measure of health harming infrastructure. Sample equations corresponding with each regression model for the outcome of T2DM can be found in Table II.1 (Equations II.1-5).

Table II.1 Summary of Cox Proportional Hazards regression models describing the associations between individual features of the neighborhood environment and incident Type 2 Diabetes Mellitus (T2DM) adjusted for individual and neighborhood-level covariates

| **Equation #*** | **Equation** | **Focal variable(s) of interest in the model** |
|---|---|---|
| II.1 | $h(T2DM) = h_0(t)\exp[\beta_{xt}(\text{age}) + \beta_x(\text{Male}) +$<br>$\beta_x(ECI) + \beta_{xt}(affluence\ T2(t)) + \beta_{xt}(affluence\ T3(t)) +$<br>$\beta_{xt}(disadvantage\ T2(t)) + \beta_{xt}(disadvantage\ T3(t)) +$<br>$\beta_{xt}(population\ density\ T2(t)) + \beta_{xt}(population\ density\ T3(t)) +$<br>$\beta_{xt}(healthcare\ T2(t)) + \beta_{xt}(healthcare\ T3(t))]$** | Healthcare resources |
| II.2 | $h(T2DM) = h_0(t)\exp[\beta_{xt}(\text{age}) + \beta_x(\text{Male}) +$<br>$\beta_x(ECI) + \beta_{xt}(affluence\ T2(t)) + \beta_{xt}(affluence\ T3(t)) +$<br>$\beta_{xt}(disadvantage\ T2(t)) + \beta_{xt}(disadvantage\ T3(t)) +$<br>$\beta_{xt}(population\ density\ T2(t)) + \beta_{xt}(population\ density\ T3(t)) +$<br>$\beta_{xt}(healthcare\ T2(t)) + \beta_{xt}(healthcare\ T3(t)) +$<br>$\beta_{xt}(Transit\ stops\ T2(t)) + \beta_{xt}(Transit\ stops\ T3(t)) +$ | Healthcare environment:<br>• Healthcare resources<br>• Transit stops<br>• Broadband internet |

|  |  |  |
|---|---|---|
|  | $\beta_{xt}(Broaband\ Internet\ T2(t)) +$<br>$\beta_{xt}(Broadband\ Internet\ T3(t))]$** |  |
| II.3 | $h(T2DM) = h_0(t)\exp[\beta_{xt}(\text{age}) + \beta_x(\text{Male}) +$<br>$\beta_x(ECI) + \beta_{xt}(affluence\ T2(t)) + \beta_{xt}(affluence\ T3(t)) +$<br>$\beta_{xt}(disadvantage\ T2(t)) + \beta_{xt}(disadvantage\ T3(t)) +$<br>$\beta_{xt}(population\ density\ T2(t)) + \beta_{xt}(population\ density\ T3(t)) +$<br>$\beta_{xt}(Grocery\ T2(t)) + \beta_{xt}(Grocery\ T3(t)) +$<br>$\beta_{xt}(Recreation\ T2(t)) + \beta_{xt}(Recreation\ T3(t)) +$<br>$\beta_{xt}(Parks\ T2(t)) + \beta_{xt}(Parks\ T3(t))]$** | Food and recreation environment:<br>• Grocery stores<br>• Recreational establishments<br>• Parks |

| | | |
|---|---|---|
| II.4*** | $h(T2DM) = h_0(t)\exp[\beta_{xt}(\text{age}) + \beta_x(\text{Male})$<br>$+ \beta_x(ECI) + \beta_{xt}(affluence\ T2(t))$<br>$+ \beta_{xt}(affluence\ T3(t)) + \beta_{xt}(disadvantage\ T2(t))$<br>$+ \beta_{xt}(disadvantage\ T3(t))$<br>$+ \beta_{xt}(health\ promoting\ T2(t))$<br>$+ \beta_{xt}(health\ promoting\ T3(t))]$ | Composite measure of health promoting resources |
| II.5 **** | $h(T2DM) = h_0(t)\exp[\beta_{xt}(\text{age}) + \beta_x(\text{Male})$<br>$+ \beta_x(ECI) + \beta_{xt}(affluence\ T2(t))$<br>$+ \beta_{xt}(affluence\ T3(t)) + \beta_{xt}(disadvantage\ T2(t))$<br>$+ \beta_{xt}(disadvantage\ T3(t))$<br>$+ \beta_{xt}(health\ harming\ T2(t))$<br>$+ \beta_{xt}(health\ harming\ T3(t))]$ | Composite measure of health harming infrastructure |

Abbreviations: ECI, Elixhauser co-morbidity index; T2DM, Type 2 Diabetes Mellitus; T, tertile.
T2 corresponds to medium density and T3 is high density. The reference was T1 (low density).
*All models adjusted for individual-level age, Elixhauser co-morbidity index (ECI) and sex, and neighborhood-level affluence, disadvantage and population density.

**The term for grocery includes grocery stores, supermarkets and warehouses. The term for recreation includes recreational facilities, golf courses and bowling alleys. The term for healthcare included ambulatory care facilities, hospitals, residential/skilled nursing facilities and pharmacies.

***Health promoting is a composite measure consisting of density of healthcare facilities, broadband internet connections, transit stops, parks, recreational facilities/bowling alleys/golf courses and grocery stores/supermarkets/warehouses.

****Health harming is a composite measure consisting of density of convenience stores, liquor and tobacco stores and fast-food restaurants.

Similar models were used for the outcome of any cardiometabolic disease, hypertension and hyperlipidemia**.**

Time-varying covariates are denoted by $z(t)$, while other covariates, $x$, are time-invariant. $B$ denotes the vector of regression coefficients associated with the vector of fixed covariates $x$, while $\beta_t$ is the regression coefficient associated with the time varying covariates.

After examining the individual components of the neighborhood environment associated with cardiometabolic conditions, I examined how the presence and/or absence of health promoting and harming features of the environment work in concert to shape health in individuals aging with a physical disability using the neighborhood typology I adapted. I characterized the neighborhood typology by reporting the area and population density as well as the mean density of health-promoting and harming infrastructure within each neighborhood type. I then ran regression models with the focal variable of interest being the neighborhood typology (Equation II.6).

Equation II.6 Cox Proportional Hazards regression models examining the association between the adapted neighborhood typology and incident Type 2 Diabetes Mellitus (T2DM), adjusted for individual and neighborhood-level covariates.

$$
\begin{aligned}
&h(Tye\ 2\ Diabetes\ Mellitus)\\
&\qquad = h_0(t)\exp\,[\beta_{xt}(\text{age}) + \ \beta_x(\text{Male})\\
&\qquad + \ \beta_x(Elixhauser\ Comorbidity\ Index) + \beta_{xt}\big(affluence\ Q1(t)\big)\\
&\qquad + \ + \beta_{xt}\big(affluence\ Q2(t)\big)\\
&\qquad + \ \beta_{xt}\big(affluence\ Q3(t)\big) + \ \beta_{xt}\big(disadvantage\ Q1(t)\big)\\
&\qquad + \ \beta_{xt}\big(disadvantage\ Q2(t)\big) + \ \beta_{xt}\big(disadvantage\ Q3(t)\big)\\
&\qquad + \beta_{xt}\big(high\ health\ promoting\ and\ health\ harming(t)\big)\\
&\qquad + \beta_{xt}\big(Average\ health\ promoting\ and\ harming(t)\big)\\
&\qquad + \ \beta_{xt}\big(low\ health\ promoting\ and\ high\ health\ harming(t)\big)\\
&\qquad + \ \beta_{xt}(low\ health\ promoting\ and\ low\ health\ harming(t))]
\end{aligned}
$$

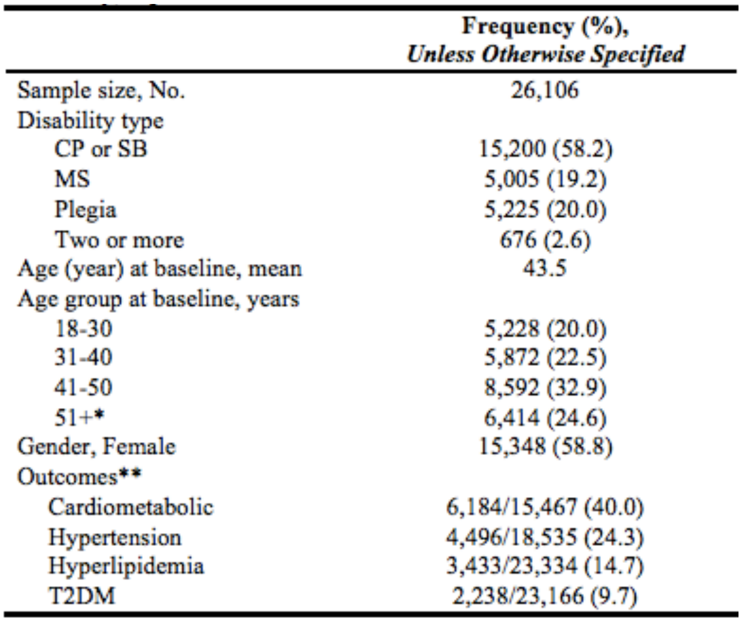
Time-varying covariates are denoted by z*(t)*, while other covariates, $x$, are time-invariant. $B$ denotes the vector of regression coefficients associated with the vector of fixed covariates $x$, while $\beta_t$ is the regression coefficient associated with the time varying covariates. Reference for the typology was neighborhoods with a high density of health promoting resources and low density of health harming features. A similar model was also used for the other outcomes of any cardiometabolic disease, hypertension and hyperlipidemia.

## 2.3 Results

*Cohort characteristics:*

Table II.2 displays characteristics of the study cohort. The cohort consisted of 26,106 individuals aging with physical disabilities acquired before the age of 50 years. The vast majority of the cohort was comprised of individuals with CP or SB (58.2%), followed by Plegia and MS. A small number of individuals (2.6%) were aging with more than one qualifying condition. The cohort was predominantly female (~60%) and was middle-aged, with a mean age of 43.5 years. Approximately 25% of individuals in our cohort were 51 years of age or older, but they were exclusively those with a diagnosis of CP or SB given these are congenital conditions and no age restriction was imposed for inclusion in the study cohort (Table II.2).

Table II.2 Baseline characteristics of the study cohort aging with a physical disability, Optum® Clinformatics® Data Mart



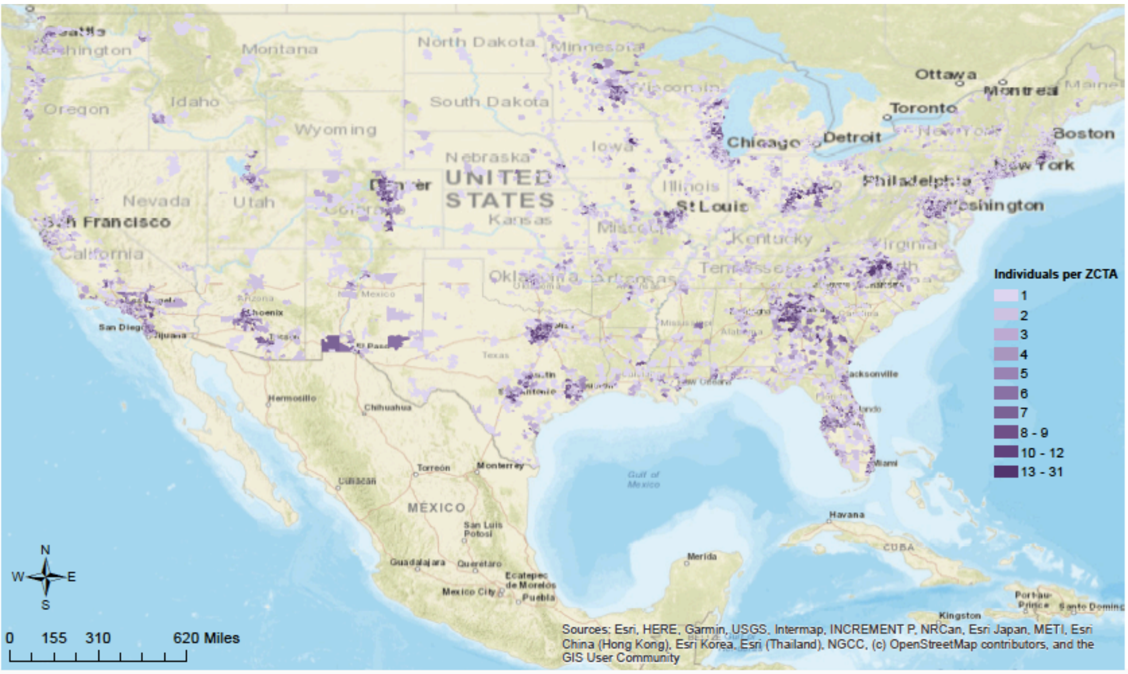
| | **Frequency (%),**<br>***Unless Otherwise Specified*** |
|---|---|
| Sample size, No. | 26,106 |
| Disability type | |
| CP or SB | 15,200 (58.2) |
| MS | 5,005 (19.2) |
| Plegia | 5,225 (20.0) |
| Two or more | 676 (2.6) |
| Age (year) at baseline, mean | 43.5 |
| Age group at baseline, years | |
| 18-30 | 5,228 (20.0) |
| 31-40 | 5,872 (22.5) |
| 41-50 | 8,592 (32.9) |
| 51+* | 6,414 (24.6) |
| Gender, Female | 15,348 (58.8) |
| Outcomes** | |
| Cardiometabolic | 6,184/15,467 (40.0) |
| Hypertension | 4,496/18,535 (24.3) |
| Hyperlipidemia | 3,433/23,334 (14.7) |
| T2DM | 2,238/23,166 (9.7) |

Abbreviations: CP, Cerebral palsy; No., Number; SB, Spina Bifida; T2DM, Type 2 Diabetes Mellitus.

*Individuals 51 years of age or older at time of index diagnosis were those with congenital conditions only. In line with definitions of early-onset disability (condition acquired by mid-life), individuals with Multiple Sclerosis or Plegia had to have their index diagnosis by age 50 years.

**These were 3-year incident outcomes. The numerator represents the number of individuals who had the event in question, and the denominator represents those who did not have a history of the condition (not prevalent).

Though the study cohort had representation from across the United States, individuals were predominantly located in the Southwest (Arizona and Texas), West (California and Denver), Midwest (Ohio, Minnesota and Wisconsin) and Northeast (New York and Washington) United States (Figure II.4).



Sources: Esri, HERE, Garmin, USGS, Intermap, INCREMENT P, NRCan, Esri Japan, METI, Esri China (Hong Kong), Esri Korea, Esri (Thailand), NGCC, (c) OpenStreetMap contributors, and the GIS User Community

Figure II.4 Geographic distribution of participants in the study cohort (N=26,106) at baseline.
Abbreviations: ZCTA, ZIP code Tabulation Area.
Darker purple shade represents areas with a higher number of cohort members.

Incident cardiometabolic events were common in this cohort during the 3-year follow-up period. Amongst individuals without a history of cardiometabolic disease, 40% had at least one diagnostic code during follow-up (Table II.2). Amongst specific cardiometabolic conditions examined, the most common was hypertension, with 24.3% of individuals with an incident diagnosis, followed by hyperlipidemia. An incident diagnosis of T2DM was the least common, although 2,238 (9.7%) individuals still had a diagnosis during the 3-years (Table II.2).

*Features of neighborhood environment:*

Tables II.3-II.6 detail the findings of the regression models examining the relationship between features of the neighborhood environment and incident cardiometabolic disease, T2DM, hypertension, and hyperlipidemia, respectively. I detail the findings below for each outcome, individually.

<u>Any cardiometabolic disease:</u>

Net of individual-level characteristics and neighborhood-level affluence, disadvantage and population density, residing in a neighborhood with higher density of healthcare resources was associated with a 6% lower risk of any cardiometabolic disease (Medium vs low: HR 0.94; 95% CI: 0.88, 1.00) (Model 1; Table II.3). With the addition of the broadband internet and transit variables, encompassing the broader healthcare environment (Model 2), density of healthcare resources was no longer statistically significant. However, residing in areas with higher density of broadband internet connections and transit stops were independently associated with a lower risk of any cardiometabolic disease (Broadband high vs low: HR 0.88, 95% CI 0.81, 0.97; Transit high vs low: HR 0.89, 95% CI 0.83, 0.95).

In the regression model that examined the association with the food and recreation environments (Model 3), higher density of recreational establishments was associated with an 11% lower risk of any cardiometabolic disease (High vs low: HR 0.89; 95% CI: 0.83, 0.96) (Table II.3). Findings were not significant for grocery stores as confidence intervals crossed one. Furthermore, in this model, park density was independently and significantly associated with lower risk of cardiometabolic disease. I observed a dose-response relationship in that findings were more pronounced for those residing in neighborhoods with the highest versus lowest density of parks (High vs low: HR 0.88; 95% CI: 0.82, 0.94).

In a composite measure considering all of these health-promoting resources, residing in a neighborhood with a high density of health promoting resources was associated with a 14% lower risk of any cardiometabolic disease compared to residing in an area with the lowest density (HR 0.86; 95% CI: 0.79, 0.94). No significant findings were observed when I considered health-harming features of the neighborhood environment comprised of tobacco, liquor and convenience stores (Model 5; Table II.3).

Though features of the built environment were the focal point of this analysis, I also noted that neighborhood-level affluence, disadvantage and population density were associated with diagnosis of incident cardiometabolic disease, although the statistical significance of findings varied across models. Generally speaking, residing in more affluent neighborhoods was associated with lower risk of disease, whilst the opposite was true for individuals residing in more disadvantaged neighborhoods (Table II.3). For example, in model 1, I noted that residing in the most affluent neighborhoods (compared to least affluent) was associated with a 14% lower risk of any cardiometabolic disease (HR 0.86; 95% CI 0.79, 0.94), whilst residing in the most disadvantaged areas was associated with a 10% higher risk (HR 1.10; 95% CI: 1.10, 1.25) compared to those residing in the least disadvantaged neighborhoods. Residing in more populous neighborhoods was consistently associated with higher risk of cardiometabolic disease across models, net of individual and neighborhood-level socioeconomic variables.

Several individual-level characteristics were also noted to be significantly associated with incident cardiometabolic disease. Older individuals and those with higher co-morbidity burden were at increased risk of cardiometabolic disease. This was consistent across all models examined (Table II.3). For example, a 10-year increase in age was associated with a 37-38% increased hazard of cardiometabolic disease, and findings were statistically significant owing to the confidence intervals not containing the null value of one. Similarly, a five-unit increase in the ECI score was associated with a 67-70% increased risk of the outcome (e.g., Model 1: HR 1.67; 95% CI: 1.50, 1.87).

Table II.3 Association between individual features of the neighborhood environment and 3-year incidence of any cardiometabolic disease among 15,467 adults aging with a physical disability; Optum's Clinformatics® Data Mart

| | **Model 1:** Healthcare | **Model 2:** Healthcare + broadband internet + transit stops | **Model 3:** Grocery stores + recreational facilities + parks | **Model 4:** Composite health promoting | **Model 5:** Composite health harming |
|---|---|---|---|---|---|
| | | | *HR (95% CI)* | | |
| ***Individual-level characteristics*** | | | | | |
| Sex, M | 1.03 (0.98, 1.09) | 1.04 (0.99, 1.09) | 1.03 (0.98, 1.09) | 1.03 (0.98, 1.09) | 1.03 (0.98, 1.09) |
| Age (years), 10 years | **1.37 (1.35, 1.40)** | **1.38 (1.35, 1.40)** | **1.38 (1.35, 1.40)** | **1.37 (1.35, 1.40)** | **1.37 (1.35, 1.40)** |
| Elixhauser (Cardio specific), 5 units | **1.67 (1.50, 1.87)** | **1.69 (1.52, 1.89)** | **1.68 (1.51, 1.87)** | **1.69 (1.52, 1.89)** | **1.68 (1.50, 1.87)** |
| ***Contextual factors*** | | | | | |
| Affluence (Ref = Low) | | | | | |
| Medium | **0.92 (0.85, 0.98)** | 0.95 (0.88, 1.02) | 0.94 (0.87, 1.01) | 0.95 (0.88, 1.03) | **0.91 (0.85, 0.98)** |
| High | **0.86 (0.79, 0.94)** | 0.93 (0.84, 1.03) | **0.91 (0.83, 0.99)** | 0.93 (0.84, 1.03) | **0.86 (0.79, 0.93)** |
| Disadvantage (Ref = Low) | | | | | |
| Medium | 1.05 (0.98, 1.13) | 1.06 (0.98, 1.14) | 1.04 (0.97, 1.11) | 1.05 (0.98, 1.13) | 1.05 (0.98, 1.13) |
| High | **1.10 (1.01, 1.20)** | **1.10 (1.01, 1.20)** | 1.07 (0.99, 1.17) | 1.08 (0.99, 1.17) | **1.10 (1.01, 1.20)** |
| Population density (Ref = Low) | | | | | |
| Medium | **1.11 (1.04, 1.19)** | **1.16 (1.08, 1.24)** | **1.12 (1.04, 1.20)** | **1.13 (1.05, 1.21)** | **1.10 (1.03, 1.18)** |
| High | **1.17 (1.10, 1.25)** | **1.26 (1.17, 1.36)** | **1.16 (1.09, 1.25)** | **1.19 (1.11, 1.27)** | **1.16 (1.09, 1.24)** |
| Healthcare Resources (Ref = Low) | | | | | |
| Medium | **0.94 (0.88, 1.00)** | 0.95 (0.89, 1.02) | --- | --- | --- |
| High | 0.97 (0.91, 1.05) | 1.01 (0.94, 1.09) | --- | --- | --- |
| Broadband connections (Ref = Low) | | | | | |
| Medium | --- | 0.95 (0.89, 1.03) | --- | --- | --- |
| High | --- | **0.88 (0.81, 0.97)** | --- | --- | --- |
| Transit stops (Ref= Low) | | | | | |
| Medium | --- | 0.98 (0.92, 1.06) | --- | --- | --- |
| High | --- | **0.89 (0.83, 0.95)** | --- | --- | --- |
| Grocery stores (Ref = Low) | | | | | |
| Medium | --- | --- | 1.05 (0.99, 1.12) | --- | --- |
| High | --- | --- | 1.05 (0.98, 1.12) | --- | --- |
| Recreation establishments (Ref = Low) | | | | | |
| Medium | --- | --- | 0.99 (0.93, 1.06) | --- | --- |
| High | --- | --- | **0.89 (0.83, 0.96)** | --- | --- |
| Parks (Ref = Low) | | | | | |
| Medium | --- | --- | **0.94 (0.88, 1.00)** | --- | --- |
| High | --- | --- | **0.88 (0.82, 0.94)** | --- | --- |
| Health harming overall (Ref = Low) | | | | | |
| Medium | --- | --- | --- | --- | 1.03 (0.97, 1.10) |
| High | --- | --- | --- | --- | 0.97 (0.91, 1.03) |
| Health promote overall (Ref = Low) | | | | | |
| Medium | --- | --- | --- | 0.95 (0.88, 1.02) | --- |
| High | --- | --- | --- | **0.86 (0.79, 0.94)** | --- |

Abbreviations: Cardio, Cardiometabolic; CI, Confidence Interval; HR, Hazard Ratio; M, Male; Ref, Reference group.
Bold effect estimates indicate statistical significance at the 0.05 level.
Density of neighborhood characteristics was computed within the ZIP code Tabulation Area (ZCTA).
For neighborhood affluence and disadvantage, “low” represents the least affluent and disadvantaged areas, whilst “high” reflects the most affluent and disadvantaged neighborhoods.
Grocery stores also consist of supermarkets, warehouses and superstores.
Recreation establishments include recreational facilities, bowling alleys and golf courses.
Outcome of any cardiometabolic disease consisted of Cardiac dysrhythmias, Heart failure, Peripheral and visceral atherosclerosis, Non-alcoholic liver disease, Chronic kidney disease, Type 2 Diabetes Mellitus, Hypercholesterolemia and, Hypertension.
Elixhauser co-morbidity index was computed during the 1-year “look-back” period.
Age was modelled as time-varying whilst sex was examined at baseline.

### Type 2 Diabetes Mellitus (T2DM):

Table II.4 highlights the findings pertaining to the outcome of T2DM. Model 1 examined the effect of healthcare resources, net of individual-level characteristics and neighborhood socio-economic measures. I noted no significant effects of density of healthcare resources on diabetes risk. When density of broadband internet connections and transit stops was added to the model (Model 2), healthcare resources remained statistically insignificant. Notably though, individuals residing in neighborhoods with a higher density of broadband internet connections were found to have lower risk of diabetes (e.g., medium vs low: HR 0.86; 95% CI: 0.77, 0.97). I observed a dose-response relationship, with findings most pronounced for those residing in areas with the highest density of broadband internet connections (Model 2; Table II.4). Density of transit stops was also independently associated with diabetes risk but an inverse association was not observed. Compared to individuals residing in neighborhoods with a low density of transit stops, those in areas with moderate transit density had a 20% higher risk of diabetes (HR 1.20, 95% CI: 1.06, 1.35).

In the model examining the effects of the food and physical activity environment of neighborhoods (Model 3), I noted that a higher density of grocery stores was associated with increased risk of diabetes (e.g., high vs low: HR 1.32; 95% CI: 1.18, 1.48) whilst higher density of recreation organizations was associated lower risk of diabetes (e.g., high vs low: HR 0.71; 95% CI: 0.64, 0.82). A dose response relationship was observed such that findings were more pronounced with increasing density of these features of the environment. Comparable and statistically significant findings were observed for independent effect of parks (e.g., high vs low: HR 0.74, 0.66, 0.82) (Model 3; Table II.4).

As was observed with any cardiometabolic disease, a composite measure of health promoting resources was significantly associated with T2DM. Individuals residing in neighborhoods with the highest density of all health promoting resources had a 34% lower risk of T2DM (HR 0.66; 95% CI: 0.57, 0.77). No significant association was observed for a composite measure of health harming infrastructure.

Generally, residence in more affluent areas was associated with lower risk of diabetes (e.g., Model 1, high vs low: HR 0.75; 95% CI: 0.65, 0.88), though significance of findings varied across models. Residence in more disadvantaged neighborhoods and within more populous areas was associated with increased risk of T2DM (e.g., population density, model 2, high vs low: HR 1.31; 95% CI: 1.13, 1.52).

Age and disease burden were independently, and strongly associated with 3-year risk of diabetes. A 10-year increase in age was associated with a 36% higher risk of diabetes (e.g., Model 4: HR 1.36; 95% CI: 1.33, 1.40). For a 5-unit increase in ECI, risk of T2DM increased by 93-97%. No significant effects for sex were observed in any of the models (Table II.4).

Table II.4 Association between individual features of the neighborhood environment and 3-year incidence of type 2 diabetes mellitus (T2DM) among 23,166 adults aging with a physical disability, Optum's Clinformatics® Data Mart

| | **Model 1:**<br>**Healthcare** | **Model 2:**<br>**Healthcare + broadband internet + transit stops** | **Model 3:**<br>**Grocery stores + recreational establishments + parks** | **Model 4:**<br>**Composite health promoting** | **Model 5:**<br>**Composite health harming** |
|---|---|---|---|---|---|
| | | | ***HR (95% CI)*** | | |
| ***Individual-level characteristics*** | | | | | |
| Sex, M | 1.02 (0.93, 1.11) | 1.02 (0.94, 1.12) | 1.02 (0.93, 1.11) | 1.02 (0.93, 1.11) | 1.02 (0.93, 1.11) |
| Age (years), 10 years | **1.36 (1.32, 1.39)** | **1.36 (1.32, 1.39)** | **1.36 (1.33, 1.40)** | **1.36 (1.33, 1.40)** | **1.36 (1.32, 1.39)** |
| Elixhauser (Cardio specific), 5 units | **1.93 (1.69, 2.21)** | **1.96 (1.71, 2.24)** | **1.95 (1.71, 2.24)** | **1.94 (1.70, 2.22)** | **1.94 (1.69, 2.22)** |
| ***Contextual factors*** | | | | | |
| Affluence (Ref = Low) | | | | | |
| Medium | 0.90 (0.81, 1.01) | 0.97 (0.86 1.10) | 0.98 (0.87, 1.09) | 0.98 (0.87, 1.11) | **0.89 (0.80, 1.00)** |
| High | **0.75 (0.65, 0.88)** | 0.89 (0.75, 1.06) | 0.86 (0.73, 1.01) | 0.93 (0.79, 1.10) | **0.74 (0.64, 0.86)** |
| Disadvantage (Ref = Low) | | | | | |
| Medium | **1.11 (0.98, 1.27)** | 1.12 (0.98, 1.27) | 1.07 (0.94, 1.22) | 1.10 (0.97, 1.25) | **1.12 (0.98, 1.27)** |
| High | **1.35 (1.17, 1.56)** | **1.31 (1.13, 1.52)** | **1.26 (1.09, 1.46)** | **1.28 (1.10, 1.48)** | **1.37 (1.18, 1.58)** |
| Population density (Ref = Low) | | | | | |
| Medium | 0.93 (0.83, 1.03) | **1.29 (1.14, 1.46)** | **1.28 (1.14, 1.44)** | **1.30 (1.16, 1.47)** | **1.24 (1.10, 1.39)** |
| High | 0.96 (0.85, 1.07) | **1.56 (1.37, 1.78)** | **1.43 (1.27, 1.60)** | **1.54 (1.37, 1.73)** | **1.46 (1.30, 1.63)** |
| Healthcare Resources (Ref = Low) | | | | | |
| Medium | 1.05 (0.93, 1.17) | 0.95 (0.85, 1.06) | --- | --- | --- |
| High | 0.97 (0.87, 1.08) | 1.03 (0.92, 1.16) | --- | --- | --- |
| Broadband connections (Ref = Low) | | | | | |
| Medium | --- | **0.86 (0.77, 0.97)** | --- | --- | --- |
| High | --- | **0.69 (0.59, 0.80)** | --- | --- | --- |
| Transit stops (Ref= Low) | | | | | |
| Medium | --- | **1.20 (1.06, 1.35)** | --- | --- | --- |
| High | --- | 0.92 (0.82, 1.04) | --- | --- | --- |
| Grocery stores (Ref = Low) | | | | | |
| Medium | --- | --- | **1.19 (1.07, 1.33)** | --- | --- |
| High | --- | --- | **1.32 (1.18, 1.48)** | --- | --- |
| Recreation establishments (Ref = Low) | | | | | |
| Medium | --- | --- | **0.87 (0.78, 0.97)** | --- | --- |
| High | --- | --- | **0.72 (0.64, 0.82)** | --- | --- |
| Parks (Ref = Low) | | | | | |
| Medium | --- | --- | **0.83 (0.75, 0.92)** | --- | --- |
| High | --- | --- | **0.74 (0.66, 0.82)** | --- | --- |
| Health harming overall (Ref = Low) | | | | | |
| Medium | --- | --- | --- | --- | 0.98 (0.88, 1.09) |
| High | --- | --- | --- | --- | 0.92 (0.82, 1.02) |
| Health promote overall (Ref = Low) | | | | | |
| Medium | --- | --- | --- | 0.90 (0.80, 1.02) | --- |
| High | --- | --- | --- | **0.66 (0.57, 0.77)** | --- |

Abbreviations: Cardio, Cardiometabolic; CI, Confidence Interval; HR, Hazard Ratio; M, Male; Ref, Reference group.
Bold effect estimates indicate statistical significance at the 0.05 level.
Density of neighborhood characteristics was computed within the ZIP code Tabulation Area (ZCTA).
For neighborhood affluence and disadvantage, “low” represents the least affluent and disadvantaged areas, whilst “high” reflects the most affluent and disadvantaged neighborhoods.
Grocery stores also consist of supermarkets and warehouses and superstores.
Recreation establishments include recreational facilities, bowling alleys and golf courses.
Elixhauser co-morbidity index was computed during the 1-year “look-back” period.
Age was modelled as time-varying. Sex was examined at baseline.

Hypertension:

I identified several independent features of the neighborhood environment associated with development of hypertension (Table II.5). In model 1, residing in neighborhoods with higher density of healthcare resources such as hospitals and ambulatory care centers was associated with lower risk of hypertension (e.g., high vs low: HR 0.90; 95% CI: 0.83, 0.98). However, in a model with the broader healthcare environment (healthcare establishments, transit and broadband internet), healthcare was no longer significantly associated with risk of hypertension (Model 2; Table II.5). Higher density of broadband internet connections was independently associated with lower risk of hypertension (e.g., high vs low: HR 0.84; 95% CI: 0.75, 0.93) whilst density of transit stops was marginally significant (high vs low HR 0.91, 95% CI: 0.84, 0.99) (Model 2; Table II.5).

When examining the food and recreation features of the built neighborhood environment (model 3), residing in neighborhoods with the highest density (versus lowest) of recreational organizations was associated with a 16% lower risk of hypertension (HR 0.84; 95% CI: 0.78, 0.94). Parks were also independently associated (Model 3; Table II.5), where a greater density of parks was associated with a 13% lower risk of hypertension, net of recreational centers and healthy food stores (HR 0.87, 95% CI: 0.80, 0.94).

Overall, a composite measure of density of health promoting resources was associated with lower risk of hypertension, with a dose-response relationship observed. Individuals residing in areas with a higher availability of health promoting resources had a 13% and 20% lower risk of hypertension for those in medium and high-density resource areas, respectively, vs. low density. No significant effects were observed for health harming infrastructure (e.g., medium vs low: HR 1.00; 95% CI: 0.92, 1.07) (Table II.5).

I also identified other neighborhood features associated with risk of hypertension, though statistical significance varied across models for these variables. Residing in a neighborhood with higher affluence scores was associated with lower risk of hypertension (e.g., model 3, food and recreation environment, high vs low: HR 0.88; 95% CI: 0.79, 0.98). Conversely, residence in more disadvantaged neighborhoods and populous areas was associated with increased risk. For example, in model 3, residing in the most disadvantaged neighborhoods was associated with a 21% higher risk (HR 1.21; 95% CI: 1.09, 1.33) whilst living in the most populous neighborhood was consistently found to be associated with a higher risk of hypertension (e.g., an 11% higher risk (HR 1.11; 95% CI: 1.03, 1.20, Model 3; Table II.5).

Net of neighborhood-level factors, I also identified several individual-level factors associated with incident hypertension. A 10-year increase in age was associated with a 52% higher risk of hypertension, irrespective of model examined (Table II.5). Findings were statistically significant owing to the fact that confidence intervals did not cross the null value of one. Similarly, a 5-unit increase in disease burden (ECI) was associated with a 51-53% increase in risk of 3-year incidence of hypertension (depending on the model examined). Unlike the other outcomes examined, sex was a significant independent risk factor for incident hypertension. For example, in model 1, males had a 19% higher risk (HR 1.19; 95% CI: 1.13, 1.27) of hypertension compared to females (Table II.5).

Table II.5 Association between individual features of the neighborhood environment and 3-year incidence of hypertension among 18,535 adults aging with a physical disability, Optum's Clinformatics® Data Mart

| | Model 1: Healthcare | Model 2: Healthcare + broadband internet + transit stops | Model 3: Grocery stores + recreational establishments + parks | Model 4: Composite health promoting | Model 5: Composite health harming |
|---|---|---|---|---|---|
| | | | *HR (95% CI)* | | |
| ***Individual-level characteristics*** | | | | | |
| Sex, M | **1.19 (1.13, 1.27)** | **1.20 (1.13, 1.27)** | **1.19 (1.13, 1.27)** | **1.19 (1.13, 1.27)** | **1.19 (1.12, 1.26)** |
| Age (years), 10 years | **1.52 (1.49, 1.55)** | **1.52 (1.49, 1.55)** | **1.52 (1.49, 1.55)** | **1.52 (1.49, 1.55)** | **1.52 (1.49, 1.55)** |
| Elixhauser (Cardio specific), 5 units | **1.51 (1.35, 1.69)** | **1.52 (1.36, 1.70)** | **1.51 (1.35, 1.69)** | **1.52 (1.36, 1.70)** | **1.51 (1.35, 1.69)** |
| ***Contextual factors*** | | | | | |
| Affluence (Ref = Low) | | | | | |
| Medium | **0.91 (0.84, 0.98)** | 0.96 (0.88, 1.05) | **0.93 (0.85, 1.00)** | 0.96 (0.88, 1.05) | **0.89 (0.83, 0.97)** |
| High | **0.84 (0.75, 0.93)** | 0.92 (0.82, 1.04) | **0.88 (0.79, 0.98)** | 0.92 (0.82, 1.03) | **0.81 (0.73, 0.90)** |
| Disadvantage (Ref = Low) | | | | | |
| Medium | **1.11 (1.02, 1.22)** | **1.12 (1.03, 1.22)** | **1.09 (1.00, 1.19)** | **1.11 (1.02, 1.21)** | **1.11 (1.02, 1.22)** |
| High | **1.24 (1.12, 1.37)** | **1.23 (1.11, 1.36)** | **1.21 (1.09, 1.33)** | **1.20 (1.09, 1.33)** | **1.24 (1.12, 1.37)** |
| Population density (Ref = Low) | | | | | |
| Medium | **1.10 (1.01, 1.19)** | **1.15 (1.05, 1.25)** | **1.10 (1.01, 1.19)** | **1.12 (1.03, 1.22)** | **1.08 (1.00, 1.17)** |
| High | **1.13 (1.05, 1.23)** | **1.20 (1.10, 1.31)** | **1.11 (1.03, 1.20)** | **1.14 (1.05, 1.23)** | **1.11 (1.02, 1.20)** |
| Healthcare Resources (Ref = Low) | | | | | |
| Medium | 0.95 (0.88, 1.02) | 0.96 (0.89, 1.04) | --- | --- | --- |
| High | **0.90 (0.83, 0.98)** | 0.94 (0.86, 1.02) | --- | --- | --- |
| Broadband connections (Ref = Low) | | | | | |
| Medium | --- | **0.89 (0.82, 0.97)** | --- | --- | --- |
| High | --- | **0.85 (0.76, 0.94)** | --- | --- | --- |
| Transit stops (Ref= Low) | | | | | |
| Medium | --- | 0.99 (0.91, 1.08) | --- | --- | --- |
| High | --- | **0.91 (0.84, 0.99)** | --- | --- | --- |
| Grocery stores (Ref = Low) | | | | | |
| Medium | --- | --- | 1.05 (0.98, 1.13) | --- | --- |
| High | --- | --- | 1.00 (0.92, 1.08) | --- | --- |
| Recreation establishments (Ref = Low) | | | | | |
| Medium | --- | --- | 1.00 (0.93, 1.08) | --- | --- |
| High | --- | --- | **0.86 (0.78, 0.94)** | --- | --- |
| Parks (Ref = Low) | | | | | |
| Medium | --- | --- | 0.99 (0.92, 1.06) | --- | --- |
| High | --- | --- | **0.87 (0.80, 0.94)** | --- | --- |
| Health harming overall (Ref = Low) | | | | | |
| Medium | --- | --- | --- | --- | 1.00 (0.92, 1.07) |
| High | --- | --- | --- | --- | 0.96 (0.89, 1.03) |
| Health promote overall (Ref = Low) | | | | | |
| Medium | --- | --- | --- | **0.87 (0.80, 0.94)** | --- |
| High | --- | --- | --- | **0.80 (0.72, 0.89)** | --- |

Abbreviations: Cardio, Cardiometabolic; CI, Confidence Interval; HR, Hazard Ratio; M, Male; Ref, Reference group.
Bold effect estimates indicate statistical significance at the 0.05 level.
Density of neighborhood characteristics was computed within the ZIP code Tabulation Area (ZCTA).
For neighborhood affluence and disadvantage, "low" represents the least affluent and disadvantaged areas, whilst "high" reflects the most affluent and disadvantaged neighborhoods.
Grocery stores also consist of supermarkets and warehouses and superstores.
Recreation establishments include recreational facilities, bowling alleys and golf courses.
Elixhauser co-morbidity index was computed during the 1-year "look-back" period.
Age was modelled as time varying. Sex was assessed at baseline.

Hyperlipidemia:

Healthcare resources were not found to be significantly associated with diagnosis of hyperlipidemia across all models (Models 1 and 2). However, in model 2, independent effects of the density of transit stops were noted when considered alongside density of healthcare resources and broadband internet. Residing in neighborhoods with the highest density of transit stops compared to the lowest density was associated with a 12% lower risk of hyperlipidemia (HR 0.88; 95% CI: 0.79, 0.97) (Model 2; Table II.6). Significant findings were not observed for broadband internet, net of other features of the neighborhood health environment.

Several significant findings were observed for the neighborhood food and recreation environment (Model 3). Living in neighborhoods with a higher density of grocery stores was associated with a higher risk of hyperlipidemia, with a dose response relationship observed (Medium vs low: HR 1.10; 95% CI: 1.01, 1.20; high vs low: HR 1.16; 95% CI: 1.05, 1.27) (Table II.6). In regards to the physical activity variables, a greater density of parks was independently associated with a 14-17% lower 3-year risk of hyperlipidemia (Model 3, Table II.6).

I did not observe statistically significant findings for either composite of health promoting or harming features (e.g., health harming medium vs low: HR 0.94; 95% CI: 0.94, 1.12) (Model II.4; Table II.6).

Amongst other features of the neighborhood environment, only population density was significant across all models examined. Residing in more densely populated neighborhoods was independently associated with a higher risk of hyperlipidemia (e.g., Model 1, medium vs low: HR 1.10; 95% CI: 1.01, 1.21). Individual-level risk factors for hyperlipidemia were found to include sex, age and comorbidity burden. Males had a higher risk of hyperlipidemia compared to their female counterparts (e.g., Model 1: HR 1.09; 95% CI: 1.02, 1.17). Similarly, older age (e.g., Model 2: HR 1.40; 95% CI: 1.37, 1.43) and higher ECI (e.g., Model 2: HR 1.30; 95% CI: 1.17, 1.45) were associated with higher risk (Table II.6).

Table II.6 Association between individual features of the neighborhood environment and 3-year incidence of hyperlipidemia among 23,334 adults aging with a physical disability, Optum's Clinformatics® Data Mart

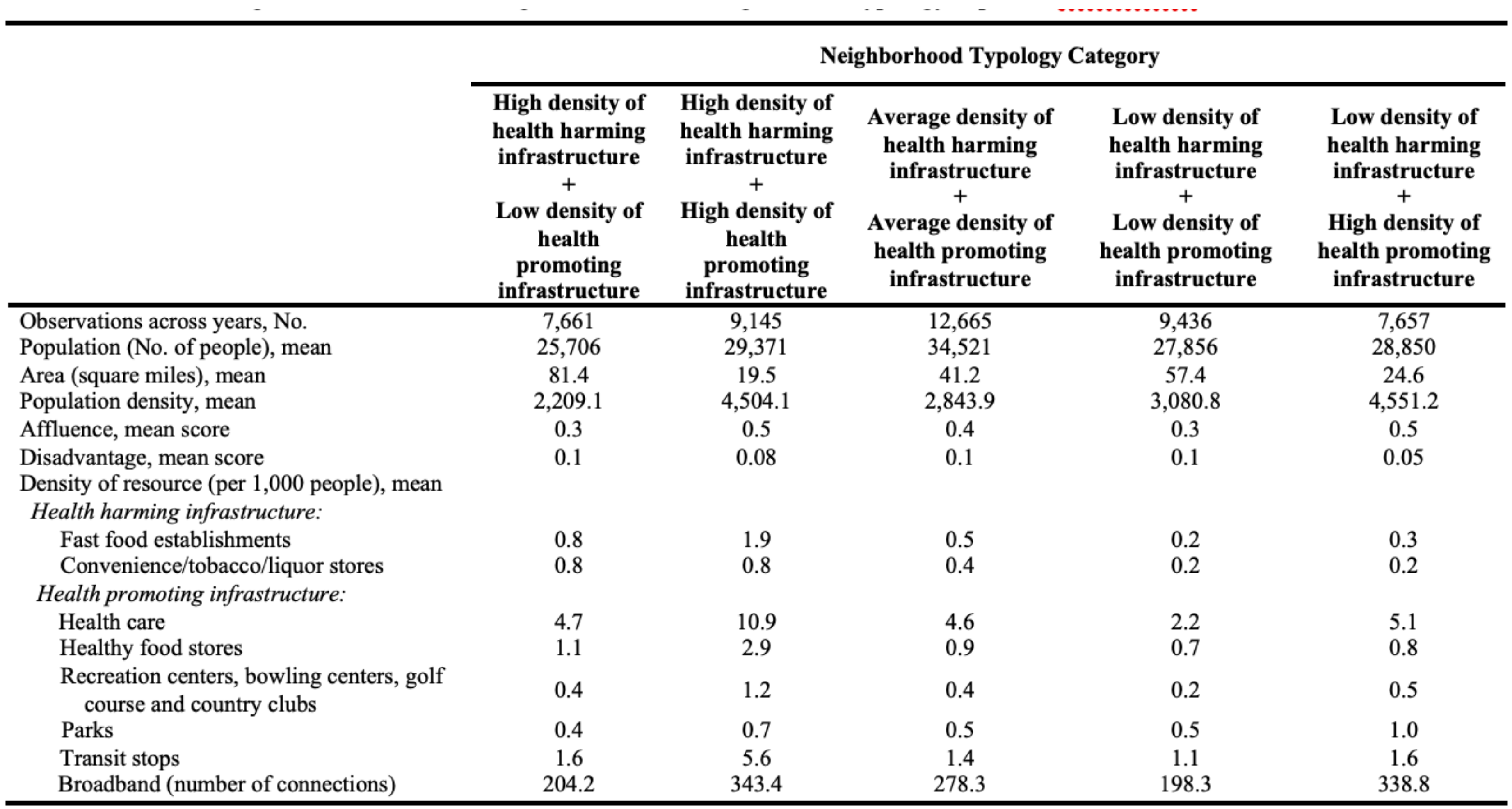
| | **Model 1:** Healthcare | **Model 2:** Healthcare + broadband internet + transit stops | **Model 3:** Grocery stores + recreational establishments + parks | **Model 4:** Composite health promoting | **Model 5:** Composite health harming |
|---|---|---|---|---|---|
| | | | *HR (95% CI)* | | |
| ***Individual-level characteristics*** | | | | | |
| Sex, M | **1.09 (1.02, 1.17)** | **1.09 (1.02, 1.17)** | **1.09 (1.02, 1.17)** | **1.09 (1.02, 1.17)** | **1.09 (1.02, 1.17)** |
| Age (years), 10 years | **1.40 (1.37, 1.43)** | **1.40 (1.37, 1.43)** | **1.40 (1.37, 1.43)** | **1.40 (1.37, 1.43)** | **1.40 (1.37, 1.43)** |
| Elixhauser (Cardio specific), 5 units | **1.30 (1.16, 1.45)** | **1.30 (1.17, 1.45)** | **1.30 (1.16, 1.45)** | **1.30 (1.16, 1.45)** | **1.30 (1.16, 1.45)** |
| ***Contextual factors*** | | | | | |
| Affluence (Ref = Low) | | | | | |
| Medium | 1.01 (0.92, 1.11) | 1.02 (0.92, 1.13) | 1.02 (0.93, 1.11) | 1.01 (0.92, 1.12) | 1.00 (0.92, 1.10) |
| High | 0.94 (0.83, 1.06) | 0.97 (0.84, 1.11) | 0.95 (0.84, 1.07) | 0.95 (0.83, 1.10) | 0.92 (0.82, 1.04) |
| Disadvantage (Ref = Low) | | | | | |
| Medium | 0.98 (0.89, 1.08) | 0.99 (0.90, 1.09) | 0.96 (0.87, 1.06) | 0.98 (0.89, 1.08) | 0.98 (0.89, 1.08) |
| High | 1.08 (0.97, 1.21) | 1.09 (0.98, 1.22) | 1.05 (0.94, 1.18) | 1.07 (0.96, 1.20) | 1.08 (0.97, 1.21) |
| Population density (Ref = Low) | | | | | |
| Medium | **1.10 (1.01, 1.21)** | **1.14 (1.03, 1.26)** | **1.11 (1.01, 1.21)** | **1.11 (1.01, 1.21)** | **1.09 (1.00, 1.20)** |
| High | **1.15 (1.05, 1.26)** | **1.23 (1.10, 1.37)** | **1.13 (1.03, 1.24)** | **1.15 (1.05, 1.30)** | **1.14 (1.04, 1.24)** |
| Healthcare Resources (Ref = Low) | | | | | |
| Medium | 0.93 (0.85, 1.01) | 0.93 (0.85, 1.02) | --- | --- | --- |
| High | 0.97 (0.88, 1.06) | 0.99 (0.90, 1.09) | --- | --- | --- |
| Broadband connections (Ref = Low) | | | | | |
| Medium | --- | 1.00 (0.90, 1.10) | --- | --- | --- |
| High | --- | 0.94 (0.83, 1.07) | --- | --- | --- |
| Transit stops (Ref= Low) | | | | | |
| Medium | --- | 1.01 (0.92, 1.12) | --- | --- | --- |
| High | --- | **0.88 (0.79, 0.97)** | --- | --- | --- |
| Grocery stores (Ref = Low) | | | | | |
| Medium | --- | --- | **1.10 (1.01, 1.20)** | --- | --- |
| High | --- | --- | **1.16 (1.05, 1.27)** | --- | --- |
| Recreation establishments (Ref = Low) | | | | | |
| Medium | --- | --- | 1.06 (0.97, 1.15) | --- | --- |
| High | --- | --- | 0.95 (0.86, 1.05) | --- | --- |
| Parks (Ref = Low) | | | | | |
| Medium | --- | --- | **0.86 (0.79, 0.93)** | --- | --- |
| High | --- | --- | **0.83 (0.76, 0.91)** | --- | --- |
| Health harming overall (Ref = Low) | | | | | |
| Medium | --- | --- | --- | --- | 1.03 (0.94, 1.12) |
| High | --- | --- | --- | --- | 0.98 (0.90, 1.07) |
| Health promote overall (Ref = Low) | | | | | |
| Medium | --- | --- | --- | 1.01 (0.92, 1.11) | --- |
| High | --- | --- | --- | 0.94 (0.83, 1.06) | --- |

Abbreviations: Cardio, Cardiometabolic; CI, Confidence Interval; HR, Hazard Ratio; M, Male; Ref, Reference group.
Bold effect estimates indicate statistical significance at the 0.05 level.
Density of neighborhood characteristics was computed within the ZIP code Tabulation Area (ZCTA).
For neighborhood affluence and disadvantage, "low" represents the least affluent and disadvantaged areas, whilst "high" reflects the most affluent and disadvantaged neighborhoods.
Grocery stores also consist of supermarkets and warehouses and superstores.
Recreation establishments include recreational facilities, bowling alleys and golf courses.
Elixhauser co-morbidity index was computed during the 1-year "look-back" period.
Age was modelled as time varying. Sex was assessed at baseline.

*Neighborhood typology:*

Table II.7 characterizes the different types of neighborhoods within the typology. Neighborhoods with a high density of health-promoting infrastructure (and low density of health-harming infrastructure) and those that were dense in both health-promoting and harming infrastructure (service-dense) had the highest population densities. Furthermore, these neighborhoods had higher mean affluence scores and lower disadvantage scores (Table II.7). Unsurprisingly, these neighborhoods also had a higher density of healthcare facilities, grocery stores, recreational facilities and transit stops compared to neighborhoods with low density of health promoting resources (irrespective of density of health harming features). Notably, service-dense neighborhoods had a *higher density* of some of these health-promoting resources compared to neighborhoods with a high density of health-promoting resources alone. For example, the density of healthcare services was almost two times higher in service-dense environments compared to areas with a high density of health harming infrastructure alone (10.9 per 1000 persons vs. 5.1 per 1000 persons) (Table II.7). Fast food restaurants and convenience, tobacco and liquor stores were more commonplace in neighborhoods with a high density of health-harming services.

Table II.7 Characterizing structural features of neighborhoods in the neighborhood typology, Optum's Clinformatics® Data Mart



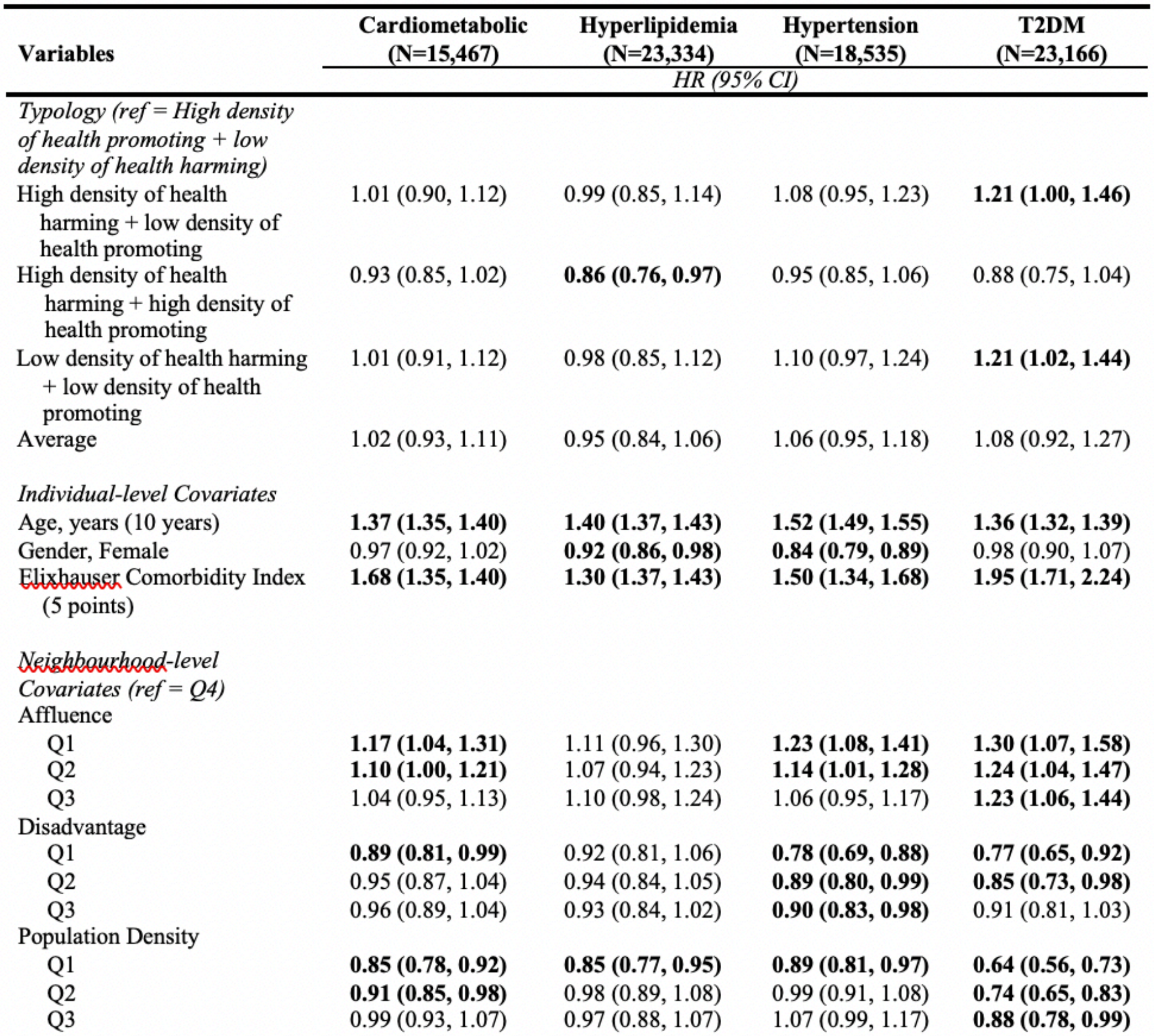
| | Neighborhood Typology Category | | | | |
|---|---|---|---|---|---|
| | High density of health harming infrastructure + Low density of health promoting infrastructure | High density of health harming infrastructure + High density of health promoting infrastructure | Average density of health harming infrastructure + Average density of health promoting infrastructure | Low density of health harming infrastructure + Low density of health promoting infrastructure | Low density of health harming infrastructure + High density of health promoting infrastructure |
| Observations across years, No. | 7,661 | 9,145 | 12,665 | 9,436 | 7,657 |
| Population (No. of people), mean | 25,706 | 29,371 | 34,521 | 27,856 | 28,850 |
| Area (square miles), mean | 81.4 | 19.5 | 41.2 | 57.4 | 24.6 |
| Population density, mean | 2,209.1 | 4,504.1 | 2,843.9 | 3,080.8 | 4,551.2 |
| Affluence, mean score | 0.3 | 0.5 | 0.4 | 0.3 | 0.5 |
| Disadvantage, mean score | 0.1 | 0.08 | 0.1 | 0.1 | 0.05 |
| Density of resource (per 1,000 people), mean | | | | | |
| *Health harming infrastructure:* | | | | | |
| Fast food establishments | 0.8 | 1.9 | 0.5 | 0.2 | 0.3 |
| Convenience/tobacco/liquor stores | 0.8 | 0.8 | 0.4 | 0.2 | 0.2 |
| *Health promoting infrastructure:* | | | | | |
| Health care | 4.7 | 10.9 | 4.6 | 2.2 | 5.1 |
| Healthy food stores | 1.1 | 2.9 | 0.9 | 0.7 | 0.8 |
| Recreation centers, bowling centers, golf course and country clubs | 0.4 | 1.2 | 0.4 | 0.2 | 0.5 |
| Parks | 0.4 | 0.7 | 0.5 | 0.5 | 1.0 |
| Transit stops | 1.6 | 5.6 | 1.4 | 1.1 | 1.6 |
| Broadband (number of connections) | 204.2 | 343.4 | 278.3 | 198.3 | 338.8 |

Abbreviations: No., Number; ZCTA, ZIP Code Tabulation Area.
Neighborhood environment typologies were examined for those without prevalent cardiometabolic disease.
Convenience stores include gas stations with adjacent convenience stores. Healthcare services include hospitals, residential care facilities, ambulatory care facilities and pharmacies. Healthy food stores consist of grocery stores, specialty food stores and warehouse or club stores.

These characteristics were computed across all years of data included in the regression model.
Neighborhood typology used in the present study was adapted from a typology created by Spring (2018). Reference: Spring A. Short- and Long-Term Impacts of Neighborhood Built Environment on Self-Rated Health of Older Adults. *Gerontologist*. 2018;58(1):36-46. doi:10.1093/geront/gnx119.

Table II.8 and Figure II.5 present the results of the regression analyses for the neighborhood typology measure. After adjustment, neighborhood typology was not significantly associated with incidence of the composite outcome of any cardiometabolic disease (Table II.8; Figure II.5A). However, significant findings were observed for specific cardiometabolic conditions examined, namely hyperlipidemia and diabetes. Compared to those living in neighborhoods with high density of health promoting and low density of health harming infrastructure (reference group), residing in service-dense neighborhoods (high density of both health promoting and health harming features) was associated with a 14% lower risk of hyperlipidemia (HR 0.86; 95% CI: 0.76, 0.97) (Table II.8; Figure II.5C). Conversely, compared to the reference neighborhood type, residing in neighborhoods with a high density of health harming and *low density of health promoting* services was associated with a 21% (HR 1.21; 95% CI: 1.00, 1.46) increased risk of T2DM (Table II.8; Figure II.5D). Similar findings were observed for low density of both health promoting and harming infrastructure. No significant associations were found between neighborhood typology categories and hypertension.

Table II.8 Association between neighborhood typology and 3-year incidence of any cardiometabolic disease, hyperlipidemia, hypertension, and type 2 diabetes mellitus, Optum's Clinformatics® Data Mart, 2007-2018



| **Variables** | **Cardiometabolic (N=15,467)** | **Hyperlipidemia (N=23,334)** | **Hypertension (N=18,535)** | **T2DM (N=23,166)** |
|---|---|---|---|---|
| | *HR (95% CI)* | | | |
| *Typology (ref = High density of health promoting + low density of health harming)* | | | | |
| High density of health harming + low density of health promoting | 1.01 (0.90, 1.12) | 0.99 (0.85, 1.14) | 1.08 (0.95, 1.23) | **1.21 (1.00, 1.46)** |
| High density of health harming + high density of health promoting | 0.93 (0.85, 1.02) | **0.86 (0.76, 0.97)** | 0.95 (0.85, 1.06) | 0.88 (0.75, 1.04) |
| Low density of health harming + low density of health promoting | 1.01 (0.91, 1.12) | 0.98 (0.85, 1.12) | 1.10 (0.97, 1.24) | **1.21 (1.02, 1.44)** |
| Average | 1.02 (0.93, 1.11) | 0.95 (0.84, 1.06) | 1.06 (0.95, 1.18) | 1.08 (0.92, 1.27) |
| *Individual-level Covariates* | | | | |
| Age, years (10 years) | **1.37 (1.35, 1.40)** | **1.40 (1.37, 1.43)** | **1.52 (1.49, 1.55)** | **1.36 (1.32, 1.39)** |
| Gender, Female | 0.97 (0.92, 1.02) | **0.92 (0.86, 0.98)** | **0.84 (0.79, 0.89)** | 0.98 (0.90, 1.07) |
| Elixhauser Comorbidity Index (5 points) | **1.68 (1.35, 1.40)** | **1.30 (1.37, 1.43)** | **1.50 (1.34, 1.68)** | **1.95 (1.71, 2.24)** |
| *Neighbourhood-level Covariates (ref = Q4)* | | | | |
| Affluence | | | | |
| Q1 | **1.17 (1.04, 1.31)** | 1.11 (0.96, 1.30) | **1.23 (1.08, 1.41)** | **1.30 (1.07, 1.58)** |
| Q2 | **1.10 (1.00, 1.21)** | 1.07 (0.94, 1.23) | **1.14 (1.01, 1.28)** | **1.24 (1.04, 1.47)** |
| Q3 | 1.04 (0.95, 1.13) | 1.10 (0.98, 1.24) | 1.06 (0.95, 1.17) | **1.23 (1.06, 1.44)** |
| Disadvantage | | | | |
| Q1 | **0.89 (0.81, 0.99)** | 0.92 (0.81, 1.06) | **0.78 (0.69, 0.88)** | **0.77 (0.65, 0.92)** |
| Q2 | 0.95 (0.87, 1.04) | 0.94 (0.84, 1.05) | **0.89 (0.80, 0.99)** | **0.85 (0.73, 0.98)** |
| Q3 | 0.96 (0.89, 1.04) | 0.93 (0.84, 1.02) | **0.90 (0.83, 0.98)** | 0.91 (0.81, 1.03) |
| Population Density | | | | |
| Q1 | **0.85 (0.78, 0.92)** | **0.85 (0.77, 0.95)** | **0.89 (0.81, 0.97)** | **0.64 (0.56, 0.73)** |
| Q2 | **0.91 (0.85, 0.98)** | 0.98 (0.89, 1.08) | 0.99 (0.91, 1.08) | **0.74 (0.65, 0.83)** |
| Q3 | 0.99 (0.93, 1.07) | 0.97 (0.88, 1.07) | 1.07 (0.99, 1.17) | **0.88 (0.78, 0.99)** |

Abbreviations: CI, Confidence Interval; HR, Hazard Ratio; N, Number; Q, Quartile; Ref, Reference Group; T2DM, Type 2 Diabetes Mellitus

Bold text indicates statistical significance at the 0.05 level.

Elixhauser comorbidity index was calculated during the 1-year "look-back" window.

Sample size reflects the number of unique individuals (not the number of observations) who are not prevalent on the condition of interest.

Neighborhood typology used in the present study was adapted from a typology created by Spring (2018). Reference: Spring A. Short- and Long-Term Impacts of Neighborhood

Built Environment on Self-Rated Health of Older Adults. *Gerontologist*. 2018;58(1):36-46. doi:10.1093/geront/gnx119.

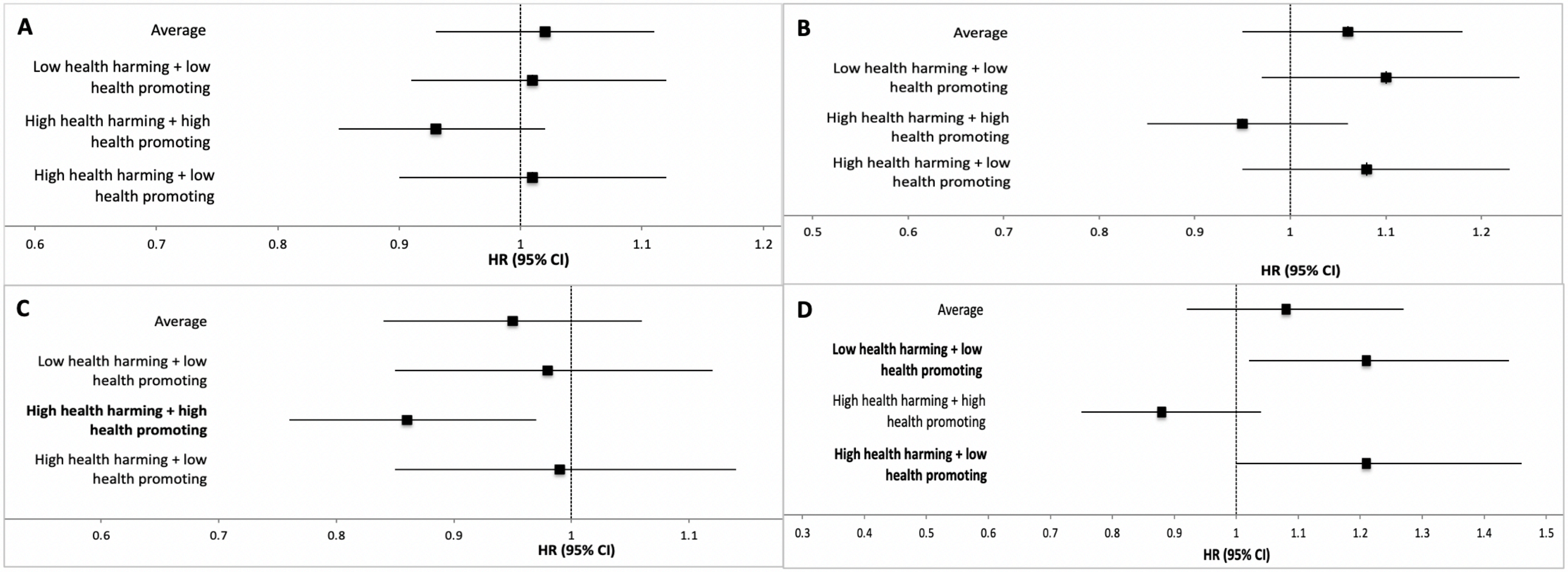


Figure II.5 Association between neighborhood typology and 3-year incidence of any cardiometabolic disease (A), hypertension (B), hyperlipidemia (C), and type 2 diabetes mellitus (D), Optum's Clinformatics® Data Mart.
Abbreviations: CI, Confidence Interval; HR, Hazard Ratio.
Bold text indicates statistical significance at the 0.05 level.
Point estimate and bars represent 95% confidence intervals.
The reference group was neighborhoods classified as having a high density of health promoting and low density of health harming infrastructure.
Models were also adjusted for individual-level age, sex and Elixhauser co-morbidity index and neighborhood-level affluence, disadvantage and population density.
Neighborhood typology used in the present study was adapted from a typology created by Spring (2018). Reference: Spring A. Short- and Long-Term Impacts of Neighborhood Built Environment on Self-Rated Health of Older Adults. *Gerontologist*. 2018;58(1):36-46. doi:10.1093/geront/gnx119.

## 2.4 Discussion

In the present study, I linked data on a cohort of individuals aging with physically disabling conditions to information on their neighborhood environments to examine the association between features of the neighborhood environment and incident cardiometabolic diseases. Residing in neighborhoods with a higher density of recreational establishments, including parks, was consistently protective against any cardiometabolic disease, hyperlipidemia, hypertension and diabetes. With the exception of incident diabetes, availability of transit stops was associated with lower risk of cardiometabolic conditions. Higher density of grocery establishments was associated with increased risk of hyperlipidemia and diabetes, only. Mixed findings were observed for healthcare facilities and broadband internet. Overall, a composite measure of health promoting resources was significantly associated with lower disease risk, with the exception of hyperlipidemia. No significant findings were noted for the composite measure consisting of any health-harming infrastructure, across any outcome examined. These findings were consistent with, and informed findings from the neighborhood typology. Within the typology, I noted that low density of health promoting resources, irrespective of density of health harming resources, was associated with *higher risk* of diabetes, adjusted for other important individual-level and neighborhood characteristics. Service-dense neighborhoods (high density of both health promoting and harming infrastructure) were found to reduce risk of hyperlipidemia.

Findings from this study provide insight into the specific features of the neighborhood environment that are important for good health outcomes for individuals aging with physical disability. Furthermore, it highlights the important role of health supportive resources in one’s environments, irrespective of health harming features. Findings have the potential to inform design of neighborhoods so that they support successful aging outcomes for this vulnerable population and provide targets for policy makers for community investment.

In this work, presence of physical activity resources (e.g., recreational facilities, parks) was associated with lower risk of all cardiometabolic outcomes examined. This suggests that opportunities for physical activity are important for individuals aging with physical disability. Participation in physical activity for individuals with disabilities has been demonstrated to reduce secondary health conditions. A survey conducted among 170 women with physical disabilities in the United States (e.g., MS, CP, polio) asked respondents about participation in a variety of physical activities including walking, jogging/running, cycling, swimming, gardening and weight lifting, including whether they had engaged in the activity in the past month and the frequency of engagement (Santiago and Coyle 2004). The results suggested that ~39% of individuals did not engage in any physical activity. After controlling for interaction between severity of secondary conditions and functional status, the development of the secondary condition of physical deconditioning was inversely related to physical activity (Santiago and Coyle 2004). Recreational facilities afford opportunities to participate in physical activities including cardiovascular fitness and strength training, which have been recommended for individuals with physical disabilities (Calder, Sole and Mulligan 2018).

Similar protective effects of recreational establishments have been observed in studies that have examined the association between various features of the neighborhood built and social environment and cardiovascular disease and diabetes in the general population. Work using data from the Multi-Ethnic Study of Atherosclerosis (MESA), a multicenter, prospective cohort study of middle-aged and older adults, reported a higher prevalence of ideal cardiovascular health with increasing density of favorable physical activity environment (Unger, et al. 2014). In separate, fully adjusted models, an environment high in physical activity resources was associated with higher odds of ideal cardiovascular health (OR 1.19; 95% CI: 1.08, 1.31) (Unger, et al. 2014). This is largely consistent with findings in this study of protective effects of recreational establishments.

I noted that even in models that adjusted for the presence of recreational facilities, higher density of parks in one's neighborhood was independently associated with lower risk of cardiometabolic disease. This suggests an independent and beneficial role of parks on cardiometabolic health. The availability of parks and similar open spaces may be particularly important for individuals aging with physical disability owing to continued challenges with accessibility within recreational and sports facilities (Rimmer, et al. 2017). Examples of challenges that indoor fitness facilities could pose for individuals with a physical disability include doors that are difficult to open, inaccessible bathrooms and equipment scattered throughout the facility. Despite the fact that the Americans with Disabilities Act (ADA) requires facilities to adhere to specific accessibility requirements, research has found that many facilities are not in compliance (Rimmer 2005; Calder, Sole and Mulligan 2018). Availability and accessibility of parks may afford individuals with physical and mobility disabilities, like those in our population aging with a physical disability, the opportunity to engage in social and physical activities without some of the barriers that exist in recreational facilities. A study in which individuals with motor or sensory disabilities were administered a questionnaire inquiring about time spent in parks, park accessibility, and barriers and facilitators to engaging in activities in parks, found that individuals with mobility disabilities positively valued urban parks; with the majority of them responding that they definitely like to spend time in parks (Blaszczyk, et al. 2020). Individuals also indicated that they spent more time in parks that were closer in proximity, especially those who were wheelchair users. Among respondents, ~40% noted their most frequent use of the park was for walking, followed by observation of the environment (Blaszczyk, et al. 2020). Walking with the use of assistive devices is a common way in which individuals with a disability can engage in physical activity (US DHHS Step it up 2015). Approximately 3% stated that they use the park most commonly as an open-air gym, which was distinct from just using it for walking (Blaszczyk, et al. 2020).

This study noted that, with the exception of incident diabetes, higher density of transit stops was associated with lower disease risk. The higher density of transit stops, a proxy in this work for access to transit, may enhance independence and participation (social, economic and health) for those with physical disabilities, as noted in previous qualitative studies (Bezyak, Sabella and Gattis 2017). It may then make it easier to access available resources in one's neighborhood. Individuals with disabilities rely on transportation to access goods such as food and medical services necessary for maintaining health (Cochran 2020). Secondary analysis of data from the European Health Interview Survey examined factors associated with reports of healthcare needs for individuals with and without disabilities (Sakellariou and Rotarou 2017). Compared to individuals without disabilities, those with severe disabilities reported significantly higher odds of reporting unmet healthcare needs due to transportation or distance problems (OR

4.32; 95% CI 2.66, 7.00) (Sakellariou and Rotarou 2017). Transit options for accessing food, healthcare, employment opportunities and physical activity establishments (e.g., gyms) may be especially important for individuals with physical disability who report barriers to walking or driving as a result of their impairment (Field and Jette 2007). This has been found to be especially true for younger individuals with disability, those with more severe disability and those who lack access to other transportation services (e.g., someone to drive them, taxi) (Field and Jette 2007). My findings of the protective role of transit were consistent with what has been observed in work in the general population. For example, findings from United Kingdom (UK) biobank noted that active patterns of travel (use of public transport, walking) were associated with significantly lower risk of cardiovascular disease (Panter, et al. 2018).

I did observe an increased risk of diabetes amongst those residing in neighborhoods with higher density of transit stops. While appearing counterintuitive, there may be some plausible explanations for these findings. Physical activity is particularly important for diabetes prevention, making active transportation key. Active transportation has been associated with lower risk of hypertension and diabetes (Furie and Desai 2012). These neighborhoods may also be characterized by other features, not captured in this study, that make engaging in active transportation more difficult. It is important to note that the mere presence of transit stops in one's neighborhood does not mean that individuals will, or can use them, as they may face additional barriers. This includes lack of walkable neighborhoods. This may also make these transportation stops less accessible if individuals have to walk or use their assistive device to reach these stops. Furthermore, these may be confounded by other factors I was unable to account for such as frequency of buses, modes of transportation available, distance to transit stops and accessibility (including quality) of buses and transit stops, which have been found to be important for active transportation in other work (Djurhuus, et al. 2014). Lastly, these areas with high density of transit stops may also afford proximity to not just health promoting amenities but also restaurants, convenience stores, and small grocers/corner stores with unhealthy foods, which could increase risk of an outcome sensitive to the food environment such as diabetes. This was noted as a potential explanation of findings in previous work conducted in employed individuals in a mid-western health system (Herrick, Yount and Eyler 2016). Authors found that adjusting for individual-level covariates and availability of supermarkets, more walkable neighborhoods were associated with a small increase in diabetes risk. They hypothesized that a higher Walk Score® was likely indicative of more urban areas which may be characterized by other features that increase diabetes risk such as access to these less healthy food options (Herrick, Yount and Eyler 2016).

The current work largely found a null association for independent effects of the food environment, with the exception of hyperlipidemia and diabetes, where a higher density of these establishments was associated with increased risk. Findings in the literature have been mixed in regards to these food establishments and cardiometabolic outcomes. A study using data from the Multi-Ethnic Study of Atherosclerosis (MESA) cohort noted that a one standard deviation improvement in favorable food stores (objective measure of chain and non-chain supermarkets and fruit and vegetable markets in a 1-mile radius) was associated with 1.22 higher odds of ideal versus poor cardiovascular health (OR 1.22; 95% CI: 1.06, 1.40). However, a subjective, survey-based measure of healthy food availability (based on questions about the availability of fresh fruits and vegetables and selection of low-fat products in one's neighborhood) was not significantly associated with cardiovascular health in a fully adjusted model (OR 1.10; 95% CI: 0.97, 1.26) (Unger, et al. 2014). Another study from the Multi-Ethnic Study of Atherosclerosis (MESA) examined the association between objective and self-reported measures of healthy food environment and incident T2DM also noted no significant association between objective measures of supermarkets and/or fruits and vegetable markets and diabetes risk (Christine, et al. 2015). Findings were statistically significant for survey-based measures of health food resources (Christine, et al. 2015).

Consist with these studies, I used objective measures of the food environment and noted null findings for most outcomes. Differences in findings across studies could be attributed to variations in populations studied or differences in the definition of neighborhoods used and/or the measure of cardiovascular disease (as it is plausible that the food environment is more important for some outcome measures than others). The differences could also be partially attributed to use of objective or subjective measures, with my work using objective measures of the food environment from NaNDA. It is plausible that subjective measures of the food environment are more sensitive measures as they more closely reflect how individuals interact with their food environment and their purchase and consumption patterns. This may be particularly important for some cardiometabolic outcomes. Also, the discrepancies in the objective and subjective measures may be tapping into different aspects of the construct such as the objective measure failing to capture the aesthetics or quality of the resources or any cost barriers to using the establishment (Moore, et al. 2008; Christine, et al. 2015; Brownson, et al.

2009). The differences in these factors across studies makes direct comparisons challenging.

Findings of increased risk of hyperlipidemia and diabetes amongst individuals residing in neighborhoods with higher density of grocery stores suggests that living near food stores does not necessarily confer benefit if they also provide access to unhealthy food. The measure of the healthy food environment I used consisted of both grocery stores as well as supermarkets and warehouses/supercenters. In each of these settings, individuals have access to both healthy food offerings (e.g., fruits and vegetables) but also options such as bakery items, snacks, and frozen foods. Prior work has found this to be particularly true in grocery stores in the United States, whereas supermarkets tend to have greater variety of healthy and affordable foods compared to grocery stores (Sallis, Nader, et al. 1986). Previous work has noted that availability of supermarkets was associated with lower prevalence of obesity and diabetes risk (Morland, Diez Roux and Wing 2006; Herrick, Yount and Eyler 2016). However, grocery stores and convenience stores were both associated with increased prevalence of obesity (Morland, Diez Roux and Wing 2006). Therefore, individuals may still choose to consume less healthy foods if available to them, especially if grocery stores are more plentiful in their neighborhoods compared to supermarkets owing to market trends (Curtis and McClellan 1995). This is especially likely for the conditions that are more linked to dietary risk. Notably, biological markers for hyperlipidemia and diabetes were found in a study to be most sensitive to dietary patterns, which might explain why we observed significant findings for these outcomes in particular (Hoffman, et al. 2004).

Higher density of broadband internet connections was associated with lower risk of all outcomes of interest, with the exception of hyperlipidemia. This was independent of other factors in the healthcare environment such as transit and healthcare facilities. Broadband internet availability is deemed a social determinant of health (Benda, et al. 2020). Owing to transportation and mobility barriers, broadband internet may be particularly important for individuals aging with disability for a variety of uses to engage and participate in society and access health promoting resources. For example, it may provide individuals aging with disability access to telemedicine, health information (improving health literacy), and ability to order groceries and items from locations that may otherwise be inaccessible to them (Benda, et al. 2020). Broadband internet also affords opportunities for employment (remote work), which may be especially important for adults with disabilities, with socio-economic status being important risk factor for cardiovascular outcomes (Unger, et al. 2014; Christine, et al. 2015).

Findings in the literature on the role of broadband internet and health have largely focused on the role of telehealth and health literacy, and presented with mixed findings. A systematic review conducted by the Community Preventive Services Task Force (CPSTF) in support of their recommendations for telehealth delivery strategies for managing chronic diseases noted that telehealth has been found to improve medication adherence (through outpatient follow-up), clinical outcomes (e.g., blood pressure control) and dietary outcomes (e.g., eating more fruit and vegetables) (Centers for Disease Control and Prevention 2020(b)). An internet survey of >400 U.S. adults with and without chronic disease found that the majority (75%) of adults reported having used the internet to seek health information and those with chronic diseases noted they were likely to see their health care provider to discuss information they found online (Madrigal and Escoffery 2019). Those with underlying chronic diseases were more likely to use the internet to track health indicators and access their health portals. Telemedicine may be particularly important for accessing long-term and highly skilled therapists (Zhou and Parmanto 2019). A systematic review of outcomes of digital interventions for individuals with disabilities (e.g., developmental disabilities and mobility impairments) in remote and underserviced areas concluded that patients reported positive experiences and improved satisfaction with care. Some had functional improvement in motor performance, language ability and self-care skills. A handful of studies also reported quality of life improvements (Zhou and Parmanto 2019). Telehealth services can include text messages with tailored education and medication information, web-based applications to track health information and set goals and 2-way communication with a health care provider in real-time, including sending them health information (Centers for Disease Control and Prevention 2020(b)). These all have the potential to support early intervention and easier access to preventive services that may mitigate risk of developing some cardiometabolic outcomes.

It is important to note that use of broadband internet for telemedicine for individuals with disabilities does present with some challenges specific to this population. This includes, but is not limited to, doing physical assessments remotely in particular those requiring navigation of peripheral devices (Annaswamy, Verduzco-Gutierrez and Frieden 2020). Furthermore, research from the Pew Research Center noted that individuals with a disability were less likely to have home broadband internet or access to devices to use the internet even when younger adults (18-64) were surveyed (Perrin and

Atske 2021). However, for individuals with physical disability who do have access to broadband internet, they may benefit from virtual management of health conditions to overcome geographic and time barriers (Forducey, et al. 2012). Telemedicine has the potential to increase access to treatment, reduce costs and enhance intervention adherence especially for cardiovascular disease where prevention is key and where preventive health measures can be done remotely (Forducey, et al. 2012). Other work has noted patients and clinicians to be in favor of using internet-based platforms for disease management including provision of educational material and integration of web-based applications that would support the patient in managing their condition(s) (Kruse, et al. 2017; Jarvis-Selinger, et al. 2011). Ability to search for, and access health information seek health care providers and become informed about their own health are protective behaviors that may also be facilitated by access to broadband.

Our findings of no significant association between internet availability and incident hyperlipidemia are consistent with an expert analysis piece which summarized data in this area and concluded no significant role of telehealth services on hyperlipidemia management (Rehman and Virani 2017). A systematic review of the effectiveness of telemedicine solutions and their components on clinical outcomes in patients with diabetes, hypertension, or dyslipidemia noted use of telemedicine programs were associated with clinically significant reductions in glycated hemoglobin amongst patients with diabetes, no significant impact on blood pressure and inconsistent findings for lipid levels amongst those with diabetes (Timpel, et al. 2020). Broadband internet for health-related uses may be most effective for *management* of hyperlipidemia amongst those with prevalent disease (which has been the focus of most interventions) but not for incident disease as was the case in our work. This may plausibly explain the non-significant findings for hyperlipidemia in the present study. Individuals may be more likely to leverage or benefit from broadband internet in cases of existing diseases.

Generally speaking, in this study, density of healthcare establishments was not found to be significantly associated with risk of cardiometabolic disease, especially when adjusted for broadband internet availability and transit. This suggests that perhaps the density of healthcare resources, alone, are not protective for these cardiometabolic conditions; rather it is the features in the environment (for which broadband and transit may be markers) that shape behaviors and choices that can protect from these conditions, before one encounters the healthcare system. Furthermore, the literature has noted that availability of ambulatory care facilities may promote earlier intervention due to accessibility of preventive care services. Previous studies have found proximity to health care services to be associated with diagnosis of vision-related ailments and preventive care, even in populations with health insurance, as is the case with the current study (Khan, Trope, et al. 2018). In this case, I was unable to assess whether these healthcare establishments were accessible or proximate to the individuals in our study or accessible (e.g., lack of ramps, narrow doorways). Therefore, it is plausible that higher density of healthcare resources does not necessarily mean they are more accessible to individuals aging with physical disability. Future studies should undertake subjective reports or environmental audits to understand whether these establishments were accessible and whether that results in different findings. Additionally, the presence of these healthcare facilities in one's neighborhood does not provide insight as to their experiences within the healthcare system or the quality of care or relationship between a patient and provider. Previous research has noted that individuals with physical disability who perceived discrimination from health care providers were less likely to seek healthcare compared to those who reported less perceived discrimination (Moscoso-Porras and Alvarado 2018). Therefore, despite a higher density of healthcare facilities, individuals may not use them if they face additional barriers in their relationship with their healthcare providers. These are factors that could not be examined in the present study.

As noted, across all models, healthcare resources were not significant once broadband internet and transit availability were included in the model (model 2). However, for any cardiometabolic disease and hypertension, a model with just healthcare resources as the focal contextual factor (model 1) was noted to be marginally significant, with the upper confidence interval at or close to 1. The association between neighborhood healthcare resources and outcomes may be confounded by broadband internet and/or transit or other variables which are proxied by the inclusion of internet and transit such as accessibility and quality of care.

As noted, in this study, the composite measure of health promoting resources was found to be protective against development of any cardiometabolic disease, hypertension and diabetes. The benefits of these individual health promoting resources that comprise the composite measure and facilitate positive health choices may explain the protective effects observed in this work. In a composite measure of health harming infrastructure (consisting of fast-food establishments and liquor, tobacco and convenience stores), I did not observe a significant association with any of the conditions examined. This is in contrast to previous work in the general population. For example, a cross-sectional study using county level information on per capita density of fast-food and full-service restaurants, and risk of mortality and prevalence of diabetes found higher county density of fast-food restaurants to be associated with increased risk of cardiovascular mortality and stroke and prevalence of T2DM (Mazidi and Speakman 2018). Similar findings were observed for full-service restaurants, with the exception of prevalence of T2DM where there was an inverse association. Similar findings have been observed in the Coronary Artery Risk Development in Young Adults (CARDIA) cohort where an increase in percentage of convenience stores within a three-kilometer buffer was associated with higher odds of coronary artery calcification but no significant association was noted for fast food chains (Kelman, et al. 2019). The authors noted that availability of other non-healthy food items sold at convenience stores but not fast-food restaurants, such as cigarettes and alcohol could contribute to observed findings, as opposed to unhealthy foods (e.g., sugar sweetened items) (Kelman, et al. 2019). The differing findings in this study may be explained by the fact that compared to the general population, individuals aging with disabilities must contend with accessibility concerns in making use of facilities (Rimmer, Riley, et al. 2004). There is literature to suggest that convenience stores and fast-food restaurants may be less accessible for individuals with physical disabilities owing to their narrow entrance and aisles, high countertops and booths and challenges reaching the doorway (Pierce 2012; Schwartz, Buliung and Wilson 2019). This is in spite of guidance outlined by the Americans with Disability Act (ACA) which requires all establishments to be constructed or modified to comply with accessibility standards (Rose 2006). Some of these facilities may be older constructions or contain some elements laid out in the ACA and thereby exempt. Therefore, for this particular population, residence in areas with a high density of health harming establishments may have an attenuated effect on cardiometabolic outcomes due to the lack of accessibility of these establishments. Additionally, in these models, the availability of health promoting resources was not accounted for concurrently. In the neighborhood typology, the absence of health promoting resources, irrespective of high or low levels of health harming infrastructure, was associated with increased risk of diabetes. In the current study, I was unable to elucidate whether these health promoting resources and their health benefits counteract harmful effects of fast-food restaurants or whether individuals with disabilities are less likely to use them in presence of health prompting resources available to them. However, it is plausible that these neighborhoods also had a high density of health promoting resources that blunted some of the adverse health effects. Lastly, the role these features in the neighborhood environment serve are outcome and population specific, and that the mechanisms that underlie the observed findings vary. Future studies, including qualitative work in populations aging with physical disability could inform how individuals aging with disabilities navigate and use these spaces, and the effect it has on health outcomes, if any.

The use of the typology measure allowed for the simultaneous consideration of both health promoting and harming infrastructure within a neighborhood, which is an important contribution. The study found that compared to neighborhoods with a high density of health promoting and low density of health harming features, service-dense areas were associated with lower risk of hyperlipidemia. Additionally, low density of health promoting resources, irrespective of density of health harming features was associated with elevated risk of diabetes. The importance of health promoting resources for diabetes risk noted in the typology is consistent with observed findings in the individual models where we noted significant features of the health environment that were protective against cardiometabolic diseases such as parks, recreational establishments and transit. I observed protective cardiometabolic effects of residing in neighborhoods with high density of health promoting/harming infrastructure, independent of area-level affluence, disadvantage, and population density. This suggests that it is the characteristics of these health-promoting resources and the benefits they afford that are important for preventing chronic health conditions in this population. The study found that neighborhoods classified as service dense had more than twice the density of healthcare facilities, recreational centers, bowling alleys, parks and grocery stores compared to neighborhoods with a high density of health promoting resources, alone. The higher availability of these resources may be particularly important for those with disabilities, affording them greater spatial access and more options to select accessible settings. Furthermore, neighborhoods with a high density of services, whether health promoting or harming, may be *distinct* from high health promoting/low health harming areas. For example, such neighborhoods may be characterized by other factors such as more accessible infrastructure and distinct social and cultural make-up. While I was unable to specifically capture these aspects in this work, future research should investigate how they impact health behaviors in those living in high density service areas.

There were some differences observed in comparing the findings of models showcasing the individual features of the neighborhood environment and this typology. It is important to note that direct comparisons are challenging owing to the fact that the models examining specific features of the environment did not consider the neighborhood as a whole, but rather focused just on specific health promoting or harming features, in the absence of the other. Considering both in tandem may allow for us to classify neighborhoods in different ways than consideration of one alone. This might also explain some of the discrepancies observed between the typology and individual neighborhood features identified.

Inclusion of the typology in this work affords a policy relevant lens to this study as it informs what should potentially be the focus of neighborhood interventions. The typology findings are advantageous in that it suggests it is not merely the absence of health-harming infrastructure that will facilitate good health, but rather, the absence of these health promoting resources which have adverse effects for health. Therefore, policies should focus on investing specifically in health-promoting resources, providing individuals aging with disability access to health-promoting resources. Additionally, though not covered in this current work, the typology introduces questions about how individuals aging with a disability navigate both these health harming features and health promoting and how availability, or lack thereof, and balance of health promoting and harming features of built environment shapes their decision making. These findings add to existing literature on the role of the environment and cardiovascular disease and afford novel insight in a population aging with disability. It also complicates our understanding of the role in a neighborhood comprised of both health promoting and harming resources. Future qualitative studies can help elucidate some of the nuances introduced by the findings of this typology, helping to elucidate mechanisms for observed findings and contextualizing them.

In addition to specific features of the neighborhood, there were also some notable findings for neighborhood-level affluence and disadvantage. With the exception of hyperlipidemia, residence in more disadvantaged neighborhoods were at increased risk of cardiometabolic disease. Disadvantaged neighborhoods may have poor quality healthcare and/or higher levels of violence and disorder (Raphael, et al. 2020; Kirby and Kaneda 2005). The poor quality of resources and lack of safety may prevent individuals from engaging in recreational activities (e.g., walking) or preventive care services that can mitigate cardiometabolic disease. Additionally, residence in areas with high levels of violence and disorder may increase stress, which is a physiological risk factor for cardiovascular diseases such as hypertension (Raphael, et al. 2020; Kirby and Kaneda 2005). The findings regarding neighborhood disadvantage are consistent with what has been observed in the literature. Neighborhood socioeconomic status is often measured through a single index of deprivation or disadvantage ( Morenoff and Lynch 2004). Studies have largely noted an association between disadvantage and a variety of health outcomes (Morenoff and Lynch 2004; Bosman, et al. 2001; Diez-Roux, et al. 1997). In this study, I used a multiple-item measure of both disadvantage and affluence. Previous studies examining a multi-item measure of socioeconomic status comprised of variables such as income, education, and racial/ethnic composition (similar to what was included in this study), have also noted disadvantage to be associated with chronic health outcomes and mortality (Ross 2000; Veugelers, Yip and Kephart 2001; Lee and Cubbin 2002; Morenoff and Lynch 2004). For example, a study using data from the Southern Community Cohort Study found that residence in the most disadvantaged neighborhoods was associated with a 41% higher risk of all-cause mortality amongst men and 77% higher risk amongst women (Warren Anderson, et al. 2018). Similar findings have been observed as it pertains to cardiovascular outcomes. In work that leveraged a neighborhood socioeconomic status indicator, higher socioeconomic scores were independently associated with higher odds of ideal cardiovascular health (Unger, et al. 2014).

When significant findings were observed for affluence, residence in these affluent areas were associated with lower risk but were no longer significant in models for availability of transit and broadband internet. Previous studies have focused largely on the adverse effects of socioeconomic disadvantage, whereas I considered both neighborhood investment and disinvestment as distinct constructs (Morenoff and Lynch 2004). While the present work was not aimed at elucidating the mechanisms through which neighborhood affluence may impact health for individuals aging with disability, there are several plausible mechanisms proposed in the literature. High levels of affluence may be a marker for norms within the neighborhood that foster health-promoting behaviors such as partaking in exercise or efforts to eat healthier diets (Clarke, Morenoff, et al. 2013). Furthermore, it may reflect higher educational attainment and health literacy skills of the community (Parker, Ratzan and Lurie 2003). The findings in this study that neighborhood-level affluence was no longer statistically significant when transit and broadband internet were added to the model may also be explained by the mediating role of these variables in the relationship between affluence and cardiometabolic disease. Though affluence was conceptualized as a confounder between features of the neighborhood environment and outcomes of interest, it is also plausible that some neighborhood features were mediators in the affluence and cardiometabolic disease pathway. When broadband internet and transit were added to the model, adjusting for these mediators may have attenuated the association between affluence and cardiometabolic disease. Future studies should undertake formal mediation analysis to parse the direct and indirect effects of the affluence on cardiometabolic health and the specific features of the neighborhood environment that might serve as mediators and potential points of intervention.

*Strengths and limitations:*

This work does present with some notable strengths. First, since individuals were required to have continuous enrollment for inclusion in the cohort, I had access to all their claims data required for me to use a longitudinal study design to examine incidence of disease. The longitudinal study design also helped in capturing the temporal relationship between neighborhood and health as well as the aging process. The chronic diseases examined in this study can have pre-clinical phases that may adversely affect health or render individuals unable to participate in their communities as they otherwise would (e.g., work). This could impact the communities to which they are able to move. This is particularly pertinent for the population under study owing to their life course disadvantage, which may influence the types of neighborhoods they are able to move to (Clarke and Latham 2014).

Neighborhoods are composed of people with different characteristics, who in some cases choose to live in different types of neighborhoods or who reside in communities due to current and historic economic, political, and other social pressures (Morenoff and Lynch 2004). Failure to account for these factors may mean that it is not necessarily features of the environment that effect development of disease, but rather one's health status. To mitigate this, I also adjusted for individual characteristics that may predict selection into neighborhoods, namely comorbid health status and age.

Additionally, I had access to updated information on an individual's neighborhood residence and thus could model updated exposure measures over time. Neighborhoods are not static but evolve dynamically over time. They undergo processes such as urbanization and gentrification that can alter the characteristics of a community including the resources that are available, quality of the neighborhood infrastructure, norms in the community and general investment. Additionally, given the longitudinal nature of the study design, individuals in the study cohort can move into and out of different neighborhoods over the course of the study. Therefore, having updated information on neighborhood environments allows for more accurate accounting of the neighborhood characteristics of cohort members over the course of the study. Not accounting for this can lead to misclassification of the exposure. If this misclassification is non-differential across outcome status, it can bias the observed effect estimate closer to the null. However, if this happens to be differential across any cardiometabolic outcome, hypertension, T2DM or hyperlipidemia then it can bias estimates towards or away from the null. If individuals residing in better neighborhoods are more likely to have better health outcomes and also to continue upward mobility then not capturing these improved environments is likely to result in under-estimating the true protective effects of better neighborhood environments.

I was also able to build on the work of previous studies which examined the effect of a handful of features of the neighborhood environment (e.g., grocery stores, recreational facilities, convenience stores) on cardiovascular health, by considering additional features of the neighborhood environment more topical to those aging with physical disability (Christine, et al. 2015; Unger, et al. 2014; Kelman, et al. 2019). Additionally, I examined both a composite variable of health promoting and harming infrastructure, and also created a typology that considers the presence of health promoting and harming features in concert, which greatly adds to understanding of neighborhood and health for those aging with disability. Use of a typology has particular advantages. Studying specific characteristics of a neighborhood, by including them all in the same regression model can be complicated by the fact that many of these dimensions are highly correlated with one another (Diez Roux and Mair 2010). This creates challenges to partitioning the effects of these characteristics on health outcomes. Conversely, neighborhoods are not just comprised of health promoting resources or health harming infrastructure and the existence of these do not occur in isolation nor do individuals interact with these resources in isolation. Therefore, a typology enables the examination of these in concert affording a more realistic examination of dynamic neighborhood environments and facilitates a deeper understanding of the features that may be driving findings in the typology.

Despite this, the present study does present with some limitations. First, while I used objective measures of the neighborhood socioeconomic and built environment from NaNDA, I was unable to get measures of the quality of the physical environment. For example, while I could accurately capture the availability of recreational facilities, I was unable to account for whether the recreational centers had ramps that would allow for individuals with physical disabilities to access these facilities or the overall aesthetics of the establishments. This has potential implications for whether individuals use, or are able to use these facilities even if they are readily available in their neighborhoods. As noted earlier, these have been described as potential explanations for discrepancies between objective and subjective measures of neighborhood environments and health (Moore, et al. 2008; Christine, et al. 2015). Specific features of the environment can serve as both facilitators of good health behaviors and outcomes, or barriers depending on factors such as quality. For example, previous work has highlighted the importance of sidewalks for engaging in physical activity amongst individuals with physical disabilities, but qualitative work has also noted that poor quality sidewalks can be a barrier for mobility and transportation amongst those with spinal cord injuries (Christensen, Holt and Wilson 2010; Newman 2010). Nonetheless, if these health-promoting resources, which were found to be protective for incident cardiometabolic disease, were not accessible or of poor quality, effects observed in the present study are likely an attenuation of true protective effects. Future studies can leverage neighborhood audits using technology such as Google Street View to supplement findings of this work to better understand the quality of infrastructure in these neighborhood environments (Rundle, et al. 2011).

I was also unable to ascertain whether individuals actually used services in their neighborhoods which makes causal inferences more challenging. Supplementary qualitative studies are required to elucidate some of the mechanisms that might explain the observed associations in a population aging with disability. This might be particularly true for factors such as broadband internet and transit which have not been examined in this population yet present with several benefits for individuals aging with disability but also have barriers to access. This can inform future population-based quantitative studies of the mechanisms through which these neighborhood features influence incident cardiometabolic disease (formal mediation analysis).

This study also required individuals to have at least 4 years of continuous enrolment on the health insurance plan to be included in the analysis. This was important for the current study to ensure that they had stable enrolment on the plan and that I could capture any clinical events over the course of the study. If there were lapses in coverage, they may have had a cardiometabolic event of interest while not actively on that plan, thereby potentially underestimating the 3-year incidence of the events in our study. However, this could also impact internal validity of study findings if I was selecting individuals in a way that is related to the exposure and outcome. It is plausible to assume that individuals who have at least four years of continuous enrolment are likely to reside in better neighborhood environments and as a result of continuous insurance coverage receive better healthcare, leading to better health outcomes. If residing in neighborhoods with a higher density of healthcare facilities is associated with lower risk of T2DM (inverse association; OR<1) then over-selecting this population as a result of the study inclusion criteria could result in the effect estimates observed to be further from the null. Therefore, I would be overestimating the true protective effect of healthcare facilities on diabetes incidence.

In conclusion, findings that neighborhoods with a high density of health promoting resources (irrespective of health-harming resources) are important for cardiometabolic health affords new insight into our understanding of the importance of a holistic look at place and context for health in this vulnerable population. I was also able to identify specific neighborhood resources important for maintaining good health in this population, namely transit stops, recreational facilities and parks and access to broadband internet connections. These supported findings of the typology and provide specific features of the environment that can be targeted for good health. The findings underscore the importance of availability of health-promoting resources to allow for individuals with early-onset disability to age successfully, and mitigate disparities in disease burden. This study of incident cardiometabolic morbidity extends existing work focused on participation and physical activity and supports the importance of upstream neighborhood interventions that have potential to mitigate disparities in later life morbidity burden for individuals aging with physical disability. Given that some of the specific features of the environment identified in this study are consistent with what has been noted in other studies in the general population suggests that investments in neighborhoods that promote good health outcomes for this population also have the potential to benefit all residents in that space. Further study of the context in which individuals with physical disabilities live, work and participate is required to characterize the structure of service dense neighborhoods. This can help to inform public health interventions and community design that accounts for the unique way in which individuals aging with physical disability navigate their neighborhood environments.

# CHAPTER III:

# Characterizing Continuity of Care and the Associated Individual and Community Factors Amongst Individuals Aging with Physical Disability

## 3.0 Introduction

Aim 1 of this dissertation informed understanding of the relationship between features of the neighborhood environment and cardiometabolic disease. However, since density of healthcare resources alone was not found to be particularly important in preventing cardiometabolic disease in Aim 1, it may suggest that it is the quality of care rather than just the presence of healthcare establishments, that warrant study. Examining health outcomes also does not adequately provide insight into the factors that result in fragmented and poor care quality for those with complex care needs. While quality of healthcare may play a role in health outcomes as well, this was not explicitly examined in Aim 1 of this dissertation. Aim 2 of this dissertation addressed this by characterizing quality of care, using a continuity of care (COC) measure, in individuals aging with physical disability and focusing on both individual-level characteristics and features of the surrounding neighborhood environment that might be associated with quality of healthcare. Care continuity reflects enduring relationships between an individual and a small set of healthcare providers, which is thought to contribute to better, and more appropriate care (Gulliford, et al. 2002; Reid, Haggerty and McKendry 2002). As a result, it represents an important quality of care metric. In the general population, it has been associated with positive health and health systems outcomes (Bayliss, et al. 2015; Amjad, et al. 2016; Cabana and Jee 2004; Cheng, Chen and Hou 2010). I conducted secondary data analysis from Optum® Clinformatics® Data Mart, leveraging a similar cohort to that created for Aim 1, in order to answer this research question. This study can facilitate understanding of the quality of care in a population aging with disability and inform future hypotheses regarding the effect of quality of care on health outcomes. Furthermore, it may identify sub-populations of individuals aging with disability who are at particular risk of fragmented care, and factors that should be the foci of interventions to improve their care.

## 3.1 Background

*Complex care needs of persons aging with a disability:*

In general, individuals with disability experience activity limitations, high rates of chronic health conditions (e.g., mental health disorders, cardiovascular disease, and obesity) and are at increased risk of premature mortality (Campbell, Sheets and Strong 1999; Lennox and Kerr 1997; Turk, et al. 2001). People aging with disability can develop similar chronic and preventable conditions that effect adults without disabilities, or those aging into disability (Campbell and Putnam 2017). This can be attributed to the aging process, the long-term effects of exposure to environmental hazards, or the cumulative effects of poor health behaviors (Campbell and Putnam 2017). These are termed "age-related chronic conditions". Additionally, persons aging with disability are at elevated risk of developing secondary health conditions (Campbell, Sheets and Strong 1999; Altman and Bernstein 2008; Rimmer 1999). These are defined as physical or mental health conditions originating directly, or indirectly from a primary disabling condition, which affects the rest of the aging process (Campbell and Putnam 2017; Jensen, et al. 2013; Smith, Molton and Jensen 2016). An example of a secondary condition is pain reported by someone with a disability who uses a wheelchair, attributed to physical overuse, compensatory injuries, or fatigue (Campbell and Putnam 2017). Common secondary health conditions for individuals with physical disabilities such as cerebral palsy (CP) and spina bifida (SB) include osteoporosis, osteoarthritis, increased spasticity and depression (Marge 1994). Secondary conditions can be distinct, but may also overlap with age-related chronic conditions noted earlier (Figure III.6). Additionally, individuals aging with disability report worse self-rated health and experience faster rates of decline in self-rated health, as they age (Clarke and Latham 2014). This is after adjusting for underlying chronic conditions and socio-demographic characteristics (Clarke and Latham 2014).

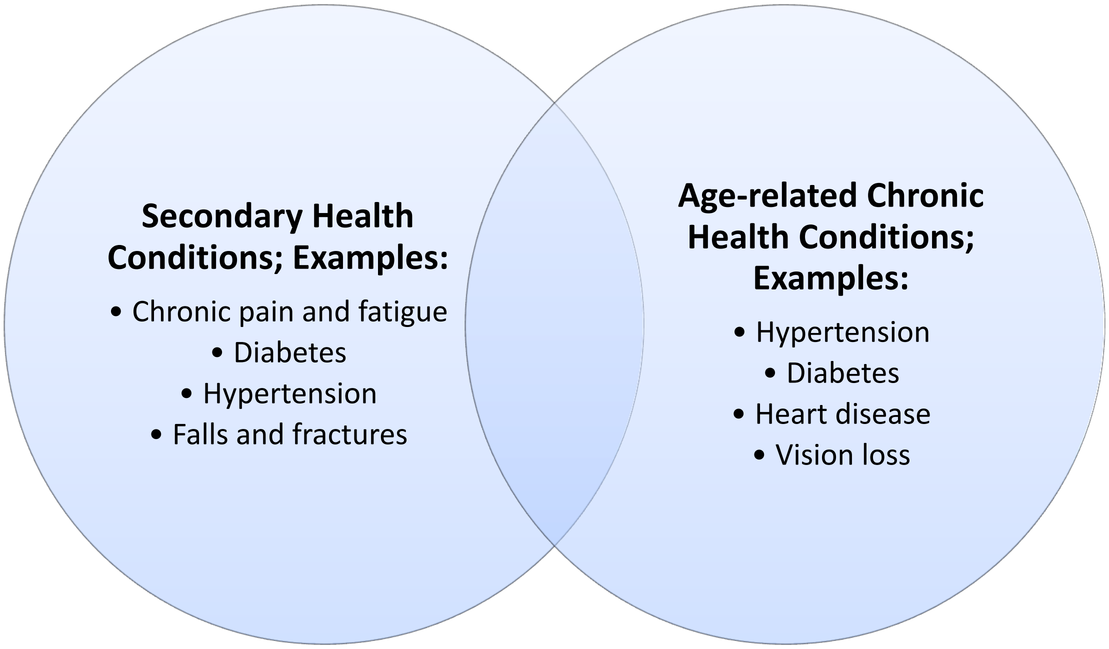


Figure III.6 Examples of secondary chronic conditions of individuals aging with disability and age-related chronic conditions of persons aging with disability and aging into disability (Adapted from: Campbell and Putnam 2017)

Adults aging with disability may exhibit signs of accelerated aging (Campbell and Putnam 2017). Despite sparse data at the population level in the United States, clinical and survey research indicate that health conditions experienced by people aging with a disability typically occur 20–25 years earlier than those without disabilities (Field and Jette 2007). “Premature aging” in this population would mean that they are more likely to enter mid- to- late-life with a higher burden of comorbid chronic conditions than the general population.

Individuals aging with a physical disability require appropriate care for their primary disability, routine preventive services (e.g., screenings) and care for secondary and age-related chronic conditions, for which they are at increased risk. As a result, they may represent a population with complex healthcare needs.

### *Barriers to healthcare for individuals with a disability:*

Persons with disability often receive poor standard healthcare (McCarthy, et al. 2006; Iezzoni, et al. 2008; Iezzoni, et al. 2000). For example, a study using data from National Household Interview Survey (NHIS) found that smokers who had mobility problems were 20% less likely to have their physician ask about their smoking histories during their annual check-up, compared to their non-disabled counterparts (Iezzoni, et al. 2000). For those with complex medical needs, such as individuals aging with disability, there is the added challenge of navigating integrated specialized services, ensuring consistent and comprehensive management of their primary disability and secondary health conditions, and visiting their primary care provider for regular preventive care (Rural Health Information Hub n.d.).

Furthermore, individuals with disabilities in the United States often face barriers to accessing care. These barriers, as summarized in work by Jackson (2004), include: 1) getting there, 2) getting in, 3) clarifying needs, 4) the doctor's clock, and 5) overcoming attitudes (Jackson 2004). The first two barriers pertain to features of the built environment, including entering the facility, navigating within the healthcare facility and the neighborhood environment, that may impede access to, or use of services. The latter three address the relationship between a care provider and the patient. Healthcare providers may hold misconceptions about persons with disabilities based on their identity as an individual with a disability (U.S. Department of Health and Human Services 2005).

A study which examined the association between perceived discrimination and healthcare-seeking behavior in people with a disability noted that the probability of not seeking care was 15% higher amongst those who self-reported discrimination (Adjusted Prevalence Ratio: 1.15, 95% Confidence Interval: 1.04, 1.28) (Moscoso-Porras and Alvarado 2018). The results were most pronounced amongst those with communication and physical disabilities (Moscoso-Porras and Alvarado 2018).

Many health services do not integrate the biopsychosocial approach to disability, which is a model that views disability as arising from a combination of factors at the physical, emotional and environmental level (U.S. Department of Health and Human Services 2005; Smeltzer 2007). Furthermore, clinicians and other allied health workers often receive little training to address the needs of individuals with disability (U.S. Department of Health and Human Services 2005). Health care providers may not be prepared to, or focused on addressing the primary disability as well as the full array of medical, physical, and psychological ailments with which a patient with disability may present. Studies have found that persons with disabilities report that healthcare providers often focus solely on their primary disability rather than their other health concerns (Panko, et al. 2004; U.S. Department of Health and Human Services 2000; U.S. Department of Health and Human Services n.d.; Iezzoni 2003; Iezzoni, Davis, et al. 2002). Both adult and pediatric primary care providers have been shown to be less likely to refer their patients with disabilities to preventive services unless they are directly related to their underlying disability (Krahn 2003).

Barriers getting to, and accessing healthcare facilities may also be particularly important for adults aging with disability. Infrastructure within clinics and features of ones' environment that impact access to healthcare facilities and providers, present another barrier for those with disabilities (Puntis, et al. 2015). In the 2005 Surgeon General's *Call to Action to Improve the Health and Wellness of Persons with Disabilities*, getting to a medical appointment, getting into the clinic and maneuvering through the clinic were identified as important factors to consider in regard to accessing needed healthcare services for persons with disabilities (U.S. Department of Health and Human Services 2005; Rural Health Information Hub n.d.). Various studies have identified these physical barriers as impediments to maintaining good health for individuals with a disability. They include, but are not limited to, availability of transportation to get to the healthcare site, access to healthcare providers, and distance to treatment centers or providers (U.S. Department of Health and Human Services 2005; Jackson 2004; Branigan , et al. 2001; Jones and Tamari 1997). Structural barriers to accessing care for individuals with disabilities also include inadequate disability parking, lack of ramps and elevators, and crowded waiting rooms (Pharr and Chino 2013). While the Americans with Disability Act (ADA) has helped address some of these barriers, they continue to persist, especially within healthcare facilities (McColl 2002; Pharr and Chino 2013).

The burden of secondary and age-related chronic conditions, contributing to complex care needs, combined with physical barriers in their communities and within healthcare facilities, can increase likelihood of care fragmentation in a population aging with disability.

*Care continuity for persons aging with disability:*

In 2003, the National Academy of Health (formerly called the Institute of Medicine) recommended that continuity of care (COC) be a primary aim for improving health care quality, in particular for older adults with multiple chronic conditions who require comprehensive medical management. This makes COC a particularly relevant metric to examine for those aging with disability.

COC refers to the quality of care received over time (Gulliford, et al. 2002). From the patient's perspective, it is the experience of a continuous, caring relationship with an identified health care professional. It speaks to both the interpersonal aspect of that relationship as well as the coordination of care over time. COC has two main elements: 1) a patient's subjective experience of care by his/her provider(s), and 2) continuous care delivery over time, captured through having a consistent team of providers (Reid, Haggerty and McKendry 2002). A patient-provider relationship with high continuity is characterized by improved relations, high levels of trust, mutual understanding, and effective communication, amongst other things (van Servellen, Fongwa and Mockus 2006; Guthrie and Wyke 2000; Mainous, et al. 2001; Gill and Mainous 1998; Guthrie, Saultz, et al. 2008).

Having a consistent set of health care providers to manage more complex conditions may result in a better understanding of the patient's conditions and less fragmentation in care (also referred to as high continuity, concentrated care, care continuity). A lack of concentrated care (fragmentation) is associated with a host of adverse health outcomes. For example, studies of older populations found that fragmented care was associated with inappropriate medication prescribing (Chu, Chen and Cheng 2012). On the other hand, high COC has been associated with positive health outcomes including fewer avoidable hospitalizations and emergency department visits, lower incidence of adverse health conditions and higher rates of preventive testing, including for aging populations and those with complex health conditions (Bayliss, et al. 2015; Amjad, et al. 2016; Cabana and Jee 2004; Cheng, Chen and Hou 2010). This makes COC an important outcome to examine.

Despite the importance of COC and the increased likelihood of care fragmentation in individuals aging with disability, to my knowledge, the literature is scant as it pertains to insight into COC in individuals aging with physical disability. In addition, while individuals with disability face a plethora of barriers to accessing care in their environments that may contribute to care continuity, there is a lack information on the specific features of the community associated with COC in this population.

### *Characteristics associated with COC in the general population:*

There is a robust body of literature examining individual-level demographic and clinical factors associated with COC in the general population. These studies have consistently found age, race, gender and pre-existing chronic health conditions to be associated with COC (Ryvicker and Russell 2018; Napolitano, et al. 2016). For example, older age and female gender were associated with higher continuity (Ryvicker and Russell 2018). Compared to White patients, Medicare beneficiaries who identified as Asian had higher COC whilst Hispanics had lower scores (Ryvicker and Russell 2018). Findings in regard to co-morbidity scores and COC have been mixed. In a population with chronic health conditions, a higher Charlson comorbidity score (measure of disease burden) was associated with lower COC (more fragmented care) (Charlson score for those with low COC: 2.7 versus 1.9 for high COC; $p<0.001$) (Napolitano, et al. 2016). Conversely, Medicare beneficiaries with chronic obstructive pulmonary disease (COPD) who had a greater number of chronic conditions had higher COC (Ryvicker and Russell 2018).

In the handful of studies that have examined medical practice-level factors, better inter-organizational communication and a greater amount of time a provider was in the clinic (one approach to measuring provider availability) were associated with higher COC in the general population (Christakis, et al. 2004). However, these factors do not capture the broader factors in ones' neighborhood that may influence whether someone with a disability is able to access their health care provider or the facility in which they practice.

Studies to date have largely examined the influence of contextual factors on health behaviors and service utilization; but their effects on COC remain understudied. One study conducted in a sample of Medicare beneficiaries with congestive heart failure (CHF) identified several neighborhood-level factors associated with COC including Census-tract level income and primary care provider density (Ryvicker and Russell 2018). Another study in a population with schizophrenia also examined area-level socioeconomic factors and density of healthcare providers as being important for COC (Fontanella, et al. 2014). They found that density of mental health centers and practicing psychologists were significantly associated with higher COC (Fontanella, et al. 2014). However, by relying solely on data from the Census or Primary Care Service Area to obtain contextual measures, these studies did not consider a broader range of neighborhood features that may influence COC for a population aging with physical disability (Fontanella, et al. 2014; Ryvicker and Russell 2018).

For individuals with physical disability there are additional barriers to navigating their neighborhood and healthcare environments, including accessibility to, and within, facilities, the availability of transportation, and proximity to healthcare services (U.S. Department of Health and Human Services 2005; Rural Health Information Hub n.d.; Rimmer, Riley, et al. 2004). In addition, local broadband internet access could facilitate access to health information and use of telemedicine services, which is a growing route through which adults with disability access care (Annaswamy, Verduzco-Gutierrez and Frieden 2020; Forducey, et al. 2012; Zhou and Parmanto 2019).

As the number of adults aging with disability grows, there is a need to understand their patterns of care continuity and to examine the role of contextual factors for their quality of care. Therefore, this Aim characterized COC amongst individuals aging with physical disabilities and identified individual and community level factors associated with higher COC. I hypothesized that individuals aging with physical disability would experience fragmented care. Additionally, I hypothesized that demographic, clinical and community-level factors, in particular healthcare availability and public transit would be associated with higher COC. Understanding care continuity in this population can afford greater insight into their quality-of-care experiences and identifying individual and community-level factors associated with care continuity that could help to identify individuals aging with disability who are at risk for fragmented care, and to inform appropriate interventions.

## 3.1 Methods

*Data source and analytical cohort:*

Data for this study were obtained from Optum® Clinformatics® Data Mart (2007-2018), a national private health insurance claims database containing the records of approximately 80 million unique individuals across the United States (Optum 2017; Mahmoudi and Kamdar 2020). I leveraged a similar cohort to the one created for Aim 1. Briefly, International Classification of Diseases, 9th edition, Clinical Modification (ICD-9-CM) codes were used to identify adults (age 18+) with a diagnosis of one of the following physically disabling conditions: 1) Cerebral palsy (CP) or Spina bifida (SB), 2) Multiple sclerosis (MS), or 3) Plegia (e.g., spinal cord injury). Individuals had at least four years of enrolment on the plan without any lapses to ensure stable membership. One year in this time frame was required for the "look-back" period, which was a duration of time used to examine co-morbidity burden. For acquired conditions, the look-back period was also used to ensure incidence of the disability (no diagnostic code for the disabling condition during this time). For acquired conditions, this look-back period was in the year preceding the qualifying diagnostic code. For congenital conditions (CP or SB), the one-year following the qualifying diagnostic code was used as the look-back period to maximize sample size of this cohort. The condition diagnosis date that met the aforementioned inclusion criteria was considered the "index date" for analysis (entry date assigned to the individual into the study cohort) (Appendix D, Figure D.7). For acquired conditions (MS and Plegias), I restricted inclusion to those individuals who were 50 years of age or younger at index date, in line with traditional frameworks for aging with disability (in which the disability is acquired within the first 4-5 decades of life)

(Verbrugge and Yang 2002; Vergrugge, Latham and Clarke 2017). Furthermore, individuals with more than one disabling condition were excluded.

The cohort was restricted to persons with a minimum of four outpatient/office visits in the one year following their index date. This is because the COC measure used in the current study requires at least 4 outpatient visits in order to produce stable estimates (Amjad, et al. 2016; Pollack, et al. 2016). Individuals with disability are high users of the healthcare system. Previous work noted ~38% of individuals with disability made more than 10 trips to their physicians in a given year, compared to 6% of working-age individuals without a disability (Kennedy, Wood and Frieden 2017). Application of this criteria resulted in 35% of the cohort being excluded. Previous studies in Medicare populations have retained ~70% of their cohort sample size after this criterion is applied (compared to 65% in this study) (Nyweide, et al. 2013). However, it is important to note that these Medicare-based studies tend to skew age distributions towards older adults (>65) due to Medicare age-eligibility rules with older adults more likely to require health care services. Use of private claims in this work resulted in a younger population who may have fewer health care visits.

Appendix D, Figures D.7 and D.8 depict the study design and the cohort creation flowchart.

### *Primary outcome measure – COC:*

The primary outcome of COC was calculated in the first year after the index date using a person's ambulatory/office visits with all health care providers. I considered outpatient visits to any specialty to capture the range of health care providers individuals aging with disability see and to capture different referral and care seeking patterns in this population. COC was operationalized using the Bice-Boxerman COC index. The Bice-Boxerman COC index represents the extent to which an individual's total number of visits for an episode or illness, over a specified time period are concentrated with a single healthcare provider (Bice and Boxerman 1977; Pollack, et al. 2016) (Formula III.1).

Formula III.1 Bice-Boxerman Continuity of Care Index (Pollack, et al. 2016)

$$(\sum_{i=1} n_i^2) - N/(N(N-1))$$

Where,
$n_i$ = number of visits that the individual has with the *i*th physician
N = total visits

The index measures the extent to which visits are concentrated amongst a small set of providers. A higher score (also referred to as better COC, higher continuity or concentrated care) is assigned to individuals who have visit patterns in which a larger share of their total visits is concentrated amongst fewer providers (Amjad, et al. 2016). The score ranges from 0 to 1. A person who receives all their care from a single provider over a given time period would receive a Bice-Boxerman COC index score of 1 (perfect COC), whilst an individual who sees a different provider at each visit would receive a score of 0.

The Bice-Boxerman COC metric is distinct from a measure that asks whether an individual has seen at least one health care provider or whether they have a usual source of care. These metrics do not provide insight into how dispersed their care visits are across providers. Appendix E, Table E.6 describes various scenarios of care dispersed across a different number of providers, for individuals with eight overall visits. It also presents their corresponding Bice-Boxerman COC index score to demonstrate how this metric is sensitive to the way in which healthcare visits are dispersed across unique providers. It is important to note that in each of the scenarios displayed in Appendix E, Table E.6, an individual would respond "yes" to a question about whether they had visited a health care provider or had a usual source of care.

The Bice-Boxerman COC index is a commonly employed measure when using administrative claims data for studies. This is because for any given person, health administrative claims data accurately captures both contact with the healthcare system and provider information, which are required to calculate this measure. The formula has been used previously in claims-based studies among populations with a variety of chronic conditions including in older adults with dementia, diabetes mellitus (DM), congestive heart failure (CHF), chronic obstructive pulmonary disease (COPD) and multi-morbidity (Amjad, et al. 2016; Chen, Tseng and Cheng 2013; Hussey, et al. 2014; Bayliss, et al. 2015).

The primary purpose of health administrative claims data is to reimburse health care providers for the service(s) they provide, with research being a secondary use (Wilson and Bock 2012; ResDAC 2018). Therefore, a new record is generated each time a patient contacts the health care system, capturing information including what happens during a medical encounter through procedure codes, the reasons for visits to inpatient or outpatient facilities through diagnostic codes, the medications that were filled by individuals, and an identifier for the patient and provider (Wilson and Bock 2012;

ResDAC 2018). Optum® Clinformatics® Data Mart contains a provider data file. Each provider is assigned a unique identifying number, which enables identification of visits to a particular provider over time. For each claim, there is a corresponding provider identification number, which can be linked back to the provider file to obtain additional information about the care provider (Optum 2014; Optum 2017). There is also a limited amount of additional information about the provider including credentials (i.e., specialty), affiliations and state of practice (Optum 2014; Optum 2017). This information is self-reported by the health care provider. In this work, a different physician identifier for a health care encounter was coded as having seen a unique provider.

For the purpose of analysis, I created a binary indicator from the computed Bice-Boxerman COC score using the median COC value for each physically disabling condition as the cut-off. The Bice-Boxerman COC score has no inherent clinical meaning, and therefore needs to be converted from a continuous value for ease of interpretation (Amjad, et al. 2016). There is no ideal cut-off(s) for this COC measure. Therefore, consistent with previous studies, I operationalized it into a binary variable (Cohen-Mekelberg, et al. 2020). For each physically disabling condition, individuals with COC scores greater than the median (0.25, 0.21 and 0.22 for individuals with CP/SB, MS, and Plegia, respectively) were considered to have high COC, whilst those equal to, or below the median were considered to have low COC.

### *Individual and community measures:*

I examined both individual- and community-level factors hypothesized to be associated with COC in persons aging with physical disability. Variables were selected *a* *priori* based on the individual-level characteristics associated with COC in the literature (age, gender, comorbid health conditions), and features of the neighborhood environment that may impact availability and/or accessibility of healthcare services, providers or facilities (Ryvicker and Russell 2018; Napolitano, et al. 2016). These factors can proximally or distally impact fragmentation of care.

Demographic information at the individual-level was obtained from Optum® Clinformatics® Data Mart. In order to protect the privacy of individuals on the plan when geographic identifiers are provided, Optum® Clinformatics® Data Mart removes socio-demographic information such as race/ethnicity and individual-level income and education. Therefore, only age and sex were provided as demographic characteristics. I modeled age, in years, at baseline as a categorical variable (18-40, 41-50, and 51+ for congenital conditions only) and sex (Male or Female). The age categories were selected based on sample size considerations and because they capture distinct phases within the life course. To capture the co-morbid disease burden of individuals, I included the Elixhauser Comorbidity Index (ECI) as a continuous variable. Briefly, the ECI is a method of categorizing comorbidities of individuals based on diagnoses codes found in administrative data (Quan, et al. 2005). Each of the 31 conditions included in the index are coded as being present or not and are summed together, with each condition given equal weight (Quan, et al. 2005). I examined the presence of these conditions during the look-back period detailed earlier. The ECI is predictive of mortality and the use of hospital resources (Menendez, et al. 2014; Chu, Ng and Wu 2010; Chang, et al. 2016). I also included a continuous variable for year of observation in the data. This was done because individuals became eligible for study inclusion at different times over a 7-year period. Inclusion of this variable would account for effects related to changes in healthcare policy or delivery that may impact COC.

An individual's ZIP code was used as an approximation for their neighborhood, given that it was the smallest spatial scale available in Optum® Clinformatics® Data Mart. Contextual information was available at the ZIP Code Tabulation Area (ZCTA) level. ZCTAs are generated by the United States Census Bureau and are generalized representations of ZIP codes, which are designated mail routes used by the U.S. Postal Service (United States Census Bureau 2015; United States Census Bureau 2020). Therefore, a crosswalk file provided by the United States Census Bureau was used to link the ZIP Codes of individuals in my cohort to a ZCTA, and subsequently their neighborhood characteristics.

Features of the built environment were obtained at the ZCTA level from the National Neighborhood Data Archive (NaNDA) (https://www.openicpsr.org/openicpsr/nanda). NaNDA is a publicly available data archive that contains information on contextual variables at various spatial scales across the United States (Social Environment and Health n.d.). The measures are theoretically derived from a variety of data sources and can be linked to cohort and claims data, including Optum® Clinformatics® Data Mart, using geographic identifiers (Social Environment and Health n.d.). I included the following measures from NaNDA: 1) transit stops (expressed as density per square miles) using data published by the Bureau of Transportation Statistics, 2) broadband internet connections (expressed as density per population) from the American Community survey (ACS), and 3) healthcare establishments (hospitals, ambulatory care facilities and residential/skilled nursing facilities; expressed as density per square miles) obtained from National Establishment Time Series (NETS) data (Walls 2015; Melendez, Mao, et al. 2020; Li, Gomez-Lopez, et al. 2020; Khan, et al. 2020). NETS provides information on businesses, non-profit and government establishments and sole proprietors (Walls 2015). Data on transit stops was included as a marker for transportation availability which may be an important means of accessing healthcare facilities and providers especially for individuals with physical disabilities for whom driving or walking to locations in their neighborhood may be challenging. Information on broadband internet connections was considered as it may represent access to telehealth services, health information, and information on health care providers for individuals aging with a disability.

I also considered the main effects of socioeconomic status on COC as that may influence the availability of resources in local areas and individual access to structural resources (e.g., information and support networks). Therefore, I included index measures of neighborhood disadvantage and affluence. These measures were created in NaNDA using source data from the United States Decennial census and the ACS (Melendez, Clarke, et al. 2020). Neighborhood disadvantage was an average of five census indicators: 1) proportion of female-headed families with children, 2) proportion of households with public assistance income or food stamps, 3) proportion of families with income below the federal poverty level, 4) proportion of population 16+ who are unemployed, and 5) proportion of non-Hispanic Black individuals (Melendez, Clarke, et al. 2020). Affluence was an average of three census indicators: 1) proportion of households with income > $75,000, 2) proportion of population aged 16+ years who are employed in professional or managerial occupations, and 3) proportion of adults with a bachelor's degree or higher (Melendez, Clarke, et al. 2020). The values ranged from 0 to 1 with higher scores indicative of higher levels of disadvantage or affluence. Previous studies have shown them to be distinct constructs and were thus included in the models as separate variables (Browning and Cagney 2003).

Data on density of healthcare facilities such as ambulatory care centers and hospitals from NaNDA provided information on the general availability of health promoting resources in one's neighborhood. However, these density-based measures do not give insight into the proximity of specific types of health care providers, the visits to whom are important to consider for shaping care patterns as are their referral patterns and the services they provide. They may also be more proximally associated with COC scores than broader structural factors. Therefore, I included measures of spatial accessibility to select health care providers. Selection of the provider specialties was informed by 1) literature on care providers that are considered to be natural sources of supplementary or conventional treatment for those with musculoskeletal and nervous system conditions, 2) conversations with clinicians, and 3) preliminary descriptive statistics conducted in the study cohort (Warmbrodt 2020; Krauss, et al. 1998; Hurvitz, et al. 2003; Carson, et al. 2009; McKay and Langworthy 2011). The selected providers were Chiropractors, Medical Specialists, Family Medicine (FM) doctors and Nurse Practitioners (NP). Internal Medicine doctors were not included as they were highly correlated with availability of FM doctors. This measure was included to reflect the fact that physician practices are not distributed at random. Furthermore, there is an emergence of advanced practice providers in the healthcare workforce. When combined with population demographic shifts, this has contributed to geographic variation in healthcare access

(Khan, Trope, et al. 2018; Davis, et al. 2018; Naylor, et al. 2019). This availability can shape visit and referral patterns that can impact COC for patients. The measure of spatial accessibility was created and made publicly available at the ZCTA-level by Naylor and colleagues (2019). Spatial accessibility was based on the idea of "potential spatial access," which is the availability of a service moderated by space, defined by Naylor and colleagues (2019) as distance (Khan 1992; Naylor, et al. 2019). The creation of this metric is described in more detail elsewhere (Naylor, et al. 2019). Briefly, it was created using data on provider location, medical claims (Medicare), and United States Census data. The National Plan and Provider Enumeration System (NPPES) is a database containing the unique 10-digit identifiers of health care providers who apply for the National Provider Identifier (NPI), alongside their specialty (US Department of Health and Human Services 2016). To identify providers actively caring for patients, Naylor and colleagues (2019) linked NPPES data to Medicare data to identify providers with one or more claims within the file. For each ZCTA, the provider accessibility was computed using the Variable-distance Enhanced 2 step Floating Catchment Area method (VE2SFCA). The final measure of provider accessibly for each ZCTA population weighted centroid is below (Formula III.2) (Naylor, et al. 2019).

Formula III.2 Calculating the provider accessibility metric at the ZIP code Tabulation Area (ZCTA) (Naylor, et al. 2019)

$$\text{Provider Accessibility}_i = \Sigma_{j \in \{tij \leq tthres}\ \underbrace{W_{ij}(t_{ij})}_{[A]} * \underbrace{\text{Availability}_j}_{[B]}$$

It consists of two components: [Formula III.2A] distance decay weights which accounted for travel time between a population site *(i)* and practice location *(j)* within a given travel time; and [Formula III.2B] a metric of provider-to-population ratio which accounted for the distance decay weighted population for each ZCTA centroid (Naylor, et al. 2019).

This measure extends traditional provider-per-capita measures in three important ways. First, it does not assume that residing in the same geographic boundary, in this case ZCTA, implies equal access to health care providers (Naylor, et al. 2019). Secondly, it mitigates boundary problems that occur when measurements are made within a specific arbitrarily created geographic space that may not accurately reflect interaction or flow amongst individuals and resources (Stewart and Rogerson 1993; Griffith 1983). In this case, the computed metric factors in distance and does not assume that individuals only access providers within their ZCTA boundaries (Naylor, et al. 2019). As a result, it relies less heavily on administratively created boundaries (e.g., ZCTAs) and allows for across-boundary interactions (Naylor, et al. 2019). Third, in the calculation, the inclusion of a distance decay function also accounts for the fact that providers that are nearby are more accessible than those further away (Naylor, et al. 2019).

To facilitate interpretation, and to be able to make comparisons amongst those who live in the most and least resourced areas, where neighborhood effects are most pronounced, the contextual variables were operationalized as tertiles (T1 = low; T2 = medium; T3 = high) (Do, Wang and Elliot 2013; Krause 1996; Spring 2018). Pearson correlation coefficients were examined across all the contextual variables to ensure that co-linearity was not a concern. All correlations were low (e.g., Plegia: Medical Specialties and Chiropractors -0.01; CP/SB: density of hospitals and availability of Medical Specialists 0.003), with the exception of the correlation between spatial accessibility of FM and NP (correlation = 1.00). While the practice patterns of FMs and NPs can vary by facility, state and whether an area is urban or rural, they often work collaboratively to care for patients in clinics and practices (Spetz, Skillman and Andrilla 2017). In order to simultaneously account for both provider types, I created an index that accounted for the combined spatial accessibility of FM doctors and NPs based on tertiles for each variable. This was required given that the individual measures were not traditional density or per capita measures that could just be combined. I took the spatial accessibility of FM and NPs, individually, and generated tertiles. Subsequently, I created three mutually exclusive categories: low, medium or high based on the intersection of the tertiles of FM doctors and NPs (Appendix F, Figure F.9).

### *Statistical analysis:*

Analyses were conducted separately for each physically disabling condition (CP/SB, MS and Plegia). This decision was made *a priori* given that the different etiologies of the conditions may shape treatment patterns and subsequently findings of the study.

To characterize COC for each condition, I computed the mean COC score amongst those who were categorized as having high and low COC. I proceeded to describe the individual-level demographic and community characteristics for each condition, across COC levels. Chi-square tests for binary and categorical variables, and 1-way ANOVA for continuous variables were used to examine differences in baseline characteristics across COC categories (low versus high).

To better understand the types of providers and the frequency with which individuals with each disabling condition see them, I used the specialty reported by the health care provider in Optum® to classify them into broader mutually exclusive specialty categories. Clinicians in the dataset could report more than one specialty so I used the first reported specialty. I computed the percent of total visits in a given year to each of the specialty types for those with high and low COC scores.

Logistic regression was used to examine the relationship between individual and community-level factors and COC (high vs. low). In model 1, I included all individual-level variables. In model 2, I added community characteristics simultaneously to those variables included in model 1. I modelled the odds of high COC using Proc Genmod and by specifying the "descending" option in SAS. I accounted for correlation amongst individuals residing in the same ZCTA using Generalized Estimating Equation (GEE) logistic regression models. The responses from the same cluster are assumed 1) to be correlated, and 2) to follow a given correlation structure. The parameter estimates from GEE models describe the effect estimate for each predictor variable, averaged across all clusters (ZCTAs). I specified a binomial distribution and a logit link function. A separate regression model (stratification) was constructed for each of the physically disabling conditions (Equation III.7). I obtained and reported adjusted odds ratios (OR) and 95% confidence intervals (CI).

Equation III.7 Logistic regression model examining the relationship between individual and community characteristics and high continuity of care (COC)

$$\text{Logit}(\Pr(Yij=1)) = \beta_0 + \beta_1 (\text{Transit T1})_{ij} + \beta_2 (\text{Transit T2})_{ij} + \beta_3 (\text{Elixhauser Comorbidity Index})_I + \beta_4 (\text{Age 41-50 years})_I \ldots + \beta_x(\text{Chiropractor T1})_{ij} + \beta_x(\text{Chiropractor T2})_{ij} + \ldots..$$

Where,
Y denotes probability of high continuity of care (vs. low)
*I* denotes subject
*j* denotes the cluster (ZCTA)
T1 represents low density and T2 represents medium density. The reference group was T3 (high density).

In sensitivity analyses, I also ran condition-specific regression models adjusting model 2 (which contained the individual and community level variables) for tertile of population density (population per square miles). This was done to examine whether access to broadband internet was confounded by urban and rural differences in population. Due to high correlations ($r = 0.80$) between population density and density of hospitals and ambulatory care centers, I excluded these variables from the models to avoid multi-collinearity.

Statistical significance was assessed at $p<0.05$ and tests were 2-sided. All analyses were conducted in SAS version 9.4 (SAS Institute, Cary, NC).

## 3.3 Results

*Cohort characteristics:*

Table III.9 presents the descriptive characteristics of the study cohort. There were 16,260 individuals in our study; 53% of them had a CP/SB diagnosis, 24% had MS and the remaining had Plegia (23%). The mean age was 49, 39 and 40 years for those with a diagnosis of CP/SB, MS and Plegia, respectively (Table III.9). The younger age for the acquired conditions (MS and Plegia) compared to the congenital conditions (CP/SB) can be partially attributed to the fact that individuals with the former conditions had to have had the diagnosis before the age of 50, to ensure compliance with traditional definitions of aging with disability. Females comprised the majority of individuals with each condition (e.g., CP/SB: 61.6% female and 38.4% male). The difference was especially pronounced for MS, which is consistent with the epidemiology of MS (Tullman 2013). Co-morbid disease burden was high in our cohort, with an average of 2.7, 2.6 and 1.5 conditions amongst those with a CP/SB, Plegia and MS diagnoses, respectively (Table III.9).

Table III.9 Individual and community-level characteristics of individuals with cerebral palsy/spina bifida, multiple sclerosis and plegia, overall and across those with high and low Bice-Boxerman continuity of care index score, Optum® Clinformatics® Data Mart

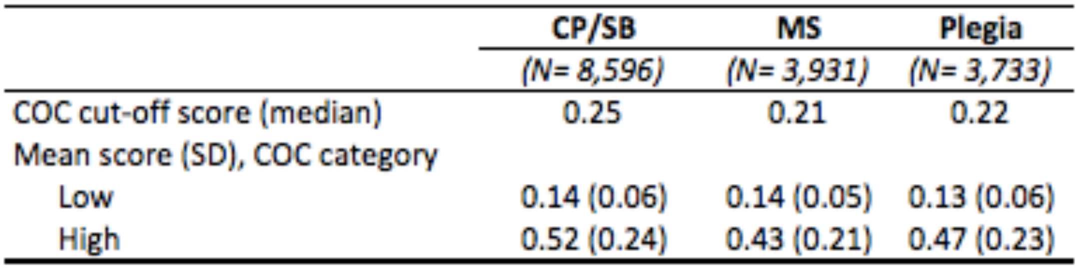
| | CP/SB | | | | MS | | | | Plegia | | | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|
| | Overall* | High COC | Low COC | P-value | Overall* | High COC | Low COC | P-value | Overall* | High COC | Low COC | P-value |
| | Column %, unless otherwise specified | | | | Column %, unless otherwise specified | | | | Column %, unless otherwise specified | | | |
| N | 8,956 | 4,221 | 4,375 | ---- | 3,931 | 1,966 | 1,965 | ---- | 3,733 | 1,878 | 1,855 | ---- |
| Continuity of Care, mean | 0.30 | 0.52 | 0.14 | ---- | 0.28 | 0.43 | 0.14 | ---- | 0.30 | 0.47 | 0.13 | ---- |
| | | | | | | | | | | | | |
| **Individual-level characteristics** | | | | | | | | | | | | |
| Age (years), mean | 48.6 | 49.9 | 47.3 | **0.0002** | 39.2 | 39.4 | 39.0 | 0.1450 | 40.2 | 41.0 | 39.3 | **<0.0001** |
| Gender, % | | | | | | | | | | | | |
| Female | 61.6 | 59.1 | 64.0 | **<0.0001** | 77.4 | 73.1 | 81.7 | **<0.0001** | 53.8 | 49.4 | 58.2 | **<0.0001** |
| Male | 38.4 | 41.0 | 36.0 | | 22.6 | 26.9 | 18.3 | | 46.2 | 50.6 | 41.8 | |
| Morbidity, mean | 2.7 | 2.6 | 2.7 | 0.0567 | 1.5 | 1.4 | 1.7 | **<0.0001** | 2.6 | 2.2 | 2.3 | **0.0400** |
| | | | | | | | | | | | | |
| **Community-level characteristics** | | | | | | | | | | | | |
| Affluence | | | | | | | | | | | | |
| Low | | 37.4 | 29.4 | | | 35.0 | 31.6 | | | 36.3 | 30.2 | |
| Medium | | 33.9 | 32.8 | **<0.0001** | | 34.1 | 32.7 | **0.0051** | | 32.8 | 34.0 | **0.0001** |
| High | | 28.7 | 37.8 | | | 30.9 | 35.7 | | | 30.9 | 35.9 | |
| Disadvantage | | | | | | | | | | | | |
| Low | | 29.6 | 36.9 | | | 30.9 | 35.7 | | | 30.7 | 35.9 | |
| Medium | | 34.8 | 32.0 | **<0.0001** | | 35.1 | 31.7 | **0.0045** | | 34.2 | 32.7 | **0.0026** |
| High | | 35.6 | 31.1 | | | 34.0 | 32.6 | | | 35.2 | 31.5 | |
| Density of transit stops | | | | | | | | | | | | |
| Low | | 45.9 | 45.6 | | | 42.6 | 41.6 | | | 46.2 | 45.9 | |
| Medium | | 20.5 | 21.4 | 0.5468 | | 23.4 | 25.7 | 0.2537 | | 21.3 | 20.0 | 0.4489 |
| High | | 33.6 | 33.0 | | | 34.0 | 32.7 | | | 32.5 | 34.2 | |
| Density of broadband internet connections | | | | | | | | | | | | |
| Low | | 37.1 | 29.7 | | | 36.3 | 30.3 | | | 36.7 | 28.8 | |
| Medium | | 33.0 | 33.7 | **<0.0001** | | 32.2 | 34.5 | **0.0002** | | 32.6 | 34.4 | **<0.0001** |
| High | | 30.0 | 36.6 | | | 31.4 | 35.3 | | | 30.9 | 35.8 | |
| Density of healthcare resources | | | | | | | | | | | | |
| Residential care/skilled nursing facilities | | | | | | | | | | | | |
| Low | | 33.0 | 33.7 | | | 33.5 | 33.1 | | | 32.5 | 34.0 | |
| Medium | | 32.3 | 34.3 | **0.0193** | | 32.9 | 33.8 | 0.8275 | | 34.3 | 32.6 | 0.5046 |
| High | | 34.7 | 32.0 | | | 33.6 | 33.1 | | | 33.3 | 33.4 | |
| Hospitals | | | | | | | | | | | | |
| Low | | 33.9 | 32.8 | | | 33.7 | 32.8 | | | 33.5 | 33.1 | |
| Medium | | 32.2 | 34.5 | 0.0698 | | 33.4 | 33.4 | 0.7579 | | 33.1 | 33.6 | 0.9485 |
| High | | 34.0 | 32.7 | | | 32.9 | 33.8 | | | 33.4 | 33.3 | |
| Ambulatory care services | | | | | | | | | | | | |
| Low | | 33.8 | 32.8 | | | 33.8 | 33.8 | | | 33.3 | 33.3 | |
| Medium | | 33.4 | 33.4 | 0.5625 | | 33.2 | 33.6 | 0.7721 | | 33.9 | 32.9 | 0.7468 |
| High | | 32.9 | 33.8 | | | 33.0 | 33.7 | | | 32.8 | 33.8 | |
| Spatial accessibility of healthcare providers | | | | | | | | | | | | |
| Chiropractors | | | | | | | | | | | | |
| Low | | 35.8 | 30.9 | | | 33.2 | 33.3 | | | 34.9 | 31.6 | |
| Medium | | 32.8 | 34.0 | **<0.0001** | | 33.3 | 33.7 | 0.954 | | 34.0 | 32.9 | **0.0175** |
| High | | 31.5 | 35.1 | | | 33.5 | 33.1 | | | 31.2 | 35.5 | |
| Medical specialists | | | | | | | | | | | | |
| Low | | 34.6 | 32.1 | | | 33.0 | 33.5 | | | 33.4 | 33.1 | |
| Medium | | 33.8 | 33.0 | **0.0047** | | 33.3 | 33.6 | 0.8831 | | 35.7 | 31.1 | **0.0032** |
| High | | 31.6 | 35.0 | | | 33.7 | 32.9 | | | 30.9 | 35.8 | |
| Family medicine/Nurse Practitioners | | | | | | | | | | | | |
| Low | | 42.0 | 36.6 | | | 39.4 | 37.8 | | | 36.5 | 40.6 | |
| Medium | | 21.1 | 22.4 | **<0.0001** | | 39.6 | 38.5 | 0.133 | | 41.5 | 35.8 | **0.0023** |
| High | | 37.0 | 40.9 | | | 21.0 | 23.7 | | | 22.0 | 23.7 | |

Continuity of care was calculated in the 1-year post index using the Bice-Boxerman continuity of care index.
High continuity of care was defined as a Bice-Boxerman continuity of care score greater than the condition specific median. Low continuity of care was defined as having a value less than or equal to the condition specific median value.
Morbidity was computed based on the Elixhauser comorbidity index.
*Percentages across tertile of neighborhood characteristics were not presented in the overall cohort since the tertiles were created within the entire cohort.
P-values are computed based on bivariate analyses, comparing individuals with low and high continuity of care scores.

*Characterizing COC across physically disabling condition:*

The mean COC score for those with CP/SB, MS and Plegia was 0.30, 0.28 and 0.30, respectively (Table III.9). Table III.10 presents the COC scores for each of the three physically disabling conditions separately. Amongst those with high COC, mean COC scores were highest for those with CP/SB (Mean: 0.52, standard deviation: 0.24), followed by 0.47 (Standard deviation: 0.23) for Plegia, and 0.43 (Standard deviation:0.21) for MS. Amongst persons classified as having low COC, the mean COC scores were similar across the three physically disabling conditions (range from 0.13 to 0.14). There was greater variability in mean COC scores for those classified as having high COC, across disability type (Table III.10).

Table III.10 Characterizing Bice-Boxerman continuity of care index across physically disabling condition, Optum® Clinformatics® Data Mart



| | **CP/SB** | **MS** | **Plegia** |
|---|---|---|---|
| | *(N= 8,596)* | *(N= 3,931)* | *(N= 3,733)* |
| COC cut-off score (median) | 0.25 | 0.21 | 0.22 |
| Mean score (SD), COC category | | | |
| Low | 0.14 (0.06) | 0.14 (0.05) | 0.13 (0.06) |
| High | 0.52 (0.24) | 0.43 (0.21) | 0.47 (0.23) |

Abbreviations: COC, continuity of care; CP/SB, Cerebral Palsy/Spina Bifida; MS, Multiple Sclerosis.
Continuity of care was calculated in the 1-year post index using the Bice-Boxerman continuity of care index.
High continuity of care was defined as a Bice-Boxerman continuity of care score greater than the condition specific median. Low continuity of care was defined as having a value less than or equal to the condition specific median value.

Across each of the physically disabling conditions examined, there were significant differences in COC by baseline demographic characteristics (Table III.9). Amongst individuals with CP/SB, those with high COC were slightly older (49.9 years versus 47.3 years; p=0.0002). Similar findings were observed for those with Plegia (Table III.9). No significant differences in age across COC groups were observed for MS (p=0.1450). Females were over-represented amongst those with low continuity, regardless of the condition examined. For example, amongst individuals with Plegia classified as having high COC, 49.4% were female (50.6% male), whilst it was 58.2% (41.8% male) for those with low COC. Differences were most pronounced for MS where 81.7% of those with low COC were female (18.3% male) (Table III.9). In bivariate analysis, those with low COC had a higher mean number of co-morbidities, and this was statistically significant for MS (low COC: 1.7, high COC: 1.4; p<0.0001) and Plegia (low COC: 2.3, high COC: 2.2; p=0.04) (Table III.9).

Using the first reported specialty of providers in Optum® Clinformatics® Data Mart, I assessed the physician specialty (taxonomy) associated with the outpatient visits across all individuals classified as having low and high COC. Overall, I observed that individuals with early-onset physical disabilities saw many different types of providers (Figure III.7) including orthopedic specialists, Obstetrics/Gynecologists (OBGYN), Internal Medicine, and Family Physicians. For individuals with high continuity, a greater number of visits were concentrated amongst fewer provider types. For example, amongst CP/SB patients with high COC, 55% of all visits were concentrated amongst Internal Medicine and Family/General Medicine doctors, whilst these provider specialties only accounted for 45% of visits for those with low COC (Figure III.7A). For those with low

COC, other notable providers included Orthopedics (6.2% for those with low continuity versus 5.0% for high continuity), NPs (4.3% for those with low COC versus 2.7% for high COC) and OBGYNs (4.0% for low COC versus 2.8% for high COC).

Amongst individuals with MS, the percentage of visits to Internal Medicine and Family Medicine/General Medicine doctors was comparable across the low and high COC categories (Figure III.7B). Notably in this cohort, 27% of visits for those with high COC were to Psychologists or Psychiatrists, compared to only 19% for those having low COC.

For individuals with a diagnosis of Plegia, 47% of all visits for those with high COC were with Internal Medicine or Family Medicine/General Medicine doctors (Figure III.7C). This was compared to only 40% amongst those with low COC. Compared to those with high COC, those with low COC had a greater percentage of their visits to Dermatologists (low COC: 3.1% versus high COC: 1.8%) and OBGYNs (low COC: 3.4% versus high COC: 2.8%).

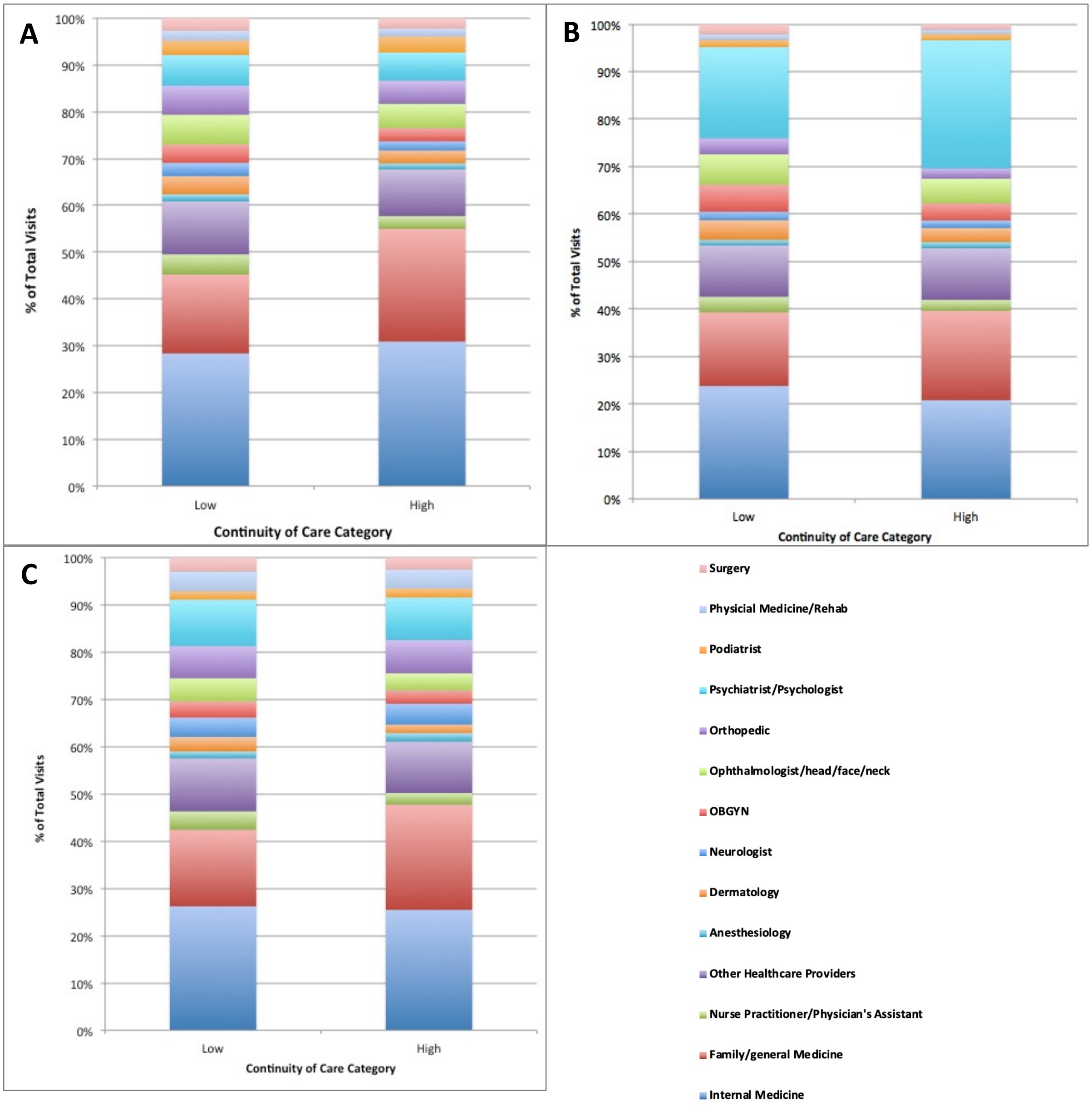


Figure III.7 Percentage of visits to different healthcare provider specialties for individuals with low and high continuity of care amongst those with cerebral palsy/spina bifida (A), multiple sclerosis (B), and plegia (C).
Abbreviations: OBGYN, Obstetrics and Gynecology.
Visit to different provider types was examined in the 1-year post index.
Provider specialty was assessed based on first self-reported care provider specialty reported in Optum® Clinformatics® Data Mart.
Continuity of care was computed in the 1-year post index-date based on the Bice-Boxerman continuity of care index score.
High continuity of care was defined as a Bice-Boxerman continuity of care score greater than the condition specific median. Low continuity of care was defined as having a value less than or equal to the condition specific median value.

Percentages calculated after excluding those where specialty could not be assigned to visit.

*Individual- and community-level factors associated with COC:*

In bivariate analyses, individuals with low and high COC varied in terms of the characteristics of the communities in which they lived. For example, amongst individuals with CP/SB, a significantly greater percentage of individuals with fragmented care (low COC) resided in areas with lower density of healthcare services such as residential care/skilled nursing facilities (32.0% vs 34.7%; p=0.0193). Significant differences were also observed for density of broadband internet connections, spatial availability of health care providers, affluence and disadvantage (Table III.9). For those with MS and Plegia, availability of broadband internet connections in one's community varied significantly across COC category, as did spatial accessibility of healthcare providers, for individuals with Plegia only.

Results from the adjusted logistic regression analyses (OR and 95% CI) are presented in Tables III.11-III.13 for each disabling condition. I discuss the results for each condition in turn, below.

CP/SB:

Results from the logistic regression models are presented in Table III.11 for individual factors (Model 1) and additional community characteristics (Model 2). Older adults with CP/SB (age 41-64 years) had 22% higher odds of concentrated care (OR 1.22, 95% CI: 1.21-1.47) compared to the youngest group (age 18-40) (Table III.11, Model 1).

Age was the strongest factor associated with concentrated care and I observed a dose-response relationship with effects most pronounced in the oldest age group. Compared to females, males had higher odds of concentrated care (OR 1.23, 95% CI: 1.13-1.34). Conversely, a higher number of comorbid health conditions was inversely associated with odds of concentrated care with a 5 unit increase in the ECI associated with 0.86 times the odds of concentrated care (OR 0.86, 95% CI: 0.78-0.94) (Table III.11).

Model 2 added the community characteristics. In this fully adjusted model, findings for demographic characteristics remained consistent. As displayed in Table III.11 and Figure III.8, I also identified several community-level factors associated with high COC. Residing in neighborhoods with low affluence scores was associated with higher odds of concentrated care (e.g., low vs high OR 1.55, 95% CI: 1.29, 1.86) net of individual factors and other community characteristics. Individuals residing in less disadvantaged neighborhoods had higher odds of high COC than individuals in more disadvantaged neighborhoods. Several features of the built environment were associated with high COC. Communities with moderate density of hospitals (medium vs high OR 0.84, 95% CI: 0.72, 0.98) and low density of residential/skilled nursing facilities (e.g., low vs high 0.72, 95% CI: 0.59, 0.88) had significantly lower odds of concentrated care. In addition to features of the built neighborhood environment, spatial accessibility of health care providers was also associated with continuous care. Residence in environments with low spatial accessibility to FM/NPs, compared to high accessibility, was associated with 1.26 times the odds of high COC (95% CI: 1.09, 1.46) (Table III.11; Figure III.8). No other features of the neighborhood environment were observed to be significantly associated with COC in adults aging with CP/SB.

Effect estimates for density of broadband internet connections did not change markedly in sensitivity analysis with inclusion of population density in the model (e.g., low vs high density; without population density: OR 1.11, 95% CI: 0.94, 1.31); with population density: OR 1.09, 95% CI 0.92, 1.29) (Appendix G, Table G.7).

Table III.11 Association between individual and community factors and high continuity of care for individuals with a diagnosis of cerebral palsy or spina bifida, Optum$^{®}$ Clinformatics$^{®}$ Data Mart

| | MODEL 1: INDIVIDUAL-LEVEL CHARACTERISTICS | | | MODEL 2: MODEL 1 + COMMUNITY-LEVEL CHARACTERISTICS | | |
|---|---|---|---|---|---|---|
| | ***OR*** | ***LCL*** | ***UCL*** | ***OR*** | ***LCL*** | ***UCL*** |
| ***Individual-level Characteristics*** | | | | | | |
| Age group, years (Ref=18-40) | | | | | | |
| 41-64 | **1.22** | **1.21** | **1.47** | **1.32** | **1.19** | **1.47** |
| 65+ | **1.51** | **1.34** | **1.71** | **1.56** | **1.38** | **1.77** |
| Elixhauser, 5 units | **0.86** | **0.78** | **0.94** | **0.83** | **0.76** | **0.92** |
| Gender, M | **1.23** | **1.13** | **1.34** | **1.22** | **1.11** | **1.34** |
| Year | **0.96** | **0.94** | **0.97** | **0.96** | **0.94** | **0.97** |
| ***Community-level Factors (Ref = High)*** | | | | | | |
| Affluence | | | | | | |
| Low | --- | --- | --- | **1.55** | **1.29** | **1.86** |
| Medium | --- | --- | --- | **1.26** | **1.10** | **1.45** |
| Disadvantage | | | | | | |
| Low | --- | --- | --- | 0.96 | 0.82 | 1.13 |
| Medium | --- | --- | --- | **1.15** | **1.01** | **1.31** |
| Density of Broadband Internet Connections | | | | | | |
| Low | --- | --- | --- | 1.11 | 0.94 | 1.31 |
| Medium | --- | --- | --- | 0.99 | 0.87 | 1.13 |
| Density of Transit Stops | | | | | | |
| Low | --- | --- | --- | 1.09 | 0.96 | 1.25 |
| Medium | --- | --- | --- | 1.15 | 0.99 | 1.34 |
| Spatial Accessibility of Chiropractors | | | | | | |
| Low | --- | --- | --- | 1.08 | 0.95 | 1.23 |
| Medium | --- | --- | --- | 1.00 | 0.89 | 1.12 |
| Spatial Accessibility of Medical Specialists | | | | | | |
| Low | --- | --- | --- | 1.07 | 0.91 | 1.27 |
| Medium | --- | --- | --- | 1.10 | 0.96 | 1.25 |
| Spatial Accessibility of Family Medicine/Nurse Practitioners | | | | | | |
| Low | --- | --- | --- | **1.26** | **1.09** | **1.46** |
| Medium | --- | --- | --- | 1.05 | 0.92 | 1.21 |
| Density of Residential Care/Skilled Nursing Facilities | | | | | | |
| Low | --- | --- | --- | **0.72** | **0.59** | **0.88** |
| Medium | --- | --- | --- | **0.84** | **0.73** | **0.96** |
| Density of Hospitals | | | | | | |
| Low | --- | --- | --- | 0.89 | 0.74 | 1.07 |
| Medium | --- | --- | --- | **0.84** | **0.72** | **0.98** |
| Density of Ambulatory Care Facilities | | | | | | |
| Low | --- | --- | --- | 1.10 | 0.87 | 1.38 |
| Medium | --- | --- | --- | 1.11 | 0.95 | 1.31 |

Abbreviations: LCL, Lower 95% confidence interval; M, Male; OR, Odds ratio; Ref, Reference; UCL, Upper 95% confidence interval.
Continuity of care was computed in the 1-year post index-date based on the Bice-Boxerman continuity of care index score.
Modelling odds of high continuity (vs low continuity).
Bold text indicates statistical significance at $p<0.05$
High continuity of care was defined as a Bice-Boxerman continuity of care score greater than the condition specific median. Low continuity of care was defined as having a value less than or equal to the condition specific median value.
Neighborhood was defined based on the ZIP code Tabulation Area (ZCTA).
Data on features of built neighborhood environment were obtained from the National Neighborhood Data Archive (NaNDA), whilst spatial accessibility of health care providers was obtained from a publicly available dataset by Naylor, et al. 2019.
All variables were adjusted for simultaneously in the models.

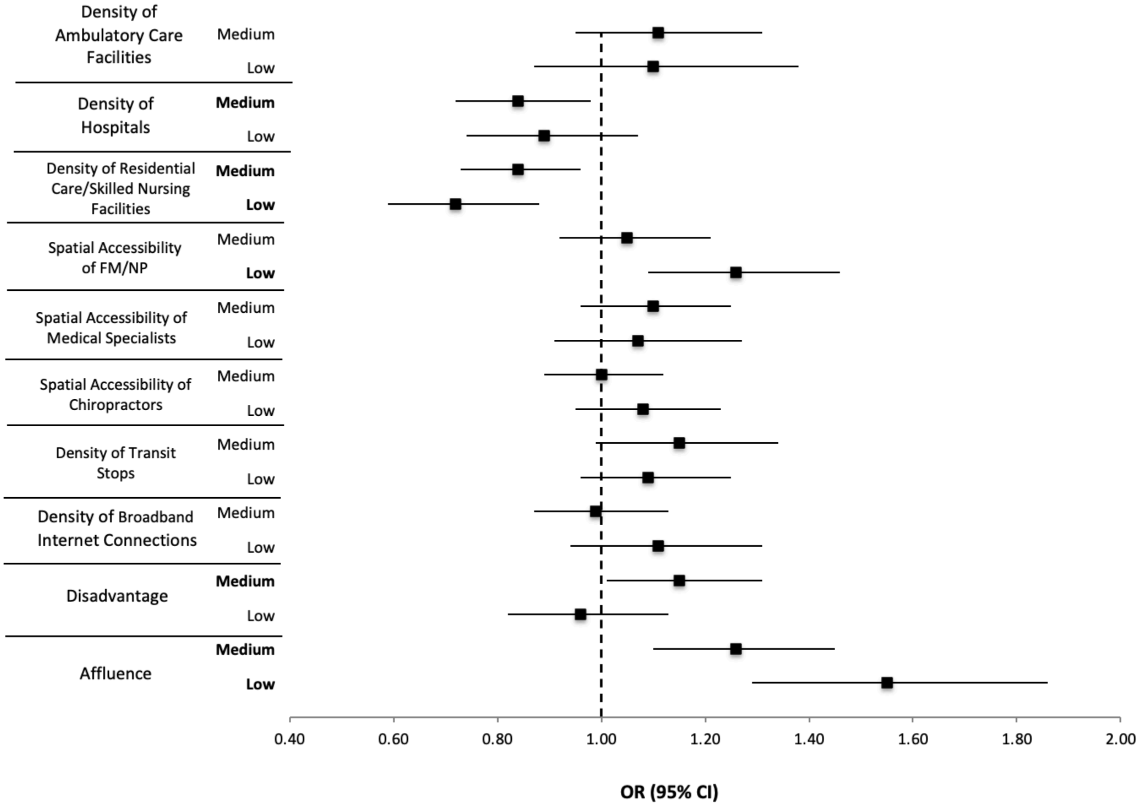


Figure III.8 Association between community characteristics and high continuity of care amongst individuals with cerebral palsy or spina bifida, Optum® Clinformatics® Data Mart.

Abbreviations: Chiro, Chiropractor; CI, 95% confidence intervals; FM, Family Medicine; NP, Nurse Practitioner; OR, Odds ratio; Res Care, Residential care/skilled nursing facility; T, Tertile.

Continuity of care was computed in the 1-year post index-date based on the Bice-Boxerman continuity of care index score.

Computed odds of high continuity (vs low).

Bold text indicates statistical significance at $p<0.05$

High continuity of care was defined as a Bice-Boxerman continuity of care score greater than the condition specific median.

Low continuity of care was defined as having a value less than or equal to the condition specific median value.

Neighborhood was defined based on the ZIP code Tabulation Area (ZCTA).

Data on features of built neighborhood environment were obtained from the National Neighborhood Data Archive (NaNDA), whilst spatial accessibility of health care providers was obtained from a publicly available dataset by Naylor, et al. 2019.

Model was simultaneously adjusted for these neighborhood characteristics as well as for individual-level age, sex and Elixhauser co-morbidity index, as well as year.

Plegia:

Table III.12 highlights the results of the findings for models 1 and 2 in the cohort with Plegia. I noted several significant individual-level factors associated with high COC. Individuals in the oldest age group (41-50 years) had significantly higher odds of high COC compared to the reference group of 18-40 years of age (OR 1.47, 95% CI: 1.28, 1.68). As was observed in the CP/SB cohort, males had higher odds of continuous care compared to females, and a greater disease burden at baseline was associated with lower odds of high COC. All findings were statistically significant. Findings for effects of age, gender and co-morbidity on COC remained consistent in the fully adjusted model (Model 2).

As it pertained to features of the built neighborhood environment, lower density of broadband internet connections (Low vs high OR 1.33, 95% CI: 1.03, 1.71) and moderate density of transit stops (Medium vs high OR 1.32, 95% CI: 1.05,1.65) in one's neighborhood were associated with high COC. Lower spatial accessibility to different Medical Specialists was associated with 1.25 times the odds of concentrated care (OR 1.25, 95% CI: 1.02, 1.52) (Table III.12; Figure III.9).

In sensitivity analysis, findings for broadband internet connections were comparable with population density included in the model (e.g., low vs high; without population density: OR 1.33, 95% CI: 1.03, 1.68; with population density: OR 1.31, 95% CI 1.01, 1.80) (Appendix G, Table G.8).

Table III.12 Association between individual and community factors and high continuity of care for individuals with a diagnosis of plegia, Optum® Clinformatics® Data Mart

| | **MODEL 1: INDIVIDUAL-LEVEL CHARACTERISTICS** | | | **MODEL 2: MODEL 1 + COMMUNITY-LEVEL CHARACTERISTICS** | | |
|---|---|---|---|---|---|---|
| | ***OR*** | ***LCL*** | ***UCL*** | ***OR*** | ***LCL*** | ***UCL*** |
| ***Individual-level Characteristics*** | | | | | | |
| Age group, years (Ref=18-40) | | | | | | |
| 41-50 | **1.47** | **1.28** | **1.68** | **1.45** | **1.26** | **1.67** |
| Elixhauser, 5 units | **0.84** | **0.74** | **0.97** | **0.81** | **0.70** | **0.93** |
| Gender, M | **1.40** | **1.23** | **1.59** | **1.43** | **1.25** | **1.63** |
| Year | **0.95** | **0.93** | **0.98** | **0.95** | **0.93** | **0.98** |
| ***Community-level Factors (Ref = High)*** | | | | | | |
| Affluence | | | | | | |
| Low | --- | --- | --- | 1.15 | 0.88 | 1.51 |
| Medium | --- | --- | --- | 1.01 | 0.82 | 1.25 |
| Disadvantage | | | | | | |
| Low | --- | --- | --- | 0.93 | 0.73 | 1.17 |
| Medium | --- | --- | --- | 1.05 | 0.87 | 1.26 |
| Density of Broadband Internet Connections | | | | | | |
| Low | --- | --- | --- | **1.33** | **1.03** | **1.71** |
| Medium | --- | --- | --- | 1.05 | 0.86 | 1.28 |
| Density of Transit Stops | | | | | | |
| Low | --- | --- | --- | 1.19 | 0.97 | 1.47 |
| Medium | --- | --- | --- | **1.32** | **1.05** | **1.65** |
| Spatial Accessibility of Chiropractors | | | | | | |
| Low | --- | --- | --- | 1.07 | 0.88 | 1.31 |
| Medium | --- | --- | --- | 1.09 | 0.91 | 1.30 |
| Spatial Accessibility of Medical Specialists | | | | | | |
| Low | --- | --- | --- | 1.03 | 0.80 | 1.32 |
| Medium | --- | --- | --- | **1.25** | **1.02** | **1.52** |
| Spatial Accessibility of Family Medicine/Nurse Practitioners | | | | | | |
| Low | --- | --- | --- | 1.21 | 0.98 | 1.50 |
| Medium | --- | --- | --- | 1.00 | 0.82 | 1.21 |
| Density of Residential Care/Skilled Nursing Facilities | | | | | | |
| Low | --- | --- | --- | 0.84 | 0.62 | 1.15 |
| Medium | --- | --- | --- | 1.02 | 0.82 | 1.28 |
| Density of Hospitals | | | | | | |
| Low | --- | --- | --- | 0.94 | 0.72 | 1.23 |
| Medium | --- | --- | --- | 0.85 | 0.67 | 1.07 |
| Density of Ambulatory Care Facilities | | | | | | |
| Low | --- | --- | --- | 0.91 | 0.64 | 1.31 |
| Medium | --- | --- | --- | 1.02 | 0.80 | 1.31 |

Abbreviations: LCL, Lower 95% confidence interval; M, Male; OR, Odds ratio; Ref, Reference; T, tertile; UCL, Upper 95% confidence interval.
Continuity of care was computed in the 1-year post index-date based on the Bice-Boxerman continuity of care index score.
Computed odds of high continuity (vs low continuity).
Bold text indicates statistical significance at $p<0.05$
High continuity of care was defined as a Bice-Boxerman continuity of care score greater than the condition specific median. Low continuity of care was defined as having a value less than or equal to the condition specific median value.
Neighborhood was defined based on the ZIP code Tabulation Area (ZCTA).
Data on features of built neighborhood environment were obtained from the National Neighborhood Data Archive (NaNDA), whilst spatial accessibility of health care providers was obtained from a publicly available dataset by Naylor, et al. 2019.
All variables were adjusted for simultaneously in the models.

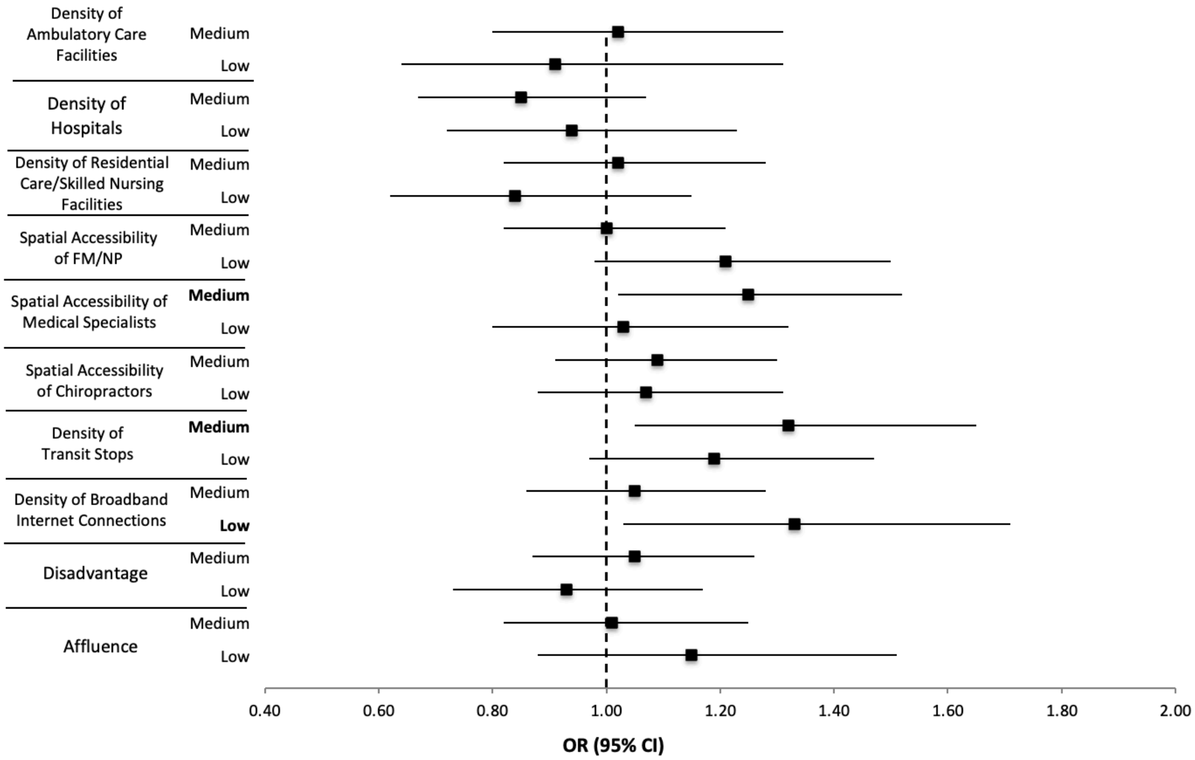


Figure III.9 Association between community characteristics and high continuity of care amongst individuals with plegia, Optum® Clinformatics® Data Mart.
Abbreviations: Chiro, Chiropractor; CI, 95% confidence intervals; FM, Family Medicine; NP, Nurse Practitioner; OR, Odds ratio; Res Care, Residential care/skilled nursing facility; T, Tertile.
Continuity of care was computed in the 1-year post index-date based on the Bice-Boxerman continuity of care index score.
Computed odds of high continuity (vs low continuity).
Bold text indicates statistical significance at $p<0.05$
High continuity of care was defined as a Bice-Boxerman continuity of care score greater than the condition specific median. Low continuity of care was defined as having a value less than or equal to the condition specific median value.
Neighborhood was defined based on the ZIP code Tabulation Area (ZCTA).
Data on features of built neighborhood environment were obtained from the National Neighborhood Data Archive (NaNDA), whilst spatial accessibility of health care providers was obtained from a publicly available dataset by Naylor, et al. 2019.
Model was simultaneously adjusted for these neighborhood characteristics as well as for individual-level age, sex and Elixhauser co-morbidity index, as well as year.

MS:

Amongst individuals with a diagnosis of MS, individual-level demographic characteristics were found to be associated with high continuity in model 1 (Table III.13). Males had 1.62 times the odds of high COC than females (OR 1.62, 95% CI: 1.39, 1.89) and a 5-unit increase in ECI was associated with 0.67 times the odds of high COC (OR 0.67, 95% CI: 0.55, 0.81). Although individuals in the oldest age group had higher odds of continuous care, age was not significantly associated with continuity of care as the confidence intervals crossed 1 (Table III.13). Findings for these individual-level demographic and clinical factors were comparable in model 2 when community characteristics were added to the model.

Few contextual factors were found to be significantly associated with high continuity in those aging with MS (Table III.13; Figure III.10). Amongst the variables examined in a fully adjusted model, only density of broadband internet connections was significantly associated with high COC (Low vs High OR 1.44, 95% CI: 1.15, 1.80). It is important to note that while statistically significant (as the confidence intervals did not cross 1), the confidence intervals were wide.

Table III.13 Association between individual and community factors and high continuity of care for individuals with a diagnosis of multiple sclerosis, Optum® Clinformatics® Data Mart

| | MODEL 1: INDIVIDUAL-LEVEL CHARACTERISTICS | | | MODEL 2: MODEL 1 + COMMUNITY-LEVEL CHARACTERISTICS | | |
|---|---|---|---|---|---|---|
| | ***OR*** | ***LCL*** | ***UCL*** | ***OR*** | ***LCL*** | ***UCL*** |
| ***Individual-level Characteristics*** | | | | | | |
| Age group, years (Ref=18-40) | | | | | | |
| 41-50 | 1.09 | 0.96 | 1.24 | 1.11 | 0.97 | 1.27 |
| Elixhauser, 5 units | **0.67** | **0.55** | **0.81** | **0.63** | **0.51** | **0.77** |
| Gender, M | **1.62** | **1.39** | **1.89** | **1.62** | **1.38** | **1.91** |
| Year | 0.98 | 0.95 | 1.01 | **0.97** | **0.94** | **1.00** |
| ***Community-level Factors (Ref = High)*** | | | | | | |
| Affluence | | | | | | |
| Low | --- | --- | --- | 1.00 | 0.77 | 1.28 |
| Medium | --- | --- | --- | 1.08 | 0.89 | 1.30 |
| Disadvantage | | | | | | |
| Low | --- | --- | --- | 0.99 | 0.80 | 1.23 |
| Medium | --- | --- | --- | 1.12 | 0.94 | 1.34 |
| Density of Broadband Internet Connections | | | | | | |
| Low | --- | --- | --- | **1.44** | **1.15** | **1.80** |
| Medium | --- | --- | --- | 1.04 | 0.88 | 1.25 |
| Density of Transit Stops | | | | | | |
| Low | --- | --- | --- | 0.96 | 0.78 | 1.17 |
| Medium | --- | --- | --- | 0.90 | 0.73 | 1.10 |
| Spatial Accessibility of Chiropractors | | | | | | |
| Low | --- | --- | --- | 0.95 | 0.78 | 1.14 |
| Medium | --- | --- | --- | 0.99 | 0.84 | 1.17 |
| Spatial Accessibility of Medical Specialists | | | | | | |
| Low | --- | --- | --- | 0.88 | 0.70 | 1.11 |
| Medium | --- | --- | --- | 0.96 | 0.80 | 1.15 |
| Spatial Accessibility of Family Medicine/Nurse Practitioners | | | | | | |
| Low | --- | --- | --- | 1.04 | 0.86 | 1.26 |
| Medium | --- | --- | --- | 0.86 | 0.71 | 1.03 |
| Density of Residential Care/Skilled Nursing Facilities | | | | | | |
| Low | --- | --- | --- | 1.03 | 0.77 | 1.36 |
| Medium | --- | --- | --- | 1.08 | 0.88 | 1.32 |
| Density of Hospitals | | | | | | |
| Low | --- | --- | --- | 1.05 | 0.81 | 1.36 |
| Medium | --- | --- | --- | 1.07 | 0.86 | 1.32 |
| Density of Ambulatory Care Facilities | | | | | | |
| Low | --- | --- | --- | 0.99 | 0.72 | 1.37 |
| Medium | --- | --- | --- | 0.99 | 0.80 | 1.24 |

Abbreviations: LCL, Lower 95% confidence interval; M, Male; OR, Odds ratio; Ref, Reference; T, tertile; UCL, Upper 95% confidence interval.

Continuity of care was computed in the 1-year post index-date based on the Bice-Boxerman continuity of care index score.

Computed odds of high continuity (vs low continuity).

Bold text indicates statistical significance at $p<0.05$

High continuity of care was defined as a Bice-Boxerman continuity of care score greater than the condition specific median. Low continuity of care was defined as having a value less than or equal to the condition specific median value.

Neighborhood was defined based on the ZIP code Tabulation Area (ZCTA).

Data on features of built neighborhood environment were obtained from the National Neighborhood Data Archive (NaNDA), whilst spatial accessibility of health care providers was obtained from a publicly available dataset by Naylor, et al. 2019.

All variables were adjusted for simultaneously in each of the models.

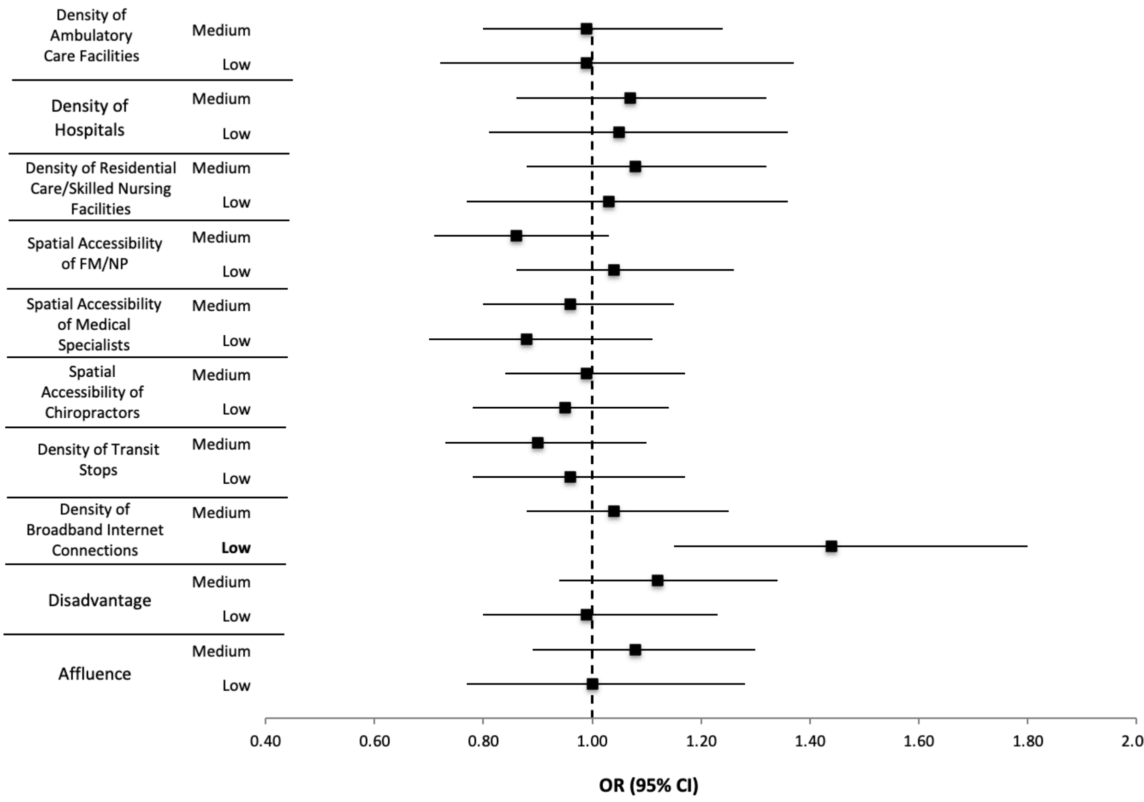


Figure III.10 Association between community characteristics and high continuity of care amongst individuals with multiple sclerosis, Optum® Clinformatics® Data Mart.
Abbreviations: Chiro, Chiropractor; CI, 95% confidence intervals; FM, Family Medicine; NP, Nurse Practitioner; OR, Odds ratio; Res Care, Residential care/skilled nursing facility; T, Tertile.
Continuity of care was computed in the 1-year post index-date based on the Bice-Boxerman continuity of care index score.
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Neighborhood was defined based on the ZIP code Tabulation Area (ZCTA).
Data on features of built neighborhood environment were obtained from the National Neighborhood Data Archive (NaNDA), whilst spatial accessibility of health care providers was obtained from a publicly available dataset by Naylor, et al. 2019.
Model was simultaneously adjusted for these neighborhood characteristics as well as for individual-level age, sex and Elixhauser co-morbidity index, as well as year.

For individuals with MS, findings for broadband internet connections were comparable when population density was added into the model for sensitivity analyses (e.g., low vs high; without population density: OR 1.44, 95% CI: 1.15, 1.80; with population density: OR 1.44, 95% CI 1.15, 1.80) (Appendix G, Table G.9).

## 3.4 Discussion

In Aim 2 of this dissertation, I characterized COC patterns amongst adults aging with physical disability and identified associated individual and community factors. Utilizing data from Optum® Clinformatics® Data Mart, I noted that even in a cohort with private health insurance, COC scores were low amongst individuals aging with disability, compared to findings in other complex care populations reported in the literature. Furthermore, those with high COC had visits dispersed across fewer different provider specialties than those with low COC, such that a greater proportion of visits were concentrated amongst Family Medicine and Internal Medicine specialties. Linking data from Optum® Clinformatics® Data Mart to community-level information on the spatial accessibility of health care providers, as well as on features of the built environment from NaNDA, I identified various individual- and- community-level factors associated with continuity of care in individuals with early-onset physical disabilities. Amongst individuals with congenital conditions (CP/SB), residing in less affluent and moderately disadvantaged neighborhoods, and having lower spatial availability to FM/NPs was associated with higher odds of concentrated care. Conversely, low density of hospitals and residential care/skilled nursing facilities in one’s neighborhood was associated with lower odds of continuous care. For those with MS and Plegia, fewer broadband internet connections and public transit stops were associated with more concentrated care patterns. Findings from this work suggest that to better understand COC in adults aging with physical disability, it is important to consider features of the built environment and spatial accessibility of health care providers, in additional to individual level factors.

To the best of my knowledge, this study is the first to extensively characterize COC in individuals aging with physical disability. Irrespective of physical disability, individuals in this study saw a variety of providers, which is consistent with the earlier conceptualization that this is complex care population given their needs to manage their primary disability, secondary health conditions and age-related diseases (Campbell and Putnam 2017). Amongst those with high COC, almost 50% of visits were to Family Medicine/General Medicine or Internal Medicine physicians. Although this has not been previously examined in a population aging with physical disability, previous work examining Usual Provider of Care (UPC) (another continuity of care metric) for individuals with multi-morbidity has noted similar findings (Bynum, et al. 2017). In a study of Medicare beneficiaries >65 years of age with two or more chronic health conditions, the primary provider of care for most patients was found to be either an Internal Medicine specialist (35%) or Family Medicine physician (28.3%) (Bynum, et al. 2017). Those with a specialist as their primary provider of care had lower COC (Bynum et al 2017). Seeing Primary Care Providers (Family Medicine or Internal Medicine doctors) as the central provider has been posited as a solution to promote better coordination for a particular individual's care. Primary Care Providers can promote better coordination by comprehensively managing conditions and referring to specialists only when necessary (gate-keepers). Therefore, at an individual-level, having a Primary Care

Provider as one's central health care provider can promote better coordination and higher COC scores for individuals within our population (Davis, et al. 2018; Bynum, et al. 2017). This may explain the greater proportion of total visits to these providers amongst individuals with high COC in this work. Future studies should use additional measures of care continuity such as the Usual Provider of Care, which examines the proportion of total visits to the most common provider to ascertain whether findings differ by whether that provider is a Primary Care Provider or Medical Specialist (Pollack, et al. 2016).

There are limited studies with which to directly compare the COC scores observed in the current study. There was one study that examined the Bice-Boxerman COC index in individuals with CP/SB, although it was a pediatric population in Taiwan (Yang, et al. 2020). The study categorized COC into low, intermediate and high, but did not provide mean scores, either overall or within categories, making direct comparisons challenging. Their intermediate and high groups had COC scores of 0.235-0.436 and 0.436+, respectively (Yang, et al. 2020). This indicates slightly higher COC scores than seen in this study population where the median overall score for those with CP/SB was 0.25 whilst the mean score was 0.14 and 0.52 for those with low and high COC, respectively. There are several studies that have examined Bice-Boxerman COC index in the general population and found them to be higher than those observed in this population aging with physical disability. For example, a study of patients with type 2 diabetes mellitus (T2DM) reported mean COC scores of 0.39 (Chen, Tseng and Cheng 2013). Amongst patients >65 years of age or older with diabetes, congestive heart failure (CHF) and chronic obstructive pulmonary disease (COPD), mean scores were 0.50, 0.55 and 0.60, respectively (Hussey, et al. 2014). Differences in the study population as well as private compared to public health insurance plans, makes direct comparisons challenging. In addition to being in different populations, these studies have been conducted in older populations, who are on publicly funded insurance plans (e.g., Medicare) whilst this study population represented those who were on a private health insurance plan. Assuming that individuals on a private health insurance plan are in better health (e.g., due to being employed or belonging to a higher socioeconomic class), one might expect the COC scores to be even lower in a population aging with a physical disability on Medicare/Medicaid, though further studies in this regard are required.

Older individuals in the current study had higher odds of concentrated care/continuous care. This is consistent with findings of previous studies in a variety of populations and using different measures of care continuity, including the Bice-Boxerman COC metric (Ryvicker and Russell 2018; Napolitano, et al. 2016; Kristjansson, et al. 2013). For example, Ryvicker and Russell (2018) found that compared to younger adults aged 65-74 years, those 75-84 years of age with CHF had higher provider continuity (Mean difference 0.0108; $p<0.0001$) with the largest effect estimates in the "oldest old" (85+ years) (Mean difference 0.0219; $p<0.0001$) (Ryvicker and Russell 2018). In the present study, there was also higher odds of continuity with older age, including a gradient observed with increasing age. Findings may be explained by psychological theories of social behavior. These theories suggest that older adults are more likely than younger adults to favor long-term relationships within limited social networks, over establishing new, and more diverse social connections (Cartensen, Isaacowitz and Charles 1999; Lockenoff and Carstensen 2004). Enduring relationships may also extend to relationships with their team of health care providers. For example.

prior research examining physician relationships has demonstrated that older adults prefer to have long-standing relationships with physicians, including one paper that found ~33% of older adults had been with their provider for over a decade (Williams-Roberts, Abonyi and Kryzanowski 2018; Williams, Haskard and DiMatteo 2007; Weiss and Blustein 1996).

Males in the present work had higher odds of concentrated care than females. This is counter to findings in the literature that have largely reported females to have higher COC scores (Ryvicker and Russell 2018; Amjad, et al. 2016). It is important to note that existing studies have largely focused on Medicare populations who would, with some exceptions, be 65+ years of age or older. The use of private health insurance data resulted in a younger cohort of women in the present work. In addition to primary and specialist care received by their male counterparts, women in the cohort may also require visits to OBGYNs for their reproductive health needs. This could increase the number of different providers they visit, thereby leading to more fragmented care as measured by the Bice-Boxerman COC index. This is supported by the fact that ~4%, 6% and 3% of total visits amongst those with CP/SB, MS and Plegia and low COC, respectively, were to a doctor who identified at least one of their specialties being an OBGYN. It suggests they play an important role in the care patterns of women. Lack of adequate training to address reproductive health needs of women with disabilities, as identified in previous studies, can additionally make it challenging to maintain consistent relationships with a single OBGYN, thereby further decreasing concentrated care for women with disabilities (Taouk, Fialkow and Schulkin 2018; Dillaway and Lysack 2015).

Large gender disparities also exist in the receipt of informal home care for disabled elderly people in the United States, with women likely to be the predominant caregivers for men with a disability (Katz, Kabeto and Langa 2000). Informal caregivers perform tasks including, but not limited to, managing healthcare appointments and transportation, which may support individuals aging with a disability in overcoming barriers to fragmented care.  Conversely, women with disabilities are more likely to be living alone and receive significantly less informal caregiving and community support (Barer 1994). This may make them particularly vulnerable to fragmented care and could further explain the findings of higher odds of concentrated care in men compared to women.

Gender differences in healthcare experiences have also been well-documented with women often assessed, diagnosed and treated with worse quality of care than their male counterparts. A literature review on gendered norms and gender bias in the treatment of pain found that men were often perceived as being stoic whereas women were described as hysterical and more sensitive to pain. Additionally, their pain was often attributed to psychological causes (Samulowitz, et al. 2018). In getting a diagnosis, women reported being mistrusted and not having their condition taken seriously (Samulowitz, et al. 2018). Women also report more negative experiences with their inpatient healthcare experiences (Elliot, et al. 2012). Therefore, women aging with physical disabilities may be more likely to switch providers, owing to more documented negative experiences within the healthcare system. Challenges getting an appropriate diagnosis for secondary health conditions could lead to seeing different healthcare providers, later diagnoses and worse COC. To better understand these differences, future studies should stratify samples by sex to better understand how differences in the relationship men and women have with medicine as an institution, and healthcare providers could contribute to observed differences in COC. Future studies using larger Medicare/Medicaid cohorts or pooling across data sources could facilitate such an analysis.

After adjusting for community-level factors, higher co-morbidity burden was significantly associated with lower odds of continuity of healthcare. This is consistent with previous work amongst older adults (Katz, McCoy and Vaughan-Sarrazin 2015; Hussey, et al. 2014; Amjad, et al. 2016). For example, a study in a population of Medicare beneficiaries with CHF, COPD and T2DM found that the Bice-Boxerman COC score was lower amongst individuals with a higher hierarchical condition category (HCC) score (Hussey, et al. 2014). The HCC is a metric that identifies patients with severe or chronic health issues, with higher scores indicative of greater health risk (Formativ Health 2018). COPD patients in the lowest quartile (less health risk) had a mean Bice-Boxerman COC index score of 0.63, compared to a score of 0.55 amongst patients in the highest quartile (highest risk) ($p<0.001$) (Hussey, et al. 2014). This may be attributed to the complexity of care providers they need to see for appropriate management of care. In a system of specialization, someone with multiple health conditions may be required to seek care from different providers to address the multitude of health needs they have (Mate and Compton-Phillips 2014). This is also consistent with prior work which identifies multi-morbidity as a driver of service utilization in Ontario, Canada (a single payer healthcare system) and has also been conceived in the Andersen and Aday Framework as a need factor for seeking care (Griffith, et al. 2019; Aday and Andersen

1974; Aday and Andersen 1981; Andersen and Newman 1973). This could be particularly true for mental health conditions. Research has shown that individuals with psychological morbidity report frequently changing of usual place of care especially in the current fragmented mental health system (Weisman, et al. 2016; Weissman, et al. 2017). In this analysis, amongst individuals with MS, a large proportion of visits were made to mental health providers across both groups. Therefore, for those with lower continuity, care may be fragmented and they may be seeking care from many providers. The findings in this study accounted for neighborhood factors that may influence referral or practice patterns, suggesting association of disease burden irrespective of where clinicians practice. While the present work was cross-sectional, concerns about reverse causality (care continuity influencing development of co-morbidity burden) were mitigated since disease burden was measured at baseline and COC scores in the following year, thereby helping to establish temporality. Nonetheless, one cannot completely rule out that fragmented care contributed to a greater disease burden.

Accounting for individual-level demographics, this study noted several community features that were associated with COC. These neighborhood features have the potential to shape healthcare decisions individuals can make including the health care providers they see for their care and the services they are able to access. For individuals aging with CP/SB, residing in neighborhoods with lower affluence scores was associated with higher odds of continuous care. Previous work in this area has noted mixed findings in regards to the relationship between income and COC. For example, work conducted in Winnipeg, Manitoba (Canada) noted that children residing in low-income neighborhoods had worse continuity of care in a single-payer publicly funded healthcare system

(Mustard, et al. 1996). This study did, however, define continuity using a metric of proportion of visits made to the most frequently seen provider, which is different from the metric in the current study. Other studies have noted an inverse association between income and COC similar to the present work. For example, work by Hussey, et al (2014) found that individuals with chronic health conditions who were in the lowest quartile of household income had the highest mean COC score compared to individuals in the highest quartile of household income (e.g., diabetes mellitus Q1 = 0.52, Q4 = 0.48; unadjusted) (Hussey, et al. 2014). Another study that considered both individual- and-environmental-level risk factors in older adults with CHF noted that higher neighborhood income was associated with lower odds of high COC, which is also consistent with the findings of my work (Ryvicker and Russell 2018).

Affluent neighborhoods represent not just the absence of disadvantage, but are characterized by distinct features such as higher levels of social control and leverage over local institutions that foster environments facilitating health (Browning and Cagney 2003). The measure of affluence in my study may also be a good proxy for health literacy. Hence, individuals residing in more affluent areas may be able to better navigate the healthcare system to access a variety of health services (Levy and Janke 2016). This could promote more active healthcare decision-making. Individuals residing in more affluent areas also have structural advantages. One of the pathways through which wealth effects health is through power, prestige, attitudes, behavior and social capital (Pollack, et al. 2013). This wealth can also afford resources and a safety net irrespective of income (National Academies of Sciences, Engineering, and Medicine 2017). Access to these resources, knowledge and networks can enhance self-efficacy and belief of one's own active role in their healthcare needs, especially amongst older adults. (Bynum, et al. 2014). These factors may promote seeking alternate care providers when one is not satisfied that their healthcare needs are being met, thereby resulting in a lower Bice-Boxerman COC score. Furthermore, residents in more affluent areas may be more likely to “shop around” for their health care providers such that they may be more likely to see a variety of providers until they find one which they like. This phenomenon has not been studied with regard to care continuity but has been established in other contexts such as amongst those with obesity (Gudzune, et al. 2014).

The findings of the relationship between affluence and COC may also be tied in with availability of specialists and disposable income. Spending for many care services is still discretionary even amongst individuals with private health insurance. Services often have co-pays, even in the case where someone has health insurance. Individuals residing in less affluent areas may be less likely to make use of these discretionary services (e.g., chiropractors), thereby decreasing the number of different providers they see and contributing to more concentrated care (higher COC). As noted earlier, practice locations for physicians, in particular specialists, are not distributed at random (Davis, et al. 2018; Khan, Trope, et al. 2018; Naylor, et al. 2019). Research conducted by Davis and colleagues (2018) compared the relationship between provider supply and county-level socioeconomic and health status (life expectancy) for Nurse Practitioners, Primary Care Physicians, Physician Assistants and Chiropractors (Davis, et al. 2018). They noted that with the exception of Nurse Practitioners, there was a higher supply of providers in areas with higher income and better health (Davis, et al. 2018). With fewer specialists practicing in one’s area, an individual may be more likely to see a smaller group of available health care providers, contributing to the higher odds of concentrated care observed in this work. Those who live in areas with greater availability of different health care providers (more affluent areas) may choose to exercise that option, thereby increasing the number of providers they see. Lastly, research has noted that social networks influence health care utilization behaviors. Therefore, dense social networks that often exist in more affluent areas may be more conducive to referrals for different health care providers leading to lower continuity of care scores (Czapka and Sagbakken 2016).

Adjusting for neighborhood affluence, I also found that individuals with CP/SB living in highly socioeconomically disadvantaged areas had lower continuity of care than those living in only moderately disadvantaged neighborhoods. Disadvantaged neighborhoods in this study were characterized by high levels of poverty, unemployment, female-headed families, households receiving public assistance income, and a high proportion of African Americans (Melendez, Clarke, et al. 2020). The disadvantage measure used in this study includes metrics which are not captured by the affluence measure and may be capturing distinct neighborhoods. Thereby it may be tapping into care experiences of these particularly disadvantaged populations. Research has found that individuals with disability, in particular older adults, tend to be more dissatisfied with their health care providers and experiences (Iezzoni, Davis, et al. 2002). Furthermore, dissatisfaction is often associated with changes in provider, so the worse healthcare experience of these disadvantaged populations may lend themselves to switching providers (Marquis, Davies and Ware Jr 1983). While I used a neighborhood-level measure of affluence and disadvantage, it is important to note that these contextual measures are derived from individual-level socio-economic information of residents and are therefore also an aggregated reflection of individual-level behaviors and socio-demographic characteristics (Diez Roux and Mair 2010).

In this work, less spatial availability of Family Medicine/Nurse Practitioner and Medical Specialists was associated with higher odds of concentrated care. Attributes of the healthcare environment, such as the supply of health care can influence health care accessibility and utilization (Continelli, McGinnis and Holmes 2010). For example, work by Harris (2003) found that past doctor-switching behavior, due to patient dissatisfaction, had the largest effect on serious consideration of alternative physicians. This result suggests that bad experiences may motivate patients to consider a broader number of alternatives (Harris 2003). With greater spatial availability, individuals may have more information and options at their disposal to switch when they are not satisfied with the care they receive. Out of network providers are generally not covered by insurance making it less likely for individuals who reside in areas with less availability of Family Physicians and Nurse Practitioners to seek care from different providers outside their communities and networks even if they are dissatisfied with their care (Medical Mutual n.d.; Iezzoni, Davis, et al. 2002). Therefore, they are likely to continue seeing the same, smaller set of providers in their communities even if not by choice, making their care appear less fragmented. Future studies should aim to understand how the dynamics of dissatisfaction with health care providers combined with a lack of availability of care providers influences preventive and diagnostic care outcomes.

Accessibility of providers can also shape the types of providers one sees and the subsequent referral patterns, which can impact a measure of COC that is based on how concentrated one’s care is amongst a small sub-set of providers. Health Maintenance Organizations (HMOs) require patients to choose a primary care provider who must refer them to specialists, thereby playing a role in coordinating care, and acting as a “gatekeeper” to subsequent providers (Blue Cross Blue Shield Network n.d.). Alternatively, other plans such as Medicare and most Preferred Provider Organizations (PPOs), don't require one to see a Primary Care Provider before seeking more specialized care (Blue Cross Blue Shield Network n.d.). In these plans, individuals are afforded more flexibility and can see any health care professional without a referral (Blue Cross Blue Shield Network n.d.). As a result, many people may see a specialist as their main doctor if they are more spatially accessible. Previous work noted that 30% of older adults with multiple chronic conditions used a specialist as their main doctor and these individuals had less continuity of care (Bynum, et al. 2017). The authors concluded that primary care providers might be providing more person-centered care and only referring out when needed, whilst specialists might be more likely to refer to other specialists (Bynum, et al. 2017). Having less spatial accessibility to specialists in one’s environment might mean that they are less likely to be the first point of contact, thereby reducing referrals to other specialists and resulting in higher COC (Bynum, et al. 2017).

In this study, I also noted that a lower density of healthcare establishments was associated with lower odds of high continuity. In settings where the providers one sees are less discretionary, such as in hospitals or residential care/skilled nursing facilities, one would expect to see more concentrated care. Greater availability of these health care establishments in their communities may afford younger and older adults with physical disabilities more access to, and use of these healthcare services when needed. In these settings, there is a care manager who assists in navigating care, allowing for greater coordination of types of providers seen and greater consistency in providers seen. Furthermore, staff often dictate care plans and arrange for follow-up care, which may not be available in the community (Hostetter and Klein 2018). Hospitals often also have care coordinators available to manage inpatient and outpatient care, which have been noted in studies to facilitate positive patient-provider relationships and reduce coordination problems among patients with complex health care needs (Williams, et al. 2019; Doty, Fryer and Audet 2012). This may explain the findings of lower density of hospitals and residential care/skilled nursing facilities being associated with lower odds of continuous care in our population with congenital conditions. While I was not able to distinguish whether greater density of these health care settings was associated with more use, future work should delve deeper into this question.

Density of broadband internet and transit stops were associated with COC for individuals with MS and Plegia. In both cases, low density was associated with higher odds of continuity. Previous studies have noted that environmental characteristics such as poor transportation infrastructure, inadequate medical services and remote treatment centers are barriers to health care access (U.S. Department of Health and Human Services 2005; Rural Health Information Hub n.d.; Mechanic and Tanner 2007; Prentice 2006). Similar factors can act as facilitators or barriers to one’s ability to see the same provider over time. To the best of my knowledge, previous studies of COC have not considered inclusion of transit at the neighborhood level. However, it is plausible that lower density of transit stops, a proxy of transit availability, is a barrier to seeing a variety of different types of providers or engaging in provider switching, instead encouraging individuals to stick with a small set of providers who are nearby. This may be particularly pertinent for individuals with physical disability who may be more likely to rely on public transit for mobility (Rosenbloom 2007). This may have made lower density of transit stops appear to promote more concentrated care. The current work was unable to examine whether this was at the expense of individual choice or positive health outcomes. Similarly, this work noted higher odds of continuity amongst those who resided in neighborhoods with low availability of broadband internet connections. Greater broadband access has been associated with greater telemedicine use (Wilcock, et al. 2019). In U.S. counties with low broadband internet availability there were 34% fewer telemedicine visits per capita compared with counties with high broadband availability (Wilcock, et al. 2019). For individuals with disabilities, telemedicine offers additional benefits such as lower cost of care, lower transportation costs, improved medication reconciliation communication, less exposure to communicable diseases, and decreased need for paid personal assistance services (Annaswamy, Verduzco-Gutierrez and Frieden 2020). Furthermore, broadband internet can support consumer health activities such as searching for, and finding providers, enabling an individual to access a variety of different health care providers (National Reseach Council 2000). Broadband access may also be a socioeconomic indicator, over and above the affluence/disadvantage measures included in the regression models, making findings similar to what was observed with the affluence measure in this work (Tomer, et al. 2020). A lack of broadband internet may also be a marker for rurality since broadband access is lower in more rural regions and there are fewer care options in more rural regions, requiring individuals to visit the small set of providers for all care needs (Tomer, et al. 2020). However, in sensitivity analysis, the inclusion of population density as a proxy for urban/rural status did not change the main findings for the broadband variable. All of this may make it more likely that individuals they seek a variety of health care providers online, thereby having less concentrated care. For individuals residing in areas without this broadband internet accessibility, access to a wide range of health care providers may not possible.

This work did identify several differences in the community features associated with high COC across disability type. While this work was not explicitly aimed at elucidating differences across disability type, reasons could include sample size, as well as differences in the quality of neighborhoods, which I was unable to elucidate in the current study. Whether the condition is acquired or congenital could also play a role. Having a congenital condition (present from birth) means an individual has been navigating the healthcare system and their environments for longer periods of time. Therefore, different factors may be more or less important for them than someone with a newly acquired disability. Individuals with CP/SB may have established relationships with a specific set of providers, as noted by higher median COC score in this cohort in the current work. Therefore, a different set of contextual factors may be important to consider for this population having navigated access to these providers for longer periods of time. Nonetheless, findings of this work do suggest that there are differences in the features of the community that are important for care continuity across the various physically disabling conditions examined. Future studies are required to explore how best to support individuals with each of the aforementioned conditions in their neighborhood environment.

*Strengths and limitations:*

This study presented with several strengths. First, use of national claims data afforded a large sample size to study these physically disabling conditions. I was also able to conduct condition-specific analyses owing to the sample size. This allowed me to examine how different features of the neighborhood environment may be important for care continuity in populations with conditions that have different development processes and etiologies. This has important implications for interventions that are targeted towards different patient populations. It can also be used for identifying individuals at risk for fragmented care to receive appropriate supports. The national sample also afforded variability in the types of neighborhood environments I was able to study.

To my knowledge, this is the first study to examine the individual- and-neighborhood-level factors associated with care continuity in individuals with CP/SB, MS and Plegia. Previous studies have been focused on other complex care populations (Amjad, et al. 2016; Ryvicker and Russell 2018; Fontanella, et al. 2014). Therefore, little is known about the care patterns and quality of care in this growing segment of the population. Furthermore, few studies have adequately studied the role of neighborhood in impacting COC, a major advantage of the current work. According to the Aday and Andersen (1974) model of access to care, there are pre-disposing (e.g., demographics), need (e.g., health conditions) and enabling (e.g., structures, distribution of health services) factors which all influence the ability of an individual to seek care (Aday and Andersen 1974). The vast majority of studies in the COC literature have studied pre-disposing and need factors. The role of enabling factors provides important insight into modifiable factors that can be target points for intervention and to help identify potentially at-risk patient populations.

I also linked data on our cohort to NaNDA to obtain objective and accurate information on neighborhood environment, reducing exposure misclassification. Self-reported measures of the neighborhood may be subject to recall bias dependent on how individuals interact with their environments and the resources available to them. For example, individuals with low COC may have a negative perception of the availability of resources in their environments. Therefore, using self-reported measures may lead to a situation where individuals with low COC report residing in poor neighborhood environments. If good environments (e.g., high density of residential care facilities in one's neighborhood) are associated with higher odds of concentrated care (which is considered to be a good outcome) (OR > 1), then misclassification could result in a larger group of individuals with low COC reporting worse environments, thereby biasing the true effect estimate away from the null and making good neighborhood environments seem more important for continuous care.

I was also able to account for important boundary effects in the measure of spatial accessibility of providers (Naylor, et al. 2019). This is important to consider given that individuals rarely navigate their environments within these pre-defined boundaries and often seek the services if health care providers outside these arbitrarily created geographic spaces. This may be particularly true for individuals who live on the edge of boundaries. Furthermore, this measure also considers a distance decay function and accounts for the fact that resources (which includes providers) are less accessible if they are further away (Naylor, et al. 2019). For individuals with physical disabilities, this could be a particularly important point owing to their limited mobility. This would afford a more accurate assessment of the role of accessibility of providers on COC.

The present study has some limitations. The study leveraged claims data and thus was limited in the measures of COC that could be examined. However, it is important to note that correlations between the Bice-Boxerman COC index used in this study and other claims-based definitions have shown correlations between 0.75 and 0.98 suggesting high concordance amongst the different measures (Pollack, et al. 2016). Nonetheless, a previous study has noted that the correlation between claims-based methods and patient-reported patient-provider continuity is not strong (Bentler, et al. 2014). Furthermore, the Bice-Boxerman COC index does not explicitly measure direct communication or co-management between clinicians (Pollack, et al. 2016). Therefore, the definition may not consider a patient's perception of a continuous relationship with their provider. Nonetheless, claims-based definitions are the only currently known method in which COC can be computed and studied in a large sample across the nation, in a feasible manner. Furthermore, it has merit in affording important insight into COC from a health systems perspective (e.g., health outcomes, testing etc.).

Secondly, the COC measure in question requires at least four visits to produce stable estimates. This might result in a study population that over-represents those that have the means and ways to see their care provider. Conversely, the restriction to at least four ambulatory care visits could be suggestive of a population with greater health needs, requiring more visits to care providers. This is a population that may have particularly complex care needs, placing them at increased risk for care fragmentation. Individuals included in the current study differed from those who were excluded due to the fact that they did not have at least 4 outpatient visits (Appendix H, Table H.10). Generally, individuals included in the cohort were older, female and had a higher number of co-morbid conditions compared to their counterparts who were excluded. Such an inclusion criteria can also impact internal validity if selection into the study is related to both the exposure (neighborhood) and outcome (Bice-Boxerman COC index). For example, if good neighborhood environments are associated with high COC (OR > 1), and by requiring individuals to have had at least 4 outpatient visits, there may be an over-selection of individuals who have the means (e.g., resources and proximity) to see the same provider (good COC) and also reside in better environments, then there is over-selection of individuals into the study cohort who reside in good environments and receive continuous care (good outcome). This would result in over-estimating the beneficial effect of neighborhood environment on COC. Conversely, if those included in the study cohort (with at least four) visits are those who have multiple chronic conditions which require a great deal of health care navigation and specialized care that may lead to fragmentation, then the study cohort may be over-selecting for individuals who reside in worse neighborhoods and have lower COC scores.

In Optum® Clinformatics® Data Mart, health care providers can report up to 2 specialties. For our analysis examining the proportion of all patient visits that were to different provider types, the first reported specialty of a physician was used. Therefore, for a clinician who had more than one specialty, we were only able to assign a visit to one specialty they reported. However, I was still correctly attributing visits to specialties reported by the physician, and not to an incorrect specialty.

Lastly, while this work addresses gaps in the COC literature by including a comprehensive set of contextual factors, there are limitations in the type of information that can be gleaned about the patient care experience in the absence of self-reported measures. COC might be explained, in part, by factors that cannot be obtained from claims data or through linkage to contextual data. Prime amongst these may be personal preferences of the person, concordance between person and provider in terms of race or gender, and shopping around for a physician until the right fit is found for personal reasons. For example, while I had information on the spatial accessibility of health care providers in a person's ZCTA, I lacked information on how the relationship between an individual and their health care providers and the availability of health care providers in their neighborhood factored into the decision-making process for the patient. Future work should aim to supplement this work with qualitative interviews to better understand whether any of these factors may also be important for COC in this population. This may also be important for mechanistic understanding of how these individual and neighborhood-level factors impact continuity scores.

In this Chapter, community-level data was linked to a cohort of individuals aging with physically disabling conditions from a private health insurance database in order to examine individual- and community-level factors associated with concentrated care. These findings contributed to the literature by characterizing COC patterns in those aging with physical disability and highlighting the complex manner in which neighborhood resources shape these care patterns. Findings from this work provide an understanding of health care continuity in a population aging with disability. Furthermore, it builds on previous published literature that focused largely on socio-demographic and clinical factors with a limited number of neighborhood-level and provider resource characteristics in other complex care populations. It highlights that for individuals with physical disabilities, the built neighborhood is important for shaping and understanding COC.

Research needs to be done to identify patient populations residing in neighborhood environments that place individuals at increased risk of care fragmentation and future studies of continuity outcomes should consider the role of the neighborhood environment. As noted in prior commentaries, policy solutions to address care fragmentation, informed by prior work on a limited number of factors associated with care fragmentation, have largely focused on shifting payment structures to ones that promote care integration, use of technologies such as Electronic Medical Records to facilitate information sharing, and advocating for decreasing reliance on specialty care (Stange 2014; Mate and Compton-Phillips 2014). These findings suggest that factors external to the healthcare system, namely the neighborhood, may also be important to factor into our thinking and understanding of care patterns for this vulnerable population. Future policies and programs aimed at promoting COC should also consider these community-level features. Furthermore, work needs to be done to better understand how the availability and accessibility, or lack thereof, of these community-level resources combined with the personal experiences in the health care system of individuals aging with physical disabilities shape their health care choices, COC patterns and ultimately health outcomes.

# CHAPTER IV:

## Relationship Between Continuity of Care and Secondary Health Conditions and Preventive Screenings Amongst Individuals Aging with a Physical Disability

### 4.0 Introduction

In Aim 2 of this dissertation, I characterized COC in individuals aging with a physical disability (Cerebral palsy, spina bifida, multiple sclerosis or plegia) using the Bice-Boxerman continuity of care (COC) index, a measure of quality of care. The results indicated that mean COC scores were low compared to other complex care populations. Furthermore, the study identified various individual and community factors associated with high continuity in this population. In particular, the study highlighted greater access to health care providers and telehealth services as being associated with visits dispersed across a greater number of providers, though it remained unclear the implications that might have on health outcomes for this population. Individuals aging with disability have complex care needs, potentially requiring consultations from a variety of specialists for appropriate care. Additionally, the attitudinal barriers they often face in their relationship with health care providers may encourage them to seek care with another provider who better meets their needs (Jackson 2004). Thus, low COC may not necessary be associated with worse health outcomes among individuals with disability, as has been noted in studies in the general population. This is because multiple care providers may be more appropriate for individuals aging with disability to meet their care needs. However, there is a paucity of empirical evidence examining the relationship between COC and the health and preventive screening outcomes for individuals aging with a disability. Aim 3 of this dissertation sought to address this important gap in the literature.

Using a cohort of individuals aging with a physically disabling condition from Optum® Clinformatics® Data Mart, this analysis examined if, and how, COC is associated with secondary health conditions as well as preventive screenings recommended for the general population. Data on health conditions and screenings were obtained from Optum® Clinformatics® Data Mart. Regression models were adjusted for important individual-level and neighborhood factors that were considered confounders of this relationship.

Findings from this chapter have the potential to inform understanding of the downstream health effects of COC in the growing population aging with disability. Results can help elucidate whether our conceptualizations of COC in the general population holds true amongst those aging with a disability. The advancement in understanding of this relationship can inform healthcare management plans for this vulnerable population to ensure their healthcare patterns are conducive to good health.

## 4.1 Background

*COC amongst adults in the general population:*

COC is the experience of a continuous, caring relationship with an identified health care professional (or professionals) over time. It can be operationalized using a variety of metrics (e.g., Bice-Boxerman COC, Usual Provider of Care), but it reflects both the interpersonal aspect of the patient-provider relationship, as well as the coordination of care over time (van Servellen, Fongwa and Mockus 2006; Guthrie and Wyke 2000; Mainous, et al. 2001; Gill and Mainous 1998; Guthrie, Saultz, et al. 2008). Higher COC is synonymous with improved relations between a healthcare provider and patient, high levels of trust, mutual understanding, and effective communication, amongst other things (van Servellen, Fongwa and Mockus 2006; Guthrie and Wyke 2000; Mainous, et al. 2001; Gill and Mainous 1998; Guthrie, Saultz, et al. 2008).

COC has been studied in a variety of complex care populations in the United States. For example, in Medicare recipients (65+ years of age) with a diagnosis of congestive heart failure (CHF), diabetes mellitus (DM) and chronic obstructive pulmonary disease (COPD), the mean Bice-Boxerman COC scores were 0.55, 0.50 and 0.60, respectively (Hussey, et al. 2014). A higher score is indicative of higher continuity. Similarly, adults with newly diagnosed diabetes had a mean score of 0.39, whilst older adults with multiple chronic conditions had scores ranging from 0.2 (for specialists) to 0.6 (for primary care) (Chen, Tseng and Cheng 2013; Bayliss, et al. 2015). Individuals with dementia tend to have higher health care costs, often seek care in outpatient or emergency department settings, and present with other co-morbid chronic health conditions. Work in this population using Medicare data noted that individuals classified as having low COC made 15.6 visits to 7.1 unique clinicians, and those with medium and high COC made 14.8 visits to 4.8 providers and 10.5 visits to 2.5 unique providers, respectively (Amjad, et al. 2016). While these results highlight a subset of studies on COC in the general population, evidence is scant in populations aging with a physical disability.

Though not directly comparable to the Bice-Boxerman COC index, continuity of primary care has also been examined using the Usual Provider of Care (UPC) index in a population with intellectual and developmental disabilities (IDD) (Plourde, et al. 2018). The UPC index examines the proportion of visits to the most frequently visited practitioner divided by all visits to clinicians. Individuals classified as having high continuity of care had scores >0.80, while those with moderate COC had UPC scores between 0.51 and 0.80, and low continuity was reflective of scores between 0 and 0.5 (Plourde, et al. 2018). In a cohort of children with cerebral palsy in Taiwan, the group with a low Bice-Boxerman COC categorization had scores less than 0.235, medium was between 0.235 and 0.436 and those in the high COC group had scores greater than, or equal to, 0.436 (Yang, et al. 2020).

These reported COC scores are generally higher (indicative of more continuous care) than those observed in Aim 2 of this dissertation which was computed using private health insurance claims data in a population aging with physical disability (median score = 0.25 for CP/SB, 0.22 for Plegia and 0.21 for MS). Crude comparison to the studies in the literature suggests that populations aging with a disability generally have lower COC scores than other complex care populations.

*Secondary health conditions in individuals with disability:*

Individuals with disabilities have high rates of premature mortality, preventable chronic conditions and mental health disorders (Campbell, Sheets and Strong 1999; Lennox and Kerr 1997; Turk, et al. 2001). Persons aging with disability are also at elevated risk of developing secondary health conditions as they age (Campbell, Sheets and Strong 1999; Altman and Bernstein 2008). These secondary conditions are defined as physical or mental health conditions originating either directly, or indirectly, from a disabling condition (e.g., compensatory muscle use in a wheelchair user resulting in pain) that affect the rest of their aging process (Campbell and Putnam 2017; Jensen, et al. 2013; Smith, Molton and Jensen 2016). Common secondary conditions include pain, mood disorders, diabetes and cardiovascular disease (Centers for Disease Control (a) 2020; Campbell and Putnam 2017). For example, adults with traumatic spinal cord injuries were found to have a higher incidence of any musculoskeletal morbidity compared to those without disability (hazard ratio [HR] 2.41, 95% confidence interval [CI] 2.30, 2.52) (Rodriguez, et al. 2021). In comparing estimates of psychological morbidity among adults with spinal cord injuries compared to their counterparts without a disability, the prevalence of any psychological morbidity (29.3% versus 11.6%), mood disorders (15.9% versus 5.4%) and central pain syndrome (1% versus 0%) were significantly higher (Peterson, Kamdar, et al. 2019).

Similar findings have been noted in a national cohort of individuals with cerebral palsy (e.g., age-standardized prevalence of men with a mood disorder was 19.5% for those with cerebral palsy and 8.1% for those without) (Whitney, et al. 2019). This also extends to incident psychological morbidity wherein these conditions have been found to be significantly higher in individuals with cerebral palsy and spina bifida (HR 1.60, 95% CI 1.55-1.65). (Peterson, Lin, et al. 2020 (b)). Similarly, adults with congenital conditions were at increased risk of any cardiometabolic disease compared to those without (HR 1.52, 95% CI 1.47-1.57) (Peterson,  Lin, et al., 2020 (a)). Individuals with cerebral palsy or spina bifida also had a higher 4-year risk of secondary health conditions such as hypertension and diabetes compared to their counterparts without a disability (Peterson, Lin, et al., 2020 (a)).

Several studies have noted that depression and anxiety are common amongst individuals with multiple sclerosis, with a lifetime prevalence of 50% for depression and 35.7% for anxiety (Siegert and Abernethy 2005; Kalb 2007). A diagnosis of depression, anxiety, or cognitive dysfunction has been shown to adversely affect a person's well-being, their perception of their disease severity, and quality of life (Joffe 2005; Lester, Stepleman and Hughes 2007). Additional conditions for which individuals with a physical disability are at elevated risk include early and late onset Alzheimer's disease and related dementias, substance abuse, and bacterial infections (Centers for Disease Control (a) 2020; Mahmoudi, Lin, et al. 2021).

Secondary conditions are considered largely preventable with access to health promoting resources including, but not limited to, adequate access to health care providers for preventive care and routine screenings as well as appropriate management (Centers for Disease Control (a) 2020). In prior qualitative work, the patient-provider relationship was one of the themes emphasized as being important for appropriate pain management (Matthias, et al. 2010). This suggests that it is important to consider the effect that a continuous patient-provider relationship, measured through COC, has on management of chronic health conditions such as pain, and to identify whether it extends to other health conditions as well.

In addition to their primary disability, persons with disability also have a higher prevalence of multi-morbidity, which is the presence of two or more health conditions. Data from Scotland noted the prevalence of multi-morbidity to be 98.7% amongst individuals with IDD (Kinnear, et al. 2018). Those with an intellectual disability presented with differing patterns of health conditions compared to the population without intellectual disabilities. Unlike the general population, where risk increases after age 50, for those with a disability, multi-morbidity was evident across the adult life course (Kinnear, et al. 2018). Similarly, findings from the Netherlands pegged multi-morbidity prevalence at 80%, with approximately 50% of individuals with IDD presenting with at least four health conditions (Hermans and Evenhuis 2014). In a clinic-based sample of middle-aged adults with cerebral palsy, prevalence of multi-morbidity ranged from 53.6% to 75.8% depending on whether the individual was obese or not (Cremer, Hurvitz and Peterson 2017). Adults with pediatric onset disabilities had almost four times the odds of multi-morbidity compared to individuals without early onset disabilities (Whitney, Whitney, et al. 2020). For individuals with a disability, this disease burden and the associated complexity of care needs has the potential to contribute to the need to see a variety of health care providers, and the subsequently lower COC scores observed in Aim 2.

### *COC and healthcare outcomes amongst adults in the general population:*

Though the literature on the health effects of COC amongst individuals aging with a disability is scant, there are a plethora of studies that have examined COC on health and health systems outcomes amongst patients with chronic health conditions in the general population.

Lower COC has been associated with incident chronic disease, mortality risk and health systems metrics such as cost, diagnostic testing frequency and hospitalizations

(Adair, et al. 2005; Bentler, et al. 2014; Adler, Vasiliadis and Bickell 2010; Amjad, et al. 2016). Utilizing self-reported patient continuity measures, higher observer-rated continuity scores were associated with a diagnosis of psychoses, and lower problem severity scores amongst individuals with a mental health diagnosis in Alberta, Canada (Adair, et al. 2005). No significant association was observed for suicide or co-morbid substance abuse. Higher patient-reported continuity was also associated with lower risk of death for Medicare beneficiaries (Bentler, et al. 2014). Findings also extend to subjective measures of health. A systematic review noted that higher reports on subjective measures of continuity were associated with greater care satisfaction (Adler, Vasiliadis and Bickell 2010). For quantitative measures, such as Usual Provider of Care, Bice-Boxerman COC and Sequential Continuity (SECON), the findings were inconsistent (Adler, Vasiliadis and Bickell 2010).

Amongst a variety of patient cohorts, including those with dementia, CHF, COPD, DM, and other chronic health conditions, lower care continuity has been associated with higher rates of hospitalization, emergency department visits and healthcare spending (Amjad, et al. 2016; Hussey, et al. 2014; Jung, et al. 2018; Barker, Steventon and Deeny 2017; Bayliss, et al. 2015; Cheng, Chen and Hou 2010; Lin and Wu 2017). Data from Taiwan examined the association between COC and avoidable hospitalizations attributed to COPD in a cohort of persons with newly diagnosed COPD (Lin and Wu 2017). Individuals classified as having medium levels of care continuity had a higher risk of avoidable hospitalizations compared to those with high COC (Lin and Wu 2017). Avoidable hospitalizations are also termed Ambulatory Care Sensitive Conditions (ACSCs) and represent those conditions for which timely and effective outpatient care can mitigate risk of hospitalization or for which timely care can prevent complications and more severe disease (University of Manitoba Center for Health Policy 2020; Agency for Healthcare Research and Quality 2001). Effects on avoidable hospitalizations were more pronounced when long-term COC scores were considered (Lin and Wu 2017). These findings were consistent with earlier work from Taiwan, in which a dose response relationship was observed between COC and ACSCs (higher COC was associated with lower rate of ACSCs) across all age groups examined (less than or equal to 18 years, 19-64 years and 65+ years of age) (Cheng, Chen and Hou 2010).

There is a growing body of evidence in older adults that COC can also be important for disease management, in particular as it relates to medications. Analysis of data from a publicly available health care system in Quebec, Canada found that patients with higher continuity, at either the physician or healthcare site level, had significantly fewer duplicated prescriptions, irrespective of their underlying chronic health conditions (Cheng and Chen 2014).

### *Age differences in chronic disease diagnoses and management in the general population:*

Research has noted differences in the time to diagnosis and management of chronic conditions for younger and older adults. Adults aged 18-39 saw a greater increase in hypertension awareness, treatment and control than older adults (age 65+) from 1999 to 2014, but hypertension control measures remained low in younger adults (Zhang and Moran 2017; Yoon, et al. 2012). Lacking a primary health care provider or lower primary care use among younger adults could partially explain findings of low diagnosis of hypertension in young adults who meet the criteria (under-diagnosis) (Steckelings, et al.

2004). Even amongst young women who did have access to care, the specialty of care provider was important (Schmittdiel, et al. 2011). In early stages of the disease, high blood pressure does not present with overt symptoms and therefore the condition may not be at the forefront for health care providers especially amongst younger populations (Mayo Clinic n.d.).

A study in primary care noted that compared to older adults, younger adults (18-31 years) were slower to get a diagnosis for hypertension (Johnson, et al. 2014). Diagnosis was quicker when young adults had underlying chronic health conditions or a female primary care provider, as they were noted to have better partnership-building skills and longer patient visits (Johnson, et al. 2014; Jolles, Clark and Braam 2012). Therefore, the literature suggests that hypertension is often under-diagnosed in young adults and knowledge of risk factors and relationships with health care providers can facilitate faster diagnosis for this population.

Similar findings have been observed for diabetes (Selvin and Parrinello 2013). Data from the National Household Interview Survey (NHIS) found that while prevalence of diabetes remained eight-fold higher amongst those 65 years of age or older (compared to younger adults aged 18-44 years), the incidence and prevalence of diabetes is increasing more rapidly amongst younger adults (National Center for Health Statistics 2013; Demmer, et al. 2013; Berkowitz, Meigs and Wexler 2013). However, analysis from the 2005-2010 National Health and Nutrition Examination Survey (NHANES), a nationally representative sample of the civilian non-institutionalized population of the United States, noted that younger individuals (30-65 years of age) had worse glycemic control compared to those >65 years or older. The authors posited that differences in treatment approaches, demographic characteristics and age-related differences in screening and diagnostic practices (given that older age could be a criterion for screening initiation) may explain these findings (Berkowitz, Meigs and Wexler 2013). Further research is required to understand whether similar patterns exist in younger versus older adults aging with disabilities and if, or how, COC could potentially shape the diagnosis process.

### *Preventive healthcare screenings:*

In addition to appropriate disease management, prevention is another important focus of public health and clinical care. Preventive health screenings are an important healthcare strategy to facilitate early diagnosis and treatment of disease, improve quality of life, and prevent premature death (Bell, et al. 2017). The aim is to detect a disease in individuals who do not have any symptoms. Early detection, when combined with lifestyle changes or disease surveillance, may reduce the risk of disease, or detect it early enough to treat it most effectively (e.g., treating cancer at an earlier stage when therapies may be more effective) (Johns Hopkins Medicine n.d.). Owing to the importance of disease screening as a quality-of-care measure, professional organizations, patient advocacy groups, and clinicians have used a combination of public policy, persuasive advertising, and direct clinical messaging, to increase uptake of screening in specific patient populations and with individual patients (Woloshin, et al. 2012).

Cholesterol and diabetes screenings are two common preventive screenings recommended in the general population. Cholesterol screening is performed via a blood draw to detect levels of cholesterol circulating in the blood. High cholesterol increases risk for cardiovascular disease (Johns Hopkins Medicine n.d.). For diabetes, clinicians can order either a fasting plasma glucose test, which measures blood glucose levels at a single time point, or an A1C test that provides average level of blood glucose over the past 3 months (National Institute of Diabetes and Digestive and Kidney Diseases 2016). Clinical practice guidelines have been created for clinicians to assist them in deciding when to initiate screenings and the frequency with which screening should be undertaken (Johns Hopkins Medicine n.d.; American Diabetes Association 2018; U.S. Preventive Services Task Force n.d.; Allan, et al. 2015).

Details of the recommended screening guidelines can be found elsewhere. Briefly, the American Diabetes Association (ADA) recommends that all adults be screened for diabetes or pre-diabetes beginning at age 45 years, irrespective of other risk factors. Individuals of any age who are overweight or obese, or have one or more additional diabetes risk factors should also be screened (Johns Hopkins Medicine n.d.; American Diabetes Association 2018; U.S. Preventive Services Task Force n.d.). If results are normal, testing is recommended every three years. In the case of abnormal results, tests can be done more frequently. For individuals who are overweight or obese and have one or more additional risk factors such as physical inactivity or first-degree relatives with diabetes and/or high cholesterol, screening is recommended earlier and more frequently (American Diabetes Association 2018). Alternatively, the U.S. Preventive Services Task Force currently only recommends screening for individuals 40-70 years of age who are overweight or obese (U.S. Preventive Services Task Force n.d.). Therefore, they recommend screening for a much narrower segment of the population.

Amongst individuals without a history of cardiovascular disease (primary prevention), cholesterol screening is recommended beginning at age 40 for men and 50 years for women (Allan, et al. 2015). Initiation of testing is recommended earlier for individuals who are at increased risk for a cardiovascular disease such as those with a family history of cardiovascular disease, diagnosis of hypertension or diabetes and/or are smokers, amongst other risk factors (Allan, et al. 2015). Repeated testing is recommended every 3–5 years for those with a Framingham risk score of less than 5%, and annually for those with a score of 5% or greater. The Framingham risk score uses data from a lipid profile combined with other risk factor information to compute a score for risk of cardiovascular disease in an individual without a history of previous cardiovascular disease (Bosomworth 2011). Computing the Framingham risk score is not recommended to inform screening decisions in those with a history of cardiovascular disease.

Screening guidelines are aimed at facilitating appropriate decision making amongst clinicians. There have been a handful of studies that have examined the facilitators and barriers for physicians to appropriately initiate screening for diabetes and cholesterol screenings in their patients. Primary Care Physicians (PCP) in Michigan were asked in semi-structured interviews about their decisions to screen a sample of patients for diabetes in line with ADA guidelines (Hafez, et al. 2017). The study found common reasons for not screening were knowledge of previously normal tests, and patient visits for other reasons (Hafez, et al. 2017). Conversely, reasons for correctly initiating screening included knowledge of previous abnormal screen and diabetes risk factors noted in the guidelines, namely weight and age (Hafez, et al. 2017). PCPs generally interpreted and correctly communicated the results to their patients. Other studies have noted that despite the presence of these clinical practice guidelines to facilitate uptake of research recommendations into clinical practice, they have failed to have a large impact in the clinical setting (Mickan, Burls and Glasziou 2011; Virani, et al. 2009; Gagliardi, et al. 2011).

### *Preventive screening in individuals with disability:*

The challenges of initiating and completing appropriate and timely preventive health screenings may be particularly poignant for individuals with a disability even in the presence of clinical guidelines. While preventive screenings are important for maintaining good health, individuals with disability are less likely to receive recommended preventive healthcare services. For example, individuals with a disability are less likely than those without a disability to receive recommended cancer screenings (Centers for Disease Control and Prevention 2020 (b)). This has implications for later-stage detection of cancer when treatment prospects are not as good and mortality rates are higher (Steele, et al. 2017; Centers for Disease Control and Prevention 2020 (b)). Amongst women aged 21 to 65 years without a disability, 81% reported getting a Pap test, compared to 66% for those with a mobility disability (Steele, et al. 2017). Similar disparities were observed for women aged 50-74 for the receipt of a mammogram (73% amongst those without a disability versus 68% for those with mobility disabilities; lowest at 61%, for those with a cognitive disability). Findings were mixed for colorectal cancer screening, where 57% of individuals without a disability received it versus 63% of individuals with mobility disabilities (Steele, et al. 2017).

Receipt of regular vaccines was also low amongst children with a disability. Only 50% of children with neurologic and neurodevelopmental conditions were found to have received the flu vaccine or to have one scheduled during the 2011-12 influenza season (Centers for Disease Control and Prevention 2013). This was lower than observed amongst children with other conditions that place them at high risk for complications from influenza (e.g., 78% of children with chronic lung disease received the flu vaccine or were scheduled to receive one during the 2011-2012 flu season) (Centers for Disease Control and Prevention 2013). A systematic review has noted mixed findings with regards to routine immunizations, with some studies finding no difference between adults with and without disability (O'Neill, et al. 2020).

Despite an elevated risk of high cholesterol (19% among those with disability compared to 17% for those without a disability) and blood pressure (37% of adults with a disability versus 29% without a disability), individuals with disability are less likely to receive preventive health services such as cholesterol and blood pressure checks (U.S. Department of Health and Human Services 2005). Falls are more common in individuals with a disability compared to the general population, yet women with disabilities are less likely to be recommended for diagnostic testing of the spine and hip and less likely to receive preventive therapy or treatment (Bachman, et al. 2006). A study conducted in Ontario, Canada, within a single-payer health care system, noted that moderate levels of disability were associated with higher odds of cholesterol testing, net of important socio-demographic and health systems factors (Lofters, et al. 2016). This suggests that perhaps those with less severe levels of physical impairment can overcome some barriers to screening, whether at the individual, clinical or neighborhood level.

*Barriers to preventive screening amongst individuals with a disability:*

Disparities in screening and receipt of preventive services may be driven by individual, environmental, physician and practice factors. In a study which asked individuals with and without a disability about the common reasons for not having received a screening (Pap test, Mammogram or Colorectal cancer screening), 9% of individuals with a disability indicated challenges getting an appointment (only 5% amongst people without a disability indicated this) and 7% reported wait times at the clinic being too long (versus 3% amongst individuals without a disability) (Steele, et al. 2017). The disparities were most pronounced for difficulties related to accessing transportation to the clinic, with 7% of those with disabilities reporting this as a challenge for not getting screened, compared to 1% of those without a disability (Steele, et al. 2017).

Furthermore, health care providers may lack awareness or the tools required to provide appropriate screening guidance for patients with disabilities, and screening settings often lack accessible medical equipment for those with physical disabilities (American Association on Health and Disability 2011). For example, health care providers may hold some misconceptions about persons with disabilities based on their identity as an individual with a disability and lack the appropriate training to provide care for individuals with a disability (U.S. Department of Health and Human Services 2005). It has been suggested that despite frequent visits to a health care provider, the focus may be on the patient's disability, missing other health procedures including recommended health screenings (American Association on Health and Disability 2011). Irrespective of whether they have a disability or not, women were more likely to get a Pap test or mammogram when it was recommended by their doctor (Steele, et al. 2017). This highlights the importance of physician's initiating the screening process for their patient, in particular those with disability. In this sense, continuous and enduring relationships with one's health care provider, which builds trust, a notion that underlies many measures of care continuity, may therefore be important to consider for screenings in individuals with disability.

In a recently conducted survey amongst practicing physicians in the United States, only 40% of clinicians reported they were confident about their ability to provide the same quality of care to patients with a disability as they do for their patients without a disability and 56% strongly agreed they welcomed patients with disability into their practices (Iezzoni, Sowmya, et al. 2021). This has been cited as contributing factors for the observed disparities in screening and preventive services affecting people with a disability (Iezzoni, Sowmya, et al. 2021). While some clinicians did not adequately account for their patient's disability when providing care, others tended to attribute all complaints to the disability and did little further investigation (e.g., little additional screening/testing) (Veltman, et al. 2001). Individuals with a disability have reported dissatisfaction with health care services along dimensions of understanding their health histories, answering medical questions and general quality of care (Iezzoni, Davis, et al. 2003). For example, a qualitative study conducted in a group of women with spinal cord injuries identified several physical and social barriers to gynecological health care (Dillaway and Lysack 2015). As it pertains specifically to social barriers, the study participants described the lack of provider education and training in caring for individuals with disability as major barriers (Dillaway and Lysack 2015).

Work aimed at identifying challenges to providing appropriate care for their patients with disability noted that physicians identify that more time is required, that they perceive their patients with disabilities as likely to age prematurely, and that they see them as having complex care needs, which are often not amenable to the tools available to family physicians (McColl, Forester, et al. 2008). They also highlighted they were less likely to examine a patient with a disability for reasons including: 1) lack of equipment that can accommodate their patient, 2) accepting a verbal report from their patient versus testing, and 3) doing partial testing when complete exams were not feasible due to challenges accessing the equipment for a patient with disability (McColl, Forester, et al. 2008). Furthermore, individuals with a disability did not get the same consideration in regard to preventive healthcare as their non-disabled contemporaries, and long-term health and maintenance of regularly scheduled care was not a priority (McColl, Forester, et al. 2008). Some reasons reported for this included patients' concerns about the number of medical appointments they had, and not wishing to come in for regular preventive care (McColl, Forester, et al. 2008). Further work is critical to elucidate how having enduring relationships between patients and their provider(s) factor into these observed disparities and provider-perceptions, in particular amongst those aging with a disability.

*COC and preventative health screenings in the general population:*

In addition to health outcomes, studies conducted in the general population have also examined the potential role of care continuity on preventive care, a metric of quality of care. Preventive care reduces risk for disease, disabilities and death and yet uptake of all appropriate clinical preventive services is low amongst Americans (Borsky, et al.

2018). To address this problem, Healthy People 2030 has placed an emphasis on increasing preventive care for individuals of all ages (U.S. Department of Health and Human Services (Healthy People 2030) n.d.). It is hypothesized that care continuity can have a positive impact on preventive services due to the personal relationship developed between a provider and patient (Gill, Mainous and Diamond, et al. 2003). Research has used the Usual Provider of Care (UPC) measure of continuity to examine receipt of eye exams, foot exams, blood pressure measurements and lipid analysis in the preceding year amongst patients with diabetes (Parchman, et al. 2002). They found a significant association between higher UPC scores and receipt of these screenings (Parchman, et al. 2002). Work conducted in a cohort of children on the extent to which continuity of provider care within a health system was associated with timely immunization administration found that higher continuity was associated with increased likelihood of being up-to-date on the Mumps-Measles-Rubella (MMR) vaccine (Christakis, Mell, et al. 2000). Findings from a study of individuals with a diagnosis of diabetes from a large, national private health plan indicate that COC was not significantly associated with routine hemoglobin tests or lipid profiles (Gill, Mainous and Diamond, et al. 2003). Other studies have found no association between continuity of primary care and mammography in populations with universal healthcare plans (Fenton, et al. 2008; Menc, Siriski and Attawar 2005). It is plausible that for high-risk and vulnerable populations such as those with disability, the benefits of continuous care for preventive screening may be even greater than in the general population.

*COC and health outcomes amongst those with a disability:*

There is limited work on COC and screening in individuals with any disability. Work conducted amongst women with intellectual and developmental disabilities (IDD) found that neither high nor moderate COC was associated with mammogram screening (Plourde, et al. 2018). Conversely, women with high and moderate COC had lower odds of receiving guideline-concordant Pap tests compared to their counterparts with low COC (Plourde, et al. 2018). The authors concluded that improving care continuity alone may not be sufficient for improving these particular screening outcomes in women with intellectual disabilities (Plourde, et al. 2018). However, this study focused only on women (owing to the screening types examined), examined a small subset of preventive screenings, and was unable to account for important contextual factors that may confound the relationship between COC and access to screenings. Amongst Medicaid recipients in Florida with IDD, high COC was associated with a 28% lower likelihood of an emergency room visit (Wood, et al. 2007). Individuals with physical disabilities may face distinct challenges to accessing health care services, which may vary across whether the condition is acquired or congenital.

In a population of children with a diagnosis of cerebral palsy conducted using Taiwan's National Health Insurance Research Database (single payer health insurance), low COC was associated with higher medical costs and a greater number of days spent in hospital over five years of follow-up compared to their peers with higher COC (Yang, et al. 2020). However, findings from a pediatric population may not apply to adults aging with disability who also contend with age-related chronic conditions and secondary conditions due to their primary disability and the aging process (Campbell and Putnam

2017). Furthermore, whilst cost-related metrics are important to consider for health systems sustainability, work is needed to examine metrics that are important for quality of life and successful aging for individuals with physical disabilities. The scant evidence and gaps in the literature suggest further work is required to examine the relationship between care continuity and various routine screenings in a population aging with physical disability.

Findings from Aim 2 of this dissertation highlighted that individuals aging with disability had low COC scores compared to older adults in the general population, both with and without chronic health conditions. The median score in a population with private health insurance was noted to range from 0.22 to 0.25 amongst individuals with cerebral palsy, spina bifida, multiple sclerosis and plegia. Additionally, individuals with disabilities have complex health care needs, including an increased risk of developing age-related and secondary health conditions. For this population, appropriately managing these health care needs might require multiple providers. Therefore, it was unknown how COC shapes screening and health outcomes in this vulnerable population aging with a disability. Aim 3 of this dissertation looked to address this gap by examining the relationship between COC and preventive screening and chronic health outcomes. This association was examined in the overall cohort and stratified by age. I hypothesized that high continuity would be inversely associated with secondary chronic health conditions and higher odds of screening. I also hypothesized that these relationships would be driven largely by younger adults aging with disability who may benefit more from care continuity for prevention and early detection. This information is crucial for understanding how care patterns play a role for successful aging in this group of adults with physical disability.

## 4.2 Methods

*Data source and cohort creation:*

I leveraged the same cohort detailed for Aim 2 of this dissertation. Briefly, I used data from Optum® Clinformatics® Data Mart, a private insurance claims database containing records of >80 million individuals across the United States (Optum 2017; Mahmoudi and Kamdar 2020). International Classification of Diseases, 9th edition, Clinical Modification (ICD-9 CM) codes were used to identify adults (age 18+) with a diagnosis of one of the following physically disabling conditions: 1) Cerebral palsy (CP) or spina bifida (SB), 2) Multiple sclerosis (MS), or 3) Plegia. Individuals with other disabling conditions and those with more than one disability were not included.

Individuals had *at least* four years of enrolment on the plan without any lapses to ensure stable membership on the insurance plan, and allow for adequate follow-up time for all cohort members. One year in this enrolment window was required for the "look-back" period, which was used to examine co-morbidity burden, and for acquired conditions, to ensure they were incident disabling conditions. For acquired conditions, this look-back period was in the year preceding the qualifying diagnostic code, whilst for CP and SB we used the one-year following the diagnostic code as the period to look for co-morbidities. The date that met these criteria was considered the "index date" for analysis (entry date assigned to the individual into the study cohort). As noted earlier, for acquired conditions (MS and Plegia), I restricted inclusion to those individuals who were less than or equal to 50 years of age at index date, in line with traditional frameworks for aging with disability in which the disability occurs within the first 4-5 decades of life (Verbrugge and Yang 2002; Vergrugge, Latham and Clarke 2017).

Given that the primary exposure in this work was continuity of care (COC), the cohort was restricted to persons with a minimum of four outpatient/office visits in the one year following their index date (Appendix D, Figure D.8). This is because the COC measure used in the current study requires at least 4 outpatient visits to produce stable estimates (Pollack, et al. 2016; Amjad, et al. 2016).

*Primary Exposure – COC:*

The exposure measure of interest was COC, measured using the Bice-Boxerman COC index. The index represents the extent to which an individual's total number of visits for an episode or illness, over a specified time period are concentrated with a small set of health care providers (Bice and Boxerman 1977; Pollack, et al. 2016). It considers both the total number of visits to health care providers in a specified time as well as the number of visits to each individual provider.

The formula is as follows (Pollack, et al. 2016):

Formula IV.1 Bice-Boxerman Continuity of Care Index (Pollack, et al. 2016)

$(\sum_{i=1} n_i^2) - N/(N(N-1))$

Where,
$n_i$ = number of visits that the individual has with the *i*th physician
N = total visits

The continuous score ranges from 0 to 1. A higher score (better continuity of care) is assigned to individuals who have visit patterns in which a larger share of their total visits is concentrated amongst fewer providers (Amjad, et al. 2016). A person who receives all their care from a single provider over a given time period would receive a Bice-Boxerman COC index score of 1 (perfect continuity of care), whilst an individual who sees a different provider at each visit receives a score of 0.

The Bice-Boxerman COC index is a commonly employed measure of COC when using administrative claims data for studies. Claims data, such as Optum® Clinformatics® Data Mart, captures details on each visit/interaction with the health care system, in addition to details on the provider or facility that provides the service. In Optum® Clinformatics® Data Mart each provider is assigned a unique, de-identified number that enables identification of visits to the same provider over time. This information was used to calculate the Bice-Boxerman COC index in the current study.

I computed the COC in the first year after the index date using all ambulatory/office visits with health care providers for each individual. I considered outpatient visits to any specialty to: 1) capture the range of health care providers individuals aging with disability should be seeing, and 2) accurately compute a COC score consisting of the different types of providers they might see for the outcomes of interest. Since the Bice-Boxerman COC score has no inherent clinical meaning, I converted it from a continuous variable for ease of interpretation, which is consistent with previous studies (Amjad, et al. 2016). There is no agreed upon cut-off(s) for this COC measure with studies using a variety of thresholds operationalizing the variable (Amjad, et al. 2016; Cohen-Mekelberg, et al. 2020; Plourde, et al. 2018). Consistent with previous studies, I operationalized COC into a binary variable, based on the condition-specific median value (Cohen-Mekelberg, et al. 2020). For each condition, individuals with COC scores greater than the median were considered to have high COC, whilst those equal to, or below the median were considered to have low COC. The median scores were 0.25, 0.21 and 0.22 for individuals with CP/SB, MS, and Plegia, respectively.

*Primary outcomes:*

I hypothesized that continuous, enduring relationships between a patient and their provider would promote improved communication and more appropriate management of their primary disability as well as other healthcare needs. This would result in improved quality of care and better management of conditions stemming from their disability (van Servellen, Fongwa and Mockus 2006; Guthrie and Wyke 2000; Mainous, et al. 2001; Gill, Mainous and Diamond, et al. 2003; Guthrie, Saultz, et al. 2008). Therefore, I selected two broad categories of outcomes that could be proximally associated with COC and are important for successful aging: 1) secondary health conditions for which individuals aging with disability are at increased risk, and 2) preventive health screening that are recommended for individuals in the general population as well.

Secondary health conditions:

As noted earlier, secondary health conditions originate directly or indirectly from a disabling condition and affect the rest of the aging process (Campbell and Putnam 2017). From a health systems perspective, these are important to consider given that they are preventable for individuals with a disability if they have access to health promoting resources, adequate access to health care providers for preventive care/routine screenings, and appropriate management (Centers for Disease Control 2020(a)). These are facets which continuous care can help to facilitate.

In the present paper, I focused on four secondary health conditions: 1) type 2 diabetes mellitus (T2DM), 2) hypertension, 3) mood disorders, and 4) pain. These conditions are those for which individuals with disability, including those aging with a physical disability, are at increased risk of developing (Centers for Disease Control 2020(a); Campbell and Putnam 2017; Peterson, Lin, et al. 2020 (a); Peterson, Lin, et al. 2021). These conditions were identified using a single ICD-9-CM or ICD-10-CM code in Optum Clinformatics® Data Mart in any position (e.g., primary diagnosis, secondary diagnosis) (Appendix I, Table I.11). A binary indicator was created for presence of the outcome. For T2DM and hypertension, the primary outcome was time, in days, to incident condition following the assigned index date. For mood disorders and pain, time to the event is more difficult to identify. Therefore, the primary outcome was the absence or presence of a diagnostic code for the condition during the follow-up period.

### Screening outcomes:

I also considered two preventive screening measures: 1) cholesterol, and 2) diabetes. These screening measures are recommended for individuals in the general population and appropriate receipt of these reflect good quality of care (Allan, et al. 2015; American Diabetes Association 2018). While the diabetes screening recommendations by the American Diabetes Association (ADA) and the United States Preventive Services

Task Force vary, this study still considered this measure in the entire population given: 1) the burden of diabetes amongst individuals with disability, 2) that clinicians may use either organizational guidelines in their clinics to guide their screening decisions (including the broader one proposed by the ADA), and 3) the Task Force is currently considering whether to modify their guidelines which would align their recommendations more closely with that of the ADA (Allan, et al. 2015; American Diabetes Association 2018; U.S. Preventive Services Task Force n.d.). Furthermore, this metric has been considered in previous studies amongst individuals with a disability (Lofters, et al. 2016). These screening outcomes were identified in Optum Clinformatics® Data Mart using Current Procedural Terminology (CPT®) codes version 4 (CPT-4) (Appendix I, Table I.12). CPT codes offer doctors and health care professionals a standardized way for coding medical services and procedures, including lab testing (American Medical Association n.d.). For each screening outcome, a binary variable was created for whether the individual had at least one relevant code for cholesterol or diabetes screening during follow-up.

*Covariates:*

The selection of covariates for inclusion in the regression models was conceptually driven, and informed by findings in Aim 2 of this dissertation. I accounted for individual- and neighborhood-level factors hypothesized to be directly, or indirectly associated with COC (exposure), and also the availability and/or accessibility of healthcare services and providers that might influence diagnoses of secondary health conditions or receipt of preventive health screenings (outcomes) (Ryvicker and Russell 2018; Napolitano, et al. 2016).

Baseline individual-level demographic and clinical information were obtained from Optum® Clinformatics® Data Mart. To protect the privacy of individuals on the plan, Optum® Clinformatics® Data Mart does not provide researchers with information on race/ethnicity or individual-level income and education when geographic identifiers are provided. Therefore, I could only include age and sex as individual-level demographic variables in our models. I modeled age, in years, at baseline as a categorical variable (18-40, 41-50, and 51+ for congenital conditions only), except for age-stratified analysis, in which age was included as a continuous variable to account for any residual confounding within the large age strata. Sex of the patient was operationalized as male or female. To capture co-morbid disease burden, Elixhauser co-morbidity index (ECI) was included as a continuous variable. The ECI is a method of categorizing comorbidities of individuals based on diagnoses codes found in administrative data (Quan, et al. 2005). Each of the 31 conditions included in the index are coded as being present or not and summed together, with each condition afforded equal weight (Quan, et al. 2005). The ECI is predictive of mortality and the use of hospital resources (Menendez, et al. 2014; Chu, Ng and Wu 2010; Chang, et al. 2016). In the current study, I computed the ECI using information obtained during the look-back period. For the secondary chronic health conditions, only, I included modified versions of the ECI in which I excluded conditions in the measure that were correlated with the outcomes of interest (Appendix C, Table C.5).

I also included covariates for neighborhood health care resources, which could influence both COC and the health outcomes under study. The neighborhood-level covariates were a subset of those used and described in detail in Aim 2. Briefly, I assumed an individual's ZIP code was a proxy for their neighborhood, given that it was the smallest spatial scale available in Optum® Clinformatics® Data Mart. ZIP codes are designated mail routes by the United States postal service (United States Census Bureau 2015; United States Census Bureau 2020). The data sources from which I obtained the contextual data created the variables at the ZIP Code Tabulation Area (ZCTA) level. ZCTAs are generated by the United States Census Bureau and are generalized representations of ZIP codes (United States Census Bureau 2015; United States Census Bureau 2020). Therefore, a crosswalk file created by the United States Census Bureau was used to link the ZIP Codes of individuals in our cohort to a ZCTA, and subsequently their neighborhood characteristics.

Features of the neighborhood environment were obtained from the National Neighborhood Data Archive (NaNDA), a publicly available data archive that contains information on contextual variables at various spatial scales across the United States including ZCTA (Social Environment and Health n.d.). The health services included from NaNDA were hospitals and ambulatory care facilities, expressed as density per square miles (Khan, et al. 2020). In NaNDA, these data were obtained directly from National Establishment Time Series (NETS) (Walls 2015). Details on NETS can be found elsewhere but briefly, it provides information on businesses, non-profit and government establishments and sole proprietors with establishments identified using North American Industry Classification System (NAICS) codes (Walls 2015).

I also included measures of neighborhood socioeconomic disadvantage and affluence that may influence the availability of resources in local areas. These measures were created in NaNDA using source data from the United States Decennial census and the American Community Survey (ACS) (Melendez, Clarke, et al. 2020). Given that previous studies have shown affluence and disadvantage to be distinct constructs, I included both in the model concurrently (Browning and Cagney 2003). Neighborhood disadvantage was an average of the following: 1) proportion of female headed families with children, 2) proportion of households with public assistance income or food stamps, 3) proportion of families with income below the federal poverty level, 4) proportion of population 16+ who are unemployed, and 5) proportion of non-Hispanic Black individuals (Melendez, Clarke, et al. 2020). Affluence was an average of three census indicators: 1) proportion of households with income greater than $75,000, 2) proportion of population aged 16+ years who are employed in professional or managerial occupations, and 3) proportion of adults with Bachelor's Degree or higher (Melendez, Clarke, et al. 2020). Values ranged from 0 to 1 with higher scores indicating higher levels of disadvantage or affluence. To facilitate interpretation and to account for the fact that neighborhood effects are often most pronounced at the extremes, I operationalized all variables from NaNDA as tertiles (T1=lowest; T3=highest) (Spring 2018; Do, Wang and Elliot 2013; N. Krause 1996).

In addition to availability of built features of the neighborhood environment, I also included information on spatial availability of specific types of health care providers. Visits to these providers may be important for shaping care patterns amongst individuals aging with disability and also be associated with the outcomes of interest (confounders). Therefore, this study also included measures of spatial accessibility to select health care providers. The provider specialties were informed by: 1) literature on care providers that are considered to be natural sources of supplementary or conventional treatment for those with musculoskeletal and nervous system conditions, 2) conversations with clinicians, and 3) preliminary descriptive statistics conducted in our study cohort (Warmbrodt 2020; Krauss, et al. 1998; Hurvitz, et al. 2003; Carson, et al. 2009; McKay and Langworthy 2011). The selected providers were Chiropractors, Medical Specialists, Family Medicine doctors and Nurse Practitioners.

The measure of spatial accessibility was created and made publicly available at the ZCTA-level by Naylor and colleagues (2019) and created using data from the National Plan and Provider Enumeration System (NPPES) (database with identifier for health care providers) and Medicare claims data (Naylor, et al. 2019; US Department of Health and Human Services 2016). The final Variable-distance Enhanced 2 step Floating Catchment Area method (VE2SFCA) formula used to compute this measure consisted of two components: 1) distance decay weights which account for travel time between a population site and practice location within a given travel time buffer, and 2) a metric of provider-to-population ratio which accounts for the distance decay weighted population for each ZCTA centroid (Naylor, et al. 2019) (Formula III.2). This measure accounts for the fact that individuals see providers outside of artificially imposed boundaries (e.g., ZCTAs) and that providers are less accessible the further away they are (distance decay function) (Naylor, et al. 2019).

Similar to NaNDA data, the variables for spatial accessibility of health care providers were operationalized as tertiles (T1 = lowest; T3 = highest). Availability of Family Medicine doctors and Nurse Practitioners were highly correlated but they often work together to care for patients in clinics affiliated with academic institutions, whilst in some other areas, Nurse Practitioners provide substantive outpatient care (Spetz, Skillman and Andrilla 2017). Therefore, the decision was made to include both. To simultaneously account for both provider types while addressing co-linearity, I created an index that accounted for the combined spatial accessibility of Family Medicine doctors and Nurse Practitioners based on tertiles for each variable. I took the individual tertiles of spatial accessibility of FM specialties and NPs and created three mutually exclusive categories based on their intersection: low, medium or high based on the intersection of the tertiles (Appendix F, Figure F.9).

*Statistical analyses:*

I examined baseline individual-level characteristics (age, sex and ECI) overall and across those classified as having low and high COC in the one-year post-index date. Chi-square tests for binary and categorical variables and 1-way ANOVA for continuous variables were used to examine whether characteristics differed significantly across COC category.

All descriptive statistics and regression models were specific to each physically disabling condition owing to different disease etiologies, differences in acquired versus congenital conditions, and potentially different disease trajectories and health care needs.

<u>Analyses for incident health conditions (diabetes and hypertension):</u>

Cox proportional hazard models were used to model the time to incident hypertension and T2DM. For each outcome, individuals with prevalent disease, as determined by having a diagnostic code for the condition of interest in the look-back period detailed earlier, were excluded from the condition-specific model. To mitigate reverse causality, in which the diagnosis or the process of obtaining a diagnosis (which might require visits to various clinicians) of hypertension or T2DM could have influenced COC scores, I excluded individuals who had a diagnosis of hypertension or T2DM in the 1-year post-index which is the period of time during which COC scores were also computed. Therefore, the first year after the index date was used to compute the COC score and the subsequent 2-years were used for follow-up. The follow-up period was capped at two years to ensure equal follow-up for all members. A schematic of the analytical plan can be found in Appendix J, Figure J.10.

Individuals were considered at-risk until the diagnosis of interest or right censored due to end of follow-up, whichever occurred first. Regression models were adjusted for age, sex, and ECI at the individual-level, and neighborhood-level density of ambulatory care centers and hospitals, affluence and disadvantage, and spatial accessibility of medical specialists and family physicians/nurse practitioners.

I examined these relationships overall, and stratified by age (< 40 and 40+ years at baseline). This was done to assess whether COC was especially important for certain age groups. Clinical recommendations for initiating screening for common chronic conditions (E.g., diabetes, hypertension, cholesterol) begin around the age of 40 years, which may influence detection of asymptomatic disease (U.S. Preventive Services Task Force 2016; Allan, et al. 2015; American Diabetes Association 2018). Furthermore, this population has a higher burden of risk factors so clinicians might initiate screening at earlier ages (Campbell and Putnam 2017). Conversely, inappropriate age-based testing could also be a concern. Age-stratified analyses enabled me to examine some of these possibilities.

The Proc Phreg procedure was used to run the Cox regression models and cluster-robust standard errors were used to account for the clustering of individuals within ZCTAs (Equation IV.8). I estimated separate Cox Proportional Hazards regression models for each of the outcomes (T2DM and Hypertension) and reported hazard ratios (HR) and corresponding 95% confidence intervals (CI).

Equation IV.8 Cox Proportional Hazards Regression model examining the association between Bice-Boxerman Continuity of Care Index and incident secondary health conditions (hypertension and diabetes) adjusted for individual and neighborhood-level covariates

$$h(\text{Hypertension}) = h_0(t)\exp[\beta_1(\text{COC high})_i + \beta_2(\text{Sex})_i + \beta_3(\text{Elixhauser Comorbidity Index})_i \ldots\ldots\beta_x(\text{Density of Hospitals T1})_{ij} + \beta_x(\text{Density of Hospitals T2})_{ij}\ldots\ldots$$

Where,
h denotes hazard of hypertension
*i* denotes subject
*j* denotes the cluster (ZCTA)
T1 represents low density, T2 represents medium density. The reference group was T3 (high density).

Analyses for potentially prevalent health conditions (mood disorders and pain):

Logistic regression models were used to examine the relationship between COC (high vs. low) and mood disorders and pain, separately. Cox Proportional Hazards models were not used owing to challenges in ascertaining incidence of these conditions and time-to these events being less relevant clinically for these conditions. All individual-level and contextual covariates were entered simultaneously into the model. The variables entered into the regression models at the individual-level were age, sex and ECI. Community-level characteristics included in the model were affluence, disadvantage and density of ambulatory care centers as well as spatial accessibility of medical specialists and family medicine doctors/nurse practitioners. For the outcome of pain, I also included spatial accessibility of chiropractors as they play an important role in management of a physical disability that might result in central pain and visits with them could also shape care patterns thereby impacting COC (Carson, et al. 2009).

Consistent with the analysis of incident secondary conditions, I excluded individuals from the analysis who had their first event during the 1-year post index during which the COC measure was calculated. This was done to mitigate reverse causality, in which the diagnosis or the process of obtaining a diagnosis (which might require visits to various clinicians in search of answers to symptoms) could have impacted the COC score itself (which is based on number of visits to different providers). This may be especially true for psychological conditions in which there are many structural, cultural and cost factors that make seeking care for mental health difficult and may impose challenges on receiving a diagnosis (Carbonell, Navarro-Perez and Mestre 2015). A schematic of the analytical plan can be found in Appendix J, Figure J.10.

I modelled the odds of having a diagnosis during the 2-year follow-up using Proc Genmod and specifying the “descending” option in SAS. I accounted for correlation amongst individuals residing in the same ZCTA using Generalized Estimating Equation (GEE) logistic regression models. The responses from the same cluster are assumed 1) to be correlated, and 2) to follow a given correlation structure. The parameter estimates from GEE models describe the effect estimate for each predictor variable, averaged across all clusters (ZCTAs). I specified a binomial distribution and a logit link function (Equation IV.9). I obtained and reported adjusted Odds Ratios (OR) and 95% Confidence Intervals (CI).

For each physically disabling condition, I conducted the analysis overall and stratified by age (<40 and 40+ years of age at baseline).

Equation IV.9 Logistic Regression model examining the association between Bice-Boxerman Continuity of Care Index and odds of secondary health conditions (pain and mood disorders) adjusted for individual and neighborhood-level covariates

$$\text{Logit}(\Pr(\text{Pain}_{ij}=1)) = \beta_0 + \beta_1 (\text{COC high})_i + \beta_2 (\text{Density of Ambulatory Care Centers T1})_{ij} + \beta_3 (\text{Density of Ambulatory Care Centers T2})_{ij} + \beta_4 (\text{Elixhauser Comorbidity Index})_i + \beta_5 (\text{Age 41-50 years})_i \ldots + \beta_x(\text{Chiropractor T1})_{ij} + \beta_x(\text{Chiropractor T2})_{ij} + \ldots..$$

Where,
Y denotes probability of Pain diagnosis (vs not)
*i* denotes subject
*j* denotes the cluster (ZCTA)
T1 denotes low density, T2 is high density and the reference group is T3 (high density).

Cholesterol and diabetes screening:

For diabetes and cholesterol screening, I computed and reported the mean number of tests administered across those with and without high COC. I compared this across COC category for each preventive test using a 1-way ANOVA. Logistic regression was used to examine the relationship between COC (high vs. low) and receipt of each of the screening outcomes. All individual-level and contextual factors were entered simultaneously into the model. I included age, sex and ECI at the individual-level. At the neighborhood-level, the models included density of ambulatory care services and spatial accessibility of Medical Specialists and Family Medicine/Nurse Practitioners.

Unlike the other outcomes, individuals who had a cholesterol or diabetes screening completed in the year following their index date were not excluded since these screenings are normally done at routine medical appointments. Furthermore, in and of themselves, these screenings do not have pre-clinical periods that would influence the number of visits made to particular healthcare providers. They were also identified using CPT codes and would not factor into the way COC is computed in claims data.

I ran separate models for cholesterol and diabetes screening, and modelled the odds of having *any* screening during the 3-year follow-up using Proc Genmod and by specifying the “descending” option in SAS. I accounted for correlation amongst individuals residing in the same ZCTA using Generalized Estimating Equation (GEE) logistic regression models. I specified a binomial distribution and a logit link function (Equation IV.10). Adjusted Odds Ratios (OR) and 95% Confidence Intervals (CI) were reported.

Equation IV.10 Logistic Regression model examining the association between Bice-Boxerman Continuity of Care Index and odds of preventive screening (cholesterol and diabetes) adjusted for individual and neighborhood-level covariates

$$\text{Logit}(\Pr(\text{Cholesterol Screening}_{ij}=1)) = \beta_0 + \beta_1 (\text{COC high})_i + \beta_2 (\text{Density of Ambulatory Care Centers T1})_{ij} + \beta_3 (\text{Density of Ambulatory Care Centers T2})_{ij} + \beta_4 (\text{Elixhauser Comorbidity Index})_i + \beta_5 (\text{Age 41-50 years})_i \ldots + \beta_x(\text{Family Medicine/Nurse Practitioner T1})_{ij} + \beta_x(\text{Family Medicine/Nurse Practitioner T2})_{ij} + \ldots..$$

Where,
Y denotes probability of cholesterol screening (vs not)
*i* denotes subject
*j* denotes the cluster (ZCTA)
T1 represents low density, T2 represents medium density and the reference was T3 (high density).

The analysis was conducted in the overall cohort and stratified by age group (<40 years and 40+ years of age). The information required to assess additional criteria that would make someone eligible for screening initiation at earlier ages was not present in these data (e.g., family history, obesity, smoking status) (Allan, et al. 2015; American Diabetes Association 2018). Therefore, I used an age criterion alone to determine eligibility for appropriate screening. For diabetes screening I leveraged an age-based definition (age 40) that encompasses the screening recommendations of both the ADA as well as the United States Preventive Services Task Force (American Diabetes Association 2018; U.S. Preventive Services Task Force n.d.). The data was lacking to compute an individual's Framingham risk score to inform whether more frequent cholesterol screening was required as well as information that would warrant more frequent diabetes screening in accordance with guidelines (Allan, et al. 2015; American Diabetes Association 2018). Therefore, a 3-year time frame during which to look for screening outcomes was chosen, as has been previously done when using claims data (Lofters, et al. 2016).

I also examined these associations in a younger population (<40 years of age). This allowed for me to examine patterns of appropriate and inappropriate screening as well as gain insight into how COC shapes the decision around preventive screening that clinicians make in a particularly vulnerable population. Research has also demonstrated that individuals with a disability are at elevated risk for adverse health events, including many risk factors that the guidelines stipulate should be grounds for initiating screening at an earlier age (e.g., obesity, smoking, physical inactivity) and that clinicians consider them a particularly vulnerable population who experience accelerated aging (Veltman, et al. 2001; McColl, Forester, et al. 2008). Therefore, healthcare providers may consider initiating screening earlier and this may vary by whether they have a continuous relationship with their healthcare provider (be it a specialist or primary care doctor). A schematic of the analytical plan can be found in Appendix J, Figure J.10.

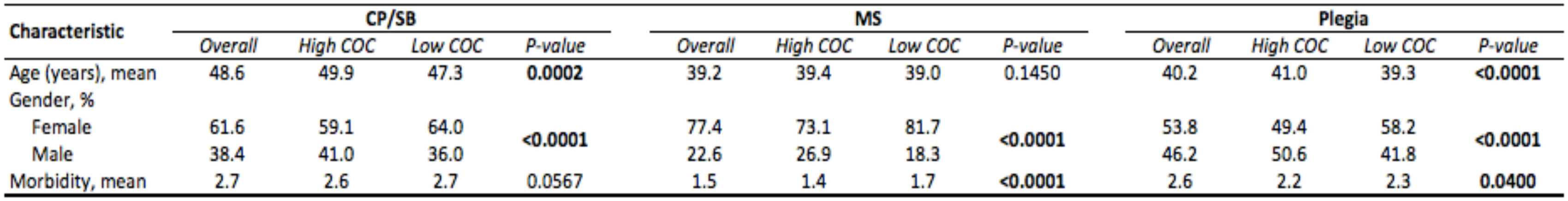
Statistical significance was set at $p<0.05$ and tests were all two-sided. All analyses were conducted in SAS version 9.4 (SAS Institute, Cary, NC).

## 4.3 Results

*Cohort description:*

Table IV.14 presents the baseline characteristics of the cohort prior to analytical exclusions. Individuals with CP/SB were older (mean age = 48.6 years) compared to those with Plegia (mean age= 40 years) and MS (mean age =39 years). The younger cohorts of individuals with Plegia and MS are likely driven by the fact that individuals with acquired disabilities had to have the condition flag by age 50 years, with no such exclusion placed for congenital conditions. The study cohort was predominantly female, especially for those with an MS diagnosis. Overall, the mean number of comorbid conditions was >1 for each of the conditions, with highest disease burden observed amongst individuals with CP/SB and Plegia (CP/SB = 2.7; Plegia = 2.6) (Table IV.14).

Table IV.14 Baseline characteristics of individuals aging with cerebral palsy/spina bifida, multiple sclerosis and plegia, overall and across those with high and low Bice-Boxerman continuity of care index score, Optum® Clinformatics® Data Mart



| Characteristic | CP/SB | | | | MS | | | | Plegia | | | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|
| | *Overall* | *High COC* | *Low COC* | *P-value* | *Overall* | *High COC* | *Low COC* | *P-value* | *Overall* | *High COC* | *Low COC* | *P-value* |
| Age (years), mean | 48.6 | 49.9 | 47.3 | **0.0002** | 39.2 | 39.4 | 39.0 | 0.1450 | 40.2 | 41.0 | 39.3 | **<0.0001** |
| Gender, % | | | | | | | | | | | | |
| Female | 61.6 | 59.1 | 64.0 | **<0.0001** | 77.4 | 73.1 | 81.7 | **<0.0001** | 53.8 | 49.4 | 58.2 | **<0.0001** |
| Male | 38.4 | 41.0 | 36.0 | | 22.6 | 26.9 | 18.3 | | 46.2 | 50.6 | 41.8 | |
| Morbidity, mean | 2.7 | 2.6 | 2.7 | 0.0567 | 1.5 | 1.4 | 1.7 | **<0.0001** | 2.6 | 2.2 | 2.3 | **0.0400** |

Abbreviations: COC, continuity of care; CP/SB, Cerebral Palsy/Spina Bifida; MS, Multiple Sclerosis.
Continuity of care was calculated in the 1-year post index using the Bice-Boxerman continuity of care index.
High continuity of care was defined as a Bice-Boxerman continuity of care score greater than the condition specific median. Low continuity of care was defined as having a value less than or equal to the condition specific median value.
Morbidity was computed based on the Elixhauser comorbidity index.
Bold text represents statistical significance at the p<0.05 level. P-value computed based on bivariate analyses comparing those with low and high continuity of care scores.

Table IV.14 also presents baseline characteristics of each physically disabling cohort across those who were classified as having low and high COC in the one year following their index date. Across all individuals with CP/SB, MS and Plegia, individuals classified as having high COC were older (e.g., Plegia: High COC = 41 years, Low COC = 39.3 years; $p<0.0001$), although this was not significantly different for the MS cohort in univariate analysis. Females were disproportionately represented amongst those with low COC, irrespective of their physically disabling condition. For example, amongst individuals with CP/SB, 59.1% of individuals with high COC were female compared to 41% who were male. However, in this same cohort, for those with low COC, 64% were female and a comparably lower 36% were male ($p<0.0001$) (Table IV.14). Disease morbidity was also higher amongst those with low COC across the CP/SB, MS and Plegia cohorts.

*COC, secondary health conditions and preventive screening:*

Applying the condition-specific analytical exclusion criteria (e.g., excluding those with an event in the same year as the COC score was computed) decreased the difference in event rates between those with low and high COC (Appendix J, Table J.13). For example, prior to any exclusions in the cohort with CP/SB, 54% of individuals with low COC had a hypertension diagnosis compared to 62.1% with high COC (difference of ~8%). After applying the exclusion criteria used for incident hypertension that difference was 3% (15.9% in those with low COC and 18.9% in those with high COC). Individuals with low COC were most likely to be excluded, which could be attributed to higher disease burden resulting in more fragmented care (lower COC scores). This further affirms the need to exclude individuals who had the event of interest in the one year following index in which the COC score was computed to mitigate reverse causality.

Receipt of preventive screenings:

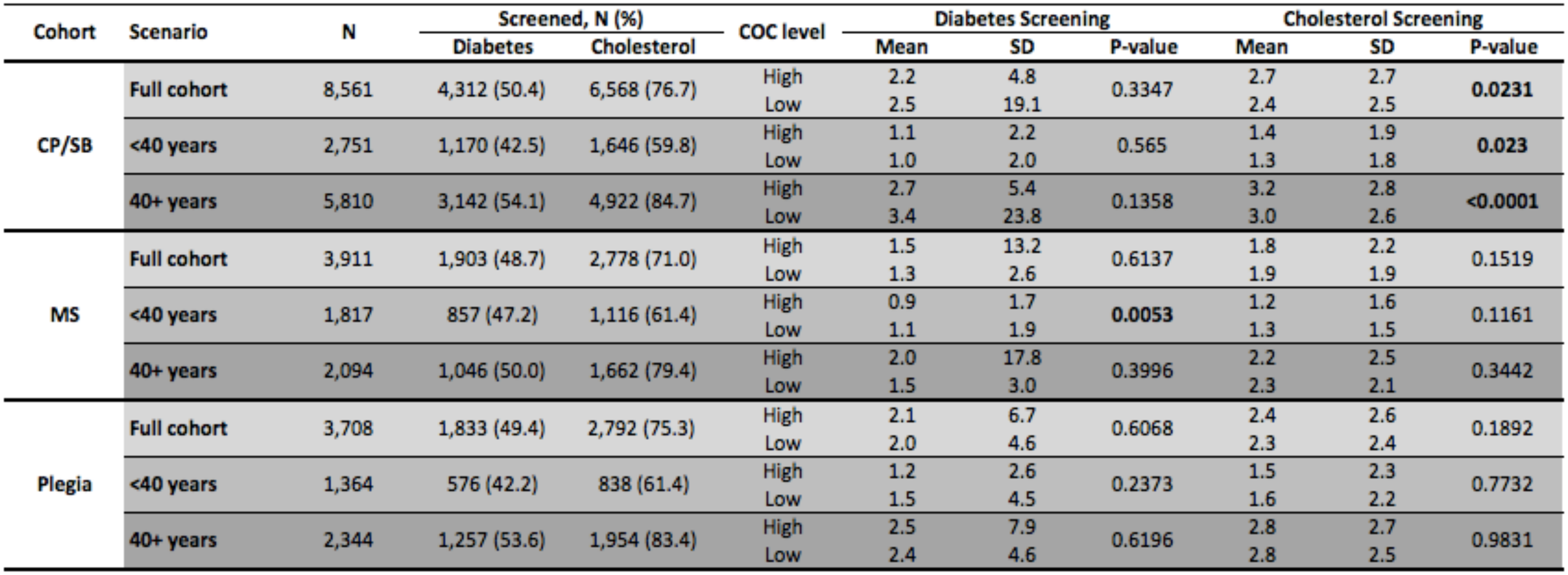
Table IV.15 presents the mean number of cholesterol and diabetes screenings conducted during follow-up for those with CP/SB, MS and Plegia, overall and by COC level. Overall, more than 70% of the cohort aging with CP/SB, MS and Plegia received at least one cholesterol test over the follow-up period. Screening was less common for diabetes but hovered around 50% (Table IV.15). Cholesterol screening was most commonplace amongst those with CP/SB, followed by Plegia, and least common for those with MS. Prevalence of diabetes screening was more comparable across each condition. Not surprisingly, across all physically disabling conditions, receipt of at least one screening was most common for individuals 40 years of age or older compared to their younger counterparts (e.g., CP/SB, <40 years = 59.8% for cholesterol screening vs 84.7% for those 40+ years).

Individuals with CP/SB averaged less than 1 screening a year for both cholesterol and diabetes screening (e.g., mean cholesterol screening of 2.2 over a 3-year follow-up for those with high COC). For diabetes screening in the full cohort, mean number of tests conducted were higher for those with low COC in the year following index (2.5 for low COC compared to 2.2 for high COC). This was largely driven by pronounced, though not statistically significant, differences in the older cohort where the mean number of tests were 2.7 and 3.4 for those with high and low COC, respectively. There was a large variability in number of tests done, in particular for those with low COC and in the cohort of individuals 40 years of age or older. Individuals with low COC had marginally lower mean number of cholesterol screenings over the 3-year period within the whole cohort (High COC= 2.7 versus low COC =2.4), less than 40 years (High COC = 1.4 vs low COC = 1.3) and the 40+ age group cohort (High COC = 3.2 vs low COC = 3.0). Findings were statistically significant in univariate analysis (Table IV.15).

Among individuals with MS, those with high COC had an average of 1.5 diabetes screenings compared to 1.3 in their counterparts with low COC. I noted that testing findings differed across age strata. Amongst young individuals with MS, average number of diabetes screenings was marginally higher in those with low COC (1.1 vs 0.9; p=0.0053) whilst among older MS patients, those with high COC had more screenings conducted. Mean number of cholesterol screenings done was comparable across those with high and low COC (Table IV.15).

As was observed with the other physically disabling conditions, younger individuals aging with Plegia had lower prevalence of preventive screenings compared to older adults. However, receipt of preventive screening did not differ significantly across those with low and high COC, irrespective of age. For example, younger adults aging with Plegia who had high continuity received 1.5 cholesterol screenings on average compared to 1.6 for those with low continuity (p=0.7732) (Table IV.15).

Table IV.15 Prevalence of any cholesterol and diabetes screening amongst those aging with cerebral palsy/spina bifida, multiple sclerosis and plegia and mean number of cholesterol and diabetes screenings stratified by continuity of care level, Optum® Clinformatics® Data Mart



| Cohort | Scenario | N | Screened, N (%) | | COC level | Diabetes Screening | | | Cholesterol Screening | | |
|---|---|---|---|---|---|---|---|---|---|---|---|
| | | | Diabetes | Cholesterol | | Mean | SD | P-value | Mean | SD | P-value |
| **CP/SB** | **Full cohort** | 8,561 | 4,312 (50.4) | 6,568 (76.7) | High | 2.2 | 4.8 | 0.3347 | 2.7 | 2.7 | **0.0231** |
| | | | | | Low | 2.5 | 19.1 | | 2.4 | 2.5 | |
| | **<40 years** | 2,751 | 1,170 (42.5) | 1,646 (59.8) | High | 1.1 | 2.2 | 0.565 | 1.4 | 1.9 | **0.023** |
| | | | | | Low | 1.0 | 2.0 | | 1.3 | 1.8 | |
| | **40+ years** | 5,810 | 3,142 (54.1) | 4,922 (84.7) | High | 2.7 | 5.4 | 0.1358 | 3.2 | 2.8 | **<0.0001** |
| | | | | | Low | 3.4 | 23.8 | | 3.0 | 2.6 | |
| **MS** | **Full cohort** | 3,911 | 1,903 (48.7) | 2,778 (71.0) | High | 1.5 | 13.2 | 0.6137 | 1.8 | 2.2 | 0.1519 |
| | | | | | Low | 1.3 | 2.6 | | 1.9 | 1.9 | |
| | **<40 years** | 1,817 | 857 (47.2) | 1,116 (61.4) | High | 0.9 | 1.7 | **0.0053** | 1.2 | 1.6 | 0.1161 |
| | | | | | Low | 1.1 | 1.9 | | 1.3 | 1.5 | |
| | **40+ years** | 2,094 | 1,046 (50.0) | 1,662 (79.4) | High | 2.0 | 17.8 | 0.3996 | 2.2 | 2.5 | 0.3442 |
| | | | | | Low | 1.5 | 3.0 | | 2.3 | 2.1 | |
| **Plegia** | **Full cohort** | 3,708 | 1,833 (49.4) | 2,792 (75.3) | High | 2.1 | 6.7 | 0.6068 | 2.4 | 2.6 | 0.1892 |
| | | | | | Low | 2.0 | 4.6 | | 2.3 | 2.4 | |
| | **<40 years** | 1,364 | 576 (42.2) | 838 (61.4) | High | 1.2 | 2.6 | 0.2373 | 1.5 | 2.3 | 0.7732 |
| | | | | | Low | 1.5 | 4.5 | | 1.6 | 2.2 | |
| | **40+ years** | 2,344 | 1,257 (53.6) | 1,954 (83.4) | High | 2.5 | 7.9 | 0.6196 | 2.8 | 2.7 | 0.9831 |
| | | | | | Low | 2.4 | 4.6 | | 2.8 | 2.5 | |

Abbreviations: CP/SB, Cerebral Palsy/Spina Bifida; MS, Multiple Sclerosis; N, Number; SD, Standard deviation.
Continuity of care was computed in the 1-year post index-date based on the Bice-Boxerman continuity of care index score.
High continuity of care was defined as having a score greater than the condition-specific median. Low continuity of care was operationalized as having a score lower than or equal to the condition-specific score.
Age used for stratification was based on age at index.
Bold text indicates statistical significance at $p<0.05$.
P-values are computed based on bivariate analyses comparing those with high and low continuity of care scores.
Screening was based on 3-years from index date.

Results for fully adjusted regression models in the complete cohort and stratified by age are presented for each condition and preventive screening below.

COC and secondary chronic health conditions:

Table IV.16 shows the fully adjusted regression results for the relationship between COC and secondary health conditions amongst individuals aging with CP/SB, Plegia and MS. Net of confounders, having high COC was associated with 0.70 times the odds of a pain diagnosis (OR 0.70, 95% CI: 0.54, 0.91) amongst those aging with MS. Upon examination of results from age-stratified analyses (Table IV.17), the effect estimate seems to be driven by younger individuals with MS. Individuals <40 years of age had significantly lower odds of pain if they had high COC vs. low COC (OR 0.61, 95% CI: 0.40, 0.94) (Table IV.17). In the older cohort, the odds were also lower and less pronounced, but findings were not statistically significant. There were no statistically significant findings observed in the overall cohort for other outcomes examined such as mood disorders, or incident T2DM and hypertension amongst those with an MS diagnosis.

While no significant findings were observed in the overall cohort with Plegia, significant findings were observed in the age-stratified analyses (Table IV.16 and Table IV.17). For younger adults (<40 years) with Plegia, high COC was associated with a 68% higher risk of incident hypertension diagnosis, net of individual and neighborhood-level factors (HR 1.68, 95% CI: 1.06, 2.67), though the confidence intervals were wide (Table IV.17). Conversely, amongst older adults with Plegia, high COC was associated with

16% lower odds of a mood disorder diagnosis (OR 0.74, 95% CI: 0.56, 0.92) during follow-up.

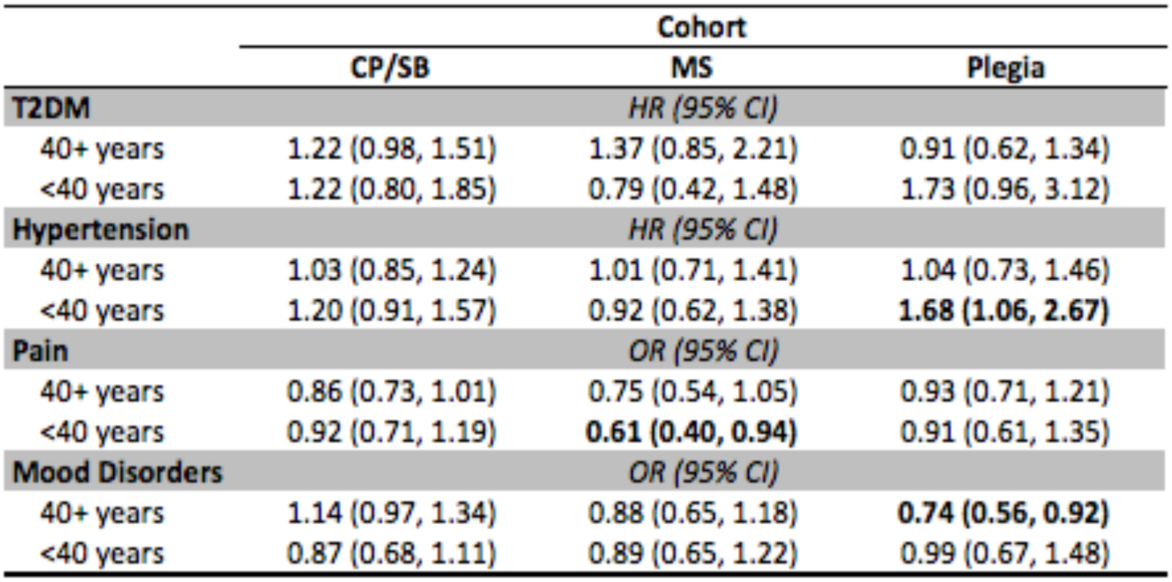
In the overall cohort of individuals with a congenital condition (CP/SB), there was no significant association between care continuity and incident T2DM or hypertension, or a diagnosis of pain or a mood disorder (Table IV.16). For example, controlling for individual and neighborhood-level factors, persons with high COC had 1.06 times the odds of mood disorder compared to their counterparts with low COC (OR 1.06, 95% CI: 0.93, 1.21), but the findings were not statistically significant. Similar findings were observed in age-stratified analyses (Table IV.17).

Table IV.16 Associations between continuity of care and secondary health conditions and preventive screening in the cohorts of individuals aging with a diagnosis of cerebral palsy/spina bifida, plegia or multiple sclerosis, Optum® Clinformatics® Data Mart

| | Secondary Health Conditions | | | | Preventive Screening | |
|---|---|---|---|---|---|---|
| **Cohort** | **T2DM** | **Hypertension** | **Pain** | **Mood Disorders** | **Cholesterol** | **Diabetes** |
| | *HR (95% CI)* | *HR (95% CI)* | *OR (95% CI)* | *OR (95% CI)* | *OR (95% CI)* | *OR (95% CI)* |
| **CP/SB** | 1.09 (0.78, 1.51) | 1.10 (0.94, 1.28) | 0.89 (0.77, 1.02) | 1.06 (0.93, 1.21) | 1.00 (0.90, 1.11) | 0.95 (0.87, 1.04) |
| **MS** | 1.13 (0.77, 1.64) | 0.99 (0.77, 1.27) | **0.70 (0.54, 0.91)** | 0.86 (0.70, 1.07) | **0.77 (0.67, 0.90)** | **0.86 (0.75, 0.98)** |
| **Plegia** | 1.09 (0.78, 1.51) | 1.22 (0.93, 1.61) | 0.92 (0.71, 1.14) | 0.81 (0.64, 1.01) | **0.80 (0.68, 0.94)** | 0.89 (0.77, 1.02) |

Abbreviations: CI, Confidence intervals; CP/SB, Cerebral Palsy/Spina Bifida; HR, Hazard ratio; MS, Multiple Sclerosis; OR, Odds ratio; T2DM, Type 2 Diabetes Mellitus.
Continuity of care was computed in the 1-year post index-date based on the Bice-Boxerman continuity of care index score.
Bold text indicates statistical significance at $p<0.05$.
Comparing high continuity vs low continuity.
Models for outcomes of incident diabetes and hypertension were adjusted for individual-level age, sex and co-morbidity burden, and neighborhood-level affluence, disadvantage, ambulatory care centers and hospitals and spatial accessibility of medical specialists and family physicians/nurse practitioners.
Models for outcome of pain was adjusted for individual-level age, sex and co-morbidity burden, and neighborhood-level affluence, disadvantage, ambulatory care centers and spatial accessibility of medical specialists, chiropractors and family physicians/nurse practitioners.
Model for outcome of mood disorders and preventive screening was adjusted for individual-level age, sex and co-morbidity burden, and neighborhood-level affluence, disadvantage, ambulatory care centers and spatial accessibility of medical specialists and family physicians/nurse practitioners.

Table IV.17 Association between continuity of care and secondary health conditions in individuals aging with cerebral palsy/spina bifida, plegia or multiple sclerosis stratified by age, Optum® Clinformatics® Data Mart



| | Cohort | | |
|---|---|---|---|
| | **CP/SB** | **MS** | **Plegia** |
| **T2DM** | | *HR (95% CI)* | |
| 40+ years | 1.22 (0.98, 1.51) | 1.37 (0.85, 2.21) | 0.91 (0.62, 1.34) |
| <40 years | 1.22 (0.80, 1.85) | 0.79 (0.42, 1.48) | 1.73 (0.96, 3.12) |
| **Hypertension** | | *HR (95% CI)* | |
| 40+ years | 1.03 (0.85, 1.24) | 1.01 (0.71, 1.41) | 1.04 (0.73, 1.46) |
| <40 years | 1.20 (0.91, 1.57) | 0.92 (0.62, 1.38) | **1.68 (1.06, 2.67)** |
| **Pain** | | *OR (95% CI)* | |
| 40+ years | 0.86 (0.73, 1.01) | 0.75 (0.54, 1.05) | 0.93 (0.71, 1.21) |
| <40 years | 0.92 (0.71, 1.19) | **0.61 (0.40, 0.94)** | 0.91 (0.61, 1.35) |
| **Mood Disorders** | | *OR (95% CI)* | |
| 40+ years | 1.14 (0.97, 1.34) | 0.88 (0.65, 1.18) | **0.74 (0.56, 0.92)** |
| <40 years | 0.87 (0.68, 1.11) | 0.89 (0.65, 1.22) | 0.99 (0.67, 1.48) |

Abbreviations: CI, Confidence intervals; CP/SB, Cerebral Palsy/Spina Bifida; HR, Hazard ratio; MS, Multiple Sclerosis; OR, Odds ratio; T2DM, Type 2 Diabetes Mellitus.
Continuity of care was computed in the 1-year post index-date based on the Bice-Boxerman continuity of care index score.
Age used for stratification was based on age at index.
Bold text indicates statistical significance at $p<0.05$.
Comparing high continuity vs low continuity of care.
Models for outcomes of incident diabetes and hypertension were adjusted for individual-level age, sex and co-morbidity burden, and neighborhood-level affluence, disadvantage, ambulatory care centers and hospitals and spatial accessibility of medical specialists and family physicians/nurse practitioners.
Models for outcome of pain was adjusted for individual-level age, sex and co-morbidity burden, and neighborhood-level affluence, disadvantage, ambulatory care centers and spatial accessibility of medical specialists, chiropractors and family physicians/nurse practitioners.
Model for outcome of mood disorders and preventive screening was adjusted for individual-level age, sex and co-morbidity burden, and neighborhood-level affluence, disadvantage, ambulatory care centers and spatial accessibility of medical specialists and family physicians/nurse practitioners.

<u>COC and preventive screening:</u>

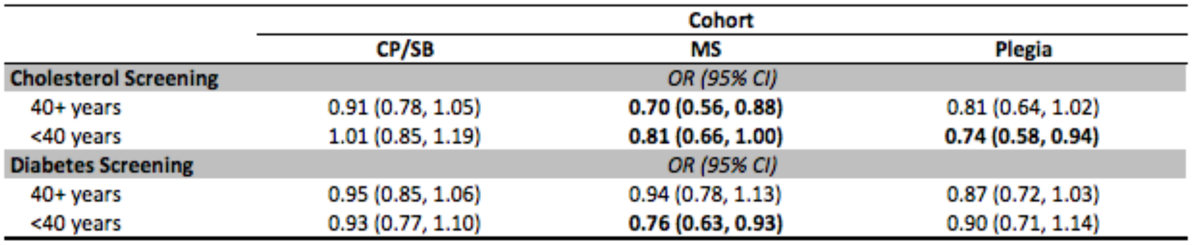
Tables IV.16 and IV.18 present the adjusted regression results for preventive screening for the overall analytical cohort and stratified by age, respectively.

Adjusting for individual-level factors and community-level characteristics, higher COC was significantly associated with lower odds of receiving both cholesterol and diabetes screenings for those with MS (Table IV.16). Individuals with high COC had 0.77 times the odds of cholesterol screening compared to their counterparts with low COC (OR 0.77, 95% CI: 0.67 0.90). Similar findings were observed for diabetes screening, though effects were slightly less pronounced (OR 0.86, 95% CI: 0.75, 0.98). Amongst young and older individuals with MS, significantly lower odds of cholesterol screening were observed for those with high COC (Table IV.18). For older MS patients, high COC was associated with 30% lower odds of receiving cholesterol screening during follow-up (OR 0.70, 95% CI: 0.56, 0.88). Effects of care continuity on cholesterol screening were less pronounced in younger adults with MS (OR 0.81, 95% CI: 0.66, 1.00). Younger MS patients also had 0.76 times the odds of receipt of a diabetes screening (OR 0.76, 95% CI: 0.63, 0.93) (Table IV.18).

In fully adjusted regression models, higher continuity was associated with 20% lower odds of receiving cholesterol screening during the follow-up period (OR. 0.80, 95% CI: 0.68, 0.94) for those with Plegia. The findings appeared to be driven by significantly lower odds of screening in younger individuals (OR 0.74, 95% CI: 0.58, 0.94). In this cohort, higher continuity was associated with 11% lower odds of diabetes screening but findings were not significant (OR 0.89, 95% CI: 0.77, 1.02) and no significant results were observed in age-stratified analyses (Table IV.16; Table IV.18).

No significant findings were observed for any of the screening outcomes in the overall cohort with CP/SB or in the age-stratified analyses.

Table IV.18 Association between continuity of care and cholesterol and diabetes screenings in individuals with cerebral palsy/spina bifida, plegia or multiple sclerosis stratified by age, Optum® Clinformatics® Data Mart



| | **Cohort** | | |
|---|---|---|---|
| | **CP/SB** | **MS** | **Plegia** |
| **Cholesterol Screening** | | *OR (95% CI)* | |
| 40+ years | 0.91 (0.78, 1.05) | **0.70 (0.56, 0.88)** | 0.81 (0.64, 1.02) |
| <40 years | 1.01 (0.85, 1.19) | **0.81 (0.66, 1.00)** | **0.74 (0.58, 0.94)** |
| **Diabetes Screening** | | *OR (95% CI)* | |
| 40+ years | 0.95 (0.85, 1.06) | 0.94 (0.78, 1.13) | 0.87 (0.72, 1.03) |
| <40 years | 0.93 (0.77, 1.10) | **0.76 (0.63, 0.93)** | 0.90 (0.71, 1.14) |

Abbreviations: CI, Confidence intervals; CP/SB, Cerebral Palsy/Spina Bifida; MS, Multiple Sclerosis; OR, Odds ratio.
Continuity of care was computed in the 1-year post index-date based on the Bice-Boxerman continuity of care index score.
Bold text indicates statistical significance at $p<0.05$.
Comparing high continuity vs low continuity of care.
Age for stratification was based on age at index date.
Models were adjusted for individual-level age, sex and co-morbidity burden, and neighborhood-level affluence, disadvantage, ambulatory care centers and spatial accessibility of medical specialists and family physicians/nurse practitioners.

## 4.4 Discussion

In this Aim, I utilized data from Optum® Clinformatics® Data Mart to examine the relationship between Bice-Boxerman COC score and diagnosis of secondary chronic health conditions and preventive health screening for individuals aging with physical disability. In the overall cohort, no significant associations between COC and hypertension, diabetes or mood disorders were observed, net of individual and community covariates. However, among individuals with MS, high care continuity was associated with lower odds of a pain diagnosis during follow-up. Findings were mixed for age-stratified analyses. Amongst individuals with MS, high COC was associated with lower odds of pain diagnosis in younger adults. Amongst individuals with Plegia, high continuity was associated with higher incidence of hypertension amongst younger adults, and lower odds of mood disorders amongst older adults. I observed that individuals with MS and Plegia who had high COC had lower odds of preventive screening, a finding that was observed consistently across types of screening amongst younger adults. To the best of my knowledge, findings from this study are the first to quantitatively examine the effect of continuous care on health and preventive screening for individuals aging with physical disability. Results provide a more nuanced understanding of conceptualization of care continuity that accounts for unique experiences of this population.

In the present study, I observed that preventive screening was high in this population over the 3-year period. Other studies have found that individuals with a disability are less likely to get screened compared to their counterparts without a disability (Centers for Disease Control 2020(b); Steele, et al. 2017). While I was not able to directly compare our study population to those without a disability, it is important to note that most research on screening amongst individuals with disability has been on breast and/or colon cancer screening and Pap tests (Centers for Disease Control 2020(b); Steele, et al. 2017; Plourde, et al. 2018). These screenings can be more invasive and present with additional barriers not seen with cholesterol and diabetes screenings that require a blood draw. Some of the traditional barriers such as use of public transportation, accessing healthcare facilities and level of disability might apply for cholesterol and diabetes screening as well (Merten, et al. 2015; Smeltzer 2007; Todd and Stuifbergen 2012; Chen, et al. 2009). However, breast and cervical cancer screenings may pose additional barriers for individuals with physical disability such as older mammography scanners requiring individuals with physical disability to stand, or newer ones not being widely available, Pap screenings requiring patients to lift themselves onto exam tables and having to position one's body in a specific way for exams (Merten, et al. 2015; Smeltzer 2007; Todd and Stuifbergen 2012; Chen, et al. 2009). There is some evidence that for individuals with mild or moderate disability, preventive screenings were done at rates comparable to those without a disability (Kung, Tsai and Chiou 2012). Therefore, with fewer barriers, diabetes and cholesterol screening might be more commonplace for individuals aging with a disability.

In this population with physically disabling conditions, screening was frequently done over the 3-year period examined. For example, in regards to diabetes, mean number of screenings ranged from 2.1-2.5 for high COC and 1.3-2.5 for low COC. Whilst individuals under 40 years of age had fewer mean numbers of screenings (range 0.9-1.2 for high COC and 1-1.5 for low COC), they were higher than might be expected based on an age criterion alone over a 3-year follow-up. Even if this was driven by abnormal screenings in prior tests, the number of individuals with at least one screening test was still considerable amongst those less than 40 years in our study (42-47% for diabetes and 59.8-61.4% for cholesterol screening). Work done in the general population with diagnosed diabetes found that 81% had a glycosylated hemoglobin test, and 65% had a lipid profile done, suggesting slightly lower screening rates in our population (Gill, Mainous and Diamond, et al. 2003). In a population with existing disease, one would expect higher screening rates to monitor the disease. Our population, however, was a mix of those with and without a history of diabetes and so it likely reflects a lower estimate than expected in a population with diagnosed disease.

It is important to note that there are other reasons that a clinician might initiate screening, even if their patient does not meet the age criteria. The guidelines outline risk factors such as family history, diabetes and hypertension as reasons to screen a patient (Allan, et al. 2015; American Diabetes Association 2018). Other factors such as obesity, family history, or smoking status might contribute to the high number of screenings observed in our population amongst younger individuals. Therefore, I was unable to conclude that it was necessarily inappropriate screening that was occurring. It is also plausible that individuals in our cohort presented with abnormal glucose and/or lipid values warranting more frequent monitoring. Most of the guidelines are centered on a population without diagnosed disease and so monitoring after a diagnosis may be more so at the discretion of the provider and patient (American Diabetes Association 2018; Allan, et al. 2015). Previous qualitative work has identified that clinicians perceive their patients with a disability to be different than their patient population without a disability (McColl et al 2008). Primary amongst these differences are their complex care needs and increased risk of premature aging (McColl, Forester, et al. 2008). These aspects, in combination with feeling ill-equipped to support them with current tools, might be a motivating factor to initiate screening at younger ages (McColl, Forester, et al. 2008).

Higher mean screening counts were observed amongst those with low COC compared to those with high COC. Continuous care promotes a sense of trust and understanding amongst patients and providers, and therefore, one would anticipate more appropriate screening given the clinician is aware of their family history and needs. Conversely, if care is fragmented (low COC) that may be less likely to occur and screening initiation may be influenced by other factors, including their status as someone with a disability.

I observed that high continuity was associated with significantly lower odds of receiving a cholesterol or diabetes screening. Counts of tests ordered do not indicate whether it is a handful of clinicians doing tests repeatedly or different clinicians ordering the test each time. The former would likely result in a care pattern of high COC and the latter, low COC, given care visits are dispersed across a greater number of providers. The findings in the literature are mixed as it pertains to the relationship between COC and health screening across different populations. In a cross-sectional analysis of patients with diabetes within a private health insurance database, provider continuity was not associated with receiving a glycosylated hemoglobin test (OR 0.61, 95% CI: 0.32-1.16) or a lipid profile (OR 0.97, 95% CI: 0.57-1.64) (Gill, Mainous and Diamond, et al. 2003). Findings were not different when COC was limited to primary care providers. These findings conflicted with the current work, but could be attributed to different patient populations and how clinicians approach preventive care for patients with a disability.

Previous work focusing on cervical and breast cancer screening has indicated that a patient's knowledge may influence screening compliance and uptake and that lack of knowledge of risk factors and required frequency of screening, are barriers. Therefore, lack of COC may preclude them from having relevant and timely discussions about screenings and risk factors (Li, et al. 2020). While health literacy is higher amongst those with employer or privately purchased health insurance compared to those with public insurance, 62% of adults with employer provided health insurance still have only intermediate health literacy (U.S. Department of Education 2006). I attempted to account for factors that may be markers of health literacy in this study population such as neighborhood affluence or disadvantage. However, that may not have adequately accounted for individual-level literacy of an individual. Therefore, differences in health literacy across populations with high and low COC may be partly responsible for some of the observed effects (residual confounding).

The health care provider is often the one who initiates preventive screenings. Therefore, the understanding that a particular provider has about screening guidelines could play an important role in the relationship between COC and screening. This is because even if a patient sees a single provider for their healthcare visits (high COC), if that provider does not adhere to, or lacks knowledge of guidelines, it can mean they will not have access to necessary screening despite their continuous care (Li, et al. 2020). It has been well established that individuals aging with a disability represent a population with complex healthcare needs (Campbell and Putnam 2017). Work done in a cohort of

Medicare beneficiaries with diabetes and heart failure found that involvement of both primary care physicians and specialists was associated with better compliance of guidelines but that specialists did tend to over-image (Johnston and Hockenberry 2016). There was a small association between COC and recommended care processes with involvement of specialists and resulted in better health outcomes (e.g., less functional impairment) (Johnston and Hockenberry 2016). Therefore, it is plausible that this high COC might come at the expense of appropriate care if they have difficulty managing the complex chronic disease needs of patients in addition to their required screening (Kern and Mainous 2001). A recent national survey of primary care physicians revealed gaps in the group's understanding of risk factors, diagnostic criteria and recommended management/prevention for pre-diabetes (Tseng, et al. 2019). For example, 25% of primary care providers would identify their patient as having pre-diabetes when they meet the criteria for diabetes and only 42% of them know the threshold for pre-diabetes (Tseng, et al. 2019). This is important as this knowledge informs decisions that clinicians make about which of their patients they screen and how frequently. In Aim 2 it was noted that those with high COC had greater proportion of visits concentrated with primary care physicians. Therefore, this could explain the lower odds of screening amongst those with high COC. Receipt of specialty care often decreases ones COC score but specialists may be able to better identify and manage complex care/specialized conditions.

Alternatively, in the present study, the lower odds of screening in those with high COC in the context of similar mean number of screenings (across those with low and high COC) may not be indicative of improper care, but rather a reflection of more appropriate monitoring of health conditions. As noted in the findings from Aim 2, individuals with high COC had care patterns wherein a greater proportion of their visits were concentrated amongst a smaller number of different specialty types (primarily Family Medicine and Internal Medicine doctors). Conversely, those with low COC had a greater share of their visits to a variety of different providers. Visits to different specialists may result not only in lower continuity scores, but also present more opportunities for tests to be ordered. This is because each clinician may be less familiar with the health status of the patient or may require a work-up before making decisions about the care of the patient. Unlike screenings such as mammograms or Pap tests, blood tests for cholesterol and diabetes can easily be run as part of a blood panel. Therefore, these findings may initially allude to over-screening. Clinicians may also be more likely to screen a patient with a disability when they do not have an enduring relationship with them (e.g., when see several different clinicians) due to evidence suggesting that clinicians often have perceptions about individuals with disability and their health and disease risk profiles (McColl, Forester, et al. 2008). Future qualitative work should examine the relationship between care continuity and screening in this population to better elucidate some of the potential mechanisms driving the observed associations in this study and the role of different health care providers.

In the overall cohort, significantly lower odds of central pain diagnosis amongst MS patients with high COC compared to those with low COC was observed. It is not entirely surprising that a signal for pain would appear for MS. The prevalence of pain amongst individuals with a diagnosis of MS is between 50-86% depending on assessment protocols and the definition of pain employed in the studies (O'Connor, et al. 2008; Bermejo, Oreja-Guevara and Diez-Tejedor 2010). Chronic neuropathic pain amongst those with MS negatively impacts their functioning and quality of life, making it likely that they seek care to address this pain, thereby reflecting a diagnostic code for it in claims data (Murphy, Bethea and Fischer 2017). Patient-centered care, which focuses on establishing open communication and positive relationships amongst a primary care physician and their patient is thought to be important for pain treatment given the limited availability of specialized pain clinics (Matthias, et al. 2010). It focuses not just on the illness but rather the patient's perception of the illness. Qualitative work examining patient-provider care and pain management has noted that given the long-term effects of chronic pain and the challenges related to its management, positive patient-provider relationships are important for pain relief and functional outcomes as they tend to need more frequent contact and longitudinal relationships with their healthcare providers (Matthias, et al. 2010). Therefore, while I was unable to examine the quality of relationships between patient and provider in our measure care continuity (Bice-Boxerman COC index), COC as a metric describes a continuous, caring relationship between individuals and their provider. Individuals with high COC may have a good patient-provider relationship resulting in more pain relief and lower odds of a pain-related visit.

Patients in community settings have also reported systemic barriers that limit access to providers when they need pain prescriptions renewed or when they experience pain flares (Upshur, Bacigalupe and Luckmann 2010). Similar findings have been observed in a qualitative study conducted within the Veteran's Affairs (VA) system, an integrated health care system (Driscoll, et al. 2018). The authors noted several advantages to receiving care for pain in such an integrated model, which included easier time getting prescriptions filled, and more treatment options (Driscoll, et al. 2018). This highlights the benefit of coordinated care in improved pain outcomes. Therefore, continuous care may mitigate pain flares due to regular and appropriate care. When appropriately managed, it may reduce need to see a care provider for pain-related health problems specifically (cared for as part of routine health care visits).

Significantly lower odds of a pain diagnosis associated with high (vs low) COC was observed amongst younger adults in age-stratified analyses. While lower odds were also observed for older adults, it was not statistically significant. Research aimed at investigating health status of older (60+) and younger (<60 years) individuals with chronic pain across the United States noted that health status was impaired to a lesser degree in older than younger adults (Wittink, et al. 2006). Older adults also reported comparable intensity of pain to younger adults but better mental health, less passive coping, and more life control (Wittink, et al. 2006). Similarly, in a study examining medical records of ~6000 Black and White adults being treated for chronic pain, older age was associated with 39% lower odds of reporting depressive symptoms (OR 0.61; CI 0.54–0.69), 32% lower odds of pain intensity (OR 0.68; CI 0.61–0.77) and 35% lower odds of symptoms related to post-traumatic stress (OR 0.65; CI 0.55–0.77) (Baker and Green 2005). These statistically significant findings held after accounting for the total number of months with pain, gender, marital status, and education. The authors concluded that unlike younger adults, older adults may: 1) develop more effective coping skills that let them adjust to living with pain, 2) they may be acclimated to higher pain thresholds and/or, 3) have lower expectations regarding their physical abilities (Baker and Green 2005; Geerlings, et al. 2002; Brantley, et al. 2002). The experiences of older adults with physical disability in our study may mirror these experiences. They might be living with these conditions for longer periods of time and have developed coping skills. Therefore, continuous care may play a less salient role for them in regards to pain management.

Our cohort with MS was predominantly comprised of women. Women have distinct experiences with pain management compared to their male counterparts, which may, in part, explain the observed findings. Across various epidemiologic studies, women report pain with greater frequency and report higher intensity of pain (Haskell, et al. 2006; Bartley and Fillingim 2013; Driscoll, et al. 2018). In addition to the pain from their primary disability, women also present with additional pain-related conditions and encounter challenges in getting care for their pain symptoms. These challenges include the complexity of their pain-related conditions, not being deemed a “credible patient” with regards to their pain symptoms (perception that their pain is not real), healthcare providers lacking knowledge when it comes to treating pain in women, and feeling like their concerns are not being heard (Wandner, et al. 2014; Driscoll, et al. 2018; Hampton, Cavalier and Langford 2015). Even though I did adjust for sex in the current models, there may be other experiences that women with MS face that could not be accounted for with adjustment for sex (e.g., gender norms and experiences). Therefore, they may benefit even more from a patient-centered consistent relationship with their healthcare provider.

It is important to note that diagnoses captured in administrative claims data reflect conditions the patient had when they sought care. Therefore, an absence of a pain diagnosis does not necessarily indicate that they do not experience any pain at all. It is plausible that with better management, pain-related conditions such as pain flares do not need to be the primary purpose of a visit to a healthcare provider such as for pain flares.

In this work, no significant relationship between COC and incident hypertension was observed in the overall cohort. However, high COC was associated with a significantly higher risk of hypertension in young adults (<40 years of age). It is plausible that the higher risk observed reflects diagnosis of pre-clinical disease amongst younger adults with continuous, enduring relationships with their health care providers (high COC). Data from the National Health and Nutrition Examination Survey (NHANES) indicated the prevalence of hypertension amongst 18–39-year-old individuals to be 22.4% (Ostchega, et al. 2020; Centers for Disease Control and Prevention 2017). Blood pressure in young adulthood has been shown to predict incident cardiovascular events in older age, making hypertension control in young adulthood particularly important (The SPRINT Research Group 2015; Thomopolous, Parati and Zanchetti 2018; Vasan, et al. 2002). Another study conducted using data from NHANES aimed to examine the association between continuity of care and identification of chronic disease in the general population (Koopman, et al. 2003). Specific to hypertension, researchers compared responses to a question about whether a clinician had told participants they had high blood pressure against blood pressure readings done as part of the NHANES examination. Those with a usual provider of care (their marker for care continuity) had 0.70 times the odds of unrecognized disease than those with no usual provider of care (OR 0.70, 95% CI: 0.10, 0.95), suggesting that individuals with continuous care were less likely to have unrecognized disease (Koopman, et al. 2003). I lacked data on blood pressure measurements for individuals in our cohort so I was unable to know whether the higher incidence of hypertension was indeed driven by detection of preclinical disease (such that those with low COC could eventually receive a diagnosis down the line as well). Nonetheless, it is plausible that the continuous relationship could allow for quicker diagnosis resulting in the observed higher risk in our study. This is likely more important for younger adults who are less likely to receive routine screening to detect hypertension unless clinicians understand their other risk factors. Therefore, COC may make a greater difference for this population.

There are several plausible explanations for how the personal longitudinal relationship between a clinician and patient, which is the theoretical underpinning for COC, would be important for early disease detection. A continuous relationship between a health care provider and patient facilitates sharing of health knowledge, recognition of changes in health status, awareness of patient desires for treatment, and opportunities for preventive intervention (Hjortdahl 1992). For example, patients with asthma have been shown to have greater communication with their health care provider when there is continuity of care and physicians have indicated that the increased knowledge of the patient that accompanies continuity is important in their clinical decision-making process (Love, et al. 2000; (Hjortdahl 1992). This has the potential to detect asymptomatic disease faster than it otherwise would by, for example, initiating testing based on this information sharing.

In stratified analysis, high COC was associated with lower odds of a mood disorder diagnosis in older adults aging with disability. Collaborative care models in which primary care doctors' work with patients and mental health specialists to treat mood disorders, such as depression, has been associated with more effective treatment for depression (Unützer, et al. 2002). High COC may afford the benefits of better-treated mental health disorders, owing to collaboration and communication amongst and individual and their care providers (Hjortdahl 1992). Therefore, individuals do not require visits for exacerbation of their existing condition. Furthermore, in this work, I was not explicitly examining incidence of mood disorders and so these mood disorders could be incident or prevalent. To have a diagnostic code appear in claims data suggests that a particular mood disorder was addressed at the visit. Additionally, mood disorders like depression, are secondary health conditions that stem directly or indirectly from their primary disability (Campbell and Putnam 2017). Therefore, better overall management of their primary disability could mitigate development or progression of severity of mood disorders.

There is a body of literature that suggests older adults tend to receive care for depression in primary care, where providers can address not only mental health needs but other co-morbid conditions as well (Park and Unutzer 2011). There are several factors that make diagnosing and managing mood disorders in older adults challenging. First, depression in older adults is often chronic or recurrent so having a continuous relationship with one's primary care provider affords an important opportunity to track depression over time. Another challenge is that older adults do not present with typical presentation of mood disorders, requiring clinicians to look for other indicators (Park and Unutzer 2011). There may also be a lot of overlap between mood disorders and other chronic illnesses in this population.  For example, in older adults, chronic pain such as that associated with arthritis is often associated with depression (Park and Unutzer 2011; Unützer, Hantke, et al. 2008). Here, an enduring relationship with one's providers can make addressing these changes easier resulting in better management. Therefore, better management may mean fewer visits for mood disorders.

Conversely, it is plausible that given I identified in Aim 2 that those with high COC had lower proportion of their visits to specialists that these conditions are simply going undetected in primary care, where older adults prefer to seek care (Park and Unutzer 2011). This is plausible given evidence that geriatric depression remains undiagnosed and untreated in primary care even though there are tools available to facilitate screening for this (Park and Unutzer 2011; Kroenke, Spitzer and Williams 2003). Nonetheless, further investigation is required to examine how the relationship between COC and mood disorders may be differentially affected by age.

It is also important to consider how pain and mood disorders are recorded in medical claims data. A pain diagnosis can be hard to identify in health records. Existing methods such as use of diagnostic codes, results from administering numeric pain scales, and pain-related medications all present with limitations. These include the lack of unique diagnostic codes, inaccuracy in pain scales and the fact that medications for treating chronic pain also have other uses (Tian, Zlateva and Anderson 2013; Sinnott, et al. 2012). Additionally, claims data relies solely on diagnostic codes and lacks the information on symptoms that are often available in electronic medical records to supplement this information (Tian, Zlateva and Anderson 2013; Sinnott, et al. 2012). It has also been indicated that there may be some discretion by the physician as to whether they code a pain or mental health diagnosis including, but not limited to, what codes they can bill and be reimbursed for, as well as lack of certainty about diagnosis, and coding other conditions of immediate focus only (Trinh, et al. 2011). Therefore, some of these coding challenges in primary care may also explain the findings of lower odds in older adults.

In the present study, the analyses were conducted separately by physically disabling condition. I did identify some differences in observed associations across the cohorts aging with physical disability. Although the aim of the present work was not to compare differences across disability type, there are several plausible explanations for these observed differences. First, it could be due to whether a condition is acquired or congenital. Individuals with congenital conditions such as CP/SB may be more apt at navigating the health care system, having had to navigate it with a disability since birth. It also means they have had a longer time to establish connections with their health care providers who may then be more aware of how to manage their conditions, including preventive screening. For some conditions, etiology and outcome examined could be important to consider. For example, Plegia represents a group of conditions that include spinal cord injuries. Traumatic spinal cord injuries occur suddenly and may have profound impacts on an individual's mental health and relationship with their health care providers in ways that perhaps other conditions that develop over time do not (Migliorini, Tonge and Taleporos 2008; Wiseman, et al. 2015). Furthermore, there may be a different set of risk factors that cluster with different physical disabilities, that I was unable to examine in this work. Therefore, that may contribute to decisions by clinicians or patients. Lastly, differences in sample size or spurious findings cannot be ruled out. Future studies are required to better understand the interplay of an individual and clinician's perception and understanding of a given disability, care patterns and health outcomes.

*Strengths and limitations:*

This work makes novel contributions to address gaps in the existing literature on COC and health for individuals aging with a physical disability and presents with several strengths. First, use of national claims data afforded a large sample size to study these early-onset physically disabling conditions. I was also able to conduct condition-specific analyses owing to the sample size. This allowed for me to mitigate the role that these conditions with different development processes and etiologies might have on effects observed in our study. This has important implications for interventions that are targeted towards these different groups and for identifying individuals at risk for fragmented care and providing appropriate supports.

This work leveraged validated algorithms and procedure codes to identify secondary chronic health conditions and preventive screenings, precluding the need for patients to remember whether they had been informed of a diagnosis, had preventive screenings done and how frequently. If this misclassification does not differ across exposure status (non-differential misclassification), then it would bias observed estimates towards the null. If it is differential across COC level, then it can bias either away or towards the null. For example, if high COC is associated with higher odds of an outcome (OR > 1), and individuals with low COC are less likely to remember having a diagnosis compared to those with high COC, then the observed association would be further from the null than the true effect.

To my knowledge, previous studies in the general population examining COC and health outcomes have not accounted for contextual factors that can be considered confounders in the relationship. In this study, I was able to examine the effect of COC on secondary chronic health conditions and preventive screenings net of neighborhood-level confounders. Practice locations for physicians, in particular specialists, are not distributed at random which can shape care patterns (COC) and access to healthcare resources can also be associated with diagnoses and screenings (Davis, et al. 2018; Naylor, et al. 2019; Khan, Trope, et al. 2018). Therefore, I was able to mitigate some of the residual confounding present in other work looking at COC and health outcomes and screenings in the general population.

The present study also employed a methodological design aimed at mitigating the effects of reverse causality in study findings. By computing COC in one year and examining disease outcomes in subsequent years, the likelihood that COC scores were influenced by a disease diagnosis in the same year where the COC was calculated was reduced. Excluding individuals who had the outcome of interest in the year where the COC score was calculated further helped to establish temporality between COC and chronic health conditions as we would not be able to properly elucidate the temporal relationship between COC and disease diagnosis when they occur in the same year. Similar methods have been used previously in studies of COC and other health outcomes (Cohen-Mekelberg, et al. 2020).

This work should be interpreted in the context of some limitations. The study leveraged claims data from Optum® Clinformatics® Data Mart and thus I was limited in the measures of COC which I could examine. The Bice-Boxerman COC index does not directly measure communication or co-management between clinicians or provide insight into the relationship between a patient and their provider (Pollack, et al. 2016). Therefore, the definition may not consider a patient’s perception of a continuous relationship or information that is shared between a patient and provider. This has been noted as being important in the decision-making schematic for clinicians when it comes to screening (Hjortdahl 1992). Claims-based definitions, however, allowed me to compute this measure in a national sample and afford important information from a health systems perspective.

Age-stratified analyses were conducted based on age criteria outlined in screening guidelines. This enabled the creation of a cohort that would be eligible for screening (American Diabetes Association 2018; Allan, et al. 2015). However, as noted earlier, there are several additional criteria that determine eligibility for screening (Allan, et al. 2015; American Diabetes Association 2018). Therefore, there may be other factors that determined initiation of screening in those groups that I could not account for. Age, however, is a strong risk factor for many individuals to have preventive screening done and affords several advantages to just examining in the whole cohort overall as it may mask some important guideline specific differences. Furthermore, this is a common approach used in other studies that have used claims data for screening studies (Lofters, et al. 2016). There are also important factors that may be associated with investigation for screening such as family history, obesity or lifestyle factors (e.g., smoking) that were unaccounted for as this information was not available in claims data.

Clinical screening guidelines also vary over time as more data become available and understanding of disease evolves. While I used the most recent guidelines to inform this work, the study cohort spanned a period from 2007-2018 over which guidelines could have changed. This update may have influenced screening practices of clinicians. However, age, which was our stratifying variable, has remained largely consistent in all guidelines and there is often also a lag between guidelines being developed and their implementation into clinical practice.

Lastly, I lacked lab and electronic medical record data important for identifying pre-clinical disease. Therefore, there may be some mis-classification of the outcome in that patients with pre-clinical disease may not have been formally diagnosed, a pre-requisite for a diagnostic code to appear in claims data. It is plausible that a condition being undiagnosed could be differential across exposure status (e.g., may be more commonplace amongst those with low COC). If high continuity is associated with increased risk of an outcome due to early detection (OR >1) then differential misclassification of the outcome across exposure status, would result in over-estimation of the true association (appear stronger than it is) since there is a systematic underestimation of the event in those with low COC.

This aim addressed an important gap in the literature related to the relationship between continuous care and diagnosis of secondary chronic health conditions and receipt of preventive screenings in individuals aging with CP/SB, MS and Plegia. I also adjusted for important individual and neighborhood level variables and stratified analyses by age. Findings from this work highlight that continuous care is associated with pain, mood disorders and hypertension, in addition to preventive screenings. Younger individuals with a disability largely drove significant findings observed in our study.

In the general population, COC is associated with positive health outcomes. Findings from this work suggest that when it comes to individuals aging with physical disability, the relationship might be more nuanced. This may be due to a variety of factors such as perceptions clinicians have of individuals aging with disability, their risk of accelerated aging and clustering of other risk factors. It suggests that we cannot apply the same conceptualizations we have in the general population to individuals aging with a disability. Furthermore, clinicians should be supported with training and guidelines to address the challenges that individuals with disabilities faces in obtaining appropriate care and emphasize forming continuous supportive relationships with their patients characterized by open communication.

# CHAPTER V:

## Public Health and Clinical Impact

Individuals aging with disabilities acquired at birth or in early- to- mid-life are increasingly living to older ages. They are at elevated risk of developing age-related diseases in addition to secondary health conditions that stem directly or indirectly from their primary disability (Campbell and Putnam 2017). Their complexity of care needs, combined with the barriers in their environment to accessing care, could lead to care fragmentation (Jackson 2004; U.S. Department of Health and Human Services 2005). Prior research in the general population has noted the importance of one's environment in facilitating participation and management of health conditions (Clarke, Morenoff, et al. 2013; Diez Roux and Mair 2010). However, there exists a paucity of evidence examining the extent to which environmental factors can support successful aging health and health systems outcomes for individuals aging with disability. The work completed in this dissertation addresses this important gap in the literature and has the potential to inform policies, programs and areas of investment that can support positive health and quality of care outcomes in this growing population.

The first Aim examined the association between specific features of the neighborhood environment, both health promoting and harming, and development of cardiometabolic disease, a common condition in this population (Peterson, Lin, et al., 2020(a)). In addition to examining a composite measure of health promoting infrastructure (consisting of healthcare resources, broadband, transit, recreational establishments, grocery stores and parks) and health harming features (consisting of fast food restaurants and convenience, liquor and tobacco stores), it builds on understanding of the role of the environment by also considering the presence of both health promoting and harming infrastructure in tandem through the use of a neighborhood typology. The study found that residence in neighborhoods with high density of health promoting resources (namely recreational establishments and parks) was protective against incident cardiometabolic disease. Mixed findings were observed for broadband, transit, and grocery stores. Density of healthcare facilities was not significantly associated with cardiometabolic outcomes suggesting that perhaps it is the features of the environment that shape behavior before one enters the healthcare system that are important to consider. Alternatively, access barriers or quality of care experiences within the healthcare system are important to consider for cardiometabolic risk, which could not be assessed using a density-based measure. Significant findings were not observed for the composite measure of health harming features across any outcomes examined. The findings from the typology largely aligned with what was observed in individual models, highlighting that the absence of health promoting features, irrespective of levels of health harming infrastructure was associated with elevated risk of diabetes.

While the first study identified several features of the environment associated with cardiometabolic health among individuals aging with physical disability, the role of healthcare was not examined beyond the density of healthcare facilities in one's neighborhood. However, it is likely that their experiences with and within the healthcare system are likely to be important in this relationship owing to their complex healthcare needs and physical and attitudinal barriers to accessing care. Therefore, the second study helped to better understand the role of the neighborhood environment in the health care experiences of individuals aging with physical disability. The second Aim characterized the quality of care experiences of individuals aging with physical disability (cerebral palsy [CP]/spina bifida [SB], multiple sclerosis [MS] and Plegia). This was done by characterizing the Bice-Boxerman continuity of care (COC) measure and examining the individual and community factors associated with that. The study found that irrespective of physical disability, individuals in the study reported low COC scores compared to other complex care populations. While they saw a variety of different specialty types (e.g., Internal Medicine, Family Physicians, Psychologists, Orthopedic specialists) for their healthcare visits, those with high COC had more visits concentrated amongst Internal Medicine or Family Physician doctors. Furthermore, I identified several community-level factors associated with high COC across physically disabling conditions including lower affluence and disadvantage, less accessibility to Family Medicine/Nurse Practitioners and Medical Specialists and lower availability of transit and broadband internet. It was hypothesized that some of these findings could have been shaped by practice patterns of specialists who tend to practice in more affluent areas, thereby providing those individuals with more options for health care providers, leading to fragmented care. Neighborhoods with less spatial access to health care providers (or the means to access them), may present individuals residing within them, few options to see different health care providers even in cases where their healthcare needs are not met by their existing providers. While that might result in more concentrated care, it remained unknown the impact it could have on health outcomes.

In the general population high COC is associated with a variety of positive health outcomes. While Aim 2 highlighted that those individuals with disability experience fragmented care and see a variety of different types of healthcare providers, it remains unclear whether the health disadvantage of lower COC in the general population also applies to those aging with a physical disability as they may need to see a variety of healthcare providers to address their complex care needs including their primary disability, secondary health conditions and age-related chronic disease. Aim 3 of this dissertation sought to address this question by examining the relationship between COC and secondary chronic health conditions and preventive screening, adjusting for important community-level factors. It further examined whether the association differed amongst younger and older adults. In the overall population with MS, high COC was associated with lower odds of pain which was hypothesized to be attributed to improved management of pain and fewer pain flare-ups requiring healthcare visits. Additionally, high COC was associated with lower odds of cholesterol and diabetes screening. In age-stratified analyses, significant results were largely observed in the younger cohort, where high COC was associated with lower odds of pain and preventive screening and higher risk of hypertension which could be attributed to more appropriate applications of screening guidelines for those with high continuity and early-detection of hypertension.

Overall, findings suggest COC to be important for appropriate management of secondary conditions and it may be particularly pertinent of younger adults aging with disability for risk factor management and early detection of disease, in particular for hypertension.

Taken together, this dissertation highlights the importance of the role of the neighborhood environment and quality of care in healthy aging for individuals aging with physical disability It also highlights that the relationship between the environment and health outcomes and quality of care measures are nuanced and complex, such that findings cannot just translate from the general population owing to their unique life course experiences and limited mobility.

As a whole, this dissertation addresses important gaps in our understanding of successful aging for individuals with physical disabilities and provides opportunities for studies to further examine some of the findings observed in this work. This overall body of work presents with some additional strengths and limitations. First, my use of claims data to study this research question enabled the capture of healthcare encounters more accurately across unique physicians and specialty types. This is because the primary purpose of claims data is for billing and reimbursement so details on encounters, and with which physicians, are quite detailed for physicians and facilities to be reimbursed for the services they provide (Wilson and Bock 2012). Asking an individual patient about the number of visits they made or to what different providers may result in recall bias, that may be shaped by their experiences with different providers. For example, they may have a tendency to either remember the providers they had positive experiences with, or conversely, might think they visited the provider they had negative experiences with more often than they actually did. Using claims data mitigates misclassification of the outcome.

Second, I leveraged linkage of health claims data to neighborhood business data (National Establishment Time Series [NETS]) to capture objective measures of neighborhood exposures. This approach can mitigate exposure and outcome misclassification that may be associated with self-reported measures. Studies have noted an association between perceived neighborhood environment and chronic health conditions, but the cross-sectional nature of these studies precludes examining directionality and whether chronic illness affects perception of their neighborhood (Park, et al. 2015). This could lead to misclassification of the exposure (neighborhood environment). If this misclassification is non-differential across outcomes examined, it would result in estimates in this study that were biased towards the null. Conversely, if the misclassification is differential across outcome status, then it can bias the findings towards or away from the null value of one. Let's assume that residing in neighborhood environments with higher density of resources is associated with lower risk of disease (inverse relationship; OR<1) and there is differential misclassification of the exposure such that individuals with more severe health conditions are likely to remember their neighborhood environments as being worse (i.e., do not go out as much and have negative views of where they live). In this case, the bias would result in an overestimation of the protective effect of neighborhoods. In other words, good neighborhood environments would appear more protective than they really are (further from null) since those with events are more likely to misclassify their environments as being poor quality.

Lastly, I also considered additional features of the neighborhood environment such as transit stops, parks and broadband internet connections not typically examined in other studies of the neighborhood environment and cardiovascular outcomes, but that are important for individuals with disability. I considered the independent impact of these features but also included them in our typology, making the findings of this study more applicable to a population aging with disability and enabling us to generate and test population specific hypotheses about the mechanisms underlying the observed associations.

Despite this, the work does present with some limitations. First, generalizability may be a concern. Optum® Clinformatics® Data Mart is a private insurance claims database, which means individuals need to either purchase this insurance themselves or obtain it through their employer. This could impact the generalizability of the findings if individuals included in the study cohort are different from those with early-onset disabilities in the general population or those on Medicare/Medicaid, for which individuals with disability are eligible (Cubanski, Neuman and Damico 2016). This study population could be reflective of a population with higher levels of functioning, as they are able to work, or belong to higher income brackets, thereby financially able to purchase the plan out-of-pocket. This may mitigate many of the health disparities that would otherwise exist amongst individuals aging with disability. However, it can also impact the internal validity and bias study results if it is associated with both the exposure and outcome. For example, let's assume that residing in neighborhoods with a high density of health harming features (e.g., tobacco stores) is positively associated with cardiovascular disease incidence (OR>1). If use of a private health insurance database for our study is preferentially selecting for individuals who live in better neighborhoods (lower density of these health harming features) and who also have lower disease incidence, then it will bias the estimate towards the null (make these features of the environment appear less harmful than they actually are). Future studies should examine these associations using Medicare/Medicaid data (publicly insured health claims data) to examine whether similar findings are observed.

Secondly, I did not have individual-level information on socioeconomic status and race as that information is excluded by Optum® when they provide geographic identifiers to data users. These individual-level characteristics could be potential confounders in the relationship between neighborhood characteristics and health outcomes. However, these individual-level variables are often aggregated up to neighborhood-level measures (e.g., neighborhood socio-economic factors). Despite this, residual confounding cannot be ruled out. If there is an inverse relationship between the exposure (high density of transit stops) and outcome (incident hypertension) and the confounder, in this case income, is positively associated with the exposure and inversely associated with the outcome, then this is a case of positive confounding bias. This can potentially result in the observed effect estimate being further from the null (appear more protective) than the true effect estimate. Disease severity represents another potential confounder that I was unable to account for in this present work owing to use of health claims data. It may influence care patterns that shape COC scores as well as development of secondary health conditions and preventive screening. Furthermore, it may also play a role in difference observed across disability type.

Lastly, I utilized a person's residential ZIP code to define boundaries of their neighborhood. The concordance between this measure and an individual's perception of their neighborhood remains unclear. However, the more limited mobility of this group might suggest they spend time within a smaller spatial area and for the features within the ZCTA to more directly influence their health (Haak, et al. 2009). Nonetheless I cannot rule out that individuals accessed neighborhood resources outside of their ZCTA and the influences that might have on their health.

By studying the role of the environments in which individual's aging with disability reside, this work emphasizes the fundamental, or upstream, causes of health and modifiable factors that should be the target of public health and policy and has important implications for clinical care. This work has the potential to inform the planning and design of communities so that they maximize access, participation, and ultimately management of health conditions for individuals aging with disability. Ensuring neighborhood environments are conducive for this population, in particular as they age, is integral to fostering health in a growing segment of the population. This research can contribute to policy interventions aimed at insuring individuals with long-term disabilities, and older adults more broadly are able to "age in place" (remain in their communities), promote independence and to navigate their environments free of barriers. This is particularly important in light of limited resources. If we can understand which neighborhood resources are important for shaping patient-provider interactions/care patterns and development of chronic health outcomes, such as cardiometabolic disease then resources can be directed there to have maximize efforts. Supporting this vulnerable population to age successfully by investing in conducive neighborhood environments, has the potential to benefit other populations age in place as well, such as older adults.

In the first study, density of health promoting resources was associated with lower risk of cardiometabolic disease. Furthermore, in examining a typology that considered simultaneously the presence of health promoting and harming infrastructure, that high density of health promoting resources, irrespective of presence of health harming features of the environment (fast food restaurants, convenience stores etc.) was protective for health. From a community design perspective, the findings of this study suggest that emphasis should be placed on the availability of health promoting resources such as parks, transit and recreational facilities.

The focus of this work on neighborhood environments, which are considered macro-level factors, has important implications population-level health impact. The *Health Impact Pyramid* describes the impact of different types of public health interventions based on the amount of effort an individual must exert in order to benefit from them, and the population-level impact they can have (Frieden 2010). The top of the pyramid includes individual education and counselling (less impact at the population-level and an individual has to expend a great deal of personal effort benefit from this). The bottom of the pyramid includes interventions aimed at changing the socio-economic and neighborhood conditions. Changing the socioeconomic conditions in which populations reside can have large population-level impacts and a given individual can benefit from positive interventions at these levels without having to expend much individual effort. This suggests the importance of interventions that change the environmental context (Frieden 2010). This is because policies and programs at this level afford healthier options to community members irrespective of education, income, service provision or other societal factors (Frieden 2010). Thus, by studying the features of the environment that act as facilitators or barriers to successful aging outcomes, this dissertation has the potential to inform interventions with a large public health impact without placing the onus on the person alone to improve their health. This would be particularly important for supporting individuals aging with physical disability who may face environmental barriers that circumvent their best efforts to improve their health. The hope is that findings of this work will spur conversations about neighborhood resources and investment and work to promote more equitable health outcomes for a vulnerable population aging with disability.

The findings from this dissertation may also benefit clinical care. If physicians and other clinical care providers are aware of the characteristics associated with care continuity, they can anticipate who their patients may be that are at increased risk of fragmented care and work with them and their other care providers in a collaborative model to mitigate this. For example, understanding the neighborhood environments of their patients and how that may impact fragmentation of their care can be factored into care plans and medical advice. This may ultimately lead to improved care and outcomes. Another notable contribution of this work is that it expands our scope of the factors that are important to consider for COC. From a policy perspective, this affords an opportunity to intervene and address some of the environmental factors that could contribute to fragmented care and invest in factors that promote high COC. From a clinical perspective, it may help provide greater insight into the care experiences of patients, allowing clinicians to better counsel and support their patients (e.g., impact of accessibility to Medical Specialists). It also presents opportunities for future research to delve into the role that accessibility to healthcare providers (and neighborhood features that facilitate that) have on an individual's decisions about changing providers and seeking alternate specialists, especially when they are not satisfied with the care they are currently receiving. Overall, the findings speak to the idea that we do not access care within a vacuum and factors outside the control of a given individual have the potential to shape care continuity. Therefore, we need to consider this in the way we think about COC and also when caring or discharging patients as where they live could shape follow-up care patterns and make them more vulnerable.

Our traditional conceptualization of health outcomes associated with COC have come about from studies conducted in populations without physical disability, including those with chronic health conditions and older adults (Adair, et al. 2005; Bentler, et al. 2014; Adler, Vasiliadis and Bickell 2010; Amjad, et al. 2016). While these do represent complex care population, experiences of individuals aging with disability are distinct owing to their life course experiences. The third Aim of this work integrated understanding of COC in individuals aging with disability from Aim 2 to assess whether the findings in the general population hold true. The findings highlight the need to develop specific guidelines to help clinicians appropriately screen their patients with disabilities for cholesterol, diabetes and other conditions, that factor in how their disability may influence their risk factor profile. The work also examined younger and older adults with early onset disabilities highlighting that care continuity and health experiences differ by age, which is important to consider in guideline development and treatment. This would provide clinicians the support they need to provide appropriate care to their patients.

Taken as a whole, this dissertation examined successful aging outcomes in individuals aging with physical disability, and advanced our understanding of the role of the neighborhood environment in health and care continuity of this particularly vulnerable population. The findings re-iterate the need to think about how factors in the places where individuals aging with disability live, work and play influence their ability to make decisions about their health. This affords a new area of emphasis for improving health and health care quality outcomes.

# APPENDICES

# APPENDIX A

## Conceptual Models for Successful Aging, Disability and Healthcare Access

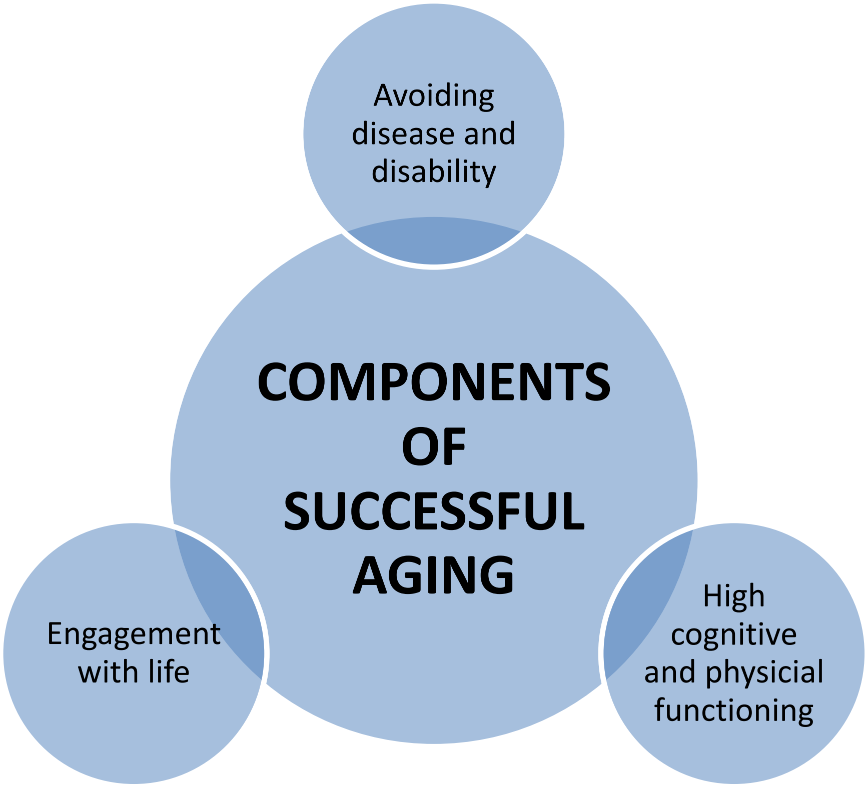


Figure A.1 Rowe & Kahn’s (1997) conceptualization of successful aging (Adapted from: Rowe & Kahn, 1997)

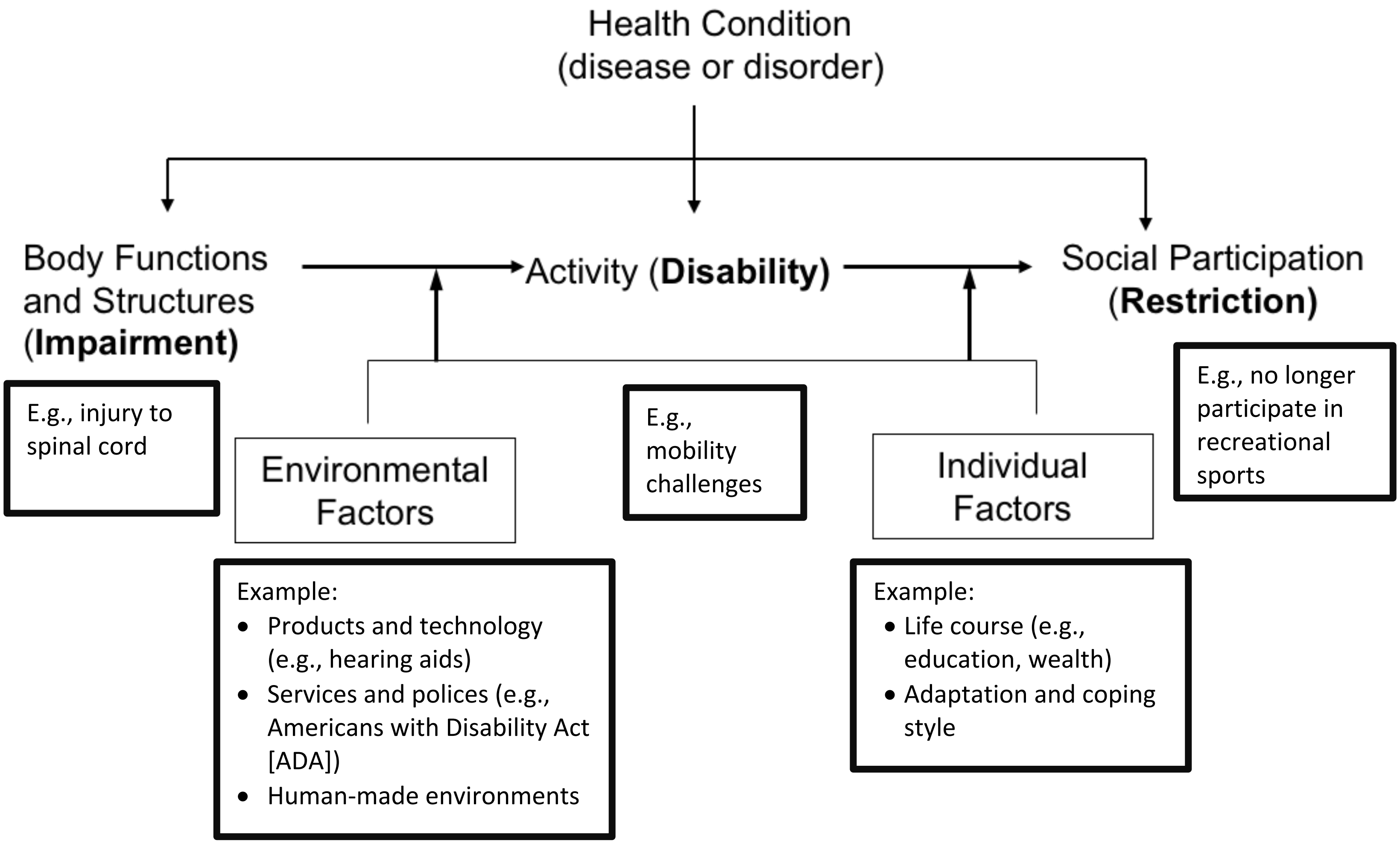


Figure A.2 International Classification of Functioning, Disability and Health (ICF) model, World Health Organization (WHO) 2001. The bold box indicates examples of each component of the ICF model (Adapted from: World Health Organization n.d.).

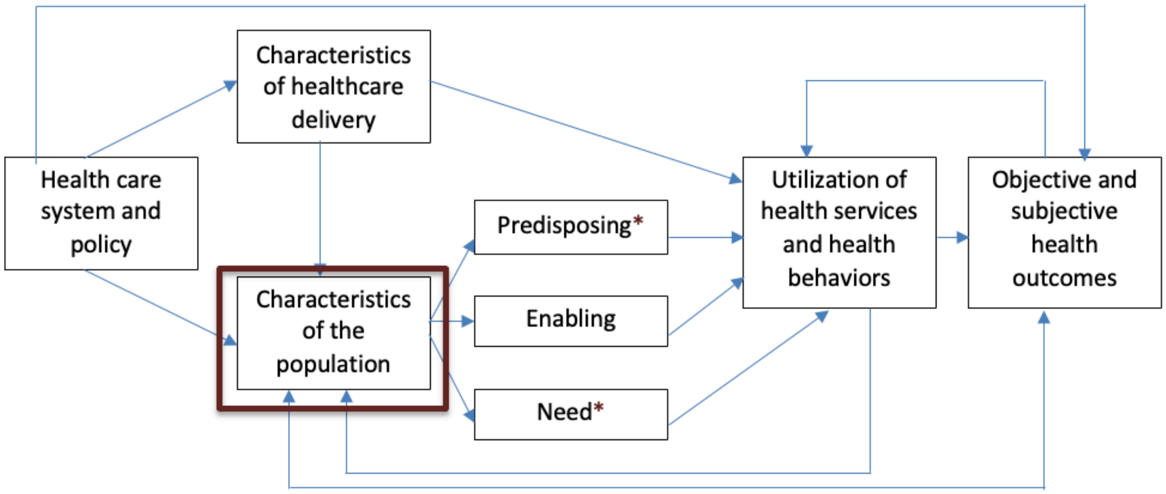


Figure A.3 Aday and Andersen framework for healthcare access. The model places emphasis on characteristics of the population (red box), specifically need (e.g., disease burden) and predisposing (e.g., insurance status) factors (asterisk) (Adapted from: Aday and Andersen 1974)

# APPENDIX B

## Diagnostic Codes for Identification of Individuals Aging with a Physical Disability and Creation of Study Cohort

Table B.1 International Classification of Diseases, 9th revision, Clinical Modification (ICD-9-CM) codes used to Identify a cohort of patients with physical disabilities in Optum® Clinformatics® Data Mart

| Physical Condition | Code | Disease Corresponding to Code |
|---|---|---|
| Cerebral Palsy | 3430<br>3431<br>3432<br>3433<br>3434<br>3438<br>3439<br>33371 | Diplegic Infantile Cerebral Palsy<br>Hemiplegic Infantile Cerebral Palsy<br>Quadriplegic Infantile Cerebral Palsy<br>Monoplegic Infantile Cerebral Palsy<br>Infantile Hemiplegia<br>Other Specified Infantile Cerebral Palsy<br>Unspecified Infantile Cerebral Palsy<br>Athetoid Cerebral Palsy |
| Spina Bifida | 74100<br>74101<br>74102<br>74103<br>74190<br>74191<br>74192<br>74193 | Spina Bifida with Hydrocephalus Unspecified Region<br>Spina Bifida with Hydrocephalus Cervical Region<br>Spina Bifida with Hydrocephalus Dorsal Region<br>Spina Bifida with Hydrocephalus Lumbar Region<br>Spina Bifida without Hydrocephalus Unspecified Region<br>Spina Bifida without Hydrocephalus Unspecified Region<br>Spina Bifida without Hydrocephalus Unspecified Region<br>Spina Bifida without Hydrocephalus Unspecified Region |
| Multiple Sclerosis | 340 | Multiple Sclerosis |
| Plegia | 34200 | Flacid Hemiplegia Affect Unspecified Side |
| | 34201 | Flacid Hemiplegia Affect Dominant Side |
| | 34202 | Flacid Hemiplegia Affect Nondom Side |
| | 34210 | Spastic Hemiplegia Affect Unspecified Side |
| | 34211 | Spastic Hemiplegia Affect Dominant Side |
| | 34212 | Spastic Hemiplegia Affect Nondom Side |
| | 34280 | Other Specified Hemiplegia Affect Unspecified Side |
| | 34281 | Other Specified Hemiplegia Affect Dominant Side |
| | 34282 | Other Specified Hemiplegia Affect Nondom Side |
| | 34290 | Unspecified Hemiplegia Affect Unspecified Side |
| | 34291 | Unspecified Hemiplegia Affect Dominant Side |
| | 34292 | Unspecified Hemiplegia Affect Nondom Side |
| | 34400 | Unspecified Quadriplegia |
| | 34401 | Quadrplegia C1-C4 Complete |
| | 34402 | Quadrplegia C1-C4 Incomplete |
| | 34403 | Quadrplegia C5-C7 Complete |
| | 34404 | Quadrplegia C5-C7, Incomplete |
| | 34409 | Other Quadriplegia |
| | 3441 | Paraplegia |
| | 80600 | Close Fracture C1-C4 W/Unspecified Spinal Cord Injury |
| | 80601 | Close Fracture C1-C4 Level W/Complete Lesion Cord |
| | 80602 | Close Fracture C1-C4 Level W/Anterior Cord Syndrome |

|  |  |  |
|---|---|---|
|  | 80603 | Close Fracture C1-C4 Level W/Control Cord Syndrome |
|  | 80604 | Close Fracture C1-C4 W/Other Spinal Cord Injury |
|  | 80605 | Close Fracture C5-C7 W/Unspecified Spinal Cord Injury |
|  | 80606 | Close Fracture C5-C7 Level W/Complete Lesion Cord |
|  | 80607 | Close Fracture C5-C7 Level W/Anterior Cord Syndrome |
|  | 80608 | Close Fracture C5-C7 Level W/Control Cord Syndrome |
|  | 80609 | Close Fracture C5-C7 W/Other Spinal Cord Injury |
|  | 80610 | Open Fracture C1-C4 W/Unspecified Spinal Cord Injury |
|  | 80611 | Open Fracture C1-C4 Level W/Complete Lesion Cord |
|  | 80612 | Open Fracture C1-C4 Level W/Anterior Cord Syndrome |
|  | 80613 | Open Fracture C1-C4 Level W/Control Cord Syndrome |
|  | 80614 | Open Fracture C1-C4 W/Other Spinal Cord Injury |
|  | 80615 | Open Fracture C5-C7 W/Unspecified Spinal Cord Injury |
|  | 80616 | Open Fracture C5-C7 Level W/Complete Lesion Cord |
|  | 80617 | Open Fracture C5-C7 Level W/Anterior Cord Syndrome |
|  | 80618 | Open Fracture C5-C7 Level W/Control Cord Syndrome |
|  | 80619 | Open Fracture C5-C7 W/Other Spinal Cord Injury |
|  | 80620 | Close Fracture T1-T6 W/Unspecified Spinal Cord Injury |
|  | 80621 | Close Fracture T1-T6 Level W/Complete Lesion Cord |
|  | 80622 | Close Fracture T1-T6 Level W/Anterior Cord Syndrome |
|  | 80623 | Close Fracture T1-T6 Level W/Control Cord Syndrome |
|  | 80624 | Close Fracture T1-T6 W/Other Spinal Cord Injury |
|  | 80625 | Close Fracture T7-T12 W/Unspecified Spinal Cord Injury |
|  | 80626 | Close Fracture T7-T12 Level W/Complete Lesion Cord |
|  | 80627 | Close Fracture T7-T12 Level W/Anterior Cord Syndrome |
|  | 80628 | Close Fracture T7-T12 W/Control Cord Syndrome |
|  | 80629 | Close Fracture T7-T12 W/Other Spinal Cord Injury |
|  | 80630 | Open Fracture T1-T6 W/Unspecified Spinal Cord Injury |
|  | 80631 | Open Fracture T1-T6 Level W/Complete Lesion Cord |
|  | 80632 | Open Fracture T1-T6 Level W/Anterior Cord Syndrome |
|  | 80633 | Open Fracture T1-T6 Level W/Control Cord Syndrome |
|  | 80634 | Open Fracture T1-T6 W/Other Spinal Cord Injury |
|  | 80635 | Open Fracture T7-T12 W/Unspecified Spinal Cord Injury |
|  | 80636 | Open Fracture T7-T12 Level W/Complete Lesion Cord |
|  | 80637 | Open Fracture T7-T12 Level W/Anterior Cord Syndrome |
|  | 80638 | Open Fracture T7-T12 W/Control Cord Syndrome |
|  | 80639 | Open Fracture T7-T12 W/Other Spinal Cord Injury |
|  | 8064 | Close Fracture Lumb Spn W/Spinal Cord Injury |
|  | 8065 | Open Fracture Lumb Spn W/Spinal Cord Injury |
|  | 80660 | Close Fracture Sacrum&Coccyx-Unspecified Cord Injury |
|  | 80661 | Close Fracture Sacr&Cocc-Cauda Equina Les |
|  | 80662 | Close Fracture Sacr&Cocc-Other Cauda Injury |
|  | 80669 | Close Fracture Sacrum&Cocc-Other Cord Injury |
|  | 80670 | Open Fracture Sacrum&Cocc-Unspecified Cord Injury |
|  | 80671 | Open Fracture Sacrum&Cocc-Cauda Equin Les |

| | | |
|---|---|---|
| | 80672 | Open Fracture Sacrum&Cocc-Other Cauda Injury |
| | 80679 | Open Fracture Sacrum&Cocc-Other Cord Injury |
| | 8068 | Close Fracture Unspecified Vertebra W/Sp Cord Injury |
| | 8069 | Open Fracture Unspecified Vertebra W/Sp Cord Injury |
| | 95200 | C1-C4 Level Spinal Cord Injury Unspec |
| | 95201 | C1-C4 Level W/Complete Les Spinal Cord |
| | 95202 | C1-C4 Level W/Anterior Cord Syndromerome |
| | 95203 | C1-C4 Level W/Central Cord Syndromerome |
| | 95204 | C1-C4 Level W/Other Spec Spinal Cord Injury |
| | 95205 | C5-C7 Level Spinal Cord Injury Unspec |
| | 95206 | C5-C7 Level W/Complete Les Spinal Cord |
| | 95207 | C5-C7 Level W/Anterior Cord Syndromerome |
| | 95208 | C5-C7 Level W/Central Cord Syndromerome |
| | 95209 | C5-C7 Level W/Other Spec Spinal Cord Injury |
| | 95210 | T1-T6 Level Spinal Cord Injury Unspec |
| | 95211 | T1-T6 Level W/Complete Les Spinal Cord |
| | 95212 | T1-T6 Level W/Anterior Cord Syndromerome |
| | 95213 | T1-T6 Level W/Central Cord Syndromerome |
| | 95214 | T1-T6 Level W/Other Spec Spinal Cord Injury |
| | 95215 | T7-T12 Level Spinal Cord Injury Unspec |
| | 95216 | T7-T12 Level W/Complete Les Spinal Cord |
| | 95217 | T7-T12 Level W/Anterior Cord Syndromerome |
| | 95218 | T7-T12 Level W/Control Cord Syndromerome |
| | 95219 | T7-T12 Level W/Other Spec Spinal Cord Injury |
| | 9522 | Lumb Spinal Cord Injury W/O Spinal Bone Injury |
| | 9523 | Sac Spinal Cord Injury W/O Spinal Bone Injury |
| | 9524 | Cauda Equina Sci W/O Spinal Bone Injury |
| | 9528 | Mx Site Spinal Cord Injury W/O Spinal Bone Injury |
| | 9529 | Unspecified Site Spinal Cord Injury W/O Spinal Bone Injury |

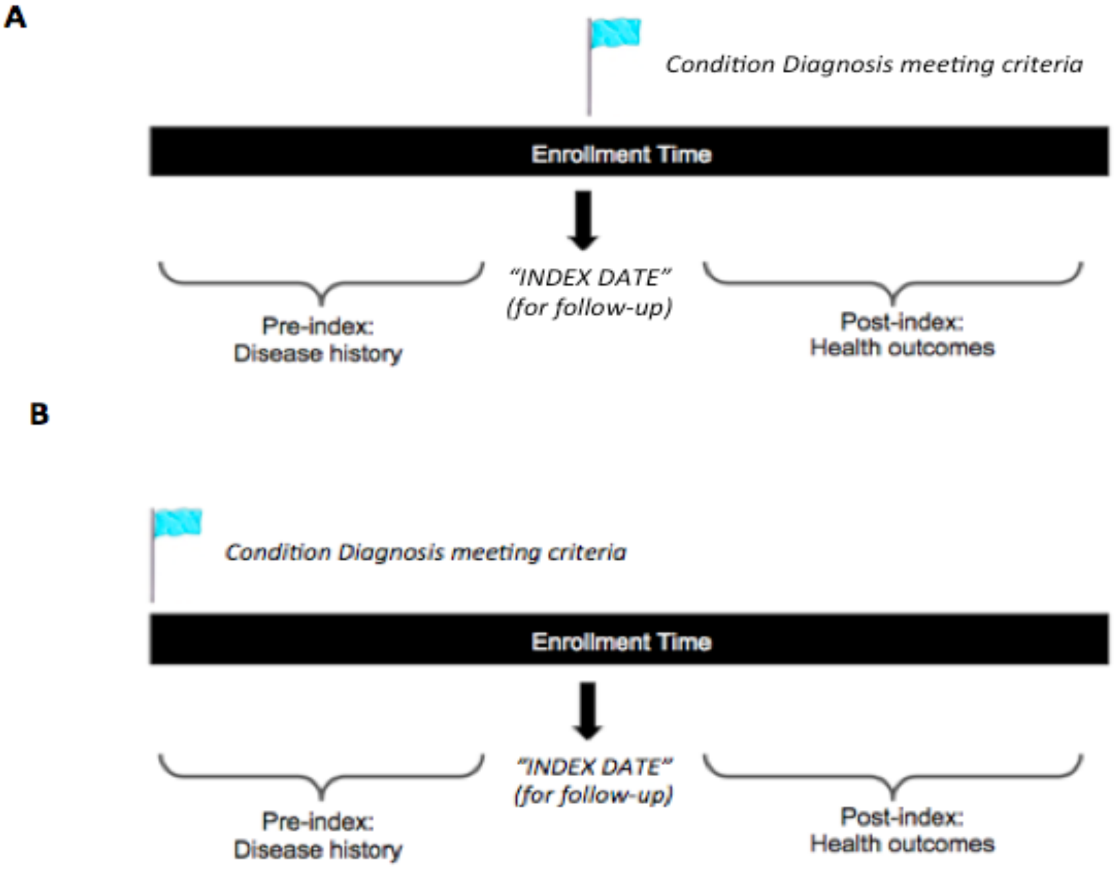


Figure B.4 Cohort creation schematic for individuals aging with acquired (A) and congenital (B) physical disabilities in Optum® Clinformatics® Data Mart

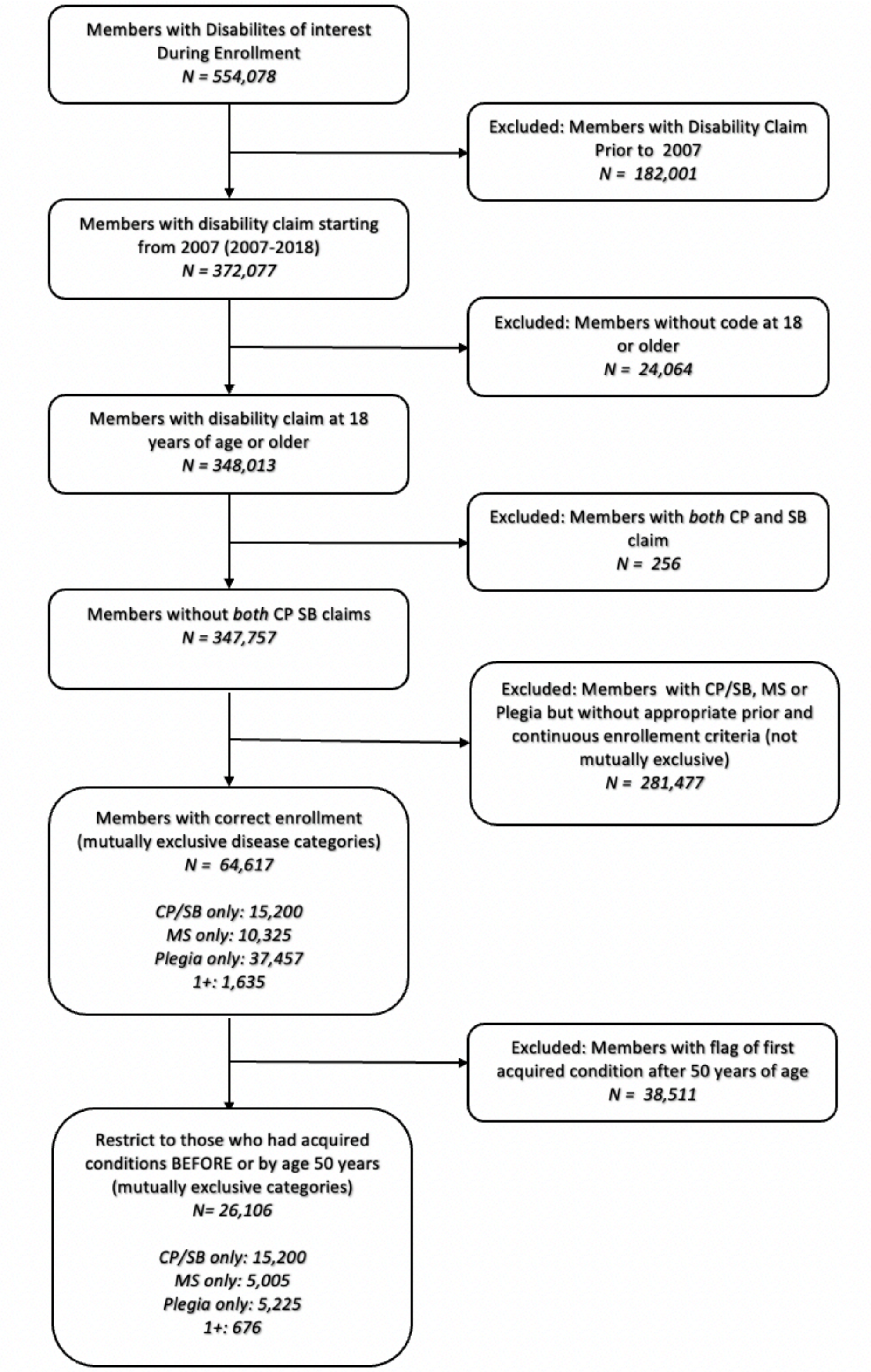


Figure B.5 Cohort creation flowchart for patients aging with physically disabling conditions for Aim 1, Optum® Clinformatics® Data Mart.
Abbreviations: CP/SB, Cerebral Palsy or Spina Bifida; MS, Multiple Sclerosis; N, Number

# APPENDIX C

## Classification of Primary Cardiometabolic Disease, Identification of Neighborhood Business Establishments and Components of Elixhauser Co-morbidity Index (ECI)

Table C.2 International Classification of Diseases, 9th and 10th Revision, Clinical Modification Codes for identifying cardiometabolic health conditions, Optum® Clinformatics® Data Mart

| Conditions | Diagnostic Codes | |
|---|---|---|
| | **ICD-9 CM** | **ICD-10 CM** |
| **Cardiac dysrhythmias** | 427.0, 427.1, 427.2, 427.31, 427.32, 427.60, 427.61, 427.69, 427.81, 427.89, 427.9, 785.0, 785.1 | I47.0, I47.1, I47.2, I47.9, I48.0, I48.1, I48.2, I48.3, I48.4, I48.91, I48.92, I49.1, I49.2, I49.3, I49.40, I49.49, I49.5, I49.8, I49.9, R00.0, R00.1, R00.2 |
| **Heart Failure** | 427.41, 427.42, 427.5, 428.0, 428.1, 428.20, 428.21, 428.22, 428.23, 428.30, 428.31, 428.32, 428.33, 428.40, 428.41, 428.42, 428.43, 428.9 | I46.2, I46.8, I46.9, I49.01, I49.02, I50.1, I50.20, I50.21, I50.22, I50.23, I50.30, I50.31, I50.32, I50.33, I50.40, I50.41, I50.42, I50.43, I50.810, I50.811, I50.812, I50.813, I50.814, I50.82, I50.83, I50.84, I50.89, I50.9 |
| **Peripheral and visceral atherosclerosis** | 440.0, 440.1, 440.2, 440.20, 440.21, 440.22, 440.23, 440.29, 440.4, 440.8, 440.9, 443.9, 557.0, 557.1, 557.9 | I70.0, I70.1, I70.201, I70.202, I70.203, I70.208, I70.209, I70.211, I70.212, I70.213, I70.218, I70.219, I70.221, I70.222, I70.223, I70.228, I70.229, I70.231, I70.232, I70.233, I70.234, I70.235, I70.238, I70.239, I70.241, I70.242, I70.243, I70.244, I70.245, I70.248, I70.249, I70.25, I70.291, I70.292, I70.293, I70.298, I70.299, I70.8, I70.90, I70.91, I70.92, I73.9, K55.0, K55.011, K55.012, K55.019, K55.021, K55.022, K55.029, K55.031, K55.032, K55.039, K55.041, K55.042, K55.049, K55.051, K55.052, K55.059, K55.061, K55.062, K55.069, K55.1, K55.8, K55.9 |
| **Liver, non-alcohol** | 571.8, 571.9 | K76.0, K76.89, K76.9 |
| **Chronic kidney disease** | 585, 585.1, 585.2, 585.3, 585.4, 585.5, 585.6, 585.9, 792.5, V42.0, V45.1, V45.11, V45.12, V56.0, V56.1, V56.2, V56.31, V56.32, V56.8 | N18.1, N18.2, N18.3, N18.4, N18.5, N18.6, N18.9, R88.0, Z49.01, Z49.02, Z49.31, Z49.32, Z91.15, Z94.0, Z99.2 |
| **Type 2 Diabetes Mellitus** | 250.00, 250.02, 250.10, 250.12, 250.20, 250.22, 250.30, 250.32, 250.40, 250.42, 250.50, 250.52, 250.60, 250.62, 250.70, | E11.00, E11.01, E11.10, E11.11, E11.21, E11.22, E11.29, E11.311, E11.319, E11.321, E11.3211, E11.3212, E11.3213, E11.3219, E11.329, E11.3291, E11.3292, |

| | | |
|---|---|---|
| | 250.72, 250.80, 250.82, 250.90, 250.92 | E11.3293, E11.3299, E11.331, E11.3311, E11.3312, E11.3313, E11.3319, E11.339, E11.3391, E11.3392, E11.3393, E11.3399, E11.341, E11.3411, E11.3412, E11.3413, E11.3419, E11.349, E11.3491, E11.3492, E11.3493, E11.3499, E11.351, E11.3511, E11.3512, E11.3513, E11.3519, E11.3521, E11.3522, E11.3523, E11.3529, E11.3531, E11.3532, E11.3533, E11.3539, E11.3541, E11.3542, E11.3543, E11.3549, E11.3551, E11.3552, E11.3553, E11.3559, E11.359, E11.3591, E11.3592, E11.3593, E11.3599, E11.36, E11.37X1, E11.37X2, E11.37X3, E11.37X9, E11.39, E11.40, E11.41, E11.42, E11.43, E11.44, E11.49, E11.51, E11.52, E11.59, E11.610, E11.618, E11.620, E11.621, E11.622, E11.628, E11.630, E11.638, E11.641, E11.649, E11.65, E11.69, E11.8, E11.9 |
| **Hypercholesterolemia** | 272.0, 272.1 | E78.0, E78.00, E78.01, E78.1 |
| **Hypertension** | 401.0, 401.1, 401.9, 402.00, 402.01, 402.10, 402.11, 402.90, 402.91, 403.0, 403.00, 403.01, 403.1, 403.10, 403.11, 403.9, 403.90, 403.91, 404.0, 404.00, 404.01, 404.02, 404.03, 404.1, 404.10, 404.11, 404.12, 404.13, 404.9, 404.90, 404.91, 404.92, 404.93, 405.01, 405.09, 405.11, 405.19, 405.91, 405.99, 437.2 | I10, I11.0, I11.9 |

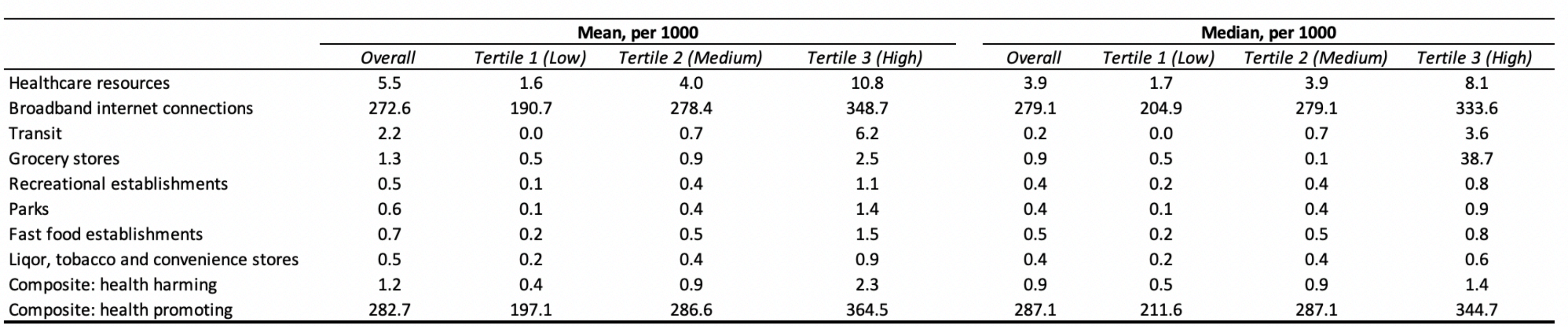
Abbreviations: ICD, International Classification of Diseases; ICD-9 CM, International Classification of Diseases, 9th Revision; ICD-10 CM, International Classification of Diseases, 10th Revision

Table C.3 North American Industry Classification System Codes used to identify business in the National Establishment Time Series (NETS) Dataset

| **Variable** | **NAICS Code** |
|---|---|
| Health care services | |
| *Ambulatory care services* | 621 |
| *Hospitals* | 622 |
| *Residential care facilities* | 623 |
| *Pharmacies* | 446110 |
| Liquor, tobacco and convenience stores | |
| *Beer, wine and liquor stores* | 4453 |
| *Cigar cigarette and tobacco stores (excluding stores which sell electronic cigarettes)* | 453991 |
| *Convenience stores without gas stations* | 445120 |
| *Gas stations with convenience stores* | 447120 |
| Grocery stores | |
| *Supermarkets and grocery stores (excluding convenience stores)* | 445110 |
| *All specialty food stores* | 4452 |
| *Warehouse clubs and supercenters* | 452311 |
| Recreation organizations | |
| *Fitness and recreational sports centers* | 71394 |
| *Golf courses and country clubs* | 713910 |
| *Bowling alleys* | 713950 |
| Limited service restaurants (e.g., fast food restaurants) | 722513 |

Abbreviation: NAICS, North American Industry Classification System
NAICS codes are standardized and used by Federal statistical agencies in classifying business establishments.
Industry information was obtained from the National Establishment Time Series (NETS) dataset.
Datasets containing curated information on each of the physical features of the neighborhood environment were obtained from the National Neighborhood Data Archive (NaNDA) [link: https://www.openicpsr.org/openicpsr/nanda].

Table C.4 Mean and median density (per 1000 individuals) of specific features of the neighborhood environment in the analytical cardiometabolic cohort



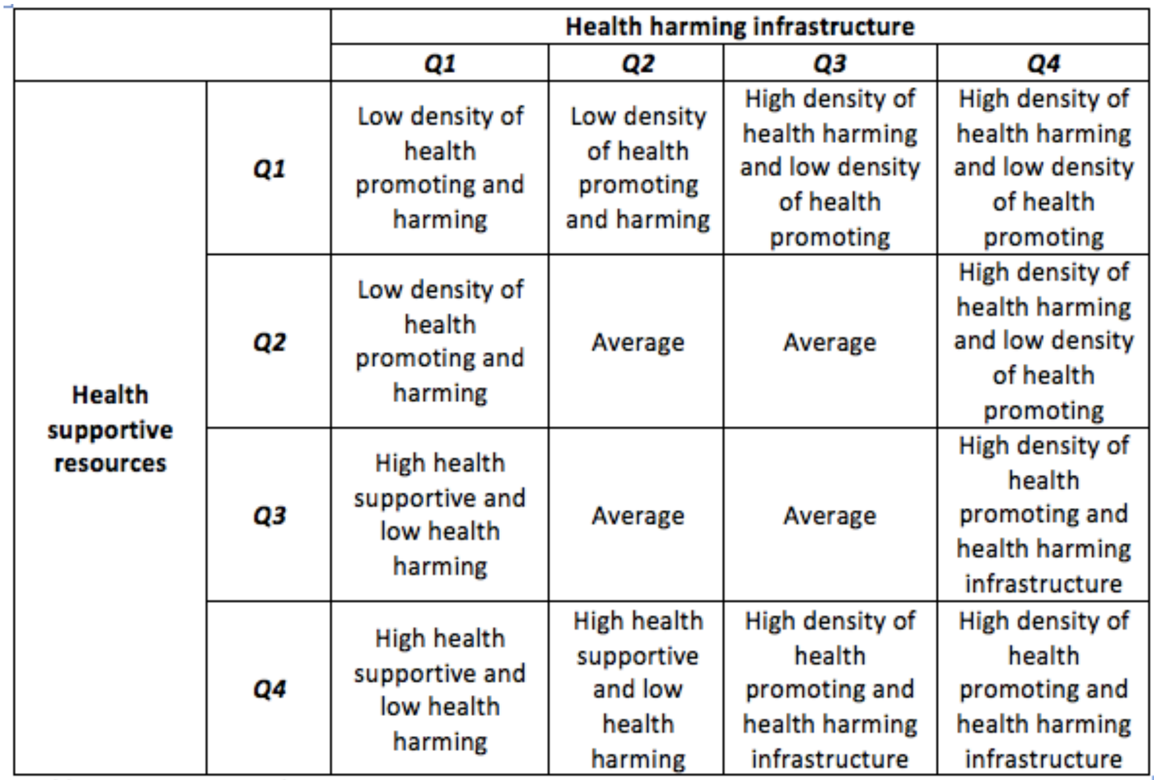
| | **Mean, per 1000** | | | | **Median, per 1000** | | | |
|---|---|---|---|---|---|---|---|---|
| | *Overall* | *Tertile 1 (Low)* | *Tertile 2 (Medium)* | *Tertile 3 (High)* | *Overall* | *Tertile 1 (Low)* | *Tertile 2 (Medium)* | *Tertile 3 (High)* |
| Healthcare resources | 5.5 | 1.6 | 4.0 | 10.8 | 3.9 | 1.7 | 3.9 | 8.1 |
| Broadband internet connections | 272.6 | 190.7 | 278.4 | 348.7 | 279.1 | 204.9 | 279.1 | 333.6 |
| Transit | 2.2 | 0.0 | 0.7 | 6.2 | 0.2 | 0.0 | 0.7 | 3.6 |
| Grocery stores | 1.3 | 0.5 | 0.9 | 2.5 | 0.9 | 0.5 | 0.1 | 38.7 |
| Recreational establishments | 0.5 | 0.1 | 0.4 | 1.1 | 0.4 | 0.2 | 0.4 | 0.8 |
| Parks | 0.6 | 0.1 | 0.4 | 1.4 | 0.4 | 0.1 | 0.4 | 0.9 |
| Fast food establishments | 0.7 | 0.2 | 0.5 | 1.5 | 0.5 | 0.2 | 0.5 | 0.8 |
| Liqor, tobacco and convenience stores | 0.5 | 0.2 | 0.4 | 0.9 | 0.4 | 0.2 | 0.4 | 0.6 |
| Composite: health harming | 1.2 | 0.4 | 0.9 | 2.3 | 0.9 | 0.5 | 0.9 | 1.4 |
| Composite: health promoting | 282.7 | 197.1 | 286.6 | 364.5 | 287.1 | 211.6 | 287.1 | 344.7 |

The analytical cohort excludes individuals with a history of any cardiometabolic disease.

Grocery stores also consisted of supermarkets, specialty food stores and warehouse clubs and supercenters). Recreational establishments consisted of recreational facilities, golf courses and country clubs and bowling alleys. Healthcare resources consisted of ambulatory care services, hospitals, residential care facilities and pharmacies.

The composite of health promoting resources consisted of health care services (ambulatory care services, hospitals, residential care facilities and pharmacies), parks, transit stops, grocery stores (supermarkets, specialty food stores and warehouse clubs and supercenters), recreational facilities (recreational and sports centers, golf courses and country clubs and bowling alleys) and households with broadband connections.

The composite measure of health harming infrastructure consisted of beer, wine and liquor stores, cigar and tobacco stores, fast food restaurants and convenience stores.



| | | **Health harming infrastructure** | | | |
|---|---|---|---|---|---|
| | | ***Q1*** | ***Q2*** | ***Q3*** | ***Q4*** |
| **Health supportive resources** | ***Q1*** | Low density of health promoting and harming | Low density of health promoting and harming | High density of health harming and low density of health promoting | High density of health harming and low density of health promoting |
| | ***Q2*** | Low density of health promoting and harming | Average | Average | High density of health harming and low density of health promoting |
| | ***Q3*** | High health supportive and low health harming | Average | Average | High density of health promoting and health harming infrastructure |
| | ***Q4*** | High health supportive and low health harming | High health supportive and low health harming | High density of health promoting and health harming infrastructure | High density of health promoting and health harming infrastructure |

Figure C.6 Typology used to Classify Neighborhood Environments based on Physical Features.

Abbreviation: Q, Quartile

Quartiles were created from the density of health promoting and health harming infrastructure in a given ZIP Code Tabulation Area (ZCTA) in a calendar year. Q1 represents the lowest density whilst Q4 represents the highest density.

The neighborhood typology used in the current study was adapted from a typology initially created by Spring (2018). Reference: Spring A. Short- and Long-Term Impacts of Neighborhood Built Environment on Self-Rated Health of Older Adults. *Gerontologist*. 2018;58(1):36-46. Doi:10.1093/geront/gnx119.

Health promoting resources consisted of health care services (ambulatory care services, hospitals, residential care facilities and pharmacies), parks, transit stops, grocery stores (supermarkets, specialty food stores and warehouse clubs and supercenters), recreational facilities (recreational and sports centers, golf courses and country clubs and bowling alleys) and households with broadband connections.

Health harming infrastructure consisted of beer, wine and liquor stores, cigar and tobacco stores, fast food restaurants and convenience stores.

Table C.5 Components of the Elixhauser Comorbidity Index and the modified version used for the analysis of chronic health conditions

| Health conditions | Original | Psychological | Cardiometabolic | Musculoskeletal |
|---|---|---|---|---|
| Congestive Heart Failure | X | X |  | X |
| Cardiac Arrhythmia | X | X |  | X |
| Valvular Disease | X | X |  | X |
| Pulmonary Circulation Disorders | X | X | X | X |
| Peripheral Vascular Disorders | X | X |  | X |
| Hypertension Uncomplicated | X | X |  | X |
| Hypertension Complicated | X | X |  | X |
| Paralysis | X | X | X | X |
| Other Neurological Disorders | X | X | X | X |
| Chronic Pulmonary Disease | X | X | X | X |
| Diabetes Uncomplicated | X | X |  | X |
| Diabetes Complicated | X | X |  | X |
| Hypothyroidism | X | X | X | X |
| Renal Failure | X | X |  | X |
| Liver Disease | X | X | X | X |
| Peptic Ulcer Disease excluding bleeding | X | X | X | X |
| AIDS/HIV | X | X | X | X |
| Lymphoma | X | X | X | X |
| Metastatic Cancer | X | X | X | X |
| Solid Tumor without Metastasis | X | X | X | X |
| Rheumatoid Arthritis/collagen | X | X | X |  |
| Coagulopathy | X | X | X | X |
| Obesity | X | X | X | X |

| | | | | |
|---|---|---|---|---|
| Weight Loss | X | X | X | X |
| Fluid and Electrolyte Disorders | X | X | X | X |
| Blood Loss Anemia | X | X | X | X |
| Deficiency Anemia | X | X | X | X |
| Alcohol Abuse | X | | X | X |
| Drug Abuse | X | | X | X |
| Psychoses | X | | X | X |
| Depression | X | | X | X |
| **Maximum Total Score** | **31** | **27** | **22** | **30** |

The ‘X’ indicates that the condition is included in the version of the Elixhauser co-morbidity index.

The modified versions exclude conditions that may be correlated with the outcome condition of interest.

Each condition is assigned equal weight. Therefore, the minimum total score in this modified Elixhauser can be 0 (indicating they do not have any of these conditions), while the maximum can be 27, 22 and 30 for psychological, cardiometabolic and musculoskeletal, respectively.

# APPENDIX D

## Cohort Creation Schematic and Flowchart Diagrams for Aim 2 and 3

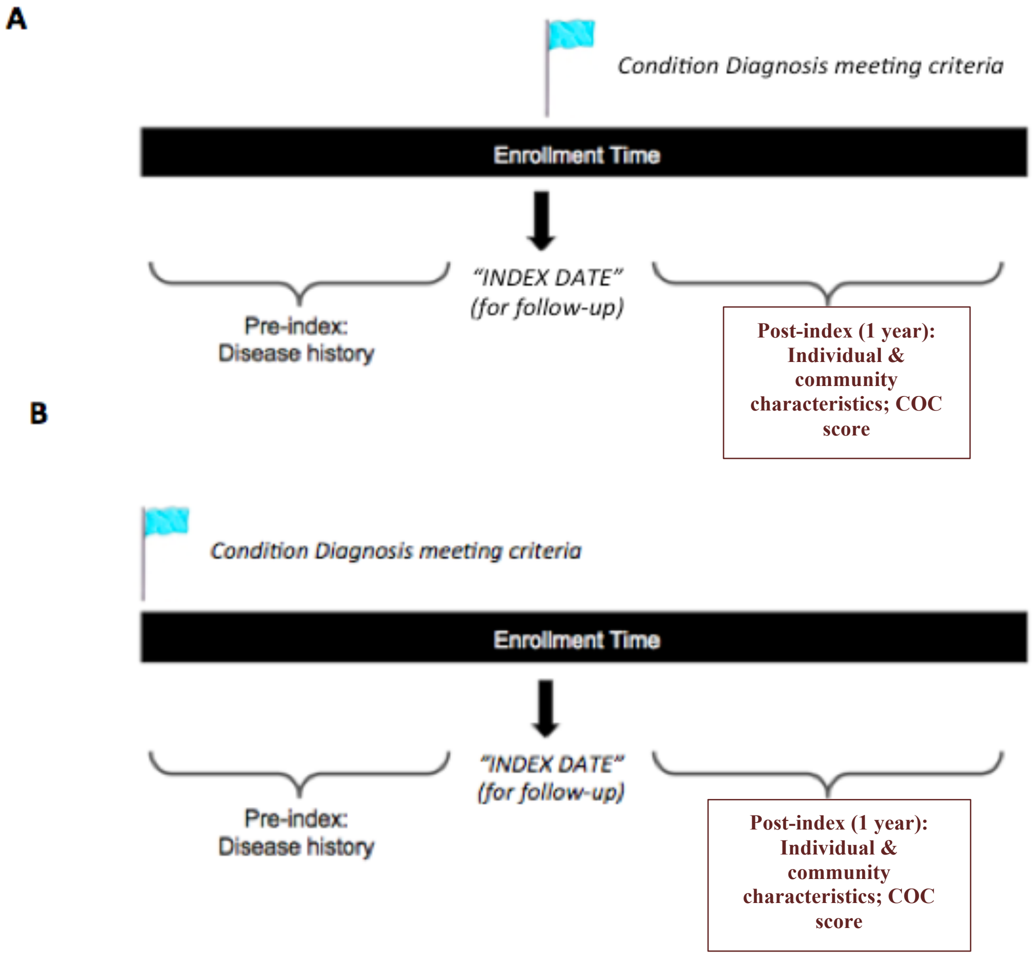


Figure D.7 Cohort creation schematic for individuals aging with acquired (A) and congenital (B) physical disabilities for Aim 2 in Optum® Clinformatics® Data Mart

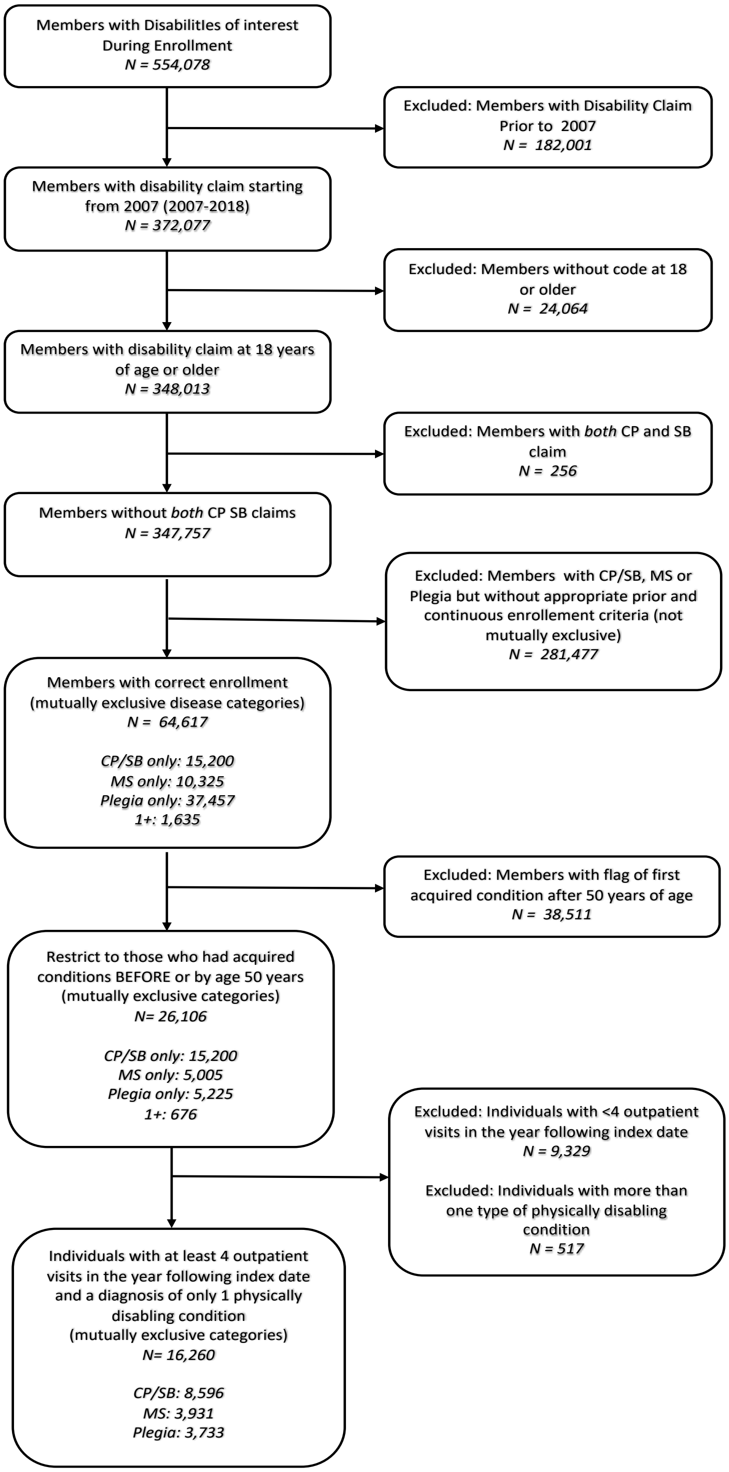


Figure D.8 Cohort creation schematic for patients aging with physically disabling conditions for Aims 2 and 3, Optum® Clinformatics® Data Mart. Abbreviations: CP/SB, Cerebral Palsy or Spina Bifida; MS, Multiple Sclerosis; N, Number.

# APPENDIX E

## Scenarios for Computing the Bice-Boxerman Continuity of Care (COC) Score

Table E.6 Examples of calculating the Bice-Boxerman Continuity of Care score

| | Total Visits | Unique docs seen | Phys A | Phys B | Phys C | Phys D | Phys E | Phys F | Phys G | Phys H | COC score |
|---|---|---|---|---|---|---|---|---|---|---|---|
| **Pt.A** | 8 | 1 | 8 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | **1.0** |
| **Pt.B** | 8 | 2 | 7 | 1 | 0 | 0 | 0 | 0 | 0 | 0 | **0.75** |
| **Pt.C** | 8 | 2 | 6 | 2 | 0 | 0 | 0 | 0 | 0 | 0 | **0.57** |

Abbreviations: COC, Continuity of Care; Docs, Doctors; Phys, Physician; Pt, Patient.
Table adapted from Amjad, et al. 2016.

# APPENDIX F

## Typology for Combined Spatial Accessibility to Nurse Practitioners and Family Medicine Doctors

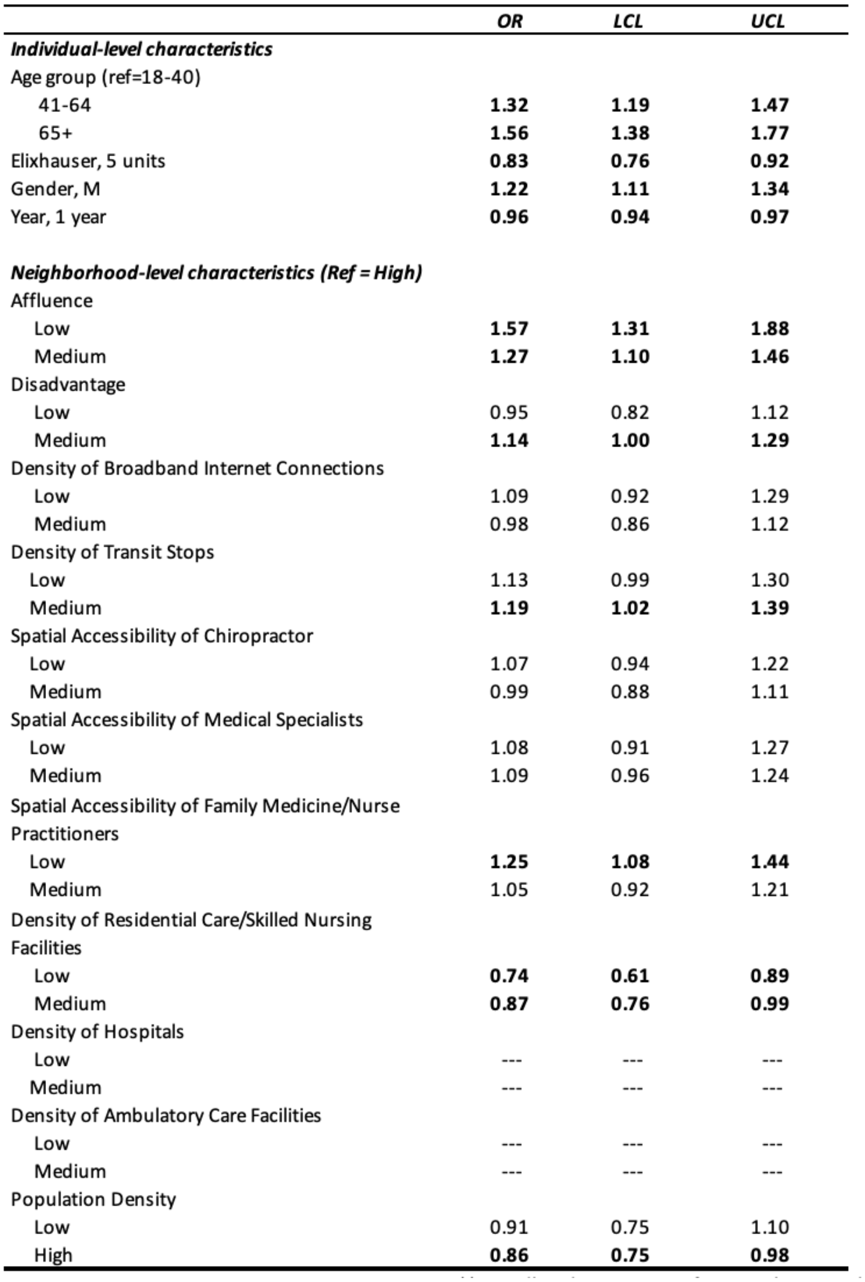
| | Tertile of FM | | | |
|---|---|---|---|---|
| Tertile of NP | | **Low** | **Medium** | **High** |
| | **Low** | *Low* | *Low* | *Medium* |
| | **Medium** | *Low* | *Medium* | *High* |
| | **High** | *Medium* | *High* | *High* |

Figure F.9 Typology used to create the combined indicator variable of spatial accessibility of Nurse Practitioners and Family Medicine physicians.
Abbreviations: FM, Family Medicine; NP, Nurse Practitioner.
Tertiles were created for each provider type, separately from the spatial accessibility of healthcare provider dataset created by Naylor, et al. 2019.

# APPENDIX G

## Sensitivity Analyses: Examining the Effect of Including Population Density in Models Examining the Association Between Individual and Community Factors and Continuity of Care (COC)

Table G.7 Results of sensitivity analyses examining individual and community-level characteristics associated with high Continuity of Care amongst individuals aging with Cerebral Palsy or Spina Bifida, Optum® Clinformatics® Data Mart



| | *OR* | *LCL* | *UCL* |
|---|---|---|---|
| ***Individual-level characteristics*** | | | |
| Age group (ref=18-40) | | | |
| 41-64 | **1.32** | **1.19** | **1.47** |
| 65+ | **1.56** | **1.38** | **1.77** |
| Elixhauser, 5 units | **0.83** | **0.76** | **0.92** |
| Gender, M | **1.22** | **1.11** | **1.34** |
| Year, 1 year | **0.96** | **0.94** | **0.97** |
| | | | |
| ***Neighborhood-level characteristics (Ref = High)*** | | | |
| Affluence | | | |
| Low | **1.57** | **1.31** | **1.88** |
| Medium | **1.27** | **1.10** | **1.46** |
| Disadvantage | | | |
| Low | 0.95 | 0.82 | 1.12 |
| Medium | **1.14** | **1.00** | **1.29** |
| Density of Broadband Internet Connections | | | |
| Low | 1.09 | 0.92 | 1.29 |
| Medium | 0.98 | 0.86 | 1.12 |
| Density of Transit Stops | | | |
| Low | 1.13 | 0.99 | 1.30 |
| Medium | **1.19** | **1.02** | **1.39** |
| Spatial Accessibility of Chiropractor | | | |
| Low | 1.07 | 0.94 | 1.22 |
| Medium | 0.99 | 0.88 | 1.11 |
| Spatial Accessibility of Medical Specialists | | | |
| Low | 1.08 | 0.91 | 1.27 |
| Medium | 1.09 | 0.96 | 1.24 |
| Spatial Accessibility of Family Medicine/Nurse Practitioners | | | |
| Low | **1.25** | **1.08** | **1.44** |
| Medium | 1.05 | 0.92 | 1.21 |
| Density of Residential Care/Skilled Nursing Facilities | | | |
| Low | **0.74** | **0.61** | **0.89** |
| Medium | **0.87** | **0.76** | **0.99** |
| Density of Hospitals | | | |
| Low | --- | --- | --- |
| Medium | --- | --- | --- |
| Density of Ambulatory Care Facilities | | | |
| Low | --- | --- | --- |
| Medium | --- | --- | --- |
| Population Density | | | |
| Low | 0.91 | 0.75 | 1.10 |
| High | **0.86** | **0.75** | **0.98** |

Abbreviations: LCL, Lower 95% confidence interval; M, Male; OR, Odds ratio; Ref, Reference; T, tertile; UCL, Upper 95% confidence interval.

Continuity of care was computed in the 1-year post index-date based on the Bice-Boxerman continuity of care index score.

Computed odds of high continuity (vs low continuity).

Bold text indicates statistical significance at $p<0.05$

High continuity of care was defined as a Bice-Boxerman continuity of care score greater than the condition specific median. Low continuity of care was defined as having a value less than or equal to the condition specific median value.

Neighborhood was defined based on the ZIP code Tabulation Area (ZCTA).

Data on features of built neighborhood environment were obtained from the National Neighborhood Data Archive (NaNDA), whilst spatial accessibility of health care providers was obtained from a publicly available dataset by Naylor, et al. 2019.

All variables were adjusted for simultaneously in the model.

Table G.8 Results of sensitivity analyses examining individual and community-level characteristics associated with high Continuity of Care amongst individuals aging with Plegia, Optum® Clinformatics® Data Mart

| | *OR* | *LCL* | *UCL* |
|---|---|---|---|
| ***Individual-level characteristics*** | | | |
| Age group (ref=18-40) | | | |
| 41-50 | **1.44** | **1.25** | **1.66** |
| Elixhauser, 5 units | **0.81** | **0.70** | **0.93** |
| Gender, M | **1.42** | **1.24** | **1.63** |
| Year, 1 year | **0.95** | **0.93** | **0.98** |
| | | | |
| ***Community-level characteristics (Ref = High)*** | | | |
| Affluence | | | |
| Low | 1.15 | 0.88 | 1.50 |
| Medium | 1.00 | 0.82 | 1.24 |
| Disadvantage | | | |
| Low | 0.93 | 0.74 | 1.18 |
| Medium | 1.04 | 0.86 | 1.25 |
| Density of Broadband Internet Connections | | | |
| Low | **1.31** | **1.01** | **1.68** |
| Medium | 1.04 | 0.86 | 1.26 |
| Density of Transit Stops | | | |
| Low | 1.18 | 0.95 | 1.46 |
| Medium | **1.31** | **1.04** | **1.65** |
| Spatial Accessibility of Chiropractor | | | |
| Low | 1.07 | 0.88 | 1.31 |
| Medium | 1.09 | 0.91 | 1.30 |
| Spatial Accessibility of Medical Specialists | | | |
| Low | 1.02 | 0.79 | 1.30 |
| Medium | **1.23** | **1.01** | **1.50** |
| Spatial Accessibility of Family Medicine/Nurse Practitioners | | | |
| Low | 1.21 | 0.98 | 1.50 |
| Medium | 0.99 | 0.82 | 1.20 |
| Density of Residential Care/Skilled Nursing Facilities | | | |
| Low | 0.79 | 0.58 | 1.06 |
| Medium | 1.00 | 0.81 | 1.24 |
| Density of Hospitals | | | |
| Low | --- | --- | --- |
| Medium | --- | --- | --- |
| Density of Ambulatory Care Facilities | | | |
| Low | --- | --- | --- |
| Medium | --- | --- | --- |
| Population Density | | | |
| Low | 0.93 | 0.69 | 1.27 |
| High | 0.91 | 0.73 | 1.13 |

Abbreviations: LCL, Lower 95% confidence interval; M, Male; OR, Odds ratio; Ref, Reference; T, tertile; UCL, Upper 95% confidence interval.

Continuity of care was computed in the 1-year post index-date based on the Bice-Boxerman continuity of care index score.
Computed odds of high continuity (vs low continuity).
Bold text indicates statistical significance at $p<0.05$
High continuity of care was defined as a Bice-Boxerman continuity of care score greater than the condition specific median. Low continuity of care was defined as having a value less than or equal to the condition specific median value.
Neighborhood was defined based on the ZIP code Tabulation Area (ZCTA).
Data on features of built neighborhood environment were obtained from the National Neighborhood Data Archive (NaNDA), whilst spatial accessibility of health care providers was obtained from a publicly available dataset by Naylor, et al. 2019.
All variables were adjusted for simultaneously in the regression model.

Table G.9 Results of sensitivity analyses examining individual and community-level characteristics associated with high Continuity of Care amongst individuals aging with Multiple Sclerosis, Optum® Clinformatics® Data Mart

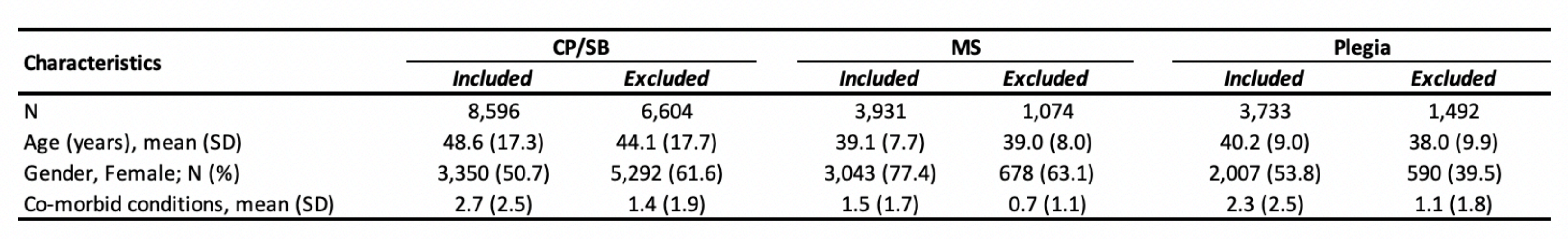
| | ***OR*** | ***LCL*** | ***UCL*** |
|---|---|---|---|
| ***Individual-level characteristics*** | | | |
| Age group (ref=18-40) | | | |
| 41-50 | 1.12 | 0.98 | 1.28 |
| Elixhauser, 5 units | **0.63** | **0.51** | **0.77** |
| Gender, M | **1.63** | **1.38** | **1.91** |
| Year, 1 year | **0.97** | **0.94** | **1.00** |
| | | | |
| ***Neighborhood-level characteristics (Ref= High)*** | | | |
| Affluence | | | |
| Low | 1.00 | 0.78 | 1.28 |
| Medium | 1.08 | 0.90 | 1.30 |
| Disadvantage | | | |
| Low | 0.99 | 0.80 | 1.23 |
| Medium | 1.12 | 0.94 | 1.34 |
| Density of Broadband Internet Connections | | | |
| Low | **1.44** | **1.15** | **1.80** |
| Medium | 1.05 | 0.88 | 1.25 |
| Density of Transit Stops | | | |
| Low | 1.00 | 0.82 | 1.23 |
| Medium | 0.94 | 0.76 | 1.16 |
| Spatial Accessibility of Chiropractor | | | |
| Low | 0.94 | 0.78 | 1.13 |
| Medium | 0.98 | 0.84 | 1.16 |
| Spatial Accessibility of Medical Specialists | | | |
| Low | 0.91 | 0.73 | 1.14 |
| Medium | 0.98 | 0.82 | 1.17 |
| Spatial Accessibility of Family Medicine/Nurse Practitioners | | | |
| Low | 1.02 | 0.84 | 1.23 |
| Medium | 0.85 | 0.70 | 1.02 |
| Density of Residential Care/Skilled Nursing Facilities | | | |
| Low | 1.15 | 0.87 | 1.52 |
| Medium | 1.15 | 0.94 | 1.40 |
| Density of Hospitals | | | |
| Low | --- | --- | --- |
| Medium | --- | --- | --- |
| Density of Ambulatory Care Facilities | | | |
| Low | --- | --- | --- |
| Medium | --- | --- | --- |
| Population Density | | | |
| Low | 0.84 | 0.64 | 1.09 |
| High | 0.90 | 0.74 | 1.09 |

Abbreviations: LCL, Lower 95% confidence interval; M, Male; OR, Odds ratio; Ref, Reference; T, tertile; UCL, Upper 95% confidence interval.
Continuity of care was computed in the 1-year post index-date based on the Bice-Boxerman continuity of care index score.
Computed odds of high continuity (vs low continuity).
Bold text indicates statistical significance at p<0.05
High continuity of care was defined as a Bice-Boxerman continuity of care score greater than the condition specific median. Low continuity of care was defined as having a value less than or equal to the condition specific median value.
Neighborhood was defined based on the ZIP code Tabulation Area (ZCTA).
Data on features of built neighborhood environment were obtained from the National Neighborhood Data Archive (NaNDA), whilst spatial accessibility of health care providers was obtained from a publicly available dataset by Naylor, et al. 2019.
All variables were adjusted for simultaneously in the regression model.

# APPENDIX H

## Sensitivity Analyses for Inclusion Criteria in Aims 2 and 3

Table H.10 Comparison of demographic characteristics of individuals included and excluded after application of the Bice-Boxerman Continuity of Care criteria



| Characteristics | CP/SB |  | MS |  | Plegia |  |
|---|---|---|---|---|---|---|
|  | *Included* | *Excluded* | *Included* | *Excluded* | *Included* | *Excluded* |
| N | 8,596 | 6,604 | 3,931 | 1,074 | 3,733 | 1,492 |
| Age (years), mean (SD) | 48.6 (17.3) | 44.1 (17.7) | 39.1 (7.7) | 39.0 (8.0) | 40.2 (9.0) | 38.0 (9.9) |
| Gender, Female; N (%) | 3,350 (50.7) | 5,292 (61.6) | 3,043 (77.4) | 678 (63.1) | 2,007 (53.8) | 590 (39.5) |
| Co-morbid conditions, mean (SD) | 2.7 (2.5) | 1.4 (1.9) | 1.5 (1.7) | 0.7 (1.1) | 2.3 (2.5) | 1.1 (1.8) |

Abbreviations: CP, Cerebral Palsy; MS, Multiple Sclerosis; N, Number; SB, Spina Bifida; SD, Standard Deviation
Continuity of Care criteria was the requirement of at least 4 outpatient/office visits in the 1 year following index date.

# APPENDIX I

## Diagnostic Codes for Identification of Chronic Secondary Health Conditions and Procedural Codes for Preventive Screenings

Table I.11 International Classification of Diseases, 9th and 10th Revision, Clinical Modification Codes for identifying the secondary health conditions of type 2 diabetes mellitus, hypertension, and mood and pain Disorders, Optum® Clinformatics® Data Mart

| **Conditions** | **Diagnostic Codes** | |
|---|---|---|
| | **ICD-9 CM** | **ICD-10 CM** |
| **Pain** | 338.0, 338.11, 338.12, 338.18, 338.19, 338.21, 338.22, 338.28, 338.29, 338.3, 338.4 | G89.0, G89.11, G89.12, G89.18, G89.21, G89.22, G89.28, G89.29, G89.3, G89.4 |
| **Mood** | 293.83, 296.00, 296.01, 296.02, 296.03, 296.04, 296.05, 296.06, 296.10, 296.11, 296.12, 296.13, 296.14, 296.15, 296.16, 296.20, 296.21, 296.22, 296.23, 296.24, 296.25, 296.26, 296.30, 296.31, 296.32, 296.33, 296.34, 296.35, 296.36, 296.40, 296.41, 296.42, 296.43, 296.44, 296.45, 296.46, 296.50, 296.51, 296.52, 296.53, 296.54, 296.55, 296.56, 296.60, 296.61, 296.62, 296.63, 296.64, 296.65, 296.66, 296.7, 296.80, 296.81, 296.82, 296.89, 296.90, 296.99, 300.4, 311 | F06.30, F06.31, F06.32, F06.33, F06.34, F30.10, F30.11, F30.12, F30.13, F30.2, F30.3, F30.4, F30.8, F30.9, F31.0, F31.10, F31.11, F31.12, F31.13, F31.2, F31.30, F31.31, F31.32, F31.4, F31.5, F31.60, F31.61, F31.62, F31.63, F31.64, F31.70, F31.71, F31.72, F31.73, F31.74, F31.75, F31.76, F31.77, F31.78, F31.81, F31.89, F31.9, F32.0, F32.1, F32.2, F32.3, F32.4, F32.5, F32.8, F32.81, F32.89, F32.9, F33.0, F33.1, F33.2, F33.3, F33.40, F33.41, F33.42, F33.8, F33.9, F34.0, F34.1, F34.8, F34.81, F34.89, F34.9, F39, R45.86 |
| **Type 2 Diabetes Mellitus** | 250.00, 250.02, 250.10, 250.12, 250.20, 250.22, 250.30, 250.32, 250.40, 250.42, 250.50, 250.52, 250.60, 250.62, 250.70, 250.72, 250.80, 250.82, 250.90, 250.92 | E11.00, E11.01, E11.10, E11.11, E11.21, E11.22, E11.29, E11.311, E11.319, E11.321, E11.3211, E11.3212, E11.3213, E11.3219, E11.329, E11.3291, E11.3292, E11.3293, E11.3299, E11.331, E11.3311, E11.3312, E11.3313, E11.3319, E11.339, E11.3391, E11.3392, E11.3393, E11.3399, E11.341, E11.3411, E11.3412, E11.3413, E11.3419, E11.349, E11.3491, E11.3492, E11.3493, E11.3499, E11.351, E11.3511, E11.3512, E11.3513, E11.3519, E11.3521, E11.3522, E11.3523, E11.3529, E11.3531, E11.3532, |

| | | |
|---|---|---|
| | | E11.3533, E11.3539, E11.3541, E11.3542, E11.3543, E11.3549, E11.3551, E11.3552, E11.3553, E11.3559, E11.359, E11.3591, E11.3592, E11.3593, E11.3599, E11.36, E11.37X1, E11.37X2, E11.37X3, E11.37X9, E11.39, E11.40, E11.41, E11.42, E11.43, E11.44, E11.49, E11.51, E11.52, E11.59, E11.610, E11.618, E11.620, E11.621, E11.622, E11.628, E11.630, E11.638, E11.641, E11.649, E11.65, E11.69, E11.8, E11.9 |
| **Hypertension** | 401.0, 401.1, 401.9, 402.00, 402.01, 402.10, 402.11, 402.90, 402.91, 403.0, 403.00, 403.01, 403.1, 403.10, 403.11, 403.9, 403.90, 403.91, 404.0, 404.00, 404.01, 404.02, 404.03, 404.1, 404.10, 404.11, 404.12, 404.13, 404.9, 404.90, 404.91, 404.92, 404.93, 405.01, 405.09, 405.11, 405.19, 405.91, 405.99, 437.2 | I10, I11.0, I11.9 |

Abbreviations: ICD, International Classification of Diseases; ICD-9 CM, International Classification of Diseases, 9th Revision; ICD-10 CM, International Classification of Diseases, 10th Revision

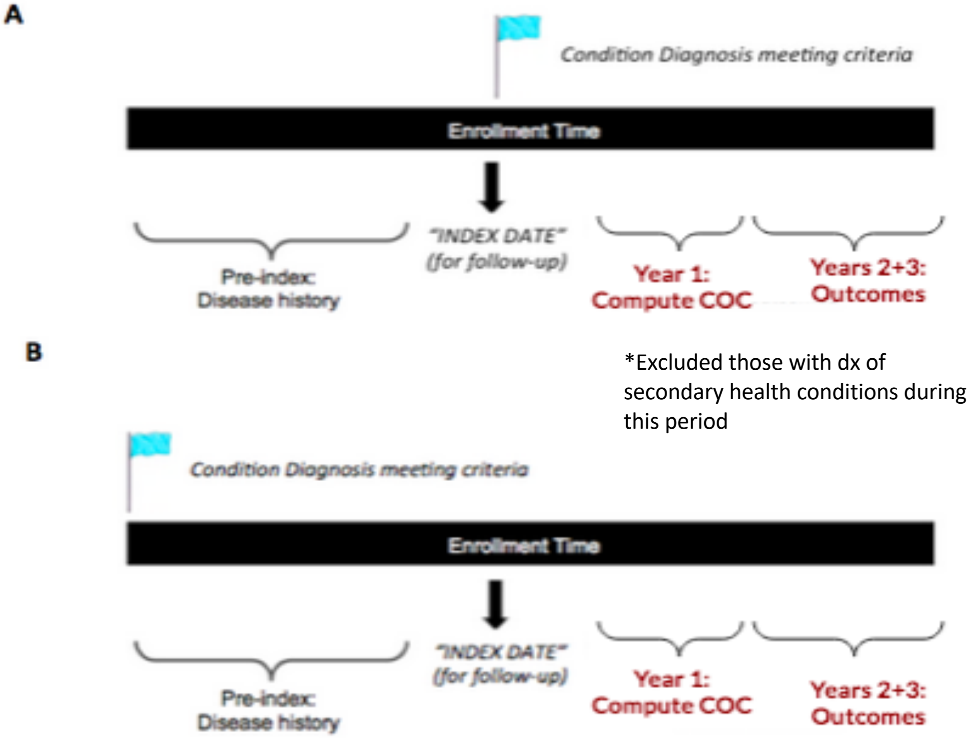
Table I.12 Current Procedural Terminology (CPT®) codes version 4 (CPT-4) for identifying diabetes and cholesterol screening, Optum® Clinformatics® Data Mart

| **Preventive Screening Test** | **CPT Code** |
|---|---|
| Cholesterol | 80061, 82465, 83718, 83719, 83721, 83722, 84478 |
| Diabetes | 82947, 82948, 82950, 82951, 82952, 82962, 83036, 83037 |

Abbreviation: CPT, Current Procedural Terminology

# APPENDIX J

## Methodological plan for Aim 3



*Excluded those with dx of secondary health conditions during this period

*Excluded those with dx of secondary health conditions during this period

Figure J.10 Cohort creation schematic for individuals aging with acquired (A) and congenital (B) physical disabilities for Aim 3 in Optum® Clinformatics® Data Mart

Table J.13 Association between continuity of care (COC) and chronic health outcomes and preventive screening in individuals aging with disability before and after exclusions for regression analysis, Optum® Clinformatics® Data Mart

| | | **HTN** | | | | **T2DM** | | | | **Mood** | | | | **Pain** | | | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| | | No exclusion | | Exclusion | | No exclusion | | Exclusion | | No exclusion | | Exclusion | | No exclusion | | Exclusion | |
| | | Row % | P-value | Row % | P-value | Row % | P-value | Row % | P-value | Row % | P-value | Row % | P-value | Row % | P-value | Row % | P-value |
| CP/SB | Low COC | 54.3 | **<0.0001** | 15.9 | **0.0118** | 22.7 | **<0.0001** | 6.3 | **0.0009** | 36.0 | 0.9404 | 17.2 | 0.8376 | 26.0 | **<0.0001** | 15.1 | **0.028** |
| | High COC | 62.1 | | 18.9 | | 27.8 | | 8.4 | | 35.9 | | 17.4 | | 22.1 | | 13.3 | |
| MS | Low COC | 31.0 | 0.6137 | 9.8 | 0.8839 | 11.7 | 0.5599 | 3.6 | 0.7331 | 34.5 | **0.0221** | 15.8 | **0.0267** | 18.1 | **0.0002** | 9.4 | **0.0011** |
| | High COC | 31.7 | | 9.7 | | 12.3 | | 3.8 | | 31.0 | | 13.0 | | 13.8 | | 6.5 | |
| Plegia | Low COC | 47.0 | **<0.0001** | 10.3 | **0.0167** | 21.6 | **0.0022** | 5.5 | 0.4509 | 42.6 | **0.0191** | 17.4 | **0.0495** | 29.3 | 0.3005 | 13.5 | 0.463 |
| | High COC | 55.0 | | 13.8 | | 25.8 | | 6.2 | | 38.8 | | 14.6 | | 27.7 | | 12.6 | |

Abbreviations: COC, continuity of care; CP/SB, Cerebral Palsy/Spina Bifida; HTN, Hypertension; MS, Multiple Sclerosis; T2DM, Type 2 Diabetes Mellitus.

Continuity of care was computed in the 1-year post index-date based on the Bice-Boxerman continuity of care index score.

Bold text indicates statistical significance at p<0.05.

P-value was computed based on bivariate analyses examining the association between high continuity of care (vs low continuity) and each of the health conditions.

Exclusion for Type 2 Diabetes Mellitus (T2DM) and hypertension were those with history of disease and also those with event in the first year (during which continuity of care was calculated).

Exclusion for pain and mood disorders were those who had event in the first year after index during which continuity of care was calculated.

# BIBLIOGRAPHY

Morenoff , JD, and JW Lynch. 2004. "What Makes a Place Healthy? Neighborhood Influences on Racial/ Ethnic Disparities in Health over the Life Course." In *Critical Perspectives on Racial and Ethnic Differences in Health in Late Life.*, edited by NB Anderson, RA Bulatao and B Cohen, 406-449. Washington (DC): National Academies Press.

Adair, CE, GM McDougall, CR Milton, AS Joyce, TC Wild, A Gordon, N Costigan, L Kowalsky, G Pasmeny, and A Beckie. 2005. "Continuity of care and health outcomes among persons with severe mental illness." *Psychiatric Services* 56 (9): 1061-1069.

Aday, LA, and RM Andersen. 1974. "A framework for the study of access to medical care." *Health Serv Res* 9 (3): 208-220.

Aday, LA, and RM Andersen. 1981. "Equity to access to medical care: A conceptual and empirical overview." *Med Care* 19 (supplement): 4-27.

Adler, R, A Vasiliadis, and N Bickell. 2010. "The relationship between continuity and patient satisfaction: a systematic review." *Family Practice* 27 (2): 171-178.

Administration for Community Living. 2018. *2017 Profile of Older Americans.* Washington, DC: inistration for Community Living.

Agency for Healthcare Research and Quality. 2001. "Guide to Prevention Quality Indicators." Accessed April 19, 2021. https://www.ahrq.gov/downloads/pub/ahrqqi/pqiguide.pdf.

Allan, GM, AJ Lindblad, AJ Comeau, J Coppola, B Hudson, M Mannarino, C McMinis, et al. 2015. "Simplified lipid guidelines: Prevention and management of cardiovascular disease in primary care." *Canadian Family Physician* 61 (10): 857-e450.

Allerton, L, and E Emerson. 2012. "British adults with chronic health conditions or impairments face significant barriers to accessing health services." *Public Health* 126 (11): 920-927.

Altman, B, and A Bernstein. 2008. *Disability and health in the United States, 2001–2005.* Hyattsville, MD: National Center for Health Statistics.

American Association on Health and Disability. 2011. "More Health Screening for People with Disabilities." Accessed April 16, 2021. https://aahd.us/wp-content/uploads/2012/03/MoreHealthScreening2011.pdf.

American Diabetes Association. 2018. "STANDARDS OFMEDICAL CARE IN DIABETES—2018." Accessed April 21, 2021. http://diabetesed.net/wp-content/uploads/2017/12/2018-ADA-Standards-of-Care.pdf.

American Medical Association. n.d. *CPT® overview and code approval* . Accessed April 23, 2021. https://www.ama-assn.org/practice-management/cpt/cpt-overview-and-code-approval.

Amjad, H, D Carmichael, A Austin, C Chang, and J Bynum. 2016. "Continuity of care and healthcare utilization in older adults with dementia in fee-for-serviec medicare." *JAMA Intern Med* 176 (9): 1371-1378.

Anand, S, C Hawkes, R de Souza, A Mente , M Dehghan , R Nuge, MA Zulyniak , et al. 2015. "Food consumption and its impact on cardiovascular disease: Importance of solutions focused on the globalized food system -- A report from the workshop convened by the World Heart Federation." *Am Coll Cardiol* 66 (14): 1590-1614.

Andersen, RM. 1995. "Revisiting the behvaioral model and access to medical care: does it matter?" *J Health Soc Behav* 36: 1-10.

Andersen, RM, and JF Newman. 1973. "Societal and individual determinants of medical care utilization in the United States." *Milbank Memorial Fund Quarterly -- Health and Society* 51 (1): 95-124.

Annaswamy, TM, M Verduzco-Gutierrez, and L Frieden. 2020. "Telemedicine barriers and challenges for persons with disabilities: COVID-19 and beyond." *Disability and Health Journal* 13 (4): 100973.

Bachman, S, M Vedrani, M Drainoni, C Tobias, and L Maisels. 2006. "Provider perceptions of their capacity to offer accessible health care for people with disabilities." *Journal of Disability Policy Studies* 3: 130-136.

Baker, TA, and CR Green. 2005. "Inter-race differences among Black and White Americans presenting for chronic pain management: The influene of age, physical health and psychosocial factors." *Pain Medicine* 6 (1): 29-38.

Bandini, LG, C Curtin, C Hamad, DJ Tybor, and A Must. 2005. "Prevalence of overweight in children with developemental disorders in the continuous national health and nutrition examination survey (NHANES) 1999-2002." *J Pediatr* 146: 738-743.

Barer, BM. 1994. "Men and women aging differently." *Int J Aging Hum Dev* 38 (1): 29-40.

Barker, I, A Steventon, and SR Deeny. 2017. "Association between continuity of care in general practice and hospital admissions for ambulatory care sensitive conditions: cross sectional study of routinely collected, person level data." *BMJ* 356: j84.

Bartley, EJ, and RB Fillingim. 2013. "Sex differences in pain: A brief review of clinical and experimental findings." *British Journal of Anasthesia* 111 (1): 52-58.

Bayliss, EA, JL Ellis, JA Shoup, C Zeng, DB McQuillan, and JF Steiner. 2015. "Effect of continuity of care on hospital utilization for seniors with multiple medical conditions in an integrated health care system." *The Annals of Family Medicine* 13 (2): 123-129.

Bell, NR, R Grad, JA Dickinson, H Singh, AE Moore, D Kasperavicius, and KL Kretschmer. 2017. "Better decision making in preventive health screening: Balancing benefits and harms." *Canadian Family Physician* 63 (7): 521-524.

Benda, N, T Veinot, C Sieck, and J Ancker. 2020. "Broadband internet access is a social determinant of health." *Am J Public Health* 110: 1123-1125.

Bentler, SE, RO Morgan, BA Virnig, and FD Wolinsky. 2014. "Do claims-based continuity of care measures reflect the patient perspective?" *Med Care Res Rev* 71 (2): 156-173.

Berke, EM, TD Koepsell, AV Moudon, RE Hoskins, and EB Larson. 2007. "Association of the built environment with physical activity and obesity in older persons." *Am J Public Health* 97 (3): 486-492.

Berkowitz, SA, JB Meigs, and DJ Wexler. 2013. "Age at type 2 diabetes onset and glycemic control: Results from the National Health and Nutrition Examination Survey (NHANES) 2005-2010." *Diabetologia* 56 (12): 2593-2600.

Bermejo, PE, C Oreja-Guevara, and E Diez-Tejedor. 2010. "Pain in multiple sclerosis: prevalence, mechanisms, types and treatment." *Rev Neurol* 50 (2): 101-108.

Bezyak, JL, SA Sabella, and RH Gattis. 2017. "Public transportation: An investigation of barriers for people with disabilities." *J Disabil Policy Stud* 28 (1): 52-60.

Bice, T, and S Boxerman. 1977. "A quantitative measure of continuity of care." *Med Care* 15 (4): 347-349.

Blaszczyk, M, M Suchocka, M Wojnowska-Heciak, and M Muszynska. 2020. "Quality of urban parks in the perception of city residents with mobility difficulties." *PeerJ* 8: e10570.

Blue Cross Blue Shield Network. n.d. *What's the difference between HMO and PPO plans?* Accessed March 31, 2021. https://www.bcbsm.com/index/health-insurance-help/faqs/topics/how-health-insurance-works/difference-hmo-ppo.html.

Booth, ML, N Owen, A Bauman, O Clavisi, and E Leslie. 2000. "Social-cognitive and perceived environment influences associated with physical activity in older Australians." *Prev Med* 31 (1): 15-22.

Borsky, A, C Zhan, T Miller, Q Ngo-Metzger, AS Bierman, and D Meyers. 2018. "Few Americans receive all high-priority, appropriate clinical preventive services." *Health Affairs* 37 (6): 925-928.

Bosman, H, HD van de Mheen, GJ Borsboom, and JP Mackenbach. 2001. "Neighborhood socioeconomic status and all-cause mortality." *American Journal of Epidemiology* 153 (4): 363-371.

Bosomworth, NJ. 2011. "Practical use of the Framingham risk score in primary prevention: Canadian perspective." *Canadian Family Physician* 57 (4): 417-423.

Botticello, AL, T Rohrbach, and N Cobbold. 2014. "Disability and the built environment: an investigation of community and neighborhood land uses and participation for physically impaired adults." *Annals of Epidemiology* 24 (7): 545-550.

Branigan , M, DE Stewart, GS Tardif, and A Veltman. 2001. "Perceptions of primary healthcare services among persons with physical disabilities - part 2: quality issues." *Medscape General Medical* 3 (2): 19.

Brantley, PJ, EL O'hea, G Jones, and DJ Mehan. 2002. "The influence of income level and ethnicity on coping strategies." *Journal of Psychopathology and Behavioral Assessment* 24 (1): 39-45.

Brown, AF, A Ang, and Pebley. 2007. "The relationship between neighborhood characteristics and self-rated health for adults with chronic conditions." *Am J Public Health* 97 (5): 926-932.

Browning, CR, and KA Cagney. 2003. "Moving beyond poverty: Neighborhood structural, social processess, and health." *Journal of Health and Social Behavior* 44 (4): 552-571.

Brownson, RC, CM Hoehner, K Day, A Forsyth, and JF Sallis. 2009. "Measuring the built environment for physical activity: state of the science." *Am J Prev Med* 36 (4(suppl)): S99-S123.

Bureau of Transportation Statistics. 2018. *The National Transit Map.* Accessed 2020. https://www.bts.gov/national-transit-map/about.

Bynum, JP, L Barre, C Reed, and H Passow. 2014. "Participation of very old adults in health care decisions." *Medical decision making* 34 (2): 216-230.

Bynum, JPW, CH Chang, A Austin, D Carmichael, and E Meara. 2017. "Outcomes in older adults with multimorbidity assoicated with predominant provider of care specialty." *Journal of the American Geriatrics Society* 65 (9): 1916-1923.

Cabana, M, and S Jee. 2004. "Does continuity of care improve patient outcomes?" *J Fam Practice* 53 (12): 974-980.

Cadarette, SM, and L Wong. 2015. "An introduction to health care administrative data." *Canadian Journal of Hospital Pharmacy* 68 (3): 232-237.

Calder, A, G Sole, and H Mulligan. 2018. "The accessibility of fitness centers for people with disabilities: a systematic review." *Disability and Health Journal* 11 (4): 525-536.

Campbell, M, and M Putnam. 2017. "Reducing the shared burden of chronic conditions among persons aging with disability and older adults in the United States through bridging aging and disability." *Healthcare* 5 (3): 56.

Campbell, ML, D Sheets, and PS Strong. 1999. "Secondary health conditions among middle-aged individuals with chronic physicial disabilities: Implications for unmet needs for services." *Assist Technol* 11 (2): 105-122.

Carbonell, A, JJ Navarro-Perez, and MV Mestre. 2015. "Challenges and bariers in mental healthcare systems and their impact on the family: A systematic integrative review." *Health & Social Care in the Community* 28 (5): 1366-1379.

Carson, EA, G Swait, IP Johnson, and C Cunliffe. 2009. "Chiropractic care amongst people with multiple sclerosis: A survey of MS therapy centres in the UK." *Clinical Chiropractic* 12: 23-27.

Cartensen, LL, DM Isaacowitz, and ST Charles. 1999. "Taking time seriously: A theory of socioemotional selectivity." *American Psychologist* 54: 165-181.

Casagrande, SS, MC Whitt-Glover, KJ Lancaster, AM Odoms-Young, and TL Gary. 2009. "Built environment and health behaviors among African Americans -- A systematic review." *Am J Prev Med* 36 (2): 174-181.

Centers for Disease Control (a). 2020. *Disability and Health Related Conditions.* September 16. Accessed April 16, 2021. https://www.cdc.gov/ncbddd/disabilityandhealth/relatedconditions.html.

Centers for Disease Control (b). 2020. *Women with Disabilities and Breast Cancer Screening.* September 15. Accessed April 16, 2021. https://www.cdc.gov/ncbddd/disabilityandhealth/breast-cancer-screening.html.

Centers for Disease Control. 2018. *Adults with Disabilities: Physical Activity is for Everybody.* September 5. Accessed April 16, 2021. https://www.cdc.gov/vitalsigns/disabilities/index.html.

Centers for Disease Control and Prevention (a). 2019. *What is Cerebral Palsy?* Accessed March 25, 2020. https://www.cdc.gov/ncbddd/cp/facts.html.

Centers for Disease Control and Prevention (b). 2019. *What is Spina Bifida?* Accessed March 25, 2020. https://www.cdc.gov/ncbddd/spinabifida/facts.html.

Centers for Disease Control and Prevention. 2017. *About the National Health and Nutrition Examination Survey.* Accessed May 5, 2021. https://www.cdc.gov/nchs/nhanes/about_nhanes.htm.

Centers for Disease Control and Prevention. 2020 (b). *Cancer Screening Prevalence Among Adults with Disabilities.* Accessed April 20, 2021. https://www.cdc.gov/cancer/dcpc/research/articles/screening-disabilities.htm.

Centers for Disease Control and Prevention. 2019. *Cigarette Smoking Among Adults with Disabilities.* Accessed April 12, 2021. https://www.cdc.gov/ncbddd/disabilityandhealth/smoking-in-adults.html.

Centers for Disease Control and Prevention. 2020. *Increasing Physical Activity Among Adults with Disabilities.* Accessed April 16, 2021. https://www.cdc.gov/ncbddd/disabilityandhealth/pa.html.

Centers for Disease Control and Prevention. n.d. *Increasing Physical Activity Among Adults with Disabilities.* Accessed April 16, 2021. https://www.cdc.gov/ncbddd/disabilityandhealth/pa.html.

Centers for Disease Control and Prevention. 2013. "Influenza vaccination practices of physicians and caregivers of children with neurologic and neurodevelopmental conditions - United States, 2011-12 influenza season." *MMWR Morb Mortal Wkly Rep* 62 (36): 744-746.

Centers for Disease Control and Prevention. 2020(b). *Telehealth Interventions to Improve Chronic Disease.* Accessed September 1, 2021. https://www.cdc.gov/dhdsp/pubs/telehealth.htm.

Chang, H, P Chen, C Yang, Y Su, and C Lee. 2016. "Comparison of Elixhauser and Charlson methods for predicting Oral cancer survival." *Medicine* 95 (7): e2861.

Chen, AY, SF Kim, AJ Houtrow, and PW Newacheck. 2010. "Prevalence of obesity among children with chronic conditions." *Obesity* 18: 210-213.

Chen, CC, CH Tseng, and SH Cheng. 2013. "continuity of care, medication adherence, and health care outcomes among patients with newly diagnosed type 2 diabetes: a longitudinal analysis." *Medical Care* 231-237.

Chen, LS, YJ Chou, JH Tsay, CH Lee, P Chou, and N Huang. 2009. "Variation in the cervical cancer screening compliance among women with disability." *Journal of Medical Screening* 16 (2): 85-90.

Cheng, S, C Chen, and Y Hou. 2010. "A longitudinal examination of continuity of care and avoidable hospitalization." *Arch Intern Med* 170 (18): 1671-1677.

Cheng, SH, and CC Chen. 2014. "Effects of continuity of care on medication duplication among the elderly." *Medical Care* 52 (2): 149-156.

Christakis, DA, AE Kazak, JA Wright, FJ Zimmerman, AL Bassett, and FA Connell. 2004. "What factors are associated with achieving high continuity of care?" *Family Medicine* 36 (1): 55-60.

Christakis, DA, L Mell, JA Wright, R Davis, and FA Connell. 2000. "The association between greater continuity and timely measels-mumps-rubella vaccination." *American Journal of Public Health* 90 (6): 962.

Christensen, K, JM Holt, and JF Wilson. 2010. "Effects of perceived neighborhood characteristics and use of community facilities on physical activity of adults with and without disabilities." *Prev Chronic Dis* 7 (5): A105.

Christine, P, A Auchincloss, A Bertoni, MR Carnethon , BN Sánchez , K Moore , SD Adar , TB Horwich , KE Watson , and AV Diez Roux . 2015. "Longitudinal associations between neighborhood physical and social environments and incident Type 2 Diabetes Mellitus: The Multi-Ethnic Study of Atherosclerosis (MESA)." *JAMA Intern Med* 175 (8): 1311-1320.

Chu, H, C Chen, and S Cheng. 2012. "Continuity of care, potentially inappropriate medication, and health care outcomes among the elderly: evidence from a longitudinal analysis in Taiwan." *Med Care* 50 (11): 1002-1009.

Chu, T, Y Ng, and S Wu. 2010. "Comparison of different comorbidity measures for use with administrative data in predicting short- and long-term mortality." *BMC Health Services Resesarch* 10 (140): 1-7.

Clarke, P, and LK George. 2005. "The role of the built environment in the disablement process." *Am J Public Health* 95 (11): 1933-1939.

Clarke, P, J Hirsch, R Melendez, M Winters, J Gould, M Ashe, S Furst, and H McKay. 2017. "Snow and rain modifying neighborhood walkability for older adults." *Can J Aging* 36 (2): 159-169.

Clarke, P, J Morenoff, M Debbink, E Golberstein, M Elliott, and P Lantz. 2013. "Cumulative exposure to neighborhood context: Consequences for health transitions over the adult life course." *Res Aging* 36 (1): 115-142.

Clarke, PJ, and K Latham. 2014. "Life course health and socioeconomic profiles of Americans with disability." *Disabiity and Health Journal* 7 (10): S15-S23.

Cochran, AL. 2020. "Impacts of COVID-19 on access to transportation for people with disabilities." *Transportation Research Interdisciplinary Perspectives* 8: 100263.

Cohen-Mekelberg, S, SD Saini, SL Krein, TP Hofer, BI Wallace, JM Hollingsworth, JPW Bynum, et al. 2020. "Association of continuity of care with outcomes in US veterans with inflammatory bowel disease." *JAMA Network Open* 3 (9): e2015899-e2015899.

Continelli, T, S McGinnis, and T Holmes. 2010. "The effect of local primary are physician supply on the utilization of preventive health services in the United States." *Health and Place* 16 (5): 942-951.

Cremer, N, EA Hurvitz, and MD Peterson. 2017. "Multimorbidity in middle-aged adults with cerebral palsy." *The American journal of medicine* 130 (6): 744.e9-744.e15.

Crimmins, EM. 2015. "Lifespan and healthspan: Past, present, and promise." *Gerontologist* 55 (6): 901-911.

Cubanski , J, T Neuman, and A Damico. 2016. *Medicare's Role for People Under Age 65 with Disabilities.* Accessed September 13, 2021. https://www.kff.org/medicare/issue-brief/medicares-role-for-people-under-age-65-with-disabilities/.

Cummins, S, M Stafford, S Macintyre, M Marmot, and A Ellaway. 2005. "Neighborhood environment and its association with self rated health: Evidence from Scotland and England." *J Epidemiol Community Health* 59 (3): 207-213.

Curtis, KA, and S McClellan. 1995. "Falling through the safety net: poverty, food assistance and shopping constraints in an American city." *Urban Anthropology and Studies of Cultural Systems and World Economic Developement* 93-135.

Czapka, EA, and M Sagbakken. 2016. ""Where to find those doctors?" A qualitative study on barriers and facilitators in access to and utilization of health care services by Polish migrants in Norway." *BMC Health Services Research* 16 (1): 1-14.

Davis, MA, R Anthopolos, J Tootoo, M Titler, JPW Bynum, and S Shipman. 2018. "Supply of healthcare providers in relation to regional socioeconomic and health status." *JGIM* 33 (4): 412-414.

de Lorgeril, M, P Salen, JL Martin, I Monjaud, J Delaye, and N Mamelle. 1999. "Mediterranean diet, traditional risk factors, and the rate of cardiovascular complications after myocardial infarction: final report of the Lyon Diet Heart Study." *Circulation* 99: 779-785.

Demmer, RT, AM Zuk, M Rosenbaum, and M Desvarieux. 2013. "Prevalence of diagnosed and undiagnosed type 2 diabetes mellitus among US adolescents: Results from the continuous NHANES 1999-2010." *Am J Epidemiol* 178 (7): 1106-1113.

DeVivo, M, and J Richards. 1996. "Marriage rates among persons with spinal cord injury." *Rehabil Psychol* 41: 321-339.

Diez Roux, A. 2001. "Investigating neighborhood and area effects on health." *Amerocam Journal of Public Health* 91 (11): 1783-1789.

Diez Roux, AV, and C Mair. 2010. "Neighborhoods and health." *Ann N Y Acad Sci* 1186: 125-145.

Diez Roux, AV, SS Merkin, D Arnett, L Chambless, M Massing, FJ Nieto, P Sorlie, M Szklo, HA Tyroler, and RL Watson. 2001. "Neighborhood of residence and incidence of coronary heart disease." *N Engl J Med* 345: 99-106.

Diez-Roux, AV, FJ Nieto, C Muntaner, HA Tyroler, GW Comstock, E Shahar, LS Cooper, RL Watson, and M Szklo. 1997. "Neighborhood environments and coronary heart disease: A multilevel analysis." *American Journal of Epidemiology* 146: 48-63.

Dillaway, HE, and CL Lysack. 2015. ""Most of them are amateurs": Women with spinal cord injury experience the lack of education and training among medical providers while seeking gynecological care." *Disability Studies Quarterly* 35 (3): 1-25.

Ding, D, JF Sallis, J Kerr, S Lee, and DE Rosenberg. 2011. "Neighborhood environment and physical activity among youth: A review." *American Journal of Preventive Medicine* 41: 442-455.

Dixon-Ibarra, A, and W Horner-Johnson. 2014. "Disability status as an antecedent to chronic conditions: National Health Interview Survey, 2006-2012." *Prev Chronic Dis* 11: 130251.

Djurhuus, S, HS Hansen, M Aadahl, and C Glumer. 2014. "The association between access to public transportation and self-reported active commuting." *International Journal of Environmental Research and Public Health* 11 (12): 12632-12651.

Do, DP, L Wang, and MR Elliot. 2013. "Investigating the relationship between neighborhood poverty and mortality risk: A marginal structural equation modeling approach." *Social Science and Medicine* 91: 58-66.

Doty, MM, A Fryer, and A Audet. 2012. "The role of care coordinators in improving care coordination: The patient's perspective." *Arch Intern Med* 172 (7): 587-588.

Driscoll, MA, MT Knobf, DM Higgins, A Heapy, A Lee, and S Haskell. 2018. "Patient experiences navigating chronic pain management in an integrated health care system: A qualitative investigation of women and men." *Pain Medicine* 19 (1): S19-S29.

Elliot, MN, WG Lehrman, MK Beckett, E Goldstein, K Hambarsoomian, and LA Giordano. 2012. "Gender differences in patients' perceptions of inpatient care." *Health Services Research* 47 (4): 1482-1501.

Ellis, LJ, R Lang, JP Shield, JR Wilkinson, JSM Lidstone, S Coulton, and CD Summerbell. 2006. "Obesity and disability -- a short review." *Obes Rev* 7 (4): 341-345.

Esposito, M, L Mao, J Finlay, I Gomez-Lopez, A Khan, P Clarke, and M Chenoweth. 2020. "National Neighborhood Data Archive (NaNDA): Eating and Drinking Places by ZIP Code Tabulation Area, United States, 2003-2017." Ann Arbor, MI: Inter-university Consortium for Political and Social Research [distributor], September 16.

Fenton, JJ, P Franks, RJ Reid, JG Elmore, and L Baldwin. 2008. "Continuity of care and cancer screening among health plan employees." *Medical Care* 46 (1): 58-62.

Field, M, and A Jette. 2007. "Secondary conditions and aging with disability." In *Secondary conditions and aging with disability*, edited by M Field and A Jette, 136-161. Washington, DC: The National Academies of Science Press.

Finlay, J, AM Khan, C Gronlund, K Sol, J Jang, R Melendez, S Judd, and P Clarke. 2020. "Weather woes? Exploring potential links between precipitation and age-related cognitive decline." *International Journal of Environmental Research and Public Health* 9011.

Finlay, J, L Mao, M Esposito, I Gomez-Lopez, A Khan, P Clarke, and M Chenoweth. 2020 (c). "National Neighborhod Data Archive (NaNDA): Arts, Entertainment, and Recreation Organizations by ZIP Code Tabulation Area, United States 2003-2017." Ann Arbor, MI: Inter-university Consortium for Political and Social Research.

Finlay, J, M Li, M Esposito, I Gomez-Lopez, A Khan, P Clarke, and M Chenoweth. 2020(a). "National Neighborhood Data Archive (NaNDA): Grocery Stores by ZIP

Code Tabulation Area, United States, 2003-2017." Ann Arbor, MI: Inter-university Consortium for Political and Social Research [distributor], 10 01.

Finlay, J, M Li, M Esposito, I Gomez-Lopez, A Khan, P Clarke, and M Chenoweth.. 2020 (b). "National Neighborhood Data Archive (NaNDA): Grocery Stores by ZIP Code Tabulation Area, United States, 2003-2017." Ann Arbor, MI: Inter-university Consortium for Political and Social Research [distributor], October 1.

Fontanella, CA, J Guada, G Phillips, L Ranbom, and JC Fortney. 2014. "Indiidual and contextual-level factors associated with continuity of care for adults with schizophrenia." *Administration and Policy in Mental Health and Mental Health Services Research* 41 (5): 572-587.

Forducey, PG, RL Glueckauf, TF Bergquist, MM Maheu, and M Yutsis. 2012. "Telehealth for persons with severe functional disabilities and their caregivers: facilitating self-care management in the home setting." *Psychological Services* 9 (2): 144.

Formativ Health. 2018. "White Paper: Understanding Hierarchical Condition Categories (HCC)." Accessed August 1, 2021. http://www.formativhealth.com/wp-content/uploads/2018/06/HCC-White-Paper.pdf.

Frieden, T. 2010. "A framework for public health action: the health impact pyramind." *Am J Public Health* 100 (4): 590-595.

Furie, GL, and MM Desai. 2012. "Active transportation and cardiovascular disease risk factors in U.S. adults." *Am J Prev Med* 43 (6): 621-628.

Gagliardi, AR, MC Brouwers, VA Palda, L Lemieux-Charles, and JM Grimshaw. 2011. "How can we improve guideline use? A conceptual framework of implementability." *Implement Sci* 6: 26.

Geerlings, SW, JW Twisk, AT Beekman, DJ Deeg, and W van Tilburg. 2002. "Longitudinal relationship between pain and depression in older adults: sex, age and physical disability." *Social Psychiatry and Psychiatric Epidemiology* 37 (1): 23-30.

Gill, JM, AG Mainous, JJ Diamond, and MJ Lenhard. 2003. "Impact of provider continuity on quality of care for persons with diabetes mellitus." *The Annals of Family Medicine* 1 (3): 162-170.

Gill, JM, and AG Mainous. 1998. "The role of provider continuity in preventing hospitalizations." *Arch Fam Med* 7: 352-357.

Goins, RT, KA Williams, MW Carter, SM Spencer, and T Solovieva. 2005. "Perceived barriers to health care access among rural older adults: A qualitative study." *J Rural Health* 21 (3): 206-213.

Goodin, D, M Corwin, D Kaufman, H Golub, S Reshef, M Rametta, V Knappertz, G Cutter, and D Pleime. 2014. "Causes of death among commercially insured Multiple Sclerosis patients in the United States." *PLoS One* 9 (8): e105207.

Griffith, DA. 1983. "The boundary value problem in spatial statistical analysis." *Journal of Regional Science* 23 (3): 377-387.

Griffith, LE, A Gruneir, K Fisher, D Panjwani, A Gafni, C Patterson, M Markle-Reid, and J Ploeg. 2019. "Insights on multimorbidity and associated health service use and costs from three population-based studies of older adults in Ontario with diabetes, dementia and stroke." *BMC Health Services Research* 19 (1): 1-11.

Gudzune, KA, WL Bennett, LA Cooper, JM Clarke, and SN Bleich. 2014. "Prior doctor shopping resulting from differential treatment correlates with differences in current patient-provider relationships." *Obesity* 22 (9): 1952-1955.

Gulliford, M, J Figueroa-Munoz, M Morgan, D Hughes, B Gibson, R Beech, and M Hudson. 2002. "What does "access to health care" mean?" *J Heal Serv Res Policy* 7 (3): 186-188.

Guthrie, B, and S Wyke. 2000. "Does continuity in general practice really matter?" *BMJ* 321: 734-736.

Guthrie, B, JW Saultz, GK Freeman, and JL Haggerty. 2008. "Continuity of care matters." *BMJ* 337: a867.

Haak, P, M Lenski, M Hidecker, M Li, and N Paneth. 2009. "Cerebral palsy and aging." *Dev Med Child Neurol* 51 (04): 16-23.

Hafez, D, DB Nelson, EG Martin, AJ Cohen, R Northway, and JT Kullgren. 2017. "Understanding type 2 diabetes mellitus screening practices among primary care physicians: A qualitative chart-stimulated recall study." *BMC Family Practice* 18 (1): 1-8.

Hampton, SB, J Cavalier, and R Langford. 2015. "The influence of race and gender on pain management: A systematic literature review." *Pain Management Nursing* 16 (6): 968-977.

Harris, KM. 2003. "How do patients choose physicians? Evidence from a national survey of enrollees in employment-related health plans." *Health Services Research* 38 (2): 711-732.

Haskell, SG, A Heapy, MC Reid, RK Papas, and RD Kerns. 2006. "The prevalence and age-related characteristics of pain in a sample of women veterans receiving primary care." *Journal of Women's Health* 15 (7): 862-869.

He, Wan, Luke J Larsen, and U.S. Census Bureau. 2014. *Older Americans with a disability: 2008-2012.* American Community Survey Reports, ACS-29, Washington, DC: U.S. Government Printing Office.

Hermans, H, and HM Evenhuis. 2014. "Multimorbidity in older adults with intellectual disabilities." *Research in Developemental Disabilities* 35 (4): 776-783.

Herrick, CJ, BW Yount, and AA Eyler. 2016. "Implications of supermarket access, neighborhood walkability and poverty rates for diabetes risk in an employee population." *Public Health Nutrition* 19 (11): 2040-2048.

Hjortdahl, P. 1992. "The influence of general practitioners' knowledge about their patients on the clinical decision-making process." *Scand J Prim Health Care* 10 (4): 290-294.

Hoehner, CM, LK Brennan Ramirez, MB Elliot, SL Handy, and RC Brownson. 2005. "Perceived and objective environmental measures and physical activity among urban adults." *American Journal of Preventive Medicine* 28 (2 Suppl 2): 105-116.

Hoffman, K, Z Birgit-Christiane, B Heiner, and W Eberhard. 2004. "A dietary pattern derived to explain biomarker variations is strongly associated with the risk of coronary artery disease." *The American Journal of Clinical Nutrition* 80 (3): 633-640.

Hostetter, M, and S Klein. 2018. *Creating Better Systems of Care for Adults with Disabilities: Lessons for Policy and Practice.* Accessed March 28, 2021. https://www.commonwealthfund.org/publications/case-study/2018/sep/systems-care-adults-disabilities.

Hurvitz, EA, C Leonard, R Ayyangar, and VS Nelson. 2003. "Complementary and alternative medicine use in families of children with cerebral palsy." *Dev Med Child Neurol* 11: 107-109.

Hussey, PS, EC Schneider, RS Rudin, DS Fox, J Lai, and CE Pollack. 2014. "Continuity and the costs of care for chronic disease." *JAMA Internal Medicine* 174 (5): 742-748.

Iezzoni, IL. 2003. *When walking fails: Mobility problems of adults with chronic conditions.* Berkeley, CA: Milbank Memorial Fund.

Iezzoni, IL, RB Davis, J Soukup, and B O'Day. 2002. "Satisfaction with quality and access to health care among people with disabling conditions." *International Journal on Quality of Health Care* 14: 369-381.

Iezzoni, L, L Ngo, D Li, R Roetzheim, R Drews, and E McCarthy. 2008. "Treatment disparities for disabled Medicare beneficiaries with stage I non-small cell lung cancer." *Arch Phys Med Rehabil* 89 (4): 595-601.

Iezzoni, LI, EP McCarthy, RB Davis, and H Siebens. 2000. "Mobility impairments and use of screening and preventive services." *Am J Public Health* 90 (6): 955-961.

Iezzoni, LI, RB Davis, J Soukup, and B O'Day. 2003. "Quality dimensions that most concern people with physical and sensory disabilities." *Archives of Internal Medicine* 163 (17): 1085-2092.

Iezzoni, LI, RR Sowmya, R Julie, B Dragama, DA Nicole, D Karen, L Tara, and GC Eric. 2021. "Physicians' perceptions of people with disability and their health care." *Health Affairs* 40 (2): 297-306.

Jackson, K. 2004. "Healthcare for people with disabilities: Making it through the maze." *Social Work Today* 12-16.

Janicki, M, A Dalton, C Henderson, and P Davidson. 1999. "Mortality and morbidity among older adults with intellectual disability: health services considerations." *Disabil Rehabil* 5-6: 284-294.

Jarvis-Selinger, S, J Bates, Y Araki, and SA Lear. 2011. "Internet-based support for cardiovascular disease management." *International Journal of Telemedicine and Applications* 2011.

Jensen, M, A Truitt, K Schomer, K Yorkston, C Baylor, and I Molton. 2013. "Frequency and age effects of secondary health conditions in indviduals with spinal cord injury: A scoping review." *Spinal Cord* 51: 882-892.

Jiang, H, and J Begun. 2002. "Dynamics of change in local physician supply: An ecological perspective." *Soc Sci Med* 54 (10): 1525-1541.

Joffe, RT. 2005. "Depression and multiple sclerosisL A potential way to understand the biology of major depressive illness." *Journal of Psychiatry & Neuroscience* 30: 9-10.

Johns Hopkins Medicine. n.d. *Screening Tests for Common Diseases.* Accessed April 21, 2021. https://www.hopkinsmedicine.org/health/treatment-tests-and-therapies/screening-tests-for-common-diseases.

Johnson, HM, CT Thorpe, CM Bartels, JR Schumacher, M Palta, N Pandhi, AM Sheehy, and MA Smith. 2014. "Undiagnosed hypertension among young adults with regular primary care use." *Journal of Hypertension* 32 (1): 65-74.

Johnston, KJ, and JM Hockenberry. 2016. "Are two heads better than one or do too many cooks spoil the broth? The trade-off between physician division of labor and patient continuity of care for older adults with complex chronic conditions." *Health Serv Res* 51 (6): 2176-2205.

Jolles, EP, AM Clark, and B Braam. 2012. "Getting the message across: Opportunities and obstacles in effective communication in hypertension care." *J Hypertens* 30 (8): 1500-1510.

Jones, KE, and IE Tamari. 1997. "Making or offices universally accessible: Guidelines for physicians." *Canadian Medical Association Journal* 156 (5): 647-656.

Jung, B, KH Cho, DH Lee, and S Kim. 2018. "The effects of continuity of care on hospital utilization in patients with knee osteoarthritis: analysis of nationwide insurance data." *BMC Health Services Research* 18 (1): 1-12.

Kaiser, P, AV Diez Roux, M Mujahid, M Carnethon, A Bertoni, SD Adar, S Shea, R McClelland, and L Lisabeth. 2016. "Neighborhood environments and incident hypertension in the multi-ethnic study of atherosclerosis." *American Journal of Epidemiology* 183 (11): 988-997.

Kalb, R. 2007. "The emotional and psychological impact of multiple sclerosis relapses." *Journal of the Neurological Sciences* 256: S29-S33.

Katz, DA, KD McCoy, and MS Vaughan-Sarrazin. 2015. "Does greater continuity of veterans administration primary care reduce emergency department visit and hospitalization in older veterans?" *J Am Geriatr Soc* 63 (12): 2510-2518.

Katz, E, and R DeRose. 2010. "The ADA 20 years later: the 2010 survey of Americans with disabilities." *The Journal of Spinal Cord Medicine* 33 (4): 345.

Katz, SJ, M Kabeto, and KM Langa. 2000. "Gender disparities in the receipt of home care for elderly people with disability in the United States." *JAMA* 284 (23): 3022-3027.

Kelman, J, LR Pool, P Gordon-Larsen, JJ Carr, JG Terry, JS Rana, and KN Kershaw. 2019. "Associations of unhealthy food environment with the developement of Coronary Artery Calcification: The CARDIA study." *Journal of the American Heart Association* 8 (4): e010586.

Kennedy, J, E Wood, and L Frieden. 2017. "Disparities in insurance coverage, health services use, and access following implementation of the Affordable Care Act: A comparison of disabled and nondisabled working-age adults." *Inquiry* 54: 1-10.

Kern, DH, and AG III Mainous. 2001. "Disease management for diabetes among family physicians and general internists: Opportunism or planned care?" *Fam Med* 33: 621-625.

Khan, A, M Li, J Finlay, M Esposito, I Gomez-Lopez, P Clarke, and M Chenoweth. 2020. "National Neigborhood Data Archive (NaNDA): Health Care Services by ZIP Code Tabulation Area, United States, 2003-2017." Ann Arbor, MI: Inter-university Consortium for Political and Social Research [distributor], 11 30.

Khan, AA. 1992. "An integrated approach to measuring potential spatial access to health care services." *Socioeconomic planning sciences* 26 (4): 275-287.

Khan, AM, GE Trope, R Wedge, YM Buys, S El-Defrawy, Q Chen, and YP Jin. 2018. "Policy implications of regional variations in eye disease detection and treatment on prince Edward Island: A repeated cross-sectional analysis 2010-2012." *BMC Health Serv Res* 18 (1): 412-414.

Khan, AM, JM Finlay, P Clarke, K Sol, R Melendez, S Judd, and GJ Gronlund. 2021. "Association between temperature exposure and cognition: A cross-sectional analysis of 20,687 aging adults in United States." *BMC Public Health* 21 (1): 1484.

Kinnear, D, J Morrison, L Allan, A Henderson, E Smiley, and SA Cooper. 2018. "Prevalence of physical conditions and multimorbidity in a cohort of adults with intellectual disabilities with and without Down Syndrome: cross-sectional study." *BMJ Open* 8 (2): e018292.

Kirby, JB, and T Kaneda. 2005. "Neighborhood socioeconomic disadvantage and access to health care." *J Health Soc Behav* 46 (1): 15-31.

Koopman, RJ, AG Mainous III, R Baker, JM Gill, and GE Gilbert. 2003. "Continuity of care and recognition of diabetes, hypertension, and hypercholesterolemia." *Archives of Internal Medicine* 163 (11): 1357-1361.

Krahn, G. 2003. "Changing concepts in health, wellness and disability." In *State of the science conference proceedings*, edited by Re- habilitation Research & Training Center: Health & Wellness Consortium, 6-19. Portland: Oregon Health & Science University.

Kraus, L, E Lauer, and R Coleman. 2018. *2017 Disability Statistics Annual Report.* Annual Report, Durham, NH: University of New Hampshire.

Krause, JS, and JL Coker. 2006. "Aging after spinal cord injury: A 30-year longitudinal study." *J Spinal Cord Med* 29 (4): 371-376.

Krause, N. 1996. "Neighborhood deterioration and self-rated health in later life." *Psychology and Aging* 11: 342-352.

Krauss, HH, C Godfrey, J Kirk, and DM Eisenberg. 1998. "Alternative health care: Its use by individuals with physical disabilities." *Arch Phys Med Rehabil* 79: 1440-1447.

Kristjansson, E, W Hogg, S Dahrouge, M Tuna, L Mayo-Bruinsma, and G Gebremichael. 2013. "Predictors of relational continuity in primary care: Patient, provider and practice factors." *BMC Family Practice* 14 (1): 1-9.

Kroenke, K, RL Spitzer, and JB Williams. 2003. "The Patient Health Questionnaire-2: validity of a two-item depression screener." *Med Care* 41 (11): 1284-1294.

Kruse, CS, M Soma, D Pulluri, NT Nemali, and M Brooks. 2017. "The effectiveness of telemedicine in the management of chronic health disease -- a systematic review." *JRSM Open* 8 (3): 2054270416681747.

Kung, PT, WC Tsai, and SJ Chiou. 2012. "The assessment of the likelihood of mammography usage with relevant factors among women with disabilities." *Research in Developemental disabilities* 33 (1): 136-143.

Lachman, S, S Boekholdt, R Luben, SJ Sharp, S Brage, K Khaw, RJG Peters, and NJ Wareham. 2018. "Impact of physical activity on the risk of cardiovascular disease in middle-aged and older adults: EPIC Norfolk prospective population study." *Eur J Prev Cardiol* 25 (2): 200-208.

LaPlante, M. 2014. "Key goals and indicators for successful aging of adults with early-onset disability." *Disabil Health J* 7 (1): S44-S50.

Law, M, K Wilson, J Eyles, S Elliott, M Jerrett, T Moffat, and I Luginaah. 2005. "Meeting health need, accessing health care: The role of neighborhood." *Health and Place* 11 (4): 367-377.

Lee, RE, and C Cubbin. 2002. "Neighborhood context and youth cardiovascular health behaviors." *American Journal of Public Health* 154: 428-436.

Lennox, N, and M Kerr. 1997. "Primary health care and people with intellectual disability: the evidencebase." *J Intellect Disabil Res* 41 (5): 365-372.

Lester, K, L Stepleman, and M Hughes. 2007. "The association of illness severity, self-reported cognitive impairment, and perceived illness management with depression and anxiety in a multiple sclerosis clinic population." *Journal of Behavioral Medicine* 30: 177-186.

Levy, H, and A Janke. 2016. "Health literacy and access to care." *Journal of Health Communication* 21 (Suppl): 43-50.

Li, G, JG Grabowski, ML McCarthy, and GD Kelen. 2003. "Neighborhood characteristics and emergency department utilization." *Acad Emerg Med* 10 (8): 853-859.

Li, M, I Gomez-Lopez, R Melendez, A Khan, P Clarke, and M Chenoweth. 2020. "National Neighborhood Data Archive (NaNDA): Broadband Internet Access by ZIP Code Tabulation Area, United States, 2014-2018." Ann Arbor, MI: Inter-university Consortium for Political and Social Research [distributor], December 14.

Li, M, R Melendez, A Khan, I Gomez-Lopez, P Clarke, and M Chenoweth. 2020. "National Neighborhood Data Archive (NaNDA): Parks by ZIP Code Tabulation Area, United States 2018." Ann Arbor, MI: Inter-university Consortium for Political and Social Research [distributor], December 7.

Li, T, J Yoon, J Luck, LN Bui, and M Harvey. 2020. "The impact of continuity of care on cervical cancer screening: How visit pattern affects guideline concordance." *Journal of Cancer Education* 1-7.

Lin, IP, and SC Wu. 2017. "Effects of long-term high continuity of care on avoidable hospitalizations of chronic obstructive pulmonary disease patients." *Health Policy* 121 (9): 1001-1007.

Lin, SF, AN Beck, BK Finch, RA Hummer, and RK Masters. 2012. "Trends in US older adult disability: exploring age, period, and cohort effects." *Am J Public Health* 102 (11): 2157-2163.

Lockenoff, CE, and LL Carstensen. 2004. "Socioemotional selectivity theory, aging, and health: The increasingly delicate balance between regulating emotions and making tough choices." *Journal of Personality* 72: 1395-1424.

Lofters, AK, SJ Guilcher, L Webster, RH Glazier, SB Jaglal, and AM Bayoumi. 2016. "Cholesterol testing among men and women with disability: the role of morbidity." *Clinical Epidemiology* 8: 313-321.

Love, MM, AG Mainous III, JC Talbert, and GL Hager. 2000. "Continuity of care and the physician-patient relationship: The importance of continuity for adult patients with asthma." *J Fam Pract* 49 (11): 998-1004.

Madrigal, L, and C Escoffery. 2019. "Electronic health behaviors among US adults with chronic disease: a cross-sectional survey." *J Med Internet Res* 21 (3): e11240.

Mahmoudi, E, and N Kamdar. 2020. "Methods and Analytic Approaches for Physically Disabled Persons Using Administrative Claims Datasets."

Mahmoudi, E, P Lin, MD Peterson, MA Meade, DG Tate, and N Kamdar. 2021. "Traumatic Spinal Cord injury and risk of early and late onset Alzheimer's disease and related dementia: Large longitudinal study." *Arch Phys Med Rehabil* 102 (6): 1147-1154.

Mainous, AG, R Baker, MM Love, DP Gray, and JM Gill. 2001. "Continuity of care and trust in one's physician: Evidence from primary care in the United States and the United Kingdom." *Family Med* 33: 22-27.

Majer, IM, WJ Nusselder, JP Mackenback, B Klijs, and PH van Baal. 2011. "Mortality risk associated with disability: a population-based record linkage study." *American Journal of Public Health* 101 (12): e9-e15.

Marge, M. 1994. "Toward a state of well-being: promoting healthy behaviors to prevent secondary conditions." In *Preventing Secondary Conditions Associated with Spina Bifida and Cerebral Palsy: Proceedings and Recommendations of a Symposium*, edited by DJ Lollar, 87-94. Washington, DC: Spina Bifida Association of America.

Marquis, MS, AR Davies, and JE Ware Jr. 1983. "Patient Satisfaction and Change in Medical Care Provider: A Longitudinal Study." *Medical Care* 21 (8): 821-829.

Martinson, M, and C Berridge. 2015. "Successful aging and its discontents: A systematic review of the social gerontology literature." *Gerontologist* 55 (1): 58-69.

Mate, KS, and AL Compton-Phillips. 2014. *The Antidote to Fragmented Health Care* . December 15. Accessed August 2, 2021. https://hbr.org/2014/12/the-antidote-to-fragmented-health-care.

Mathis, A, R Rooks, and D Kruger. 2015. "Improving the neighborhood environment for urban older adults: Social context and self-rated health." *Int J Environ Res Public Health* 13 (1): 1-13.

Matthias, MS, AL Parpart, KA Nyland, MA Huffman, DL Stubbs, C Sargent, and MJ Bair. 2010. "The patient-provider relationship in chronic pain care: providers' perspectives." *Pain Medicine* 11 (11): 1688-1697.

Mayo Clinic. n.d. *High blood pressure (hypertension).* Accessed May 6, 2021. https://www.mayoclinic.org/diseases-conditions/high-blood-pressure/symptoms-causes/syc-20373410.

Mazidi, M, and JR Speakman. 2018. "Association of fast-food and full-service restaurant densities with mortality from cardiovascular disease and stroke, and prevalence of diabetes melitus." *Journal of the Amerinca Heart Association* 7 (11): e007651.

McCarthy, E, L Ngo, R Roetzheim, T Chirikos, D Li, R Drews, and LI Iezzoni. 2006. "Disparities in breast cancer treatment and survival for women with disabilities." *Ann Intern Med* 145 (9): 637-645.

McColl, M. 2002. "A house of cards: Women aging and spinal cord injury." *Spinal Cord* 40: 371-373.

McColl, MA, A Jarzynowska, and SED Shortt. 2010. "Unmet health care needs of people with disabilities: Population level evidence." *Disabil Soc* 25 (2): 205-218.

McColl, MA, D Forester, SE Shortt, D Hunter, J Dorland, M Godwin, and W Rosser. 2008. "Physician experiences providing primary care to people with disabilities." *Healthcare Policy* 4 (1): e129.

McKay, ND, and J Langworthy. 2011. "A survey of accessibility and utilisation of chiropractic services for wheelchair-users in the United Kingdom: What are the issues?" *Chiropractic & Manual Therapies* 19 (1): 1-7.

McLaughlin, S, A Jette, and C Connell. 2012. "An examination of helath aging across a conceptual continuum: Prevalence estimates, demographic patterns, and validity." *Journal Gerontol Ser A* 67: 783-789.

Meade, MA, E Mahmoudi, and SY Lee. 2015. "The intersection of disability and healthcare disparities: A conceptual framework." *Disability Rehabilitation* 7 (7): 632-641.

Mechanic, D, and J Tanner. 2007. "Vulnerable people, groups, and populations: Societal view." *Health Affairs* 26: 1220-1230.

Medical Mutual. n.d. *HMO vs. PPO Insurance Plans* . Accessed August 14, 2021. https://www.medmutual.com/For-Individuals-and-Families/Health-Insurance-Education/Compare-Health-Insurance-Plans/HMO-vs-PPO-Insurance.aspx.

Melendez, R, L Mao, A Khan, I Gomez-Lopez, P Clarke, and M Chenoweth. 2020. "National Neighborhood Data Archive (NaNDA): Public Transit Stops by ZIP Code Tabulation Area, United States 2014-2018." Ann Arbor, MI: Inter-university Consortium for Political and Social Research [distributor], December 14.

Melendez, R, P Clarke, A Khan, I Gomez-Lopez, M Li, and M Chenoweth. 2020. "National Neighborhood Data Archive (NaNDA): Socioeconomic Status and

Demographic Characteristics of ZIP Code Tabulation Areas, United States, 2008-2017." Ann Arbor, MI: Inter-university Consortium for Political and Social Research [distributor].

Menc, VH, VH Siriski, and D Attawar. 2005. "Does continuity of care mattern in a universally insured population?" *Health Services Research* 40 (2): 389-400.

Menendez, M, V Neuhaus, C Niek van Dijk, and D Ring. 2014. "The Elixhauser Comorbidity method outperforms the Charlson Index in predicting inpatient death after Orthopaedic surgery." *Clin Orthop Relat Res* 472 (9): 2878-2886.

Merten, JW, JL Pomeranz, JL King, M Moorhouse, and RD Wynn. 2015. "Barriers to cancer screening for people with disabilities: A literature review." *Disability and Health Journal* 8 (1): 9-16.

Michael, Y, T Beard, D Choi, S Farquhar, and N Carlson. 2006. "Measuring the influence of built environments on walking in older adults." *J Aging Phys Act* 14 (3): 302-312.

Mickan, S, A Burls, and P Glasziou. 2011. "Patterns of 'leakage' in the utilisation of clinical guidelines: a systematic review." *Postgrad Med J* 87: 670-679.

Migliorini, C, B Tonge, and G Taleporos. 2008. "Spinal cord injury and mental health." *Aust N Z J Psychiatry* 42 (4): 309-314.

Minkler, M, and P Fadem. 2002. ""Successful aging": A disability perspective." *J Disabil Policy Stud* 12 (4): 229-235.

Molton, IR, and KM Yorkston. 2017. "Growing older with a physical disability: A special application of the successful aging paradigm." *Journals of Gerontology - Series B* 72 (2): 290-299.

Moore, LV, AV Diez Roux, JA Nettleton, and DR Jr Jacobs. 2008. "Association of the local food environment with diet quality: A comparison of assessments based on surveys and geographic systems: the Multi-Ethnic Study of Atherosclerosis." *American J Epidemiol* 167 (8): 917-924.

Morland, K, AV Diez Roux, and S Wing. 2006. "Supermarkets, other food stores, and obesity: The atherosclerosis risk in communities study." *Am J Prev Med* 30 (4): 333-339.

Morland, K, S Wing, and A Diez Roux. 2002. "The contextual effect of the local food environment on residents' diets: the atherosclerosis risk in communities study." *American Journal of Public Health* 92 (11): 1761-1767.

Moscoso-Porras, MG, and GF Alvarado. 2018. "Association between perceived discrimination and healthcare-seeking behavior in people with a disability." *Disability and Health Journal* 11 (1): 93-98.

Mozaffarian, D, MB Katan, A Ascherio, MJ Stampfer, and WC Willet. 2006. "Trans fatty acods and cardiovascular disease." *N Engl J Med* 354: 1601-1613.

Mozaffarian, D, PW Wilson, and WB Kannel. 2008. "Beyond established and novel risk factors: lifestyle risk factors for cardiovascular disease." *Circulation* 117 (23): 3031-3038.

Murphy, KL, JR Bethea, and R Fischer. 2017. "Neuropathic Pain in Multiple Sclerosis—Current Therapeutic Intervention and Future Treatment Perspectives." In *Multiple Sclerosis: Perspectives in Treatment and Pathogenesis*, edited by IS Zagon and PJ McLaughlin, 53-70. Brisbane (AU): Codon Publications.

Mustard, CA, T Mayer, C Black, and B Postl. 1996. "Continuity of pediatric ambulatory care in a universally insured population." *Pediatrics* 98: 6.

Napolitano, F, P Napolitano, L Garofalo, M Recupito, and IF Angelillo. 2016. "Assessment of continuity of care among patient with multiple chronic conditions in Italy." *PLoS One* 11 (5): e0154940.

National Academies of Sciences, Engineering, and Medicine. 2017. *Communities in action: Pathways to health equity.* Washington (DC): The National Academies Press.

National Center for Health Statistics. 2013. "Early release of selected estimates based on data from the 2012 National Health Interview Survey: Diagnosed diabetes." Accessed April 21, 2021. www.cdc.gov/nchs/nhis/released201306.html.

National Institute of Diabetes and Digestive and Kidney Diseases. 2016. *Diabetes Tests & Diagnosis.* Accessed April 21, 2021. https://www.niddk.nih.gov/health-information/diabetes/overview/tests-diagnosis.

National Institute of Neurological Disorders and Stroke. 2019. *Multiple Sclerosis Information Page.* Accessed March 20, 2020. https://www.ninds.nih.gov/Disorders/All-Disorders/Multiple-Sclerosis-Information-Page.

National Reseach Council. 2000. *Networking Health: Prescriptions for the Internet.* Washington (DC): The National Academies Press.

National Rural Health Resource Center. n.d. *Using Claims Data* . Accessed April 16, 2021. https://www.ruralcenter.org/population-health-toolkit/data/using-claims-data.

Naylor, KB, J Tootoo, O Yakusheva, SA Shipman, JP Bynum, and MA Davis. 2019. "Geographic variation in spatial accessibility of US healthcare providers." *PLoS one* 14 (4): e0215016.

Newman, SD. 2010. "Evidence-based advocacy: Using photovoice to identify barroers and facilitators to community participation after spinal cord injury." *Rehabilitation Nursing* 35 (2): 47-59.

Nyweide, DJ, DL Anthony, JP Bynum, RL Strawderman, WB Weeks, LP Casalino, and ES Fisher. 2013. "Continuity of care and the risk of preventable hospitalization in older adults." *JAMA Intern Med* 173 (20): 1879-1885.

O'Connor, AB, SR Schwid, DN Hermann, JD Markman, and RH Dworkin. 2008. "Pain associated with multiple sclerosis: systematic review and proposed classification." *Pain* 137 (1): 96-111.

Okoro, CA, NTD Hollis, AC Cyrus, and S Griffin-Blake. 2018. "Prevalence of disabilities and health care access by disability status and type among adults -- United States, 2016." *Morbidity and Mortality Weedkly Report* 67 (32): 882-887.

O'Neill, J, F Newall, G Antolovich, S Lima, and M Danchin. 2020. "Vaccination in people with disability: a review." *Human Vaccines & Immunitherapeutics* 16 (1): 7-15.

Optum . 2014. "Basic Data Elements." *Optum Clinformatics Data Mart.* Accessed April 14, 2021. https://www.optum.com/content/dam/optum/resources/productSheets/Clinformatics-Data-Mart.pdf.

Optum. 2017. *Optum Clinformatics Data Mart.* Accessed April 14, 2021. https://www.optum.com/content/dam/optum/resources/productSheets/Clinformatics_for_Data_Mart.pdf.

Ostchega, Y, CD Fryar, T Nwankwo, and DT Nguyen. 2020. "Hypertension Prevalence Among Adults Aged 18 and Over: United States, 2017–2018." *NCHS Data Brief* 364: 1-8.

Palladino, R, RA Marrie, A Majeed, and J Chataway. 2020. "Evaluating the risk of macrovascular events and mortality among people with Multiple Sclerosis in England." *JAMA Neurol* 77 (7): 820-828.

Panko, RJ, ML Breslin, LI Iezzoni, and KL Kirschner. 2004. *It takes more than ramps to solve the crisis of healthcare for people with disabilities.* Chicago, IL: Rehabilitation Institute of Chicago.

Panter, J, O Mytton, S Sharp, S Brage, S Cummins, AA Laverty, K Wijndaele, and D Ogilvie. 2018. "Using alternatives to the car and risk of all-cause, cardiovascular and cancer mortality." *Heart* 104 (21): 1749-1755.

Parchman, ML, JA Pugh, PH Noel, and AC Larme. 2002. "Continuity of care, self-management behaviors, and glucose control in patients with type 2 diabetes." *Med Care* 40 (2): 137-144.

Park, M, and J Unutzer. 2011. "Geriatric depression in primary care." *The Psychiatric Clinics of North Amerinca* 34 (2): 469-x.

Park, N, Y Jang, B Lee, and D Chiriboga. 2015. "Relationship between perceived neighborhood environment and depressive symptoms in older Korean Amerincas: Do chronic disease and functional disability modify it?" *Asian Am J Psychol* 6 (2): 174-180.

Parker, R, S Ratzan, and N Lurie. 2003. "Health literacy: A policy challenge for advancing high-quality health care." *Health Affairs* 22 (4): 147-153.

Perrin, A, and S Atske. 2021. *Americans with disabilities less likely than those without to own some digital devices.* Accessed June 1, 2021. https://www.pewresearch.org/fact-tank/2021/09/10/americans-with-disabilities-less-likely-than-those-without-to-own-some-digital-devices/.

Peterson, M, P Lin, N Kamdar, E Mahmoudi, C Marsack-Topolewski, H Haapala, K Muraszko, and E Hurvitz. 2021. "Psychological morbidity among adults with cerebral palsy and spina bifida." *Psychological Medicine* 51 (4): 694-701.

Peterson, M, P Lin, N Kamdar, E Mahmoudi, MM Schmidt, HJ Haapala, and EA Hurvitz. 2020 (a). "Cardiometabolic morbidity in adults with cerebral palsy and spina bifida." *The American Journal of Medicine* 133 (12): e695-e705.

Peterson, MD, M Berri, P Lin, N Kamdar, G Rodriguez, E Mahmoudi, and D Tate. 2021. "Cardiovascular and metabolic morbidity following spinal cord injury." *The Spine Journal* 21 (9): 1520-1527.

Peterson, MD, N Kamdar, DG Whitney, S Ng, A Chiodo, and DG Tate. 2019. "Psychological morbidity and chronic disease among adults with traumatic spinal cord injuries: a cohort study of privately insured beneficiaries." *The Spine Journal* 19 (10): 1680-1686.

Peterson, MD, P Lin, N Kamdar, E Mahmoudi, CN Marsack-Topolewski, H Haapala, K Muraszko, and EA Hurvirz. 2020 (b). "Psychological morbidity among adulst with cerebral palsy and spina bifida." *Psychological Medicine* 51 (4): 694-701.

Peterson, MD, P Lin, N Kamdar, EA Hurvitz, and E Mahmoudi. 2021. "Psychological, cardiometabolic, musculoskeletal morbidity and multimodbidity among adults with cerebral palsy and spina bifida: a retrospective cross-sectional study." *Am J Phys Med Rehabil* Ahead of Print.

Pharr, J, and M Chino. 2013. "Predicting barriers to primary care for patients with disabilities: A mixed-methods study of practice administrators." *Disability and Health Journal* 6: 116-123.

Phelan, E, L Anderson, A LaCroix, and E Larson. 2004. "Older adults' views of "successful aging" -- How do they compare with researchers' definitions?" *J Am Geriatr Soc* 52: 211-216.

Pierce, L. 2012. "Barriers to access: Frustrations of people who use a wheelchair for full-time mobility." *Rehabil Nursing* 23 (3): 120-125.

Plourde, N, HK Brown, S Vigod, and V Cobigo. 2018. "The association between continuity of primary care and preventive cancer screening in women with intellectual disability." *American Journal on Intellectual and Developemental Disabilities* 123 (6): 499-513.

Pollack, C, P Hussey, R Rudin, D Fox, J Lai, and E Schneider. 2016. "Measuring care continuity: A comparison of claims-based methods." *Medical Care* 54 (5): e30-e34.

Pollack, CE, C Cubbin, A Sania, M Hayward, D Vallone, B Flaherty, and PA Braveman. 2013. "Do wealth disparities contribute to health disparities within racial/ethnic groups?" *J Epidemiol Community Health* 67 (5): 439-445.

Prentice, JC. 2006. "Neighborhood effects on primary care access in Los Angeles." *Social Science and Medicine* 62: 1291-1303.

Pruchno, R, M Wilson-Genderson, and F Cartwright. 2012. "The texture of neighborhoods and disability among older adults." *J Gerontol B Psychol Sci Soc Sci* 67 (1): 89-98.

Puntis, S, J Rugkasa, A Forrest, A Mitchell, and T Burns. 2015. "Associations between continuity of care and patient outcomes in mental health care: a systematic review." *Psychiatric Services* 66 (4): 354-363.

Putnam, M, I Molton, A Truitt, A Smith, and M Jensen. 2016. "Measures of aging with disability in U.S. secondary data sets: Results of a scoping review." *Disabil Health J* 9: 5-10.

Quan, H, V Sundararajan, P Halfon, A Fong, B Burnand, J Luthi, LD Saunders, CA Beck, TE Feasby, and WE Ghali. 2005. "Coding algorithms for defining comorbidities in ICD-9-CM and ICD-10 administrative data." *Med Care* 43 (11): 1130-1139.

Raphael, E, J White, X Li, K Cederin , MM Glymour, K Sundquist , J Sundquist , and R Hamid. 2020. "Neighborhood deprivation and mental health among immigrants to Sweden." *Epidemiology* 31 (3): e25-e27.

Rehman, H, and SS Virani. 2017. *Managing Hyperlipidemia On the Go: Using Mobile Technology to Lower Cholesterol Levels.* Accessed September 1, 2021. https://www.acc.org/latest-in-cardiology/articles/2017/08/03/08/27/managing-hyperlipidemia-on-the-go.

Reid, RJ, JL Haggerty, and R McKendry. 2002. *Defusing the confusion: concepts and measures of continuity of healthcare.* Research Reports, Vancouver, BC: Center for Health Services and Policy Research, University of British Columbia.

ResDAC. 2018. *Strengths and Limitations of CMS Administrative Data in Research.* Accessed April 20, 2021. https://resdac.org/articles/strengths-and-limitations-cms-administrative-data-research.

Rimmer, J, S Padalabalanarayanan, L Malone, and T Mehta. 2017. "Fitness faciiteis still lack accessibility for people with disabilities." *Disabiity and Health Journal* 10 (2): 214-221.

Rimmer, JH. 1999. "Health promotion for people with disabilities: the emerging paradigm shift from disability prevention to prevention of secondary conditions." *Physical therapy* 79 (5): 495-502.

Rimmer, JH. 2005. "The conspicuous absence of people with disabilities in public fitness and recreation facilities: Lack of interest or lack of access?" *American Journal of Health Promotion* 19 (5): 327-329.

Rimmer, JH, B Riley, E Wang, A Rauworth, and J Jurkowski. 2004. "Physical activity participation among persons with disabilities: barroers and facilitators." *American Journal of Preventive Medicine* 26 (5): 419-425.

Rodriguez, G, M Berri, P Lin, N Kamdar, E Mahmoudi, and MD Peterson. 2021. "Musculoskeletal morbidity following spinal cord injury: A longitudinal cohort study of privately-insured beneficiaries." *Bone* 142: 115700.

Rose, V. 2006. *RESTAURANTS AND HANDICAPPED ACCESSIBILITY.* Accessed September 1, 2021. https://www.cga.ct.gov/2006/rpt/2006-R-0335.htm.

Rosenberg, DE, DL Huang, SD Simonovich, and B Belza. 2013. "Outdoor built environment barriers and facilitators to activity among midlife and older adults with mobiity disabiities." *The Gerontologist* 53 (2): 268-279.

Rosenbloom, S. 2007. "Transportation Patterns and Problems of People with Disabilities." In *The Future of Disability in America*, edited by MJ Field and AM Jette . Washington (DC): National Academies Press (US).

Ross, CE. 2000. "Neighborhood disadvantage and adults depression." *Journal of Health and Social Behavior* 41: 177-187.

Rosso, AL, AH Auchincloss, and YL Michael. 2011. "The urban built environment and mobility in older adults: a comprehensive review." *Journal of Aging Research* 2011: 816106.

Rowe, J, and R Kahn. 1997. "Successful aging." *Gerontologist* 37: 433-441.

Rundle, AG, MDM Bader, CA Richards, KM Neckerman, and JO Teitler. 2011. "Using Google Street View to audit neighborhood environments." *American Journal of Preventive Medicine* 40 (1): 94-100.

Rural Health Information Hub (b). n.d. *Ecological Models.* Accessed June 3, 2021. https://www.ruralhealthinfo.org/toolkits/health-promotion/2/theories-and-models/ecological.

Rural Health Information Hub. n.d. *Specific Healthcare Needs of People with Disabilities* . Accessed April 15, 2021. https://www.ruralhealthinfo.org/toolkits/disabilities/1/specific-needs.

Ryvicker, M, and D Russell. 2018. "Individual and environmental determinants of provider continuity among urban older adults with heart failure: a retrospective cohort study." *Gerontology and Geriatric Medicine* 4.

Sakellariou, D, and ES Rotarou. 2017. "Access to healthcare for men and women with disabilities in the UK: Secondary analysis of cross-sectional data." *BMJ Open* 7 (8): 1-9.

Sallis, JF, MF Floyd, DA Rodriguez, and BE Saelens. 2012. "Role of built environments in physical activity, obesity, and cardiovascular disease." *Circulation* 125 (5): 729-737.

Sallis, JF, PR Nader, JW Rupp, CJ Atkins, and WC Wilson. 1986. "San Diego surveyed for heart-healthy foods and exercise facilities." *Public Health Reports* 101 (2): 216-219.

Samulowitz, A, I Gremyr, E Eriksson, and G Hensing. 2018. ""Brave men" and "emotional women": A theory-guided literature review on gender bias in health care and gendered norms towards patients with chronic pain." *Pain Research and Management* 6358624.

Santiago, MC, and CP Coyle. 2004. "Leisure-time physicial activity and secondary conditions in women with physical disabilities." *Disability and Rehabilitation* 26 (8): 485-494.

Schiller, JS, JW Lucas, BW Ward, and JA Peregoy. 2012. "Summary health statistics for U.S. adults: National Health Interview Survey, 2010." *Vital Health Stat* 252: 1-207.

Schmittdiel, J, JV Selby, B Swain, SL Daugherty, TK Leong, M Ho, KL Margolis, p O'Connor, DJ Magid, and K Bibbins-Domingo. 2011. "Missed opportunities in cardiovascular disease prevention? Low rates of hypertension recognition for women at medicine and obstetrics-gynecology clinics." *Hypertension* 57: 717-722.

Schwartz, N, R Buliung, and K Wilson. 2019. "Disability and food access and insecurity: A scoping review of the literature." *Health and Place* 57: 107-121.

Selvin, E, and CM Parrinello. 2013. "Age-related differences in glycemic control in diabetes." *Diabetologia* 56 (12): 2549-2551.

Shumway-Cook, A, A Paula, A Stewart, L Ferrucci, MA Ciol, and JM Guralnik. 2003. "Environmental components of mobility disability in community-living older persons." *Journal of American Geriatric Society* 51 (3): 393-398.

Siegert, RJ, and DA Abernethy. 2005. "Depression in multiple sclerosis: A review." *Journal of Neurology, Neurosurgery and Psychiatry* 76: 469-475.

Sinnott, PL, AM Siroka, AC Shane, JA Trafton, and TH Wagner. 2012. "Identifying neck and back pain in administrative data: defining the right cohort." *Spine* 37 (10): 860-874.

Smeltzer, SC. 2007. "Improving the health and wellness of persons with disabilities: A call to action too important for Nursing to ignore." *Nurs Outlook* 55: 189-195.

Smith, A, I Molton, and M Jensen. 2016. "Self-reported incidence and age of onset of chronic comorbid medical conditions in adults aging with long-term physicial disability." *Disabil Heal J* 9: 533-538.

Social Environment and Health. n.d. *National Neighborhood Data Archive (NaNDA).* Accessed March 18, 2020. https://seh.isr.umich.edu/signature-projects/nanda/.

Spetz, J, SM Skillman, and CHA Andrilla. 2017. "Nurse practitioner autonomy and satisfaction in rural settings." *Medical Care Research and Review* 74 (2): 227-235.

Spring, A. 2018. "Short- and long-term impacts of neighborhood built environment on self-rated health of older adults." *The Gerontologist* 58 (1): 36-46.

Stange, KC. 2014. "The problem of fragmentation and the need for integrative solutions." *Annals of Family Medicine* 7: 100-103.

Steckelings, UM, M Stoppelhaar, AM Sharma, HU Wittchen, P Krause, B Kupper, W Kirch, et al. 2004. "HYDRA: Possible determinants of unsatisfactory hypertension control in German primary care patients." *Blood Press* 13: 80-88.

Steele, CB, JS Townsend, EA Courtney-Long, and M Young. 2017. "Cancer screening prevalence among adults with disabilities, United States, 2013." *Preventing Chronic Disease* 14: 160312.

Steeves, JA, EJ Shiroma, SA Conger, D Van Domelen, and TB Harris. 2019. "Physical activity patterns and multimorbidity burden of older adults with different levels of functional status: NHANES 2003-2006." *Disability and Health Journal* 12 (3): 495-502.

Stewart, F, and PA Rogerson. 1993. "GIS and spatial analytical problems." *International Journal of Geographical Information Systems* 7 (1): 3-19.

Strawbridge, W, M Wallhagen, and R Cohen. 2002. "Successful aging and well-being: Self-rated compared with Rowe and Khan." *Gerontologist* 42: 727-733.

Sundquist, K, M Winkleby, H Ahlen, and SE Johansson. 2004. "Neighborhood socioeconomic environment and incidence of coronary heart disease: a follow-up study of 25,319 women and men in Sweden." *Am J Epidemiol* 159: 655-662.

Taouk, LH, MF Fialkow, and JA Schulkin. 2018. "Provision of reproductive healthcare to women with disabilities: A survey of obstetrician-gynecologists' training, practices, and perceived barriers." *Health Equity* 2 (1): 207-215.

The SPRINT Research Group. 2015. "A randomized trial of intensive versus standard blood-pressure control." *N Engl J Med* 36 (8): 2103-2116.

The Trust for Public Land. 2016. "The Trust for Public Land Makes Park Information Database and Platform Availble to Millions."

Thomopolous, C, G Parati, and A Zanchetti. 2018. "Effects of blood pressure-lowering treatment on cardiovascular outcomes and mortality: Effects of different classes of antihypertensive drugs in older and younger patients (Overview and meta-analysis)." *J Hypertens* 36 (8): 1637-1647.

Tian, TY, I Zlateva, and DR Anderson. 2013. "Using electonic health records data to identify patients with chronic pain in primary care setting." *Journal of the American Medical Informatics Association* 20 (e2): e275-e280.

Timpel, P, S Oswald, P Schwarz, and L Harst. 2020. "Mapping the evidence on the effectiveness of telemedicine interventions in diabetes, dyslipidemia, and hypertension: An umbrella review of systematic reviews and meta-analyses." *Journal of Medical Internet Research* 22 (3): e16791.

Todd, A, and A Stuifbergen. 2012. "Breast cancer screening barriers and disability." *Rehabilitation Nursing* 37 (2): 74-79.

Tomer, A, L Fishbane, A Siefer, and B Callahan. 2020. *Digital Prosperity: HOW BROADBAND CAN DELIVER HEALTH AND EQUITY TO ALL COMMUNITIES.* Washington (DC): Metropolitan Policy Program at Bookings.

Trinh, NH, SJ Toun, J Sousa, S Regan, CA Bedoya, TE Chang, M Fava, and A Yeung. 2011. "Using electonic medical records to determine the diagnosis of clinical depression." *International Journal of Medical Informatics* 80 (7): 533-540.

Tseng, E, RC Greer, P O'Rourke, HC Yeh, MM McGuire, AL Albright, JA Marsteller, JM Clark, and NM Maruthur. 2019. "National survey of primary care physicians' knowledge, practices, and perceptions of prediabetes." *Journal of General Internal Medicine* 34 (11): 2475-2481.

Tufts University . 2019. *Q. What is cardiometabolic disease and how is it different from cardiovascular disease?* Accessed June 3, 2021. https://www.nutritionletter.tufts.edu/ask-experts/q-what-is-cardiometabolic-disease-and-how-is-it-different-from-cardiovascular-disease/.

Tullman, MJ. 2013. "Overview of the epidemiology, diagnosis, and disease progression associated with multiple sclerosis." *Am J Manag Care* 19 (2 Suppl): S15-S20.

Turk , M, J Scandale, P Rosenbaum, and R Weber. 2001. "The health of women with Cerebral Palsy." *Women's Issues* 12 (1): 153-168.

U.S. Department of Education. 2006. *The health literacy of America's adults: Results from the 2003 National Assessment of adult literacy (NCES 2006-483).* Washington (DC): National Center for Education Statistics.

U.S. Department of Health and Human Services (Healthy People 2030). n.d. *Preventive Care.* Accessed April 2021, 2021. https://health.gov/healthypeople/objectives-and-data/browse-objectives/preventive-care#cit1.

U.S. Department of Health and Human Services. n.d. *Achieving the Promise: Transforming Mental Health Care in America: Final Report.* Final Report, Washington (DC): DHSS Pub.

U.S. Department of Health and Human Services. 2000. *Healthy People 2010: Undertaking and improving health 2nd Ed.* Washington (DC): U.S. Government Printing Office.

U.S. Department of Health and Human Services. 2005. *The Surgeon General's Call To Action To Improve the Health and Wellness of Persons with Disabilities.* Rockville, MD : US Department of Health and Human Services, Office of the Surgeon General.

U.S. Preventive Services Task Force. 2016. "Screening for high blood pressure in adults: Recommendation Statement." *Am Fam Physician* 15: 300-302.

U.S. Preventive Services Task Force. n.d. *Screening for Prediabetes and Type 2 Diabetes.* Accessed April 21, 2021. https://www.uspreventiveservicestaskforce.org/uspstf/recommendation/screening-for-prediabetes-and-type-2-diabetes.

UCLA Statistical Consulting Group. n.d. *What Does Cronbach's Alpha Mean? | SPSS FAQ.* Accessed August 9, 2021. https://stats.idre.ucla.edu/spss/faq/what-does-cronbachs-alpha-mean/.

Unützer , J, M Hantke , D Powers , L Higa , E Lin , S D Vannoy, S Thielke, and MY Fan. 2008. "Care management for depression and osteoarthritis pain in older primary care patients: A pilot study." *Int J Geriatr Psychiatry* 23 (11): 1166-1171.

Unützer , J, W Katon , CM Callahan, Williams JW Jr, E Hunkeler, L Harpole, M Hoffing, et al. 2002. "Improving mood-promoting access to collaborative treatment." *JAMA* 288 (22): 2836-2845.

Unger, E, AV Diez-Roux, DM Lloyd-Jones, MS Mujahid, JA Nettleton, A Bertoni, SE Badon, H Ning, and NB Allen. 2014. "Association of neighborhood characteristics with cardiovascular health in the multi-ethnic study of atherosclerosis." *Circ Cardiovasc Qual Outcomes* 7 (4): 524-531.

United Nations Department of Economic and Social Affairs. 2017. *World Population Ageing 2017 - Highlights.* (ST/ESA/SER.A/397), New York: United Nations.

United States Census Bureau. 2018. *Older People Projected to Outnumber Children for First Time in U.S. History.* March 13. Accessed April 14, 2020. https://www.census.gov/newsroom/press-releases/2018/cb18-41-population-projections.html.

United States Census Bureau. 2015. "ZIP Code Tabulation Areas (ZCTAs™) ." Accessed April 16, 2021. https://www2.census.gov/geo/pdfs/education/brochures/ZCTAs.pdf.

United States Census Bureau. 2020. *ZIP Code Tabulation Areas (ZCTAs).* Accessed July 21, 2020. https://www.census.gov/programs-surveys/geography/guidance/geo-areas/zctas.html.

University of Manitoba Center for Health Policy. 2020. *Concept: Ambulatory Care Sensitive (ACS) Conditions* . Accessed April 19, 2021. http://mchp-appserv.cpe.umanitoba.ca/viewConcept.php?printer=Y&conceptID=1023.

University of Washington. 2021. *Data Resources in the Health Sciences.* August 19. Accessed September 11, 2021. https://guides.lib.uw.edu/c.php?g=99209&p=642709.

Upshur, CC, G Bacigalupe, and R Luckmann. 2010. ""They don't want anything to do with you": Patient views of primary care management of chronic pain." *Pain* 11 (12): 1791-1798.

US Department of Health and Human Services. 2016. "Privacy Impact Assessment." Accessed April 2021, 2021. https://www.hhs.gov/sites/default/files/cms-national-plan-and-provider-enumeration-system.pdf.

van Servellen, G, M Fongwa, and DE Mockus. 2006. "Continuity of care and quality care outcomes for people experiencing chronic conditions: A literature review." *Nursing Health Sci* 8: 185-195.

Vasan, RS, JM Massaro, PW Wilson, S Seshadri, PA Wolf, D Levy, RB D'Agostino, and Framingham Heart Study. 2002. "Antecedent blood pressure and risk of cardiovascular disease: The Framingham Heart Study." *Circulation* 105 (1): 48-53.

Veltman, A, DE Stewart, GS Tardif, and M Branigan. 2001. "Perceptions of primary healthcare services among people with physical disabilities, part 1: access issues." *Medscape General Medicine* 3: 18.

Verbrugge, LM, and LS Yang. 2002. "Aging with disability and disability with aging." *J Disabil Policy Stud* 12 (4): 253-267.

Vergrugge, LM, K Latham, and PJ Clarke. 2017. "Aging with disability for midlife and older adults." *Res Aging* 39 (6): 741-777.

Veugelers, PJ, AM Yip, and G Kephart. 2001. "Proximate and contextual socioeconomic determinants of mortality: Multilevel approaches in a setting with universal health care coverage." *American of Journal of Epidemiology* 154: 725-732.

Virani, T, L Lemieux-Charles, DA Davis, and W Berta. 2009. "Sustaining change: Once evidence-based practices are transferred what then?" *Healthcare Quarterly* 12: 89-96.

Walls, D. 2015. "NETS overview: National Establishment Time-Series (NETS) database."

Wandner, LD, MW Heft, BC Lok, AT Hirsh, SZ George, AL Horgas, JW Atchison , CA Torres , and ME Robinson . 2014. "The impact of patients' gender, race, and age on health care professional' pain management decisions: An online survey using virtual human technology." *International Journal of Nursing Studies* 51 (5): 726-733.

Warmbrodt, R. 2020. *Cerebral Palsy and Chiropractic Care.* Accessed April 8, 2021. https://www.cerebralpalsyguidance.com/cerebral-palsy/treatment/chiropractic-care/.

Warren Anderson, S, WJ Blot, XO Shu, JS Sonderman, M Steinwandel, MK Hargreaves, and W Zheng. 2018. "Associations between neighborhood environment, health behaviors, and mortality." *Amrican Journal of Preventive Medicine* 54 (1): 87-95.

Weisman, JD, D Russell, J Beasley, M Jay, and D Malaspina. 2016. "Relationships between adult emotional states and indicators of health care utilization: Findings from the National Health Interview Survey 2006-2014." *Journal of Psychosomatic Research* 91: 75-81.

Weiss, LJ, and J Blustein. 1996. "Faithful patients: the effect of long-term physician-patient relationships on the costs and use of health care by older Americans." *American Journal of Public Health* 86 (12): 1742-1747.

Weissman, JD, D Russell, M Jay, JM Beasley, D Malaspina, and C Pegus. 2017. "Disparities in health care utilization and functional limitations among adults with serious psychological distress, 2006-2014." *Psychiatric Services* 68: 653-659.

Wheeler, SB, TM Kuo, D Durham, B Frizzelle, K Reeder-Hayes, and AM Meyer. 2014. "Effects of distance to care and rural or urban residence on receipt of radiation therapy among North Carolina Medicare enrollees with breast cancer." *N C Med J* 75 (4): 239-246.

White, DK, AM Jette, DT Felson, MP Lavalley, CE Lewis, JC Torner, MC Nevitt, and JJ Keysor. 2010. "Are features of the neighborhood environment associated with disability in older adults?" *Disabil Rehabil* 32 (8): 639-645.

Whitney, D, S Warschausky, S Ng, E Hurvitz, N Kamdar, and M Peterson. 2019. "Prevalence of mental health disorders among adults with Cerebral Palsy: A cross-sectional analysis." *Ann Intern Med* 171 (5): 328-333.

Whitney, DG, AI Alford, MJ Devlin, MS Caird, EA Hurvitz, and MD Peterson. 2019. "Adults with cerebral palsy have higher prevalence of fracture compared with adults without cerebral palsy independent of osteoperosis and cardiometabolic disease." *Journal of Bone and Mineral Research* 34 (7): 1240-1247.

Whitney, DG, RT Whitney, NS Kamdar, EA Hurvitz, and MD Peterson. 2020. "Early-onset noncommunicable disease and multimorbidity among adults with pediatric-onset disabilities." *Mayo Clinic Proceedings* 95 (2): 274-282.

Wilcock, AD, S Rose, AB Busch, HA Huskamn, L Uscher-Pines, B Landon, and A Malhotra. 2019. "Association between broadband internt availability and telemedicine use." *JAMA Internal Medicine* 179 (11): 1580-1582.

Williams, MD, GB Asiedu, D Finnie, C Neely, J Egginton, R Finney, LJ Rutten, and RM Jacobson. 2019. "Sustainable care coordination: A qualitative study of primary care provider, administrator, and insurer perspectives." *BMC Health Services Reseach* 19 (1): 92.

Williams, SL, KB Haskard, and MR DiMatteo. 2007. "The therapeutic effects of the physician-older patient relationship: effective communication with vulnerbale older patients." *Clinical Interventions in Aging* 2 (3): 453.

Williams-Roberts, H, S Abonyi, and J Kryzanowski. 2018. "What older adults want from their health care providers." *Patient Experience Jouranl* 5 (3): 81-90.

Wilson, J, and A Bock. 2012. *White Paper: The benefit of using both claims data and electronic medical record data in health care analysis.* Accessed April 14, 2021. https://www.optum.com/content/dam/optum/resources/whitePapers/Benefits-of-using-both-claims-and-EMR-data-in-HC-analysis-WhitePaper-ACS.pdf.

Wiseman, TA, K Curtis, M Lam, and K Foster. 2015. "Incidence of depression, anxiety and stress following traumatic injury: A longitudinal study." *Scandinavian Journal of Trauma, Resuscitation and Emergency Medicine* 23 (1): 1-9.

Wittink, HM, WH Rogers, AG Lipman, BH McCarberg, MA Ashburn, GM Oderda, and DB Carr. 2006. "Older and younger adults in pain management programs in the United States: Differences and similarities." *Pain Medicine* 7 (2): 151-163.

Woloshin, S, LM Schwartz, WC Black, and BS Kramer. 2012. "Cancer screening campaigns -- getting past uninformative persuasion." *N Engl J Med* 367: 1677-1679.

Wood, D, A Hall, T Hou, P Wludyka, and J Zhang. 2007. "Continuity of care to prevent emergency room use among persons with intellectual and developemental disabilities." *Journal of Policy and Practice in Intellectual Disabilities* 4 (4): 219-228.

World Health Organization. n.d. *International Classification of Functioning, Disability and Health (ICF).* Accessed June 12, 2021. https://www.who.int/standards/classifications/international-classification-of-functioning-disability-and-health.

World Health Organization. 2011. *World report on disability.* WHO Library Catalogue, Geneva, Switzerland: WHO Press.

Yang, ND, CH Yin, YM Hung, SJ Huang, CC Lee, and TJ Kuo. 2020. "Continuity of care is associated with medical costs and inpatient days in children with cerebral palsy." *International Journal of Environmental Reseach and Public Health* 17 (8): 2913.

Yen, I, Y Michael, and L Perdue. 2009. "Neighborhood environment in studies of health of older adults: A systematic review." *Am J Prev Med* 37 (5): 455-463.

Yoon, PW, CD Gillespie, MG George, and HK Wall. 2012. "Control of hypertension among adults -- National Health and Nutrition Examination Survey, United States, 2005-2008." *MMWR* 61: 19-25.

Zarb, G, and M Oliver. 1993. *Ageing with a disability -- What do they expect after all these years?* . London, England: University of Greenwich.

Zhang, Y, and AE Moran. 2017. "Trends in the prevalence awareness, treatment, and control of hypertension among young adults in the United States, 1999 to 2014." *Hypertension* 70 (4): 736-742.

Zhou, L, and B Parmanto. 2019. "Reaching people with disabilities in underserved areas through digital interventions: a systematic review." *Journal of Medical Internet Research* 21 (10): e12981.

Zullig, LL, GL Jackson, D Provenzale, JM Griffin, S Phelan, and M Van Ryn. 2012. "Transportation - A vehicle or roadblock to cancer care for VA patients with colorectal cancer?" *Clin Colorectal Cancer* 11 (1): 60-5.