UNIVERSITY OF CALIFORNIA

Los Angeles

Walking through the life course:

Evaluation of total walking patterns among older adults, adults with disabilities, and immigrants in the United States

A dissertation submitted in partial satisfaction of the requirements for the degree Doctor of Philosophy in Community Health Sciences

by

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ABSTRACT OF THE DISSERTATION

Walking Through the Life Course: Analyses of Total Walking as Health Outcome using 2017 National Household Travel Survey Data

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Public health and transportation literature documents links between walking and overall wellbeing among people of all ages. However, quantifications of these links frequently reflect only one type of walking, such as exercise walking or walking for transportation. Often, this work concentrates on healthy, working age adults. This results in limited understanding of how total walking cumulatively relates to overall health status, especially among other populations. Demographic shifts in the United States will result in population aging, which informs a sense of urgency around understanding how older and more disability-burdened groups will engage in walking, and how socioeconomic contexts in which they reside will shape these patterns. This dissertation used data from the 2017 National Household Travel Survey, which measures travel behaviors to quantify total walking patterns among subsamples of older adults, people with disabilities, and young adults. Each of the three interrelated studies used a theoretical framework informed by the Life Course Perspective and Social Ecological Model to develop multivariable statistical models predicting walking outcomes. Findings indicate that older adult walking frequency correlates most strongly with gender, overall health status, and household vehicle access. Mobility disability status, overall health status, use of mobility devices, and educational attainment were also highly correlated with any walking among older adults. Among disabled and non-disabled working-age adults, number of household vehicles and population density of residential area correlated with total weekly walk count; health and disability statuses did not. Mobility disability and health statuses did, however, predict odds of participation in any total walking in the past week among this group. Among young adults (18-25,) patterns in total walking vary according to immigrant status. Each study contextualizes these results and potential applications to public health research and practice. For example, findings could help guide community-based organizations' interventions to promote walking, highlighting specific subpopulations amenable to such efforts. Taken together, results of this dissertation highlight the need for more nuanced analyses of walking as it relates to physical activity and transportation mobility, both of which relate to overall wellbeing across the life course.

The dissertation of Gabriela Eva Lazalde is approved.

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DEDICATION

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LIST OF ACRONYMS AND KEY TERMS

Acronyms

ADL	Activities of Daily Living
CI	Confidence interval
IRR	Incidence rate ratio
NHTS	National Household Travel Survey
OR	Odds ratio
PWMD	Person[s] with mobility disability
RQ	Research question
SD	Standard deviation
SES	Socioeconomic status
US	United States

Key Terms

Non-elderly/working-age adults	Ages 18-64
Older adults	Ages 65 and older
Total walking	All forms of walking, including walking for leisure and utilitarian walking
Young adults	Ages 18-25

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In preparation

1. **Lazalde, G.E**. Understanding active community mobility among non-elderly disabled adults in the United States: An analysis of the National Household Travel Survey 2017. 2024.
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Chapter 1: Introduction

Public health scholars have increasingly sought to investigate how walking behaviors directly and indirectly affect health outcomes. An extensive literature documents the benefits of walking for exercise, establishing its role as protective factor against premature morbidity and mortality among a range of populations, including among adults in the United States (US) and comparable countries.[1,2] Walking outside of exercise (e.g., transportation walking, walking while completing daily tasks at work or home,) may also confer health benefits by contributing to physical activity totals.[3] Walking may also contribute to overall wellbeing when as a standalone transportation mode or as a component of other modes; interdisciplinary literature increasingly focuses on how transportation mobility enables access to necessary health preserving goods and services such as nutritious foods, supportive social environments, and health care services.[4–6] These specific conceptualizations of walking have contributed to a siloed understanding of how all types of walking cumulatively affect overall health, especially among populations at specific life stages in the US. Relatively few studies have investigated how life course-specific factors known to influence health such as aging, disability, and immigration relate to total walking behaviors at the population level in the United States. This dissertation aims to address this gap by quantitatively describing patterns in total walking (i.e., walking for all purposes, see Figure A) and how they relate to health factors while considering additional individual-level characteristics and the household- and community-level contexts that may also inform walking behaviors.

In each of the three studies comprising this dissertation, I assess links between various indicators of health, walking behaviors, and social and geographic contexts. I conceptualize total walking as a health outcome rather than as a predictor of overall health status or of specific health outcomes such as total physical activity levels. Though complex and bidirectional associations link walking and wellbeing together, the approach of framing walking as a health outcome among specific subpopulations of adults in the US provides a novel contribution to public health research.

Among aging, disabled, and immigrant populations, research identifying health disparities and risk factors, including those relevant to overall physical activity levels and access to transportation mobility, can inadvertently highlight potential deficits or risks among these groups. Highlighting how these populations experience different exposures to risk, especially those presumed to relate to personal decisions or habits, can reinforce harmful ideas including that health outcomes and cumulative harms depend wholly or heavily on individual behavior choices and that innate characteristics of specific groups determine members' health risk profiles. The Social Ecological Model and Life Course Perspective can each be used to challenge these ways of thinking. Both inform the theoretical approaches used throughout this dissertation. These theories recognize that while individual-level factors including, but not limited to behavioral choices, influence health outcomes to an extent, extra-individual, interrelated contexts also shape these choices.[7–9] The Life Course approach also recognizes that historical conditions from the individual to population-level, also influence future health.[9] By assessing walking as a health outcome with immediate and longer-term implications for health, this dissertation aims to help provide applicable knowledge to public health researchers to better understand the associations between individual traits and behaviors and the broader environments in which they occur. Results could be used to inform policies and programs that enhance or promote opportunities for walking at the community level and beyond to promote better and more equitable population health.

Each of my three dissertation studies, presented as individual chapters, focuses on total walking patterns among one specific US subpopulation and addresses a series of interrelated questions about how these patterns relate to overall health status. Analyses also consider effects of other health-related factors such as disability status and overall physical activity levels, along with the contexts in which these occur. The remainder of this chapter introduces remaining content, describing shared elements across papers, and includes a review of the overarching theoretical frameworks informing the specific conceptual models tested in each paper. I also present an overview of the 2017 National Household Travel Survey data used throughout this dissertation.

Overview of Study Aims

Each of my three dissertation aims, presented as individual chapters, focuses on total walking patterns among specific US subpopulations, intended to represent interrelated life course stages. This section offers an overview of motivations for selecting these populations and introduces the series of interrelated questions addressed within.

Aim 1 - Older adults (65 years and older)

My first research question (RQ1-1) asked whether individual’s self-reported mobility disability status predicts engagement in and frequency of total weekly walking. Trends in population-level aging, a serious demographic concern in the US, motivated this question, along with the remaining research questions in this study. Specifically, demographers have predicted that while at the population-level, US adults may experience longer lifespans than previous generations, some will experience disproportional risk burdens of chronic health conditions that reduce quality of life, while others will experience associated premature health declines and or early death.[10] Engaging in more physical activity, including in the form of more total walking, could help prevent some of these outcomes, yet most US older adults report activity levels that fail to meet current recommendations for optimal health.[11] Older adults commonly report walking as a preferred avenue for physical activity with relatively low barriers to participation; even short bouts can offer benefits to this population's physical and cognitive health.[12] However, population health research related to older adult walking often concentrates only on walking for exercise. Researchers and public health practitioners frame walking as a valuable tool for recovery or preservation of functionality throughout the aging process, which the evidence supports, but do not always consider how engaging in non-exercise-specific walking may contribute to health benefits. Whether older adults engage in any walking, for exercise or otherwise, and how frequently they do so, likely depends on several factors including their general health status, whether they have mobility limitations related to their physical or cognitive health or their built and social environments. This perspective motivates the remaining research questions for Aim 1 of (RQ1-2) what additional individual-, household-, and community-level factors are associated with total walking and (RQ1-3) how correlates of total walking behaviors may differ when comparing the outcomes of walking participation and walking frequency among older adults.

Aim 2 -Working-age adults (18-64 years) with and without mobility disabilities

My second research aim seeks to understand patterns of total walking among working-age adults with and without mobility-related disabilities. Analyses of 18–64-year-olds often overlook disability, deliberately or passively excluding disabled research participants, or assumes that overall health status appropriately proxies for disability. Yet this conceptualization may obscure the role of physical and cognitive disability, which can affect mobility without determining overall health status, on total walking participation. My research questions for this paper ask (RQ2-1) whether working-age adults with and without mobility-related disabilities differ in their total walking frequency and participation, (RQ2-2) whether overall health status modifies the associations between disability status and walking, and (RQ3-3) among those with mobility-related disabilities, what specific disability-related factors (e.g., chronicity of conditions, use of mobility aids) correlate with total walking participation.

Previous research has identified associations between disability status and difficulty accessing walking for exercise and as a transportation mode.[13–15] In this work, researchers frequently posit walking behavior as dependent on disability status, yet having a disability, even one related to mobility, does not necessarily preclude walking, nor does it always relate to poor overall health, especially among non-elderly adults.[16] The benefits of walking may accrue regardless of one's disability or overall health status, though the associations between these factors remain underexplored. Findings from these analyses provide valuable insight relevant to understanding total walking patterns among those with and without mobility-related disabilities, which I hypothesized would differ.

Aim 3 – Young adults (18-25) and immigrant status

Immigrants represent a substantial and growing proportion of the US population with unique health profiles with respect to available resources with which to protect and improve health. Their walking behaviors remain little explored outside of specific circumstances and subpopulations, and especially at life stage representing transition from childhood to adulthood. To begin to address this gap, Aim 3 focuses on assessing the association between immigrant status and total walking among young adults. My first analysis assessed whether those born outside the US reported different total walking frequencies compared to US born young adults

(RQ 3-1.) I then determined how total walking frequency is associated with age of arrival among immigrants (RQ 3-2) and how this association shifts with consideration of additional individual-, household-, and community-level factors including overall health and disability status (RQ 3-3).

Shared purpose

Overall, this dissertation furthers explanations of how overall health status, disability status, and contextual factors independently and jointly predict walking trends among important segments of the US population. As the US population of older adults, people with disabilities, and immigrants grows, understanding how walking behaviors vary at the population level among these groups can help inform future research and interventions targeting health promotion.

Methods

This section introduces key aspects of the methodologies used throughout this dissertation. The first section explains key constructs and how they fit into theoretical frameworks informing the overall conceptual model for the three studies. I present an overarching conceptual model which guides the dissertation as a single work. The final section of this chapter describes the 2017 National Household Travel Survey data which I use throughout the dissertation.

Overall Conceptual Model and Theoretical Perspectives

Total walking

To help guide my investigation of linkages between walking and health throughout the life course in the US in a way that addresses some of the gaps in the literature introduced in the previous section and elaborated upon in each empirical chapter, I developed an overarching conceptual framework. Central to the framework is the understanding of my key outcome – total walking. Public health researchers often frame exercise walking as a predictor of various health outcomes and results of their studies provide evidence for walking as a relatively accessible behavior that can prevent many chronic health conditions among many populations.[17–19] Within this framing, walking for exercise falls into one domain of physical activity as defined by the World Health Organization; the others include household (e.g., childcare, cleaning, gardening,) leisure (e.g., sports, training and conditioning, dancing,) occupational, and transport.[20] Yet walking can also contribute to any of the other four domains of physical activity, which also have known associations with health outcomes.[20–22] Recognizing this, some interdisciplinary scholars have sought to assess how more broadly scoped definitions of walking affect health.[1] The intersection of health and transportation represents one such area where interest in these topics grows.[23] Transportation researchers Kang, et al. separate walking into two broad categories within the transportation literature: recreational walking and utilitarian walking.[24] Their classification of walking types, alongside the WHO definition of physical activity, informed my conceptualization of total walking, which I illustrate this in Figure A. Within each empirical paper in this dissertation, the focal outcome relates to the construct of total walking, which includes walking among several domains of physical activity and recognizes the potential for overlap between walking types. For example, walking as transportation may double as a choice driven by desire to accomplish physical activity; leisure walking trips may bundle together with walking required to accomplish daily tasks such as child or pet care.[24] I present details related to operationalization of specific outcome variables in each chapter's methods section and elaborate on how overarching potential strengths and limitations of this approach may affect interpretation of findings in the conclusion chapter.

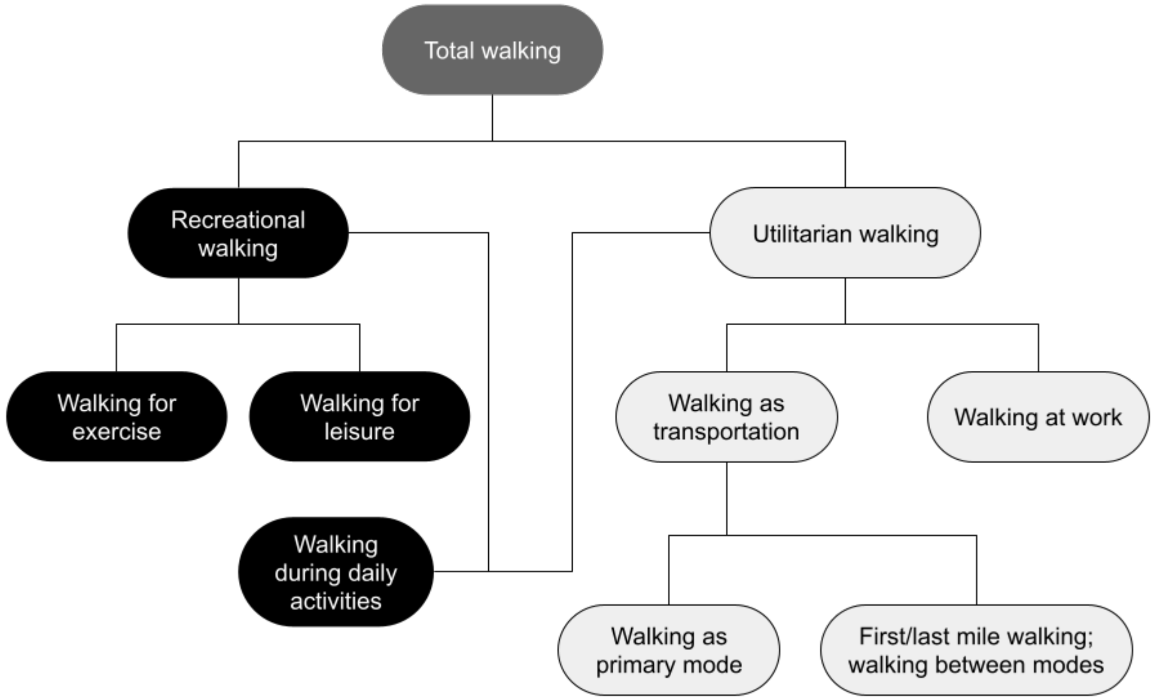


Figure A: Components of total walking

Theoretical frameworks

The Life Course Perspective and Social Ecological Models inform research questions and interpretation of analyses informing responses to the questions I assess regarding the connections between total walking and health throughout this dissertation. The role that built and social environments play in influencing physical activity and other health-related behaviors has received increasing attention in public health and other fields' research in recent decades. One frequently referenced theoretical framework is the Social Ecological Model, which posits that health outcomes are shaped by individual-level behaviors which take place in interrelated and interdependent intrapersonal, interpersonal, community, institutional, and policy-level contexts.[25] Noted developmental psychologist Uri Bronfenbrenner first presented the Social Ecological Model in a seminal textbook on child development in the 1970's, and McLeroy, Bibeau, Steckler, and Glanz's 1988 Ecological Perspective expanded on this work, adapting it to better suit health-related research.[25,26] McLeroy et al. argued that individuals apply "knowledge, attitudes, self-concept, [and] skills" at the intrapersonal level to make health-affecting decisions.[25] Interpersonal level relationships with primary social connections including close family, friends, and co-workers who may share intangible support such as knowledge and emotional support and material resources within their networks also shape health decisions and subsequent behaviors.[25,26]

These influence aggregate interpersonal level factors, which themselves shape the next level of institutional factors which comprise the formal and informal rules shaping socially acceptable home and work lives.[26] Institutional factors embed within community level spaces, which comprise "organizations, institutions, and informal networks within defined boundaries" such as neighborhoods or self-assigned membership within a specific religious, linguistic, or ethnic group.[25] Finally, the framework's outermost level encompasses public policy, which are the local, state, and national regulations that affect and are affected by each preceding level.[25,26] By identifying factors that affect health and contextualizing them within these five interrelated levels, public health researchers and practitioners can examine complex patterns in health outcomes and their determinants. This approach of contextualizing risk and mitigating factors for specific health outcomes within specific levels of influence—while not always explicitly named as a Social Ecological approach—is frequently used in research relevant to walking and health; I used aspects of this approach to develop the overarching conceptual framework for the studies in this dissertation.[6,11,16]

Despite its utility, Social Ecological models do have a few limitations. One critical limitation of the Social Ecological model is the difficulty of understanding the degree of influence of each contextual level. While it is tempting to assume that more distal influences have less of a direct effect on transportation outcomes, exceptions to this pattern may emerge. For example, community-level decisions about where to build and maintain sidewalks and roads may have more of an influence on individuals' decisions to walk to a location regardless of an individuals' physical ability or internalized desires to walk. Further, the Social Ecological model does not explicitly refer to the role of individual-level agency in altering extra-individual factors. For example, heads of households can sometimes select the type of neighborhood in which they live, and therefore, the types of transportation infrastructure to which they have access. Much research in the transportation field speaks to the role of this type of residential self-selection with respect to ways to access desired employment, educational, or other socioeconomic opportunities.[27,28] Finally, the Social Ecological model can be used to conceptualize individuals' present circumstances but does not consider historical influences that have led to these circumstances.[25] This issue affects the study of transportation mobility patterns older adults and immigrants in particular since historical conditions such as their prior employment and conditions including transportation infrastructure in sending counties can shape travel decisions in the present.[29–31]

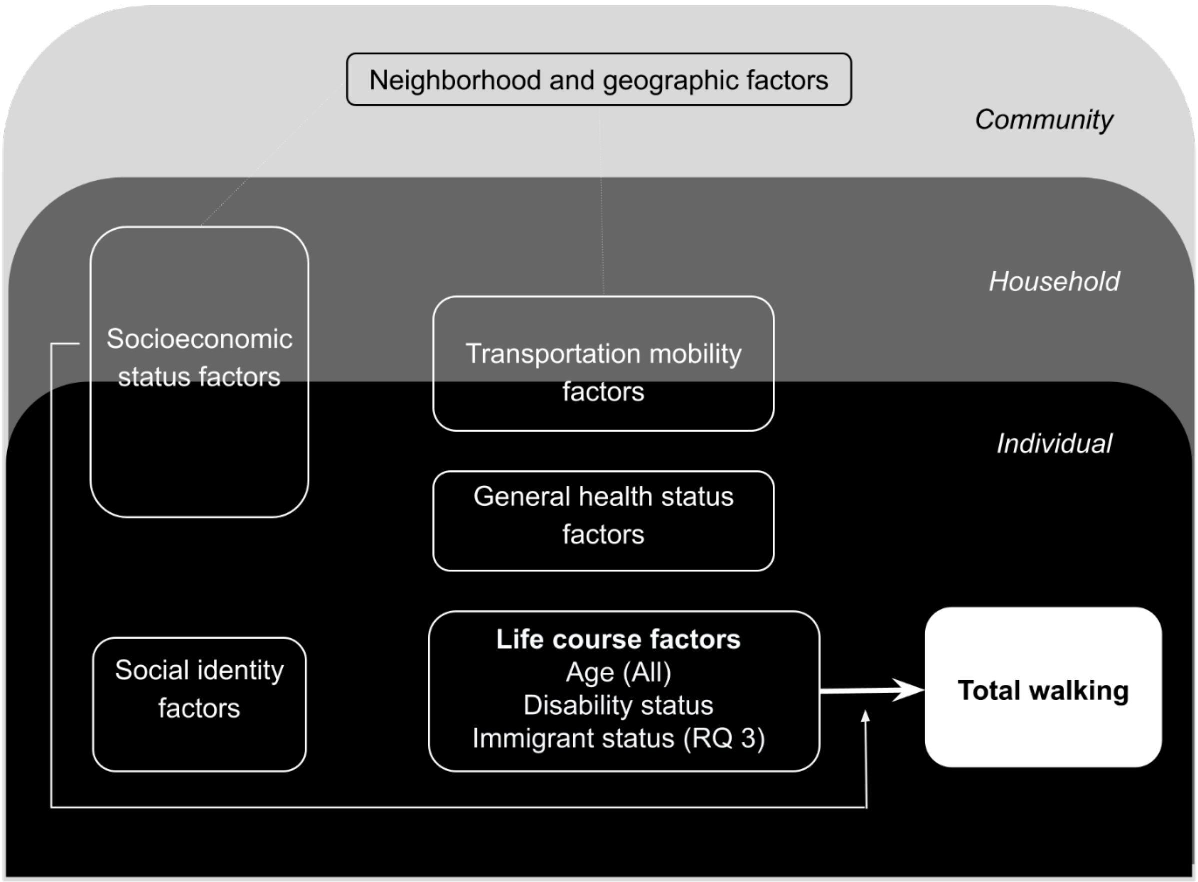
For this reason, my theoretical approaches incorporate elements of the Life Course Perspective, which more adequately capture the role of past experiences and current individual and extra-individual level agency in determining health outcomes. The Life Course Perspective can help explain how life experiences and milestones from birth onwards both mediate and supplement understanding of outcomes in health and wellbeing.[32] Events and environments in earlier life stages culminate to influence later circumstances and these circumstances may ultimately result in different outcomes. Life Course Perspective comprises five key principles with encompass both individual-level and extra-individual influences in one's present circumstances and in their personal history. The five principles of Life Course Perspective explain how early life exposures influence later life outcomes.[32,33] First, the principle of (1) lifespan development recognizes that life circumstances, including one's daily behaviors and health status, change over time. Some of these changes depend on one's (2) agency, or the ability to choose to behave in a variety of ways as dictated by (3) time and place, or the socioeconomic and environmental circumstances that one inhabits as determined by broader historical and political developments (e.g., period effects.[33]) Significant milestones in one's life are affected by previous milestones or events as laid out by the principle of (4) timing (e.g.,, critical development windows.[33]) Finally, the principle of (5) linked lives dictates that although individual circumstances and preferences can vary immensely from person to person, because people share context with others in their geographic and social proximity, individuals' actions often affect others' lives (e.g., relational and other social ties, cohort effects.[33]) Researchers in public health and transportation utilize many of these principles either explicitly or implicitly in studies focused on understanding walking behaviors within specific populations.[34–38]

For example, researchers highlight the importance of the principle of time and place in examples from a recent literature review cataloging pathways between transportation and health including: the connection between exposure to transportation-related air and noise pollution and both immediate health risks such as asthma, rother respiratory problems, and low sleep quality and longer-term consequences like elevated risk of certain cancers.[37] Another study using these principles found more frequent use of active transportation forms and resulting improved cardiometabolic health among people who live in more walkable neighborhoods.[38] The principle of linked lives is evident in research demonstrating that among specific populations of older adults including those living in a low-density urban area in the US, undocumented immigrants in the US, and low-income older adults in a UK housing project, those with more expansive social networks are less likely to report transportation difficulties in access to necessary health care services and food and less likely to experience feelings of social isolation, a known predictor of early mortality.[39–41] These examples illustrate Life Course Perspective's ability to contextualize the experiences of individuals to better understand their walking-related health outcomes and behaviors as the culmination of past experiences and foundation for later life.

Despite its utility, Life Course Perspective also has some drawbacks. One such limitation relates to difficulty associated with gathering information about past experiences; reliance on individuals' recall can lead to biased data, but often reduces costs of data collection, enabling larger sample sizes better suited for quantitative analyses. Another limitation consists of the difficulties assessing and disentangling effects of multiple levels of contextual factors. For example, individuals may simultaneously engage in health behaviors influenced by personal or family life events, their perceptions of these events, and more distal, broader historical events. Challenges introduced by these limitations have likely resulted in Life Course Perspective-driven analyses focused more narrowly on individual-level factors, thereby flattening individual and social histories, inaccurately assessing social histories. Integrating elements of Social Ecological Model to analyses informed by Life Course Perspective can help address some of these limitations.

Figure B shows the framework linking together the models that guided analyses in each study. Informed by the Social Ecological Model, the framework contextualizes groupings of constructs representing specific aspects of individual's daily lives into a series of nested levels: Individual, household, and community. Some variables comprising each grouping of factors remain consistent throughout analyses. In each analysis, I consider the effect of educational attainment or current student status as part of the socioeconomic status factors. I also include an individual's annual household income in this grouping, resulting in these indicators bridging the individual- and household- levels. Similarly, transportation mobility factors in analyses include individual-level driver's licensure status and number of available vehicles. within each household. The later variable, alongside the household income variable reflects the life course perspective's linked lives principle. Availability and quality of infrastructure and related resources including roads, sidewalks, and public transportation services occupy the community and geographic levels and influence individual- and household-level mobility decisions.[37] According to the Social Ecological Model, influences at the individual level have the strongest effects on daily choices while those at more distal levels have correspondingly distal effects.[7]

Figure B: Overarching conceptual framework



Data Source – 2017 National Household Travel Survey

The National Household Travel Survey (NHTS) collects information from a nationally representative sample of United States residents and has the primary goal of understanding patterns in travel by the non-institutionalized population.[42] The Federal Highway Administration has conducted the survey at regular intervals of approximately five to seven years since the 1950's.[43] Data collected inform regular reports to US Congress and government agencies on national-level trends in travel, highlighting evolving norms in transportation behaviors as they relate to economic and land development and demographic trends. NHTS data also inform federal, state, and local agency responses to transportation-related needs and preferences.[43] Additionally, assessment of environmental conditions and practices, safety measures, human behaviors, and energy use related to transportation in academic and commercial applications rely on this data source.[43] NHTS data are particularly useful for public health research related to transportation as a social determinant of health because they offer a publicly available large, sample of rich sociodemographic and behavioral characteristics at the individual-, household- and neighborhood-levels comprising data from a sample designed to represent the overall US population.

For the 2017 sample, 129,696 households including 264,234 individuals provided data about 923,572 trips.[44] Response rates for the initial recruitment survey which resulted in initiation of individual-level retrieval survey, varied by geography and averaged 30.4% nationally. [44] Among participating households, approximately 51.4% responded for a total response rate of 15.6%.[44] Roughly 60% of these households completed surveys online, primarily on a desktop or laptop computer. [44] Approximately one fifth of all online surveys were completed on a tablet or smartphone, while an additional 30% of respondents reported via phone; the remainder were completed using some combination of phone and online reporting.[44] Each study within this dissertation used at least one unique subsample of these data for analyses, which I describe in each chapter.

Data used throughout these analyses come from the 2017 NHTS public use files. The 2017 NHTS public use files comprise four interrelated data sources within the NHTS. Files contain information about the households participating the survey (recruitment data, completed by one household member, with some confirmation of individual-level data in the next components), individuals' travel diary responses (trip data), participants' non-travel diary person-level data (retrieval data), and detailed information about each vehicle within each household (vehicle data.[44]) Given this project's use of the individuals as the units of analyses and planned inclusion of individual-level variables from the recruitment, retrieval, and travel surveys only, the first stages of data analysis required merging of these files and select variables.

Most of the public use file data already underwent processing by Westat, resulting in relatively low missingness and consolidation of some information to preserve participant privacy in secondary analyses. [44] Low missingness of essential demographic variables including age and sex within the public use files reflects NHTS' efforts to capture this information using both the recruitment survey and confirmation steps in the household retrieval survey(s.) Any imputation processes reflected in the public use files for the survey deemed necessary or beneficial by NHTS staff were designed to reflect American Communities Survey 5-year estimates of US population demographics; these data also guided development of the survey weights for public use.[45] These processes maximize representativeness and power of future statistical tests. After merging the files, I carried out descriptive analyses on sociodemographic, travel, and health-related variables representing constructs central to my analyses. Throughout the analytic process, I consulted with other researchers using these data to confirm appropriateness of my variable operationalizations, my decisions to conduct unweighted analyses without imputing or otherwise altering data to account for any missingness.

Each of the following empirical chapters provide additional details regarding how I prepared NHTS data subsamples for each study. These descriptions include details related to operationalization of focal predictor and outcome variables. I include an overview of the strengths and limitations of the 2017 NHTS data as pertinent to these studies in the Conclusions chapter.

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Chapter 2: Aim 1 - Total walking among older adults in the United States

Introduction

In coming decades, older adults—those 65 and older—will comprise an increasing proportion of the population of the United States (US.)[1] As part of the aging process, members of this population will experience declines in physical and cognitive functioning which may manifest as poor health status and disability.[2–4] Though aging represents a normal part of the life course, loss of mobility—one's ability to physically travel throughout the community—can compound aging-related health problems. Limited mobility reduces overall life space among older adults, which can drive and accelerate physical and cognitive decline through mechanisms including social isolation , poor nutrition, and reduced access to health care.[5–9] Walking is a key component of mobility through its links to transportation, a known social determinant of health.[10,11] Older adults have described walking as a preferred and relatively accessible form of physical activity.[12,13] Though researchers have investigated how walking for transportation and leisure influence older adult health, fewer studies focus on population-level patterns of total (i.e., walking for any purpose, including both transportation and leisure) walking participation and frequency among older adults in the US. Limited evidence about how total walking patterns may differ among different subpopulations of older adults in the US contributes to challenges for public health and policy professionals seeking to promote walking to preserve mobility and overall wellbeing.[14] This study aims to quantify factors influencing US older adults' total walking behaviors using data from the 2017 National Household Travel Study (NHTS.) Theory-driven analyses will assess how mobility disability status, age, and overall health status may affect walking patterns among older adults in the US while accounting for additional individual-, household- and community-level factors such as driver status, household vehicle availability, and neighborhood rurality. Knowledge from this study can inform future policy and programmatic interventions looking to preserve mobility and thereby enhance health among US older adults.

Background and Literature Review

Many studies on older adult health and walking have focused on quantifying the health effects of walking while considering walking a form of physical activity.[13,15,16] These studies find that older adults who report walking for exercise have better physical and cognitive health outcomes.[17–21] Benefits of walking confer to older adults with pre-existing health conditions;[22,23] when they engage in walking for non-exercise purposes (e.g., for transportation);[24] and with low intensity or limited distances of walking.[25,26] Studies measuring walking objectively using pedometers or smartphone apps to gauge step count found that modest increases in daily step count correspond to better cardiovascular and mental health outcomes among adults in the US.[20,27] Researchers argue that policies and programs to promote walking may serve a valuable function for population level health through these mechanisms.[27–29] However, questions remain about walking's accessibility for older adults, especially among those with health conditions and disabilities that limit mobility.[13,30] Researchers have quantified physical and cognitive limitations using metrics such as one's ability to independently walk a certain distance or use of mobility aids.[31] Those with mobility limitations may still engage in total walking that confers health benefits, despite potential difficulties.[32] These individuals may require assistance from mobility devices, another person, or specific environmental features (e.g., level surfaces, adequate lighting, spaces to rest,) but still stand to gain from interventions to facilitate their mobility through increased walking participation or frequency. A better understanding of older adults' baseline walking patterns could facilitate the design and implementation of effective walking promotion programs and policies that consider a range of limitations and make appropriate built and social environment modifications to confer maximum population-level benefits.

Another research area relevant to older adult health and walking focuses on identifying built and social environment factors influencing walking for transportation or leisure purposes; many of these studies frame transportation mobility as a social determinant of health and provide evidence that increased mobility predicts better health outcomes.[10,33] In their influential 2008 review of built environment effects on walking, Saelens and Handy defined the built environment as "as the part of the physical environment that is constructed by human activity," and conclude that elements such as ramps, sidewalks, and lighting may influence older adults' behaviors in particular given their more frequent physical impairments compared to younger adults.[34] A more recent review and meta-analysis substantiates this claim as well.[35] Mirzaei et al acknowledge some overlap between built environments and perceptions of these environments, which would fall under the social environment umbrella.[36] In addition to attitudes towards built environment conditions, other social environment factors that researchers have studied in conjunction with their role in walking behaviors include: individuals' marital status, availability of a walking partner, and the level of activity required for their daily activities (e.g., at their workplace or through their role in providing care to family members.)[37–39]

One recent longitudinal study among Medicare beneficiaries found that neighborhood aesthetic factors and trust among neighbors encourages increased walking and use of transportation modes that require some walking such as public transportation.[40] Another analysis found that perceptions of dangerous driving predict reduced walking among older adults in several Texas cities, while perceptions of protected sidewalks and walkways predicts increased walking.[41] These results held even after accounting for socioeconomic factors and participants' ability to walk moderate distances without difficulty; yet researchers noted that both of these factors linked to lower socioeconomic status among older adults in the US.[41] In a separate study featuring a private health care organization-based sample in a similar Central Texas location, Ory et al. found that social support proxied by marital status, availability of a walking partner, and whether participants reported usually walking a dog in their household predicted more frequent walking while perceptions of low walkability and fear of falling predicted less frequent walking.[39] These studies give insight into correlates of walking frequency but do not interrogate whether or how correlates for any walking participation (i.e., whether one walks at all) may differ. These findings align with past studies regarding perceptions of neighborhood disorder wherein researchers used neighborhood Walk Score,™ a proprietary metric of neighborhood walkability, and Google Maps images data to assign scores of neighborhood disorder to residential areas, concluding that higher Walk Score ™ and decreased disorder correlated with older adults' frequency of walking.[42,43] Walk Score ™ and neighborhood disorder had a smaller, but non-negligible role in their decisions surrounding walking participation (i.e., whether older adults walked at all.[43–45]) Conclusions drawn across studies on built and social environment predictors of walking refer to the need for more research on what factors promote walking participation and higher walking frequency among older adults, especially those in groups often excluded from research studies.[39,44,45] Identification of these factors may provide valuable insight to promoting healthy aging especially among racially, ethnically, and socioeconomically constrained older adults with and without mobility-related health conditions in the US who currently participate in limited walking compared to peers with higher socioeconomic statuses.[14,39,41]

Multidisciplinary researchers have used National Household Travel Survey (NHTS) data in studies relevant to older adult walking and health. Operationalization of walking varies across these studies, frequently relying on data from the travel diary portion of the NHTS, which reflect a single day of travel.[46] For example, in a series of recent analyses using NHTS data and additional data sources, researchers identified barriers and facilitators to neighborhood walking among older adults, a majority of whom reported no neighborhood walks on their assigned travel diary day.[47] Limited green space, living in neighborhoods that have been historically racially segregated, worker status, car ownership, and living in less dense residential areas all correlate with decreased participation in neighborhood-based (i.e., walks that begin and end within one's residential areas) walking trips assessed using self-reported walking in the past seven days.[47–49] Yet despite providing insight into population-level neighborhood walking patterns among older adults in the US, these studies had some limitations. The walking outcome used in these studies relied on travel diary data, which was unavailable for over 30% of the older adults included in the 2017 NHTS.[50] Further, these analyses did not consider walking beyond self-reported loop trips beginning and ending at one's residential address, nor did they consider disability's role in walking among their study sample, despite the known influence of disability status on participation in a range of physical activities, including walking among older adults in the US.[23,51] Another NHTS-based analyses did consider disability's effect on overall transportation mobility – which included, but did not focus on walking—and found that older minority women tend to report fewer daily trips if they live in rural areas, live with their children or another adult, do not drive themselves, and have lower educational attainment levels.[52] An analysis of the 2009 NHTS data found that older adults who fall into the oldest age category of those over 85, live in rural areas, are Black (compared to all other races/ethnicities), and who live with non-elderly adults (vs. those who live alone or with other older adults) more frequently reported "long-term immobility."[53] Researchers quantified this condition using self-reported status of not leaving their homes for one week or longer prior to their randomly assigned travel day. [53] This analysis did not consider general health as a potential determinant or moderator of mobility behaviors and instead assessed mobility-disability status using duration of self-reported time without traveling outside their home.[53]Altogether, these studies relied on measures of purpose- or location-specific walking, or multiple types of mobility that include walking, as a mobility outcome, and did not always consider the full scope of health-related factors with known associations with walking adoption and frequency among older adults. The limited scope and specificity of these findings highlights a need for analyses focusing on total walking, regardless of setting of or motivation for walking. These types of analyses may help clarify how to increase older adults' overall mobility as a means of promoting healthy aging. Further evaluation of whether and how a theory-informed selection of individual-, household- and community-level measures including a broader range of health factors affect overall walking may help explain which subpopulations of older adults may be most in need of walking promotion or overall mobility-focused interventions in the future.

Overall, past studies have important, but distinct motivations and implications for future research and practice relevant to older adult walking and health compared to the present analyses. Rather than framings setting or purpose-specific (e.g., neighborhood-based, exercise- or transportation-focused) walking as an input to overall health, my analyses instead focus on assessing weekly walking participation and frequency as a distinct health outcome. Past studies have found that among older adults, exercise walking provides direct health benefits at relatively low volumes and durations; less directly, gerontology and transportation studies have linked general transportation mobility, which may involve walking, as a correlate of access to health-promoting factors including access to care, social engagement, and overall sense of wellbeing.[18,45,54] Thus, total walking, or lack thereof, may correlate with overall health of older adults. I consider how all walking correlates with related, but distinct factors including mobility disability, general health, and personal identify factors while considering key household- and community-level context in which walking occurs. This will provide better understanding of what factors predict increased frequency of walking and correlate with any participation in walking in the past week among a representative sample of older adults in the US. Further, analyses will quantify mobility disability's influence on walking patterns in a growing population. Findings can inform policies and programs to encourage older adult walking may not be optimally designed or targeted. The conceptual model presented in the next section guided analyses with the goal of providing this additional understanding.

Methods

Research Questions

Informed by gaps in the research identified in the previous section, this study sought to address a central set of three interrelated research questions. First, among older adults in the US, (RQ1) are individual-level mobility limitations, represented through self-reported mobility disability status, associated with participation in and frequency of total walking? As indicated in Figure 1 below with the RQ1 box, the first sub-aim for this analysis quantifies associations between mobility disability status and total walking patterns in the analytic sample of US older adults. I hypothesized that mobility disability status would be associated with reduced total weekly walking participation (i.e., whether older adults reported at least one walk in the past week, for any purpose) and frequency (i.e., low, medium, or high level of total walking trips reported in the past week) among older adults.

The second research question asks which specific individual-, household-, and community-level factors predict participation in and frequency of walking among US older adults. The box labeled RQ2 in Figure 1-1 highlights theoretically relevant factors linked to mobility disability and walking outcomes at the individual, household, and community levels. I grouped constructs acting at the same contextual level to illustrate model building processes. Initial models included covariates from the individual level, which include socioeconomic and personal identity factors of educational attainment, working status, and race and ethnicity. The next models retained these factors and added household-level socioeconomic status indicators of income and home ownership status, alongside additional household-level factors indicating household composition and personal vehicle availability. The final set of models layered in community factors such as neighborhood rurality, presented in the topmost box. I include census region in this grouping as well, though it serves primarily as a control for potential sample bias since this geographic distinction is likely too large to account for true regional variation in factors that may influence walking such as culture and weather. I hypothesized that engaging in any walking, and frequency of walking would correlate with the indicated factors at the individual-, household-, and community level, and that the strength of associations would be higher among household-level and individual-level factors compared to community-level factors. The final research question (RQ3) asks how these factors compare when evaluating the two walking outcomes examined throughout. I hypothesized that factors associated with higher walking frequency would be similar, though not identical to those associated with any walking participation. The following sections further elaborate on the formation of this conceptual model and the analytic approach it guided.

Conceptual framework

The association between individual-level mobility limitations and walking comprise the focal association of this study. Researchers have identified mobility as a determinant of healthy aging, but many older adults face mobility difficulties that may contribute to participation in and frequency of walking.[33,55] Walking is an important component of transportation mobility, which can determine access to health-preserving resources such as health care services and nutritious food.[10,56–58] Walking also constitutes a popular and relatively accessible form of physical activity; participation in walking can help with meeting physical activity targets, which promotes optimal health.[13] One may assume that mobility-disabled older adults engage in the less walking compared to those without mobility disabilities. This relationship likely varies by definitions of mobility disability and across specific walking contexts and outcomes; for example, those with the most severe ambulatory limitations may be unable to walk under any circumstances and would therefore report no walking of any type while those with less severe ambulatory constraints may still report some walking, though perhaps with the assistance of another person or a mobility device and with fewer trips in a given time period compared to someone without any mobility disabilities. This study interrogates these assumptions through assessment of whether and how often older adults with and without mobility disabilities participate in all-purpose walking.

The mobility disability measure I use throughout depends on two factors: whether individuals report 1) travel difficulties imposed by “a[ny health] condition[s] or handicap[s]” and 2) transportation-related behaviors that indicate mobility challenges.[59] Further, the definition of walking used throughout encompasses ambulation with support (e.g., with use of mobility aids,) does not limit walking to a specific setting, and does not specify minimal distance or duration of walking. Regardless of whether NHTS participants identify as having a mobility disability, older adults may experience mobility limitations that affect walking behaviors if they have insufficient physical assistance in the form of access to and using needed mobility devices of built environment supports, or social support such as the assistance of family members, friends. These factors may affect multiple types of walking, including walking for exercise and as part of professional or personal activities within and beyond one's home. Conversely, social and environmental conditions may discourage transportation-related walking in favor of driving a personal vehicle, receiving rides from friends, family, or using other transportation modes that require little to no walking. I include selected covariates designed to reflect these patterns in my analyses to help clarify the association between mobility limitations and overall walking. Figure 1-1 locates covariates in the contexts in which older adults live.

The covariates for these analyses nest within three levels informed by the Social Ecological model, which posits that individuals exist within interrelated progressively broader contexts.[60] At the individual level, I include factors with known associations with mobility limitations and walking behaviors among older adults in the US. This includes demographic factors such as age and gender, which have significant associations with patterns in aging, transportation use, and walking as related to transportation and physical activity.[47,61,62] Poor health status has been associated with reduced participation in leisure-time physical activity but when researchers have investigated other types of physical activity (e.g., work, transportation, household activity) these associations' strength and direction lack clarity.[33,63–66] Mobility aids influence use of non-walking forms of transportation and may enable greater participation in walking compared to those without access to these resources.[67] Finally, having a driver's license has been linked to increased transportation access and use among older adults in the US but does not necessarily correlate with all walking behaviors.[68,69] An extensive driving cessation literature documents how declines in health tend to correlate with reduced driving but not necessarily total cessation or surrendering of licensure.[70–72] I included the individual-level socioeconomic factors of race and ethnicity, educational attainment, and employment status, which have correlated with disability and walking related outcomes in other studies.[73–75]

At the household level, I include additional variables: household income, household composition, and availability of personal vehicles. In previous analyses, these factors tend to act together to shape frequency of walking for transportation.[76] For example, having a higher income increases likelihood of personal vehicle ownership and availability of a personal vehicle decreases reliance on utilitarian walking or other modes of transportation involving some walking; it may also result in increased availability of leisure time in which to engage in walking since non-driving modes tend to be take more time compared to driving.[77,78] At the same time, having access to a personal vehicle and higher financial and schedule-related flexibility may increase individuals' ability to access green spaces or facilities dedicated to exercise where they may engage in leisure time physical activity, including walking. Finally, variables at the community-level reflect broader social conditions in which older adults engage in walking.

These include neighborhood rurality, proportion of homes owned, and census region. In terms of neighborhood rurality, those living in more urban areas may engage in more walking for transportation given likely higher density of destinations to which one may walk. People who choose to live in more urbanized areas may also live in places where home ownership is less common; but conversely, areas with less home ownership may also reflect a lack of access to

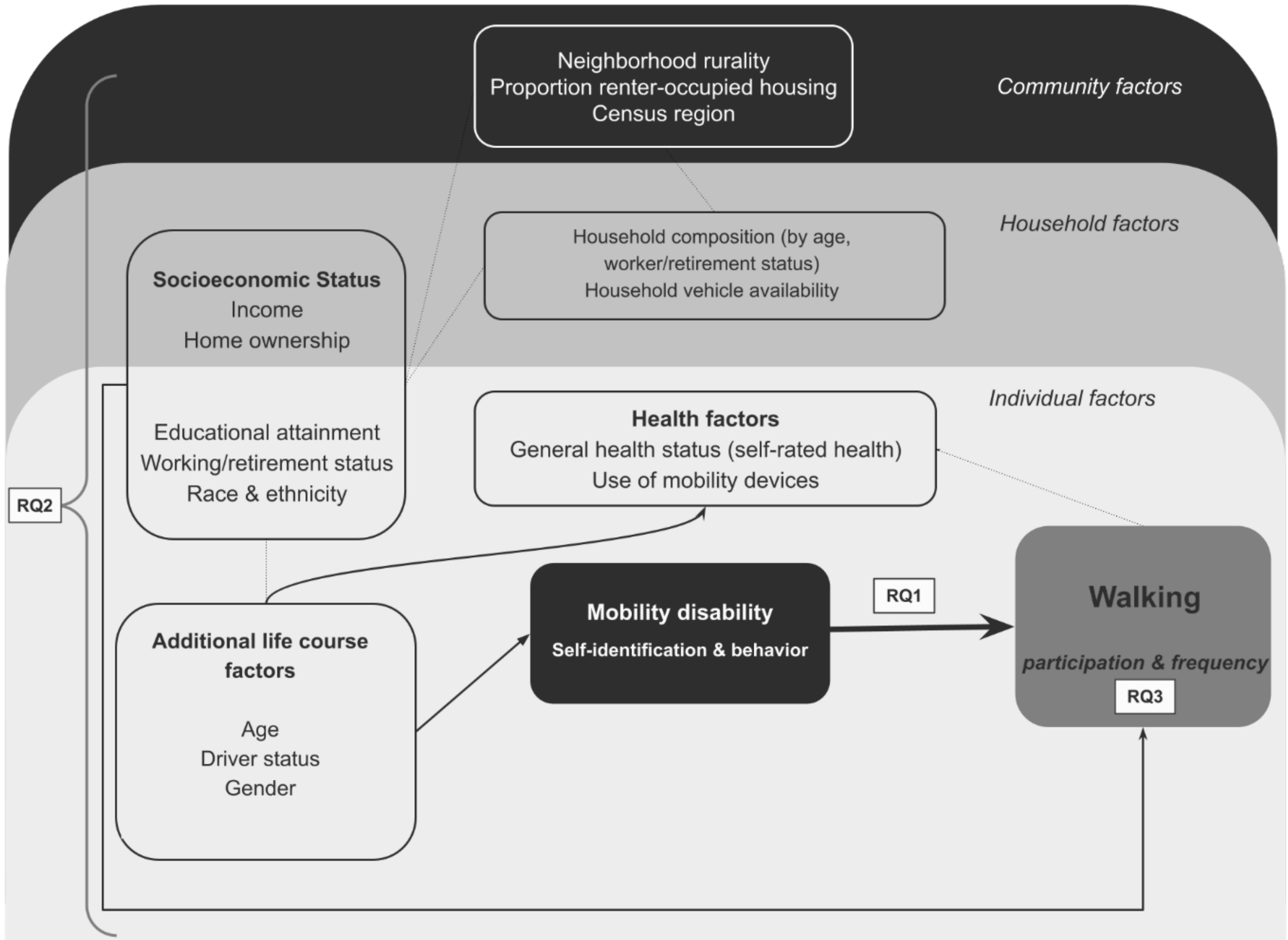


Figure 1-1: Aim 1 Conceptual framework

financial resources that would also allow more non-utilitarian walking. Inclusion of the census region term was informed by previous studies' inclusion of this term in previous studies working with these data.[46] I hypothesized that each of these factors would be associated with both mobility status and walking behaviors to a degree, but that differences in walking patterns by mobility limitations would vary when accounting for these factors. The next section describes the data source I used to test the associations described in this conceptual framework, including details on how I operationalized the variables that proxy constructs described, and my hypotheses about how these constructs influence older adults' all-purpose walking.

Data

2017 National Household Travel Survey

The 2017 National Household Travel Survey (NHTS) public use files contain data used for these analyses. The survey captured information related to the travel patterns of non-institutionalized individuals; Chapter 1 contains additional details related to NHTS methodologies.[59] My analyses for this study relied primarily on data from the retrieval survey portion where participants report typical travel behaviors and sociodemographic information. I also used travel diary data to construct the homebound status variable and for sensitivity analyses.

Key outcome: past week total walking

For this study's main outcome variables, I used data reflective of the count of total walk trips participants reported taking over the past 7 days. Participants of the 2017 NHTS responded to the question "[i]n the past 7 days, how many times did you take a walk outside, including walks to exercise, go somewhere, or to walk the dog (e.g., walk to a friend's house, walk around the neighborhood, walk to the store, etc.)?"[59] Count responses ranged from 0 to 40. Since this question did not limit walking to specific durations, intensity, or purpose types (i.e., walking for transportation, leisure, and exercise), they may more faithfully reflect total walking in the past week in comparison to relying on responses from the single day travel diary portion of the data. However, quality of both sources of walking data likely suffers due to recall bias.[79] I operationalized multiple walking variables based on these count data to have flexibility to test different types of statistical models.

Treating total walking outcomes as a categorical variable allowed me to assess both participation in any total walking (i.e., whether participants reported 0 or 1 or more walks for any purpose) and frequency of walking. In generating 4-level categorical variables, I coded those who reported no walks as 0s; the remaining 3 categories describe those who walked with low (1-2 walks), moderate (3-6 walks), and high (7+ walks) frequencies according to their self- reported number of walks in the past 7 days. This operationalization allows for consideration of the assumption that the portion of the sample who reported no walks may include both those who cannot walk (e.g., due to severe mental or physical limitations) and those who elect not to walk (e.g., due to preference or temporary circumstances such as weather, injury, work, or childcare obligations.) Results relying on walk count data may have less practical significance, especially when using methods that model participation and extent of participation separately (i.e., two-part models that account for potential differences between walkers and non-walkers.) Intuitively, older adults who reported 1 walk likely have different typical walking behaviors compared to those reporting 0 walks. However, the one-walk difference between 0 and 1 likely reveals more about walking behavior overall compared to differences between intervals of other walk counts (i.e., those who walk 4 time per week vs. 3 likely have more in common with each other.) This logic informed the decision to group total walk counts into categories that parallel categories used to describe frequency of use of other transportation modes in the NHTS. This operationalization potentially also reduces the influence of week-to-week variance on the self-reported nature of this variable while still maintaining the ordered nature of walking patterns likely to occur regularly among older adults.

Key predictor: Mobility disability status

I used mobility disability status as the focal predictor variable for these analyses. This variable categorizes the older adult sample into two groups according to whether they reported having mobility disability. Figure 1-2 depicts the pathways by which participants could meet mobility disability criteria. The right side of the chart shows the first of these potential pathways. If a participant reported they have a "condition or handicap that makes it difficult to travel outside of the home," I categorized them as mobility disabled.[59] Two groups of participants answered additional questions related to specific travel limitations, either as a follow-on question if they responded affirmatively about conditions or handicaps or as a standalone question if they reported being 80 or older. The latter group responded to the follow-on series about specific travel limitations regardless of whether they identified as having any travel-limiting conditions. As part of this additional list of questions, participants indicated whether they have "given up driving altogether," "limited driving to daytime," or have "reduced day to day travel. [59]" If participants noted any of these specific limitations, I categorized them as mobility disabled. I selected these three limitations as criteria given their relevance to overall transportation mobility in the gerontology and transportation literature I reviewed.[44,68,72]

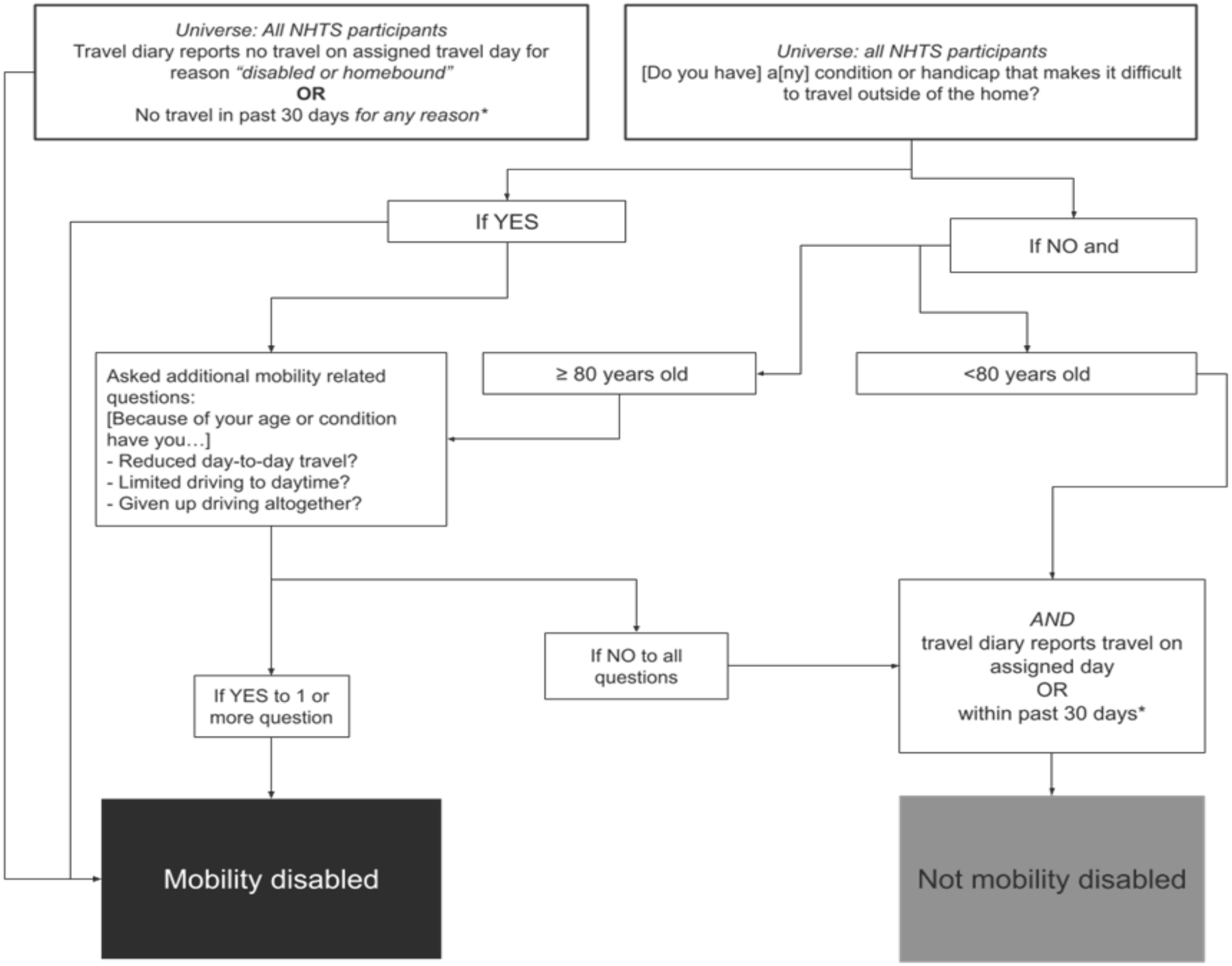


Figure 1-2:Determination of mobility disability status

The left side of Figure 1-2 illustrates the second main pathway to inclusion in the mobility disabled category, which depends on data from the travel diary portion of the survey. While under 14% of individuals in the NHTS 2017 sample reported not leaving their home at least once on their randomly assigned travel day, the proportion of those who reported not leaving their home was higher (37.3%) among those reporting disabilities.[80] To capture a wider range of individuals who exhibit behaviors indicating mobility disability, I considered the group of individuals who reported not making at least one trip on their travel day. These individuals answered two follow-up questions regarding their lack of travel. First, they reported when they last traveled, selecting from the options of the day before their assigned travel day, within 7 days of the assigned travel day, and within 30 days of the assigned travel day.[59] I categorized as disabled all who indicated that they did not travel within the 30 days prior to their assigned travel day since this likely indicates a significant physical or cognitive impairment. Participants who did not travel on their assigned day next selected the reason for this from a list including poor weather, illness, no need to travel for work, and being "homebound or disabled." Individuals who selected "homebound or disabled" were categorized as mobility disabled, regardless of last travel day reported. Researchers using NHTS data in the past used a similar operationalization, relying on duration of staying home as an indicator of mobility.[53] Since the measure of mobility disability includes both those who self-identify as mobility disabled through their conditions or disabilities that make travel difficult and through their limited participation in travel, this mobility disability status variable captures a more complete picture of mobility disabled older adults than prior studies.[81–83] This may allow new insights into the mobility needs of potentially overlooked population.

Individual-level covariates

All NHTS participants self-reported their gender as either male or female and their age in years. I hypothesized that patterns in walking among older adults would vary according to these variables. I hypothesized that compared to men, women would report greater proportion of mobility limitations, and that gender differences in all-purpose walking would persist when accounting for additional socioeconomic factors at the individual, household, and community levels. While women reported higher instances of mobility disadvantage and a greater proportion of women report experiencing barriers to neighborhood walking in some previous studies, in others studies, women report greater frequency of walking for leisure compared to men with similar socioeconomic characteristics.[47,62,84,85] Rather than treat age as a continuous variable as it was reported in NHTS, I grouped participants by age categories: of 65-74, 75-84 and 85 years or older. The youngest age included (65 years) represents the age at which older adults in the US qualify for Medicare and frequently enter retirement. The range of ages reflects commonly used stages of aging research with each category representing younger, middle, and oldest older adults.[86] I hypothesized that differences in walking participation and frequency by age would emerge, with those in the oldest age group more often reporting no walking and less frequent walks compared to younger older adults with similar characteristics. Older and sicker groups have reported less engagement in walking across studies among older adults in the US.[47,62] To proxy overall health status, I used self-rated health, a known correlate of overall mortality among older adults in the United States.[87] Participants responded to a question asking how they would generally describe their health condition, selecting from the options of excellent, very good, good, fair, and poor. I created a binary variable collapsing the smallest fair and poor categories together, and good, very good, and excellent together. I considered additional individual-level factors to proxy socioeconomic status. These included: highest level of educational attainment, separating into two groups those who reported having a college degree or higher and those with less than college degree, race and ethnicity using the US Census Bureau's categories, and working status using 3 categories to describe whether individuals reported their typical weekday activities as working, retired, or other. Finally, I included a handful of additional individual-level factors describing mobility behaviors such as driver status, an indicator of whether one reported having a driver's license, and use of one or more mobility-related assistive devices (e.g., wheelchair, walker, cane.)

Household-level covariates

Household-level factors were designed to reflect aspects of the immediate built and social environments in which US older adults live. These factors include annual household income and home ownership status, key components of socioeconomic status, which NHTS collected at the household level. Both wealth, proxied by home ownership in this study, and income, proxied by working status and annual household income, have significant influence on social participation, overall health status, and patterns of disability including severity, chronicity, and age of onset among US older adults. They represent access to flexible resources that one may use to mitigate impact of disability throughout the aging process.[88] I hypothesized that those with lower incomes, those still working into older adulthood, and those who do not own their homes would more frequently report having mobility disabilities, no walking participation, and lower number of weekly walks in higher proportions compared to those with higher incomes and who report owning their homes. Wealthier older adults tend to report fewer disabilities compared to those with lower socioeconomic statuses.[3,31] I tested for multicollinearity among these variables prior to including them together in models.

Previous investigations of the effect of social support on older adults' participation in physical activity have shown that the availability of activity partners predicts higher rates of participation, which may relate to walking behavior.[39,89] At the same time, those who live with another person may have less of a need to engage in transportation-related walking or walking for household activities, though this may depend on all parties' access to a personal vehicle, ability to drive this vehicle, and general availability throughout the day as related to working status. I hypothesized that household composition based on the count of household members would predict walking patterns among older adults. I included a binary variable indicating whether households had access to at least one vehicle. Past studies have found that household vehicle availability has links to transportation behavior, including reduced use of public transportation and increased rates of driving into older ages in US households.[90,91] Directionality and strength of this association with respect to non-transportation-related walking, if any, remains uncertain.[76] Individuals with vehicle access may exhibit reduced transportation-related walking but increased leisure-time walking, potentially due to the time savings related to driving compared to other forms of transportation. Participation in exercise and leisure walking has been linked to higher income, another predictor of vehicle ownership, among older adults.[45,84] This relates to past findings that those with lower incomes may engage in more utilitarian walking due to lack of alternatives (e.g., dependent or captive public transportation users).[78,90] Taken together, results of these previous studies related to household vehicle access, income, and overall household composition inform my hypothesis that older adults who live alone, have lower income, and who live in households with at least one vehicle will more frequently report no weekly walking or participation in a low number of weekly walks compared to older adults living in households without at least one car. Overall, as predicted in other analyses adopting

Social Ecological approaches, I hypothesize that all household factors will have weaker associations between walking patterns compared to individual-level factors.[60]

Community-level covariates

Community-level covariates describe characteristics of the neighborhoods in which older adults may engage in walking. Specifically, I include a binary version of census block-level neighborhood rurality and a 4-level categorical indicator of census region to characterize communities where participants live. NHTS determined both factors using residential addresses and corresponding information from the US Census Bureau.[92] These factors may reflect elements of the physical environment such as quality of infrastructure including sidewalks, street crossings, weather, and lighting, which have been linked to physical activity and walking patterns among US older adults.[14] Further, I included proportion of renter-occupied housing within the census block group as a binary variable with those living in areas with 25% or more of homes occupied by renters in one category and those living in areas with less than 25% renter occupied homes in the other. In some areas, higher proportion of renter occupied housing may act as a proxy for neighborhood-level poverty since home ownership correlates with wealth; in these cases, I would expect to see more utilitarian walking given the association of wealth with greater access to personal vehicles as alternatives to transportation walking. However, in other cases, higher levels of residential renting may reflect high demand for housing in areas with highest access to destinations accessible by walking. I hypothesized that this, and all community-level covariates would be associated with both walking participation and frequency, though to a lesser extent than household- and individual-level factors.

Analytic Approaches

The first steps for addressing my study questions involved conducting descriptive analyses of the 2017 NHTS data. I followed the inclusion criteria described in Figure 1-3 to generate the analytic sample. I then assessed the distribution of key variables and carried out tests of association with focal predictor and outcome. Results from these analyses provided preliminary responses to the first research question of whether individual-level mobility limitations predict engagement in and frequency of walking among US older adults. They further informed the types of statistical models I used to test the remaining hypotheses.

To begin to address the second research question of what individual-, household, and community-level factors predict walking behaviors among the analytic sample I performed tests of association between covariates and the focal predictor and outcome variables. This enabled me to select covariates that supported hypotheses about associations between walking outcomes and disability status and enabled me to preliminarily assess their relevance to future multivariable models predicting walking behaviors among the analytic sample. Prior to the final stage of analyses, I conducted tests of association between variables falling into the same contextual level to assess risk of potential collinearity prior to adding groups of variables into regression models.

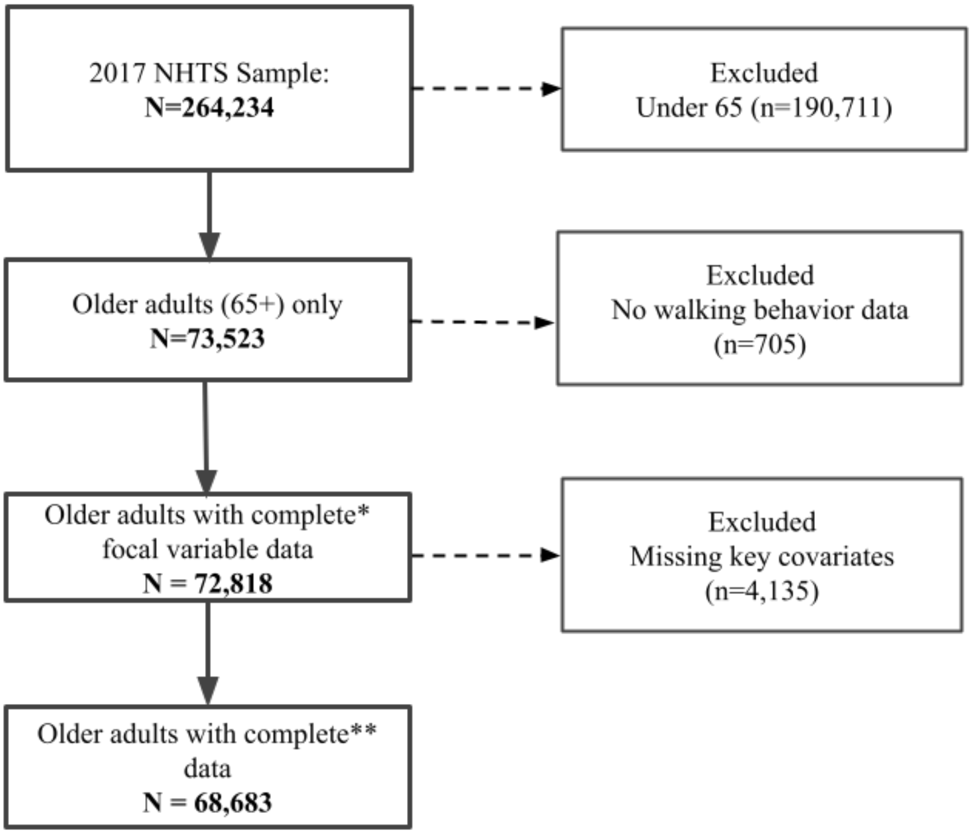
The final component of my analyses consisted of building and evaluating multivariable regression models predicting participation in and frequency of weekly walking. In my initial model building, I used the conceptual framework to include nested groupings of covariates. I compared model fits using statistical criteria appropriate for each model. Previous studies using NHTS 2017 data used multi-part regression models, recognizing that different components of mobility may have different predictors.[67,93] Similarly, I considered multi-part models that would consider walking participation and frequency as distinct processes that could act on subpopulations of older adults not engaging in weekly walking. Within these models, one subpopulation represented includes older adults who would consistently report no walking, perhaps due to permanent or long-term physical or cognitive states resulting in inability to walk. The other group consists of incidental zeroes, or those who reported zero walks in the week of the NHTS data collection period due to impermanent circumstances (e.g., because of inclement weather, temporary illness, work or childcare obligations). Exploration of zero-inflated models alongside other types of regression models in these analyses was guided by the goal of differentiating between these two processes, conceptual difference between these populations, precedent in related literature, and previously reported distribution of the walking outcome variable among older adults. I elected not to use survey weights in the models given my inclusion of many of the factors used to construct the weights provided in the models themselves (e.g., household income, census region, age, gender.) Additionally, preliminary analyses demonstrated limited differences between weighted and unweighted distribution of variables in this population. Model specifications accounted for clustering in the nested data through use of robust standard errors. All tests of significance relied on a threshold of 0.05. Finally, I tested alternative model specifications comparing separate models predicting walking participation (i.e., any walking), and walking frequency (i.e., intensity of participation of walking among only those reporting at least one walk.) All analyses used Stata software (17.0.) The next section describes the findings from these analyses.

Results

Analytic Sample

The analytic sample for this study comprises 68,955 adults aged 65 and older. After restricting the sample by age, I also excluded those missing data for key covariates. Less than 1%

of the older adults in the sample lacked data corresponding to the key outcome of weekly walking or the key predictor of mobility disability status. Specifically, 0.51% of all NHTS 2017 participants over 65 (377 of the 73,523) had missing values for any of the variables used to construct the mobility disability variable and 0.49% (358) did not report weekly walk counts; 30 individuals were missing both the focal predictor and outcome variable. Less than 7% had missing data related to one or more other key variates. Among those 65 or older, 5.47% (n=4,019) did not report household income and 0.36% (n=256) did not report their race and ethnicity. Overall, only household income, race/ethnicity, self-rated health, worker status, home ownership status, percentage of renter-occupied housing, and block group rurality had any degree of missingness. Given the relatively low missingness and preliminary nature of these analyses, I did not modify the analytic sample data and chose to proceed as planned while excluding participants with any missing values. Figure 1-3 displays the process of constructing the analytic sample.



* No older adults with complete weekly walking data had missing data for variables used to determine mobility disability status
** Key covariates included: self-rated health, age, race/ethnicity, worker status, driver status, household income, household vehicle count, census region, household composition, census block group rurality, census block group percentage of renter-occupied housing, home ownership status, use of assistive devices.

Figure 1-3: Construction of analytic sample, Aim 1

Descriptive analyses

Weekly walking. Among older adults included in the analyses, the mean number of walks reported in the past week was 5.09. Most older adults in the sample reported at least 1 walk in the past 7 days, with 30.08% reporting at least 7 walks. Among those who reported at least one walk (n=47,668), mean reported walk count was 7.34, with 43.34% reporting taking 7 or more walks in the past week. Figure 1-4 shows the distribution of walk counts reported among the analytic sample and among only those who reported at least one walk (right.) Given the skewed distribution and evidence of peaks at reported walk count values of 7, 14, and 21, I 1) used categorical walking rather than raw walk count in remaining analyses and 2) proceeded with testing statistical models that account for excessive 0's.

Table 1 compares proportions of those reporting at least one walk to those reporting no walks by key sociodemographic characteristics. Overall, proportions of those who reported at least one walk and those who reported no walking the past week were statistically significantly different across most sociodemographic characteristics considered in these analyses. Exceptions were home ownership status and status of living in block groups with 25% or more of housing occupied by renters.

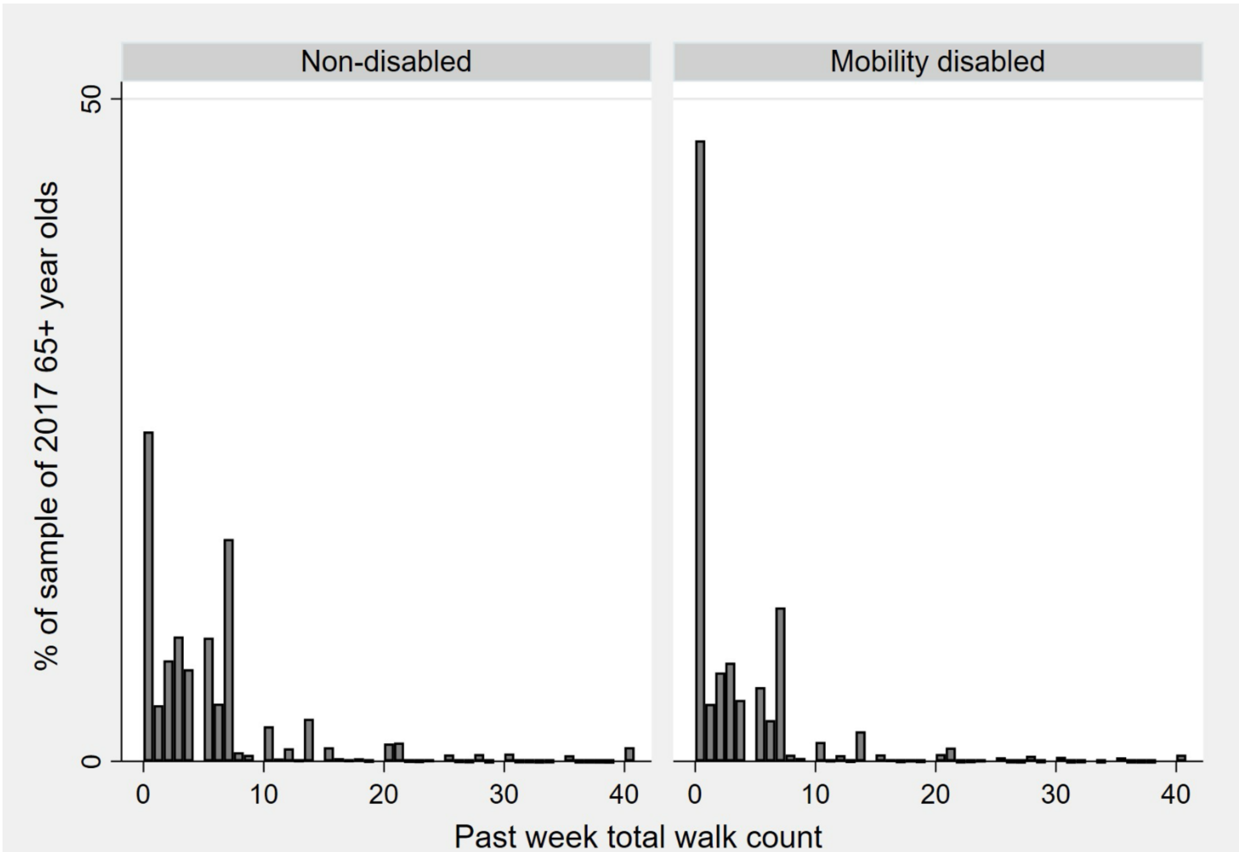


Figure 1-4: Distribution of walk counts reported – all (left), among those reporting 1+ walk (right)

Table 1-1: NHTS 2017 US Older adults (65+) by self-reported weekly walking participation

				0 walks reported		1+ walks reported		Total	
				n= 21,015	%	n=47,668	%	N=68,683	%
Individual-level factors	Social identity factors	Gender	Male	8,901	42.36	23,302	48.88	32,203	46.89
			Female	12,114	57.64	24,366	51.12	36,480	53.11
		Age	65-74	11,770	56.01	32,113	67.37	43,883	63.89
			75-84	6,624	31.52	12,459	26.14	19,083	27.78
			85+	2,621	12.47	3,096	6.49	5,717	8.32
		Race/ ethnicity	Non-Black & Non-Hispanic	18,761	89.27	43,192	90.61	61,953	90.2
			Black and/or Hispanic	2,254	10.73	4,476	9.39	6,730	9.8
		Educational Attainment	< College degree	14,298	68.04	26,379	55.34	40,677	59.22
			College degree+	6,717	31.96	21,289	44.66	28,006	40.78
		Worker status	Retired	17,748	84.45	38,582	80.94	56,330	82.01
			Working	3,267	15.55	9,086	19.06	12,353	17.99
		Driver status	Non-driver	3,278	15.6	3,496	7.33	6,774	9.86
			Driver	17,737	84.4	44,172	92.67	61,909	90.14
	Health factors	Mobility disability status	Mobility disabled	8,353	39.75	9,468	19.86	17,821	25.95
			Non-disabled	12,662	60.25	38,200	80.14	50,862	74.05
		Self-rated health	good-excellent	14,961	71.19	41,510	87.08	56,471	82.22
			poor-fair	6,054	28.81	6,158	12.92	12,212	17.78
		Mobility devices used	0	16,143	76.82	43,767	91.82	59,910	87.23
			1+ device	4,872	23.18	3,901	8.18	8,773	12.77
Household-level factors		Household Vehicle	none	653	3.11	1,805	3.79	2,458	3.58
			1+	20,362	96.89	45,863	96.21	66,225	96.42
		Home ownership	Non-owner	2,535	12.06	5,956	12.49	8,491	12.36
			Owner	18,480	87.94	41,712	87.51	60,192	87.64
		Lives alone	Lives with 1+ person	15,863	75.48	34,736	72.87	50,599	73.67
			Lives alone	5,152	24.52	12,932	27.13	18,084	26.33
Community-level factors		Rural block	Non-rural block	15,566	74.07	33,990	71.31	49,556	72.15
			Rural block	5,449	25.93	13,678	28.69	19,127	27.85
		Census region	Northeast	3,305	15.73	7,838	16.44	11,143	16.22
			Midwest	3,357	15.97	6,888	14.45	10,245	14.92
			South	9,415	44.8	19,550	41.01	28,965	42.17
			West	4,938	23.5	13,392	28.09	18,330	26.69
		% rental homes	<25% renter occupied homes	12,921	61.48	29,324	61.52	42,245	61.51
			25+ % renter occupied homes	8,094	38.52	18,344	38.48	26,438	38.49

*Except for % rental homes and home ownership status, all proportions of walkers compared to non-walkers were statistically significantly different at the 0.05 level

Mobility Disability. With respect to mobility limitations, 25.95% of older adults in the analytic sample met criteria for inclusion in the mobility disabled category. In comparison, 21% of people over 65 reporting ambulatory difficulty and 34% reported any disability overall in the 2018 US older adult population according to Census Bureau American Community Survey estimates.[89] The characteristics I used to determine mobility disability status among the NHTS sample had some, but not complete overlap with ACS criteria for these types of disability. The disability status factors section of Table 1 further describes the distribution of the variables I used to operationalize mobility disability status. These included having any type of condition or handicap that makes travel difficult (19.07%), reporting any of three specific travel limitations -- not driving at night (9.64%), having given up driving altogether (6.42%), and reducing overall travel (17.61%) due to health conditions, handicap, or age. Additional parameters included reporting not leaving their home for over 30 days prior to the assigned travel day (1.39%) and reporting lack of travel on their assigned travel day due to being homebound or disabled (3.11%.) Taken together the six items corresponding to overall mobility disability status had a Cronbach's alpha score of 0.71.

Additional covariates. In this sample, over 31% have a college degree or higher and 10.31% are non-Hispanic Black or Hispanic/Latino of any race. In Census estimates of the 2020 US population of older adults, an estimated 31% have a bachelor's degree or higher, 10% are non-Hispanic Black and 8% are Hispanic or Latino.[94] With respect to income and working status, 37% of US older adults lived in households with incomes of less than $50,000 (shown in Appendix A) and 20% of those over 65 remained in the workforce while 47.26% and 15.55% of the analytic sample fell into those categories, respectively. [94] In the analytic sample, 71.19% expressed having very good or excellent health while estimates within the non-institutionalized population of US older adults is 45%. Table 1-1 also further illustrates the distribution of key covariates among the analytic sample.

Research Question 1: Do older adults with and without mobility disability report similar patterns in participation in and frequency of weekly walking?

To quantify any associations between mobility disability status and walking outcomes, I conducted tests of association between my key predictor and outcome variable. In terms of walking participation, 60.25% of mobility disabled older adults in the sample reported no walks in the past week while 19.86% of those without mobility disability reported no walking; the difference is statistically significant. Next, I calculated the mean walk count for those with (3.60, SD: 5.93) and without disabilities (5.61, SD: 6.99,) and found a statistically significant difference through the two-sample rank-sum test. I next conducted comparable tests of association for categorical walking outcomes. I present results in Table 1-2, which yielded similar patterns. Overall, I found preliminary evidence to support the hypothesis that those with and without mobility disabilities have different patterns in participation in and frequency of walking. These results are specific only to the sample population and only when considering the focal predictor and outcome exclusively. The next series of analyses examined additional factors associated with walking and mobility disability status and how these may vary when accounting for variation in socioeconomic status and other factors that likely complicate these associations.

Table 1- 2. Self-reported weekly walk count by mobility disability status

	Non-disabled		Mobility disabled		Total	
Walk count	n	%	n	%	n	%
0	12,662	24.89	8,353	46.87	21,015	30.60
1-2	6,037	11.87	1,969	11.05	8,006	11.66
3-6	15,296	30.07	3,708	20.81	19,004	27.67
7+	16,867	33.16	3,791	21.27	20,658	30.08
Total	50,862	100	17,821	100	68,683	100

Pearson chi2(3) = 3120.6309 Pr = 0.000

Research Question 2: Among older adults with and without mobility disability, what disability-related factors (such as age and overall health status) correlate with participation in and frequency of weekly walking? [How] does this change when accounting for additional individual-, household-, and community-level factors?

To begin to assess correlations between mobility disability status, total walking outcomes, and known covariates with these focal variables, I first conducted tests of bivariate associations to compare those who reported at least one walk in the past week and those who reported no walks across all categories of covariates. With the exceptions of living in neighborhoods with 25% or greater renter-occupied homes and home ownership status, all individual-, household-, and community-level factors, all other covariates showed statistically significant differences in proportion of older adults who reported one or more walk in the past week compared to those reporting no walks. To further assess potential connections between these factors and walking patterns, I next conducted similar tests for self-reported weekly walking but operationalized the outcome into 4-levels: 0, low (1-2 walks), medium (3-6 walks), and high (7+ walks) frequencies to preliminarily assess patterns of walking frequency. Of all predicted covariates, only home ownership status was not statistically significantly associated with this outcome. With respect to mobility disability status, the proportion of those reporting having mobility disability differed significantly across all covariates. Appendix 1-A reports results of further tests of association between key covariates and walking frequency. In tests for collinearity conducted according to broader grouping of covariates as per the conceptual framework, none of the covariates selected appeared to be collinear when compared to each other.

Following these preliminary tests, I next generated regression models informed by the conceptual framework to quantify the associations between mobility disability and walking patterns while accounting for selected individual, household, and community-level factors. Distribution of walk counts reported by older adults in this sample suggested an overdispersal of 0 values; more older adults reported no walking than would align with past findings. To further assess overdispersion, I conducted additional tests of association between walk count and potential indicators of participants' overall physical activity and capabilities. Among those who reported 0 walks, over 30% reported that they regularly engage in physical activity on a weekly basis, and over 10% of non-walkers reported that they typically engage in physical activity at a vigorous level for 30 or more minutes at a time. Additionally, 28.8% of participants reported using walking as a means of transportation on a daily, weekly, or monthly basis and 1.98% (n=417) of those who reported no walking in the past week reported walking to public transportation on their assigned travel day. With this, and the overall distribution of walk count in mind, I first fitted ordered logistic regression and zero-inflated ordered logistic regression models to simultaneously predict the probability of walking participation and frequency of walking, an ordered categorical variable. Data met the assumptions required to use these types of models, interpretation of results may prove less straightforward than other types of models.[95] As a sensitivity analysis, I also generated alternative models using top-coded, but otherwise unaltered walk count data to compare negative binomial, zero-inflated negative binomial, and zero-inflated Poisson models' fits. Appendix 1-B displays these results. Overall, zero-inflated models yielded better model fit statistics and suited the unexpectedly high count of 0 walks reported. Given the goal of describing general trends in walking frequency rather than exact counts, I elected to continue the approach of using zero-inflated ordered logistic regression models for further model building. While the planned nested approach yielded informative results, after considering tradeoffs between model parsimony and fit, I simplified covariates used within the models and generated new analyses. Appendix 1-C displays the results of the initial nested model building protocol described in the methods, while Table 1-3 highlights results of the best-fitting, final models.

Overall, Model 5 yielded the best fit for simultaneously modeling walking participation and frequency. This model included all individual-level covariates including those describing overall health status, household variables, and community-level variables. The bottom portion of Table 3 provides insight into factors associated with walking participation (i.e., whether older adults reported at least one walk in the past week) from the logit portion of the zero-inflated ordered logistic regression model. Within this model, those who reported having a mobility disability had reduced probability of reporting participating in any walking by a factor of 0.69 (95% CI 0.65-0.73) compared to those without mobility disabilities when all other attributes held constant. This negative association between mobility disability status remained in the ordered logistic regression portion of the model describing the other outcome of walking frequency among those reporting one or more walks. However, this association exhibited reduced strength compared to that between mobility disability status and any total walking. Those with mobility disability had 0.94 times the odds of walking at the next highest frequency interval compared to those without mobility disability (95% CI 0.88-0.99.) Similarly, reporting poor to fair health and use of mobility aids were both statistically significantly associated with reduced odds of any total walking participation and with reduced odds of higher frequencies of total walking. The strength of these associations decreased among those who reported at least one walk. Additional significant predictors of both no and less frequent walking included female gender, living in a

Table 1-3: Nested zero-inflated ordered logistic regression (ziologit) models predicting US older adult walking frequency (upper) & participation (lower)

Total walking frequency (ordered logistic regression among those reporting 1+ walk)			Model 1: Disability status OR	95% CI	Model 2: + individual-level factors OR	95% CI	Model 3: + health factors OR	95% CI	Model 4: + Household factors OR	95% CI	Model 5: + Community factors OR	95% CI
FOCAL PREDICTOR	Mobility disability		0.78***	[0.74,0.82]	0.83***	[0.79,0.87]	0.95	[0.89,1.00]	0.93*	[0.88,0.99]	0.94*	[0.88,0.99]
Social identity factors (individual level)	Gender	female			0.75***	[0.72,0.77]	0.74***	[0.72,0.77]	0.73***	[0.70,0.75]	0.73***	[0.71,0.76]
	Age (years, ref: 65-74)	75-84			1.04	[0.99,1.08]	1.02	[0.98,1.06]	1.02	[0.98,1.06]	1.03	[0.99,1.07]
		85+			0.98	[0.90,1.05]	0.94	[0.87,1.02]	0.93	[0.86,1.00]	0.95	[0.88,1.03]
	Educational attainment	College+			0.97	[0.94,1.00]	0.96*	[0.92,0.99]	0.96*	[0.93,1.00]	1.01	[0.97,1.05]
	Worker status	Worker (ref: non-worker)			1	[0.95,1.04]	0.99	[0.95,1.03]	0.99	[0.94,1.03]	1	[0.95,1.04]
	Driver status	Driver (ref: non-driver)			1.11**	[1.04,1.19]	1.05	[0.98,1.13]	1.19***	[1.10,1.30]	1.17***	[1.07,1.27]
	Race/ethnicity	Black (any ethnicity) or Hispanic (any			0.87***	[0.82,0.92]	0.88***	[0.83,0.93]	0.86***	[0.81,0.91]	0.88***	[0.83,0.93]
Health factors	Health status	Poor/fair health (ref: good-excellent)					0.82***	[0.77,0.86]	0.82***	[0.77,0.87]	0.80***	[0.76,0.85]
	Mobility device use	Uses mobility device					0.83***	[0.77,0.90]	0.82***	[0.76,0.89]	0.81***	[0.75,0.88]
Household factors	Household vehicle access	1+ vehicle							0.74***	[0.66,0.82]	0.71***	[0.63,0.79]
	Home ownership	Owns							0.96	[0.91,1.01]	0.90***	[0.85,0.95]
	Household composition	Lives							1.12***	[1.07,1.16]	1.13***	[1.09,1.18]
Neighborhood	Block rurality	Rural block									1.58***	[1.52,1.64]
	Census region	Northeast									1	[1.00,1.00]
		Midwest									0.88***	[0.83,0.93]
		South									1.06*	[1.01,1.12]
		West									1.04	[0.99,1.10]
Total walking participation (inflate model, logistic regression predicting reporting 0 walks)												
			Model 1: Disability status		Model 2: + individual-level factors		Model 3: + health factors		Model 4: + Household factors		Model 5: + Community factors	
FOCAL PREDICTOR	Mobility disability		0.30***	[0.27,0.33]	0.46***	[0.44,0.48]	0.71***	[0.67,0.75]	0.69***	[0.66,0.73]	0.69***	[0.65,0.73]
Social identity factors (individual level)	Gender	female			0.86***	[0.83,0.88]	0.83***	[0.81,0.86]	0.81***	[0.78,0.84]	0.81***	[0.78,0.84]
	Age (years, ref: 65-74)	75-84			0.86***	[0.82,0.89]	0.81***	[0.78,0.85]	0.81***	[0.78,0.85]	0.82***	[0.79,0.85]
		85+			0.80***	[0.75,0.85]	0.71***	[0.66,0.76]	0.70***	[0.65,0.74]	0.70***	[0.66,0.75]
	Educational attainment	College+			1.49***	[1.44,1.55]	1.44***	[1.39,1.49]	1.46***	[1.41,1.51]	1.48***	[1.42,1.53]
	Worker status	Worker (ref: non-worker)			0.90***	[0.86,0.94]	0.87***	[0.83,0.91]	0.86***	[0.82,0.90]	0.87***	[0.83,0.91]
	Driver status	Driver (ref: non-driver)			1.32***	[1.25,1.40]	1.04	[0.98,1.11]	1.32***	[1.23,1.41]	1.32***	[1.23,1.41]
	Race/ethnicity	Black (any ethnicity) or Hispanic (any			1.01	[0.95,1.07]	1.05	[0.99,1.11]	0.98	[0.92,1.04]	1.02	[0.96,1.09]
Health factors	Health status	Poor/fair health (ref: good-excellent)					0.56***	[0.54,0.59]	0.57***	[0.54,0.60]	0.56***	[0.54,0.59]
	Mobility device use	Uses mobility device					0.57***	[0.54,0.61]	0.56***	[0.53,0.60]	0.57***	[0.53,0.60]
Household factors	Household vehicle access	1+ vehicle							0.42***	[0.38,0.47]	0.41***	[0.37,0.46]
	Home ownership	Owns							0.83***	[0.78,0.87]	0.81***	[0.77,0.86]
	Household composition	Lives							1.18***	[1.13,1.23]	1.19***	[1.14,1.24]
Neighborhood factors	Block rurality	Rural block									1.27***	[1.22,1.32]
	Census region	Northeast									1	[1.00,1.00]
		Midwest									0.89***	[0.84,0.94]
		South									0.93**	[0.88,0.98]
		West									1.24***	[1.17,1.31]
constant			5.27***	[4.35,6.38]	2.26***	[2.11,2.41]	3.15***	[2.94,3.38]	6.84***	[6.13, 7.64]	6.47***	[5.77,7.26]
Cutpoints		1	0.12***	[0.09,0.16]	0.00***	[0.00,0.00]	0.00***	[0.00,0.00]	0.00***	[0.00,0.00]	0.00***	[0.00,0.00]
		2	0.33***	[0.30,0.38]	0.18***	[0.17,0.19]	0.16***	[0.15,0.18]	0.13***	[0.12,0.15]	0.14***	[0.13,0.16]
		3	1.52***	[1.44,1.61]	1.18***	[1.09,1.27]	1.08*	[1.00,1.18]	0.89*	[0.80,0.99]	0.96	[0.86,1.07]
Model characteristics		N	68683		68683		68683		68683		68683	
		DF	6		20		24		30		38	
		ll(model)	-89840.26		-89230.89		-88668.07		-88350.36		-87901.75	
		AIC	179692.53		178501.77		177384.14		176760.71		175879.51	
		BIC	179747.35		178684.52		177603.43		177034.83		176226.72	

household with one or more vehicles, reporting owning one's home, and living in the Midwest (compared to the Northeast) census region. Older adults in this sample who continue to work for pay (compared to being retired,) of older ages (in the 75-84 and 85+ year old range compared to 65–74-year-olds,) and who live in the South (compared to those living in the Northeast) had reduced odds of engaging in any walking. However, these factors did not significantly predict total walking frequency.

With respect to positive associations with total walking participation and higher frequency of past week total walking, predictors included: reporting being a driver, living alone, and living on a rural block. Those who reported having a college-level or higher educational attainment had 1.48 (95% CI 1.43-1.53) times higher odds of engaging in any total walking compared to those with lower educational attainment. This pattern did not hold for total walking frequency. Those who reported at least one past week walk and who reported living in the South had somewhat higher predictions of higher frequencies of walking (OR 1.06, 95% CI 1.01-1.12), though living in the South predicted reduced walking participation (OR 0.93, 95% CI 0.88-0.98.) Factors that did not significantly predict walking frequency included age category and living in the West census region. Race and ethnicity were not associated with walking participation.

Patterns in directionality of associations of predictors held constant across the nested model series though in most cases, the strength of these associations attenuated as the models considered additional covariates. For example, in the simplest model (Model 1) featuring only mobility disability status, those with mobility disability have 0.30 times (95% CI 0.27-0.33) the odds of those without mobility disability of reporting any walking in the past week and 0.78 times the odds of reporting walk count in the next most frequent category if they reported any walking (95% CI 0.74-0.82.) Mobility disability status' odd ratios increase to 0.93 and 0.69 for walking frequency and participation in Model 5 but remain statistically significant while accounting for additional individual-, household-, and community-level factors. Overall, these models support the hypothesis that across all levels of socioecological context, older adults' personal identity factors, health factors, and social and built environments may affect walking patterns. Walking participation and frequency share some overlapping predictors with some exceptions, which the next series of analyses aimed to help clarify.

Research Question 3: How do predictors of total weekly walking participation and frequency compare among older adults in the US?

Analyses completed as part of the previous section preliminarily address the third and final research question. Overall, predictors associated with decreased walking frequency also demonstrated associations with reduced odds of reporting any walking. These included having a mobility disability, reporting poor or fair health status, using a mobility device, and female gender at the individual-level. Additional factors associated with both reduced total walking participation and frequency included living in a household with 1 or more personal vehicles, and home ownership at the household level and at the community level, living in the Midwest. Factors associated with increased walking frequency were similar to those associated with increased probability of any walking participation among US older adults in this sample as well. These factors included: being a driver, living alone, and living on a rural block. Other factors were typically significantly associated with only one walking outcome but had similar directionality across the outcomes.

Sensitivity analyses. To further interrogate these findings, I conducted sensitivity analyses using alternative models. Specifically, I generated an ordered logistic regression model (without the zero-inflation) and a poisson model to predict walking exclusively among those reporting 1 or more walk, and a third logistic regression model among the full sample to predict only walking participation (i.e., any walks vs. no walks.) In the first two models, mobility disability status was significantly associated with lower walking frequency, but the odds for non-mobility disabled individuals were very similar (ORs 0.94 and 0.99 95% CIs 0.88-0.99 and 0.98-1.00, respectively.) In the model predicting walking participation only, those with mobility disability had 0.69 times the odds of those without mobility disability of reporting any walking when all other factors held constant (95% CI 0.65-0.73.) Falling into older age categories and reporting remaining in the workforce similarly predicted reduced odds of walking participation though this pattern did not hold for walking frequency. Conversely, Black or Latino race and ethnicity was associated with reduced walking frequency but not reduced walking participation. Across all three models, female gender, having a personal vehicle in the household, home ownership, and living in the Midwest were also associated with reduced walking frequency and participation. Increased walking participation and frequency were associated with living on a rural block, living alone, and having a driver's license across all three models. Having a college education or higher and living in the West significantly predicted only increased odds of walking participation, but not higher walking frequency while living in the South predicted only increased odds of walking frequency.

Some variation in strength of these associations provides additional support to the hypothesis that walking frequency and participation are distinct processes with some shared correlates. These further analyses yielded evidence to support the hypothesis that while many predictors across walking frequency and participation remain consistent in directionality, they diverge in strength of association. Appendix 1-D displays key results in detail.

Discussion

The United States' aging population will require additional programmatic and policy support to protect and enhance health throughout the aging process. This study used data from the 2017 National Household Travel Survey to provide insight into key factors for consideration by those designing programs and implementing support for walking—one potential method for enhancing physical and mental health — among older adults in the US. In alignment with past studies, findings from this study show that most older adults engage in at least some walking weekly. Most older adults in the analytic sample (69.4%) reported taking at least one walk in the past week and over 30% reported walking seven or more times in the past week. A larger proportion of older adults with mobility disability (60.25 %) reported no walking in the past week compared to those without mobility disabilities (19.86 %.) Yet approximately one in five mobility disabled older adults reported taking at least seven walks in the past week. This finding emerged during initial analyses related to the first central research question of this study, which asked whether older adults with and without mobility disabilities reported engaging in different past week overall walking patterns. This likely reflects the diversity of physical and cognitive functionalities represented among those with mobility disabilities as defined in this sample and among the overall population of older adults in the US.

In zero-inflated ordered logistic regression analyses that simultaneously modeled walking participation and frequency, the associations between mobility disability status and walking participation and frequency showed similar patterns. When mobility disability status was the sole predictor, mobility disabled older adults had higher odds of reporting taking no walks in the past seven days when compared to those without mobility disability. Among older adults in this sample who reported walking participation in the past week (i.e., taking one or more walks,) mobility disability had a smaller, but still negative association with more frequent walking. This suggests that mobility disability status negatively influences walking, which aligns with past studies' findings and my initial hypothesis that disability status predicts less walking overall. In multivariable regression models considering covariates at multiple levels of influence, the association between mobility disability and walking outcomes attenuated dramatically. The odds of disabled older adults reporting no walking went from 0.30 times to 0.69 times those of non-disabled individuals in comparing the simplest model with only mobility disability, to the final and best fitting model with the full range of covariates. Given that walking has the potential to support to physical health-promoting daily exercise and mental health-promoting preservation of independence through increased transportation mobility, this finding encourages walking promotion and mobility supports for older adults. Findings demonstrated higher risk of limited walking for those with mobility disability, suggesting that mobility disabled older adults may require additional support to participate in supported forms of walking or alternatives to walking. However, further analyses yielded more nuanced insight related to the connections between mobility disability and walking outcomes while addressing the remaining research questions of whether and how additional individual-, household-, and community-level factors may shift these associations among older adults in the US.

Multivariable analyses addressed this study's second and third research questions regarding how social and environmental factors nested within multiple levels of context may influence walking participation and frequency outcomes among older adults. Findings suggest that specific subgroups of US older adults, including those with mobility disabilities in this sample, had reduced odds of walking participation. Generally, these trends remained stable in their directionality when predicting walking frequency; I note exceptions. In accordance with the broadest hypotheses illustrated in my conceptual model, results of multivariable modeling provided evidence that factors at the individual-, household-, and community-levels each correlate with walking participation and frequency outcomes among older adults in this sample. I hypothesized that more distal factors such as census region and neighborhood rurality, which represent the community-level environment, would tend to have weaker associations with both outcomes. This relates to the Social Ecological model's perspective that one's social identity, personal decisions, and health status affect more immediate health behaviors while simultaneously, extra-individual factors shape circumstances and opportunities in which these more immediate conditions for individual behaviors manifest.[60] Findings from the best fitting models broadly supported these hypotheses, with most covariates showing significant correlation with walking outcomes. Some of these findings can inform future research and applications related to older adult walking and support of healthy population aging.

With respect to individual-level predictors of walking patterns among older adults aside from mobility disability, my multivariable analyses generated valuable information regarding strength and direction of associations between several social identity and health-related factors and how they link to walking frequency and participation outcomes. The first series of covariates I tested represented social identity factors, or individual-level traits that relate to the present life stage of older adults in the sample. I included gender as a key covariate since gender has significant associations with both disability status and walking. Compared to men, women more often report mobility disability, more severe mobility disability, and at younger ages, which likely affects women more often reporting less physical activity and less walking for exercise than men in past studies.[96,97] This finding may reflect a degree of survivorship bias related to women tending to outlive men, though often in impaired physical and cognitive conditions, and women having more concerns around the safety of walking outdoors compared to men at all ages.[74,98,99] I hypothesized that my findings would indicate less frequent walking and lower walking participation among women and in zero-inflated ordered logistic regression models, women had significantly lower odds of walking at higher frequencies and lower odds of reporting any walking compared to men. The strength of this association changed relatively little across multivariable models with different specifications, indicating that gender plays a substantial role in predicting walking outcomes. Those designing and implementing interventions promoting all types of walking may wish to specifically target women and may wish to assess and aim to mitigate factors women report as barriers to specific contexts of walking (e.g., walking for transportation, walking in green spaces.) Studies related to how built environment modifications influence modal choices and engagement with green spaces among older adults in specific US cities may help inform the type of intervention that could be used to promote walking in other locations and environments.[100,101]

Past studies' conclusions that individuals from historically marginalized racial and ethnic groups tend to engage in more utilitarian walking, occupational physical activity that may feature more walking, and less leisure walking inspired the inclusion of a variable indicating race and ethnicity.[47,90,102–104] They also informed my hypothesis that these factors would correlate with different walking patterns among older adults from more marginalized racial and ethnic groups though directionality remained uncertain. Interestingly, compared to older adults who reported being non-Latino and non-Black, Black older adults of any ethnicity and Latino older adults of all races reported reduced walking frequency in models gauging this outcome simultaneously with (RQ2) and separately from (RQ3) walking participation. However, the Black and Latino older adults in this sample did not report differences in walking participation compared to the other group, all other factors held equal. These differences suggest a need to consider how historical and ongoing experiences of marginalization might affect opportunities for walking participation among minoritized older adults, and to invest in identification and preservation of resources that encourage safe, health-promoting walking among older adults who already report some degree of total walking regularly.[103,105]

I hypothesized that older adults in the most advanced life stages signified by oldest age in years would more frequently report less frequent walking and no walking participation. Although a higher proportion of those 85 year of age or older reported no walking participation compared to those in the 65-74 and 75-84 year old categories, (45.9%, 34.7%, and 26.8%, respectively,) in descriptive analyses, in multivariable regression analyses, age was not statistically significantly associated with walking frequency. However, those in the oldest age categories did have lower odds of walking participation compared to those in younger groups (0.82, 95% CI 0.78-0.85 and 0.70, 95% CI 0.79-0.85, respectively.) This finding suggests that chronological age may better serve as a predictor of reduced walking participation compared to predicting walking frequency. Those older than 85 were, as hypothesized, at highest risk for engaging in no walking. Public health practitioners may take from this finding motivation to first determine whether intervening on walking participation behavior would make sense for this age group and if so, how to do so safely. Alternatively, finding more accessible means to the ends that walking may satisfy in younger age groups (e.g., transportation, physical activity, mental engagement,) may be a more worthwhile goal for oldest adults. Conversely, those in younger age groups may represent those most amenable to behavioral changes, especially with respect to walking frequency. Interventions seeking to increase walking among older adults who already engage in some walking may wish to avoid upper age limits since factors aside from age may play a more influential role in determining walking frequency. The strength of the association between age and both walking outcomes tested lessened when additional factors typically associated with age (e.g., working status, overall health status) were included. This underscores the importance of considering these factors alongside age when targeting groups of older adults for walking-related inventions.

Educational attainment, working status, and home ownership status represented aspects of older adults' socioeconomic status, which I hypothesized would have statistically significant associations with walking frequency and participation in models testing these outcomes simultaneously and separately. Compared to retired older adults, those who reported continued workforce participation were less likely to report any walking in the past week. Working status, the binary variable indicating whether older adults in the sample remained in the workforce predicted reduced walking participation but not reduced walking frequency. Older adults who had a college educational or higher had over 1.4 times the odds of those with less than a college education of reporting walking participation; this directionality and strength somewhat paralleled findings in other analyses of walking patterns variation by educational attainment.[49,106] There may be overlap between groups of older adults with lower educational attainment and who do not have the means to retire at younger ages, and this group may have fewer socioeconomic resources, including leisure time. However, the non-significant associations for walking frequency do not align with this explanation. Additionally, home ownership status, which I posited as an indicator of greater wealth, was associated with reduced odds of walking participation and to a lesser degree, lower walking frequency. This somewhat surprising result may relate to homeowners having alternatives to walking for their transportation and physical activity needs. Future researchers may wish to further interrogate the role of occupational status and educational attainment on all-purpose walking patterns of older adults.

Driver's licensure and vehicle ownership status were two factors I hypothesized would correlate with walking outcomes. Modeling results showed that compared to non-drivers, older adults with who drive reported more walking participation and more frequent walking, while household vehicle availability predicts reduced walking frequency and highly reduced walking participation odds. These seemingly contrasting results make interpretation of these covariates together challenging, especially since their strength and directionality remained largely unchanged across all zero-inflated ordered logistic regression models and in simpler models predicting walking participation and frequency separately. Past studies linked driving cessation to poorer overall health outcomes among aging populations; reduced walking could be one mechanism through which these patterns occur.[68,71] However, these results could also indicate that the measure I used to assess total walking among this sample does not accurately reflect behaviors, especially among the oldest adults, given the unexpected results. If household level vehicle ownership indicates that household members use driving for most of their transportation needs, then it would make sense that older adults from car-owning households would report less walking participation and frequency if they cannot feasibly engage in transportation-related walking. A potential takeaway from findings related to household vehicle availability could be motivation for future researchers to consider how living in a household without a vehicle, whether by choice or by economic circumstances, affects transportation and non-transportation walking behavior among older adults.

Though mobility disability status served as the focal predictor for walking outcomes across analyses in this study, I hypothesized that additional health-related indicators that likely relate to mobility disability status, including overall health status and use of mobility aids, would independently predict walking patterns. Specifically, I anticipated that older adults who reported better overall health status may walk at higher proportions and more frequently, in alignment with past findings and that accounting for use of mobility aids would affect the strength of the association between mobility disability status and walking outcomes.[81,107,108] I included health factors in addition to disability status as a test of past disability scholar's arguments that health status and disability, though related, can and do influence daily lives of disabled individuals separately and that mobility aids often help reduce disparities between physical activity of disabled and non-disabled older adults.[109,110] Overall, the best fitting models predicting walking participation and frequency together and separately suggest that older adults in better health and who do not use mobility devices indeed participate in walking at higher proportions and with more frequency compared to than those in poor or fair health and those who use mobility aids, respectively. Mobility aid users had only about half of the odds of reporting any walking participation compared to non-mobility aid users; the strength and directionality of this association was similar for health status and walking participation. For walking frequency, the associations for both mobility aid use and health status had the same directionality, but much lower strength with only approximately 0.8 times the odds of those in good to excellent health and non-mobility aid users. Those attempting to target older adults at risk for reduced overall mobility, especially in conjunction with walking participation, may wish to focus on mobility aid users, even if they may not classify themselves as mobility disabled since this behavior may be similarly linked to determining walking participation. Conversely, programs and policies seeking to increase walking frequency among older adults may wish to give equal weight to self-identifying mobility disabled older adults and adults who may use mobility aids who have similar, though not identical patterns of walking less frequently compared to non-disabled and non-mobility aid using older adults, all other factors held equal. Overall, accounting for health factors reduced the contrast between walking participation among mobility disabled and non-mobility disabled older adults, and especially seemed to influence the association between mobility disability status and walking frequency. Past studies focused on measuring the associations between walking and health status as an outcome; these analyses' inverse framing but similar findings with respect to directionality add support for bidirectionality in the true relationship between mobility disability and overall wellbeing among older adults.[6,111,112]

Although I hypothesized that remaining household- and community-level factors would correlate with walking behaviors among older adults in the US, only household composition and neighborhood rurality yielded statistically significant results that could inform public health and policy applications. Specifically, I found that living in a rural area strongly predicted both increased walking participation and higher walking frequency compared to living in non-rural areas. These findings may relate to past findings linking increased green space to increased leisure walking activity since some rural areas may have more green space compared to non-rural areas.[101,113,114] While an extensive literature documents connections between older adults' transportation mode choices and the built environments in which they live, future analyses may wish to further examine whether known patterns change when considering older adults' non-transportation walking, and especially when considering health and disability statuses in addition to age. Additionally, rurality likely affects patterns in personal vehicle use, which residential selection likely shapes; older adults' residential selection patterns may continue to change in response to economic patterns that differ from those of previous generations.[115]

Household composition, as proxied by living alone, had a surprisingly small correlation to walking outcomes, given that past studies found that social support proxied by marital status appeared to correlate with physical activity engagement.[39,41] This finding could speak to the differences between walking for leisure or for exercise and total walking. Those who walk for leisure may be encouraged to do so by incentive of spending time with family or a pet, or may feel safer walking if they are not alone.[39] However, in this sample, older adults who lived alone reported more walking compared to those who lived with at least one other person. This may speak to a few potential explanations such as that people who live alone may represent the most healthy and independent older adults whose physical and cognitive strengths enable them to live alone. Further these types of older adults may be overrepresented in the 2017 NHTS data.

Associations between factors beyond the household-level including neighborhood rurality and census region and walking participation and frequency did not exhibit consistency in directionality nor strength across models. While census region-related findings may reflect that older adults' walking patterns truly vary little across these regions, intra-regional diversity may have a homogenizing effect on these patterns. For example, a city in the northeast may not be as different from a city in the South whereas rural areas in those respective regions' effects on walking patterns may differ. Boundaries for these regions reflect decisions by the US census bureau rather than true cultural or climate distinctions and may thus not be appropriately scaled for assessing patterns shaped by cultural norms or climate. The more stable and stronger correlation between living in a rural block and increased walking frequency and participation may support the idea that more immediate environments have a stronger influence on total walking patterns. These outcomes may relate to past studies' findings that presence of more fast-moving vehicles discourages walking among older adults.[39,115] Other studies highlighted an inverse correlation of walking and neighborhood disorder factors such as limited trust of one's neighbors or damaged infrastructure.[30,45,116] Perhaps the rural neighborhoods represented in this sample have fewer of these neighborhood elements related to perceptions of danger, resulting in perception of outdoor spaces as more appealing or safer to walk in by older adults included. Generally, the community-level factors considered in these analyses provided less actionable insights relevant to promoting older adults' total walking compared to household- and individual-level factors. Future analyses should consider alternative indicators of neighborhood characteristics that may affect older adults' walking behaviors so they may then be altered or preserved in efforts to promote healthy aging through safe walking.

Study Limitations

This study was subject to several limitations. Due to the cross-sectional nature of the NHTS data, I cannot draw conclusions related to directionality of the associations between mobility disability and walking outcomes, nor between any of the additional covariates and walking outcomes. Though a novel contribution of the study was framing walking as a desirable, health-related outcome due to its potential to contribute mental and physical health benefits, the lack of comparison data from the same population at multiple points in time prevents certainty around whether mobility disability causes decreases in walking frequency and participation. Other limitations relate to the sample. While the sample sizes were large enough to consider many factors in complex models, the sample may differ from the population of older adults because of the relatively high rates of good health status reported. As a counter, the rate of disability was about on par with national estimates, but this may reflect that my definition of disability included more than it would have if relying solely on self-identification of disabled. This relates to challenges in recruiting survey participants; and while older adults are typically among the most responsive populations, since this study relied on use of an online portal, this approach may have been a barrier to many older adults, especially those with worse general health and potentially, more severe disabilities. This relates to survivorship as another potential source of this bias. This bias is likely present in many of the studies focused on older adult physical activity, especially those focused on older adults living in community since those with the most severe mobility disabilities may be more likely to be living in institutional facilities and thus absent from the data. Those excluded from the sample and those least likely to have proxy support may similarly overlap with those with the most severe mobility disabilities, who like experience higher rates of morbidity and mortality. Another limitation of this study relates to covariates' imperfect representations of real-world conditions. This may have contributed the non-significant associations observed between walking outcomes and covariates excluded from best fitting models but included in the original conceptual model such as percentage of renter occupied housing and more detailed indicators of race, ethnicity, and neighborhood rurality. NHTS data can be linked with additional data sets and future analyses could consider integration of additional data to better proxy some of these covariates.

Study strengths

Despite these limitations, this study advances knowledge related to healthy aging among older adults in part due to several methodological and theory-related strengths. For example, the study's population represents a large and relatively diverse collection of US older adults. Although I did not utilize the NHTS-provided weights since they were designed to be applied only to the entire NHTS population, these findings may still model patterns among older adults in the US overall given the relatively low missingness and relative similarity to other US population-level samples of older adults. In past studies related to older adult walking patterns, samples were comparatively small, focused on limited walking context (e.g., walking for exercise, walking in their neighborhood,) and may have included limited consideration of health and/or disability related variables. That this study considered a more expansive definition of mobility disability that could capture older adults who may have limited mobility due to cognitive or other "invisible disability" type of impairments represents another strength. Past studies have focused on either self-identification as mobility disabled or have categorized participants as disabled based on their self-reported physical functionality using measures such as ADL's.[31,40] In contrast, the measure used here captures both self-identifying disabled older adults, and older adults who reported having travel-related limitations due to specific behaviors, regardless of whether they classify themselves as having travel-relevant disabilities. Having the ability to use this type of measure also relates to the relatively large sample size. Another sample size-related benefit that sets this study apart from others assessing walking behaviors among older adults was the inclusion of multiple-levels of factors related to participants' social and built environments along with their individual-level drivers of behavior. Accounting for multiple levels of predictors allowed me to better isolate the potential effect of mobility disability and other health-relevant factors on walking patterns.

Finally, this study relied on complex modeling processes that may imperfectly capture real world conditions, but that align with methodological and theoretical approaches in the literature.[47,67] Specifically, zero-inflated ordered logistic regression models fit for the data well, but also made theoretical sense since processes of walking participation and walking frequency are clearly interrelated and occurring simultaneously in the older adult population. Although the measures of disability status and categorical walking count differ from those used in some past studies, as previously stated, the former may yield a more complete picture of mobility disabled older adults in the US and the latter parallels operationalization of other transportation mobility-related outcomes.

This study was also strengthened by its theoretical foundations. Analyses took into consideration research across multiple disciplines including public health, gerontology, and transportation; results help contribute to interdisciplinary dialogue. This study generated novel evidence to promote treatment of disability and health status as distinct, though potentially interrelated constructs that influence, but do not control individuals' daily lives. Overall, findings from this study preliminarily address gaps in the public health, aging, and transportation literature regarding the links between mobility disability and patterns in total walking among older adults in the United States. In future research, inclusion of more health factors may be valuable for those designing policies and programs related to healthy aging initiatives. However, few studies include detailed data on both the places in which older adults reside and the state of their disability and health. Future analysts of this and future NHTS data may wish to integrate health-specific studies such as the National Health Interview Survey (NHIS,) and comparable state-level data sets such as the California Health Interview Study.[10,117,118] Combining data sources may enable closer interrogation of some interesting findings from this study, such as how overall health status and disability status, or specific elements of disability status, may interact to jointly affect walking behaviors among other groups of individuals. Although these analyses addressed the gap in the literature regarding the role of mobility limitations and total walking among older adults in the United States, work remains related to remaining questions and potential applications of this and future work. Through using a multi-component definition of mobility limitations, this work may have classified more older adults with cognitive or less severe physical limitations differing from those more commonly associated with mobility limitations into that category. Future research should identify types or degree of disability more specifically so that future interventions to promote walking or mobility more generally among older adults can more precisely suit their needs. This may include considering what types of mobility-aids or other devices they rely on to ensure the accessibility of interventions. Aside from their physical and cognitive diversity, mobility-limited older adults may also differ in terms of their socioeconomic status, cultural practices, and place-related characteristics that can affect how and whether they chose to engage in walking. This study provided some evidence to support this given the apparent influence of female gender, educational attainment, and race and ethnicity on some, but not all, patterns of walking among older adults in the 2017 NHTS sample. This has implications for generating programming and policies related to walking promotion. For instance, programs that attempt to engage already active and/or healthy older adults should not assume that mobility-disability related accommodations would not be needed. Conversely, programs attempting to connect mobility-disabled older adults to opportunities to walking should not assume that this population lacks support – whether social or environmental – to engage in walking. Ultimately, this study generated evidence to promote treatment of disability and health status as distinct, though potentially interrelated constructs that influence, but do not control individuals' daily lives.

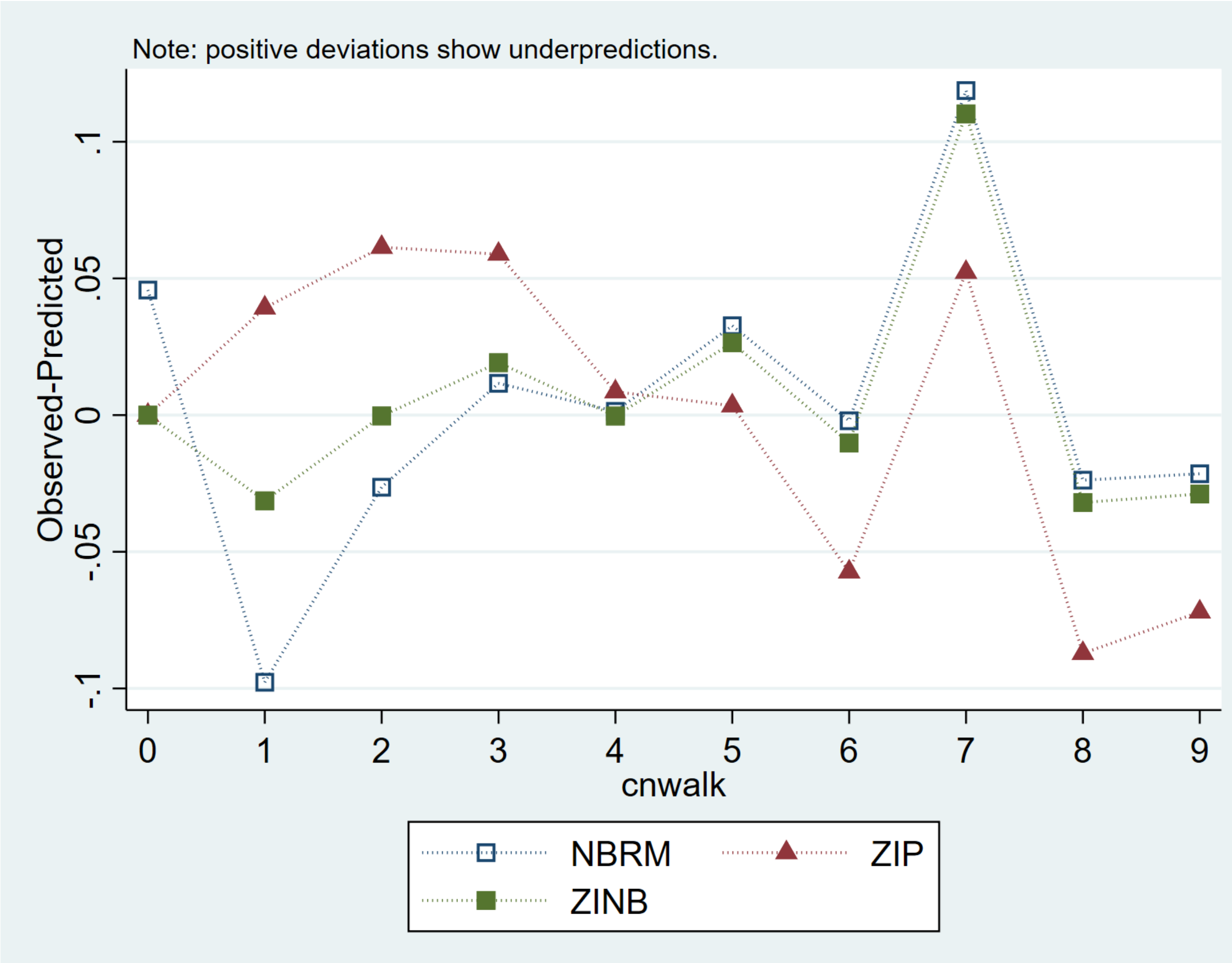
In conclusion, the abundance of significant findings in this study highlights the importance of considering older adults health and mobility disability statuses when designing programs, policies, and environments to promote walking as a component of healthy aging. Preliminary findings underscore past studies' arguments that walking is an accessible and commonly practiced activity for many older adults in the US, including many who have mobility disabilities. Multivariable regression models guided by my theoretical framework accounted for individual-level health and social identity factors, household-, and community-level environments. I used them to test remaining hypotheses related to how these factors, along with mobility disability status, are associated with walking behaviors among older adults in the 2017 NHTS. Unlike past studies in the public health field, these analyses focused on walking outcomes outside of walking only for physical activity. Further, analyses considered transportation-focused elements often absent from public health-based analyses such as availability of household vehicles, and whether older adults reported having a driver's license. Conversely, this study used a public health-informed approach to a data source and topic more often used and considered by transportation researchers. This motivated inclusion of a novel mobility-disability measure, and health-relevant factors such as overall health status and use of mobility devices. Analyses validated some prior findings from relevant public health, transportation, and gerontology literature. For example, I found that women, less educated, and sicker older adults, may be at particular risk for low engagement in walking compared to their male, more educated, and healthier counterparts. Other results – such as those suggesting that walking patterns vary by race and ethnicity, rurality, vehicle ownership, and drivers' status--call for further investigation to understand drivers of these differences. Ultimately, the results of this study provide novel information suggesting the importance of considering health, disability, and multiple social and built environmental factors when evaluating patterns of walking participation and frequency among older adults.

Appendix 1-A: Detailed sample characteristics by categorical walk variable

** All covariates were statistically significant with p-values of 0.05 or less with the exceptions of Neighborhood 25% renter occupied homes and home ownership status.*

Walks reported in past week		0		1-2		3-6		7+		Total
		n	%	n	%	n	%	n	%	Count
Binary SRH	poor-fair	6054	28.81	1391	17.37	2364	12.44	2403	11.63	12212
Has handicap or condition that makes travel difficult		6695	31.86	1473	18.4	2475	13.02	2455	11.88	13098
Has not left home in 30+ days		1597	7.6	209	2.61	194	1.02	134	0.65	2134
Reports any of: having given up driving, does not drive at night, has reduced overall travel		7261	34.55	1718	21.46	3198	16.83	3188	15.43	15365
Reports 30+ minutes of physical activity in past week		13082	62.25	6393	79.85	16726	88.01	18353	88.84	54554
Uses 1+ mobility device		4872	23.18	932	11.64	1516	7.98	1453	7.03	8773
Has chronic condition		6143	29.24	1344	16.79	2260	11.9	2282	11.05	12029
Proxy responded		5123	24.38	1556	19.44	3157	16.61	3229	15.63	13065
College degree or higher attained		6717	31.96	3416	42.67	8611	45.31	9262	44.83	28006
Gender	female	12114	57.64	4485	56.02	10273	54.06	9608	46.51	36480
Age	65-74	11770	56.01	5398	67.42	12696	66.81	14019	67.86	43883
	75-84	6624	31.52	1987	24.82	5086	26.76	5386	26.07	19083
	85+	2621	12.47	621	7.76	1222	6.43	1253	6.07	5717
Race/ethnicity	NH white	17799	84.7	6806	85.01	16232	85.41	17999	87.13	58836
	NH Black/Af-Am	1189	5.66	428	5.35	1066	5.61	997	4.83	3680
	NH Asian	513	2.44	205	2.56	502	2.64	436	2.11	1656
	NH Other	449	2.14	159	1.99	372	1.96	481	2.33	1461
	Hispanic/Latino-any race	1065	5.07	408	5.1	832	4.38	745	3.61	3050
Does not drive		3278	15.6	770	9.62	1379	7.26	1347	6.52	6774
Still in workforce		3267	15.55	1508	18.84	3514	18.49	4064	19.67	12353
Household income less than $50k		11039	52.53	3512	43.87	8403	44.22	9505	46.01	32459
Neighborhood 25% renter occupied homes		8094	38.52	3143	39.26	7393	38.9	7808	37.8	26438
Do not own home		2535	12.06	974	12.17	2403	12.64	2579	12.48	8491
Census region	Northeast	3305	15.73	1295	16.18	3088	16.25	3455	16.72	11143
	Midwest	3357	15.97	1322	16.51	2726	14.34	2840	13.75	10245
	South	9415	44.8	3186	39.8	7704	40.54	8660	41.92	28965
	West	4938	23.5	2203	27.52	5486	28.87	5703	27.61	18330
Neighborhood rurality	rural	5449	25.93	1803	22.52	4860	25.57	7015	33.96	19127
	small town	5180	24.65	2073	25.89	4716	24.82	4876	23.6	16845
	suburban	4591	21.85	1908	23.83	4237	22.3	3674	17.78	14410
	second city	3959	18.84	1502	18.76	3348	17.62	3159	15.29	11968
	urban	1836	8.74	720	8.99	1843	9.7	1934	9.36	6333
Block rurality	Rural	5449	25.93	1803	22.52	4860	25.57	7015	33.96	19127
Household vehicle count	0	653	3.11	286	3.57	713	3.75	806	3.9	2458

Appendix 1-B: Model fit for alternative specification of walking (walk count)



Appendix 1-C: Nested preliminary zero-inflated ordered logistic regression (ziologit) models predicting US older adult walking frequency (upper) & participation (lower)

Walking - Frequency			Model 1: Disability status		+ individual-level factors		Model 3: + health factors		Model 4: + Household factors		Model 5: + Community factors	
			OR	95% CI	OR	95% CI	OR	95% CI	OR	95% CI	OR	95% CI
FOCAL PREDICTOR	Mobility disability	Mobility disabled	0.78***	[0.74,0.82]	0.83***	[0.79,0.87]	0.95	[0.89,1.00]	0.93*	[0.87,0.98]	0.93*	[0.88,0.99]
Identity factors	Gender	female			0.75***	[0.72,0.77]	0.74***	[0.72,0.77]	0.73***	[0.70,0.75]	0.73***	[0.71,0.76]
	Age (years, ref: 65-74)	75-84			1.04	[1.00,1.08]	1.02	[0.98,1.06]	1.01	[0.97,1.05]	1.03	[0.99,1.07]
		85+			0.98	[0.90,1.06]	0.94	[0.87,1.02]	0.92	[0.85,1.00]	0.95	[0.88,1.03]
	Educational attainment	College+			0.97	[0.94,1.01]	0.96*	[0.93,0.99]	1.01	[0.97,1.05]	1.05*	[1.01,1.09]
	Worker status	Worker (ref: non-worker)			1	[0.95,1.04]	0.99	[0.95,1.03]	0.99	[0.94,1.04]	0.99	[0.95,1.04]
	Driver status	Driver (ref: non-driver)			1.10**	[1.03,1.18]	1.04	[0.97,1.12]	1.18***	[1.09,1.29]	1.17***	[1.08,1.28]
	Race/Ethnicity (ref: Non-Hispanic White)	Black, non-Hispanic			0.93	[0.86,1.00]	0.95	[0.88,1.02]	0.90**	[0.84,0.97]	0.90**	[0.83,0.97]
		Asian, non-Hispanic			0.86**	[0.77,0.95]	0.86**	[0.77,0.96]	0.87*	[0.78,0.97]	0.94	[0.84,1.04]
		Other, non-Hispanic			1.14*	[1.01,1.29]	1.16*	[1.03,1.31]	1.14*	[1.01,1.29]	1.11	[0.99,1.26]
		Latino/Hispanic, any race			0.79***	[0.73,0.86]	0.80***	[0.73,0.87]	0.79***	[0.73,0.86]	0.82***	[0.75,0.89]
Health factors	Health status	Poor/fair health (ref: good-excellent)					0.81***	[0.77,0.86]	0.81***	[0.76,0.86]	0.79***	[0.75,0.84]
	Mobility device use	Uses mobility device					0.83***	[0.76,0.90]	0.82***	[0.76,0.89]	0.81***	[0.75,0.88]
Household factors	Vehicle availability	1+ household vehicle							0.74***	[0.66,0.83]	0.73***	[0.66,0.82]
	Household Income	>$50k							0.87***	[0.83,0.90]	0.91***	[0.87,0.94]
	Home ownership	Ref: rents home							0.98	[0.93,1.03]	0.94*	[0.89,1.00]
	Household composition(ref: lives alone)	1+ working adult							0.96	[0.90,1.03]	1.08***	[1.04,1.12]
		1+ retired adult							0.93*	[0.89,0.98]	0.94	[0.88,1.01]
Community factors	n'hood composition (ref <24% renter-occupied housing)	25%+ Renter-occupied housing									0.91***	[0.87,0.95]
	Block rurality (ref: rural)	Small town									0.67***	[0.63,0.70]
		Suburban									0.57***	[0.54,0.60]
		Second city									0.60***	[0.57,0.64]
		Urban									0.71***	[0.66,0.76]
	Census Region	Northeast									1	[1.00,1.00]
		Midwest									0.88***	[0.83,0.93]
		South									1.06*	[1.01,1.12]
		West									1.04	[0.99,1.10]
Cutpoints		1	-2.13	[-2.41, -1.8	-15.78	[-18.00,-13.5	-16.77	[-18.78, -14.	-18.08	[-18.45, -17.	-19.3	[-19.64,-18.95]
		2	-1.09	[-1.22, -0.9	-1.73	[-1.81, -1.64	-1.82	[-1.89, -1.72	-2.12	[-2.22,-2.02]	-2.45	[-2.57, -2.33]
		3	0.42	[0.37-0.47	0.16	[0.08,0.24]	-0.072	[-0.01,0.15]	-0.23	[-0.34,-0.13]	-0.55	[-0.66,-0.42]
N			68,683		68,683		68,683		68,683		68,683	
df			6		26		30		40		55	
ll (model)			-89,840.26		-89,217.69		-88,657.81		-88,299.80		-871,812.57	
AIC			179,692.50		178,487.40		177,365.60		176,679.60		175,735.10	
BIC			179,747.40		178,725.00		177,594.11		177,045.10		176,237.70	

Exponentiated coefficients; 95% confidence intervals in brackets; * p<0.05, **p<0.01, **; cutpoints are non-transformed

Walking - Participation	Model 1: Disability status		+ individual-level factors		Model 3: + health factors		Model 4: + Household factors		Model 5: + Community factors	
	OR	95% CI	OR	95% CI	OR	95% CI	OR	95% CI	OR	95% CI
Mobility disabled	0.30***	[0.27,0.33]	0.46***	[0.44,0.48]	0.71***	[0.67,0.75]	0.70***	[0.66,0.74]	0.69***	[0.66,0.73]
female			0.85***	[0.83,0.88]	0.83***	[0.80,0.86]	0.81***	[0.78,0.84]	0.81***	[0.78,0.84]
75-84			0.86***	[0.82,0.89]	0.82***	[0.78,0.85]	0.82***	[0.78,0.85]	0.82***	[0.79,0.85]
85+			0.80***	[0.75,0.85]	0.71***	[0.67,0.76]	0.70***	[0.65,0.75]	0.71***	[0.66,0.75]
College +			1.49***	[1.44,1.55]	1.44***	[1.39,1.49]	1.42***	[1.37,1.48]	1.44***	[1.39,1.50]
Worker (ref: non-worker)			0.90***	[0.86,0.94]	0.87***	[0.83,0.91]	0.89***	[0.85,0.94]	0.89***	[0.85,0.94]
Driver (ref: non-driver)			1.32***	[1.25,1.40]	1.04	[0.98,1.11]	1.31***	[1.23,1.40]	1.30***	[1.22,1.40]
Black, non-Hispanic			1.06	[0.99,1.15]	1.12**	[1.04,1.21]	1.02	[0.95,1.11]	1.09*	[1.01,1.18]
Asian, non-Hispanic			1	[0.90,1.12]	0.98	[0.88,1.10]	1.02	[0.90,1.14]	0.98	[0.88,1.11]
Other, non-Hispanic			1.05	[0.94,1.18]	1.11	[0.99,1.25]	1.09	[0.97,1.23]	1.04	[0.92,1.17]
Latino/Hispanic, any race			0.95	[0.88,1.03]	0.97	[0.89,1.05]	0.97	[0.89,1.05]	0.97	[0.89,1.06]
Poor/fair health (ref: good-excellent)					0.56***	[0.53,0.59]	0.57***	[0.54,0.60]	0.57***	[0.54,0.59]
(ref: no mobility devices used)					0.57***	[0.54,0.61]	0.56***	[0.53,0.60]	0.56***	[0.53,0.60]
(ref: no household vehicles)							0.42***	[0.38,0.47]	0.42***	[0.37,0.47]
>$50k							1.08***	[1.04,1.13]	1.10***	[1.05,1.14]
Owns home							0.81***	[0.77,0.86]	0.81***	[0.77,0.86]
1+ working adult							0.75***	[0.70,0.80]	1.08***	[1.04,1.13]
1+ retired adult							0.84***	[0.81,0.88]	0.74***	[0.70,0.80]
25%+ Renter-occupied housing									0.84***	[0.80,0.87]
Small town									0.82***	[0.78,0.86]
Suburban									0.73***	[0.70,0.77]
Second city									0.72***	[0.68,0.76]
Urban									0.80***	[0.74,0.86]
Northeast									1	[1.00,1.00]
Midwest									0.90***	[0.84,0.95]
South									0.94*	[0.89,0.98]
West									1.24***	[1.18,1.31]

Appendix 1-D: Alternative specifications for modeling walking patterns among Older Adults in the US using 2017 NHTS Data

Appendix 1-D: Alternative model specifications for total weekly walking among NHTS 2017 older adult sample

	Ordered Logistic Regression			Poisson			Logistic Regression		
	Walk frequency						Walk participation		
PWMD status	0.75***	0.71	0.78	0.89***	0.87	0.91	0.69***	0.65	0.73
Female	0.75***	0.73	0.78	0.90***	0.89	0.91	0.81***	0.78	0.84
65-74	1.00	1	1	1.00	1	1	1.00	1	1
75-84	0.89***	0.86	0.92	0.95***	0.94	0.96	0.82***	0.79	0.85
85+	0.76***	0.72	0.81	0.88***	0.85	0.9	0.70***	0.66	0.75
College degree or higher	1.29***	1.25	1.32	1.11***	1.1	1.12	1.48***	1.42	1.53
Worker	0.91***	0.88	0.95	0.96***	0.95	0.97	0.87***	0.83	0.91
Driver	1.33***	1.25	1.42	1.18***	1.15	1.22	1.32***	1.23	1.41
Black and Hispanic Race/Ethn (F	0.96	0.92	1.01	0.98	0.96	1.01	1.02	0.96	1.09
Fair-poor health	0.59***	0.56	0.61	0.78***	0.76	0.8	0.56***	0.54	0.59
Uses mobility device	0.57***	0.54	0.61	0.74***	0.72	0.77	0.57***	0.53	0.6
Household vehicle	0.46***	0.42	0.5	0.70***	0.67	0.72	0.41***	0.37	0.46
Owns home	0.83***	0.79	0.87	0.93***	0.91	0.94	0.81***	0.77	0.86
Lives alone	1.19***	1.15	1.23	1.07***	1.06	1.09	1.19***	1.14	1.24
Rural Block	1.45***	1.41	1.5	1.15***	1.13	1.16	1.27***	1.22	1.32
Census region (Northeast)	1.00	1	1	1.00	1	1	1.00	1	1
Midwest	0.87***	0.83	0.92	0.95***	0.93	0.97	0.89***	0.84	0.94
South	0.98	0.94	1.02	0.99	0.97	1.01	0.93**	0.88	0.98
West	1.16***	1.11	1.21	1.07***	1.05	1.08	1.24***	1.17	1.31
Constant				2.19***	2.11	2.26	6.47***	5.77	7.26
cut1	0.18***	0.16	0.2						
cut2	0.31***	0.28	0.34						
cut3	1.05	0.96	1.15						
Observations	68683			68683			68683		
aic	176666.27			212703.75			78960.19		
bic	176849.01			212868.22			79124.66		

Exponentiated coefficients; 95% confidence intervals in brackets

* p<0.05 ** p<0.01 *** p<0.001

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Chapter 3: Aim 2 - Patterns in walking behaviors among working-aged mobility disabled and non-disabled adults in the United States

Introduction

While researchers have identified walking as a determinant of overall health status through mechanisms including promoting physical activity and enabling higher levels of transportation mobility, not all populations of adults in the US, those with disabilities included, readily access these benefits from walking.[1,2] Over 10% of the US adult population reports having some type of mobility-related disability; these disabilities frequently affect individuals' actual and perceived ability to participate in walking, thus altering associated health risks and benefits.[3,4] Few studies have quantified associations between mobility disability status and total walking among non-elderly adults at the population level in the US. Instead, studies tend to focus on populations at specific stages in the life course or on limited types of walking. Many studies focus on walking patterns among older adults or walking among people with health conditions that more frequently affect older individuals.[5–7] While disabled individuals more often experience chronic health conditions compared to their non-disabled counterparts, adaptations younger adults make to walking behaviors in response to their disabilities, if any, may vary from those older adults make.[3,8] Differences in overall health factors and lifestyle needs may influence walking behaviors among young adults with disabilities in distinctive ways compared older adults and compared to non-disabled adults with otherwise similar backgrounds.[4,9,10]

As an example, compared to older adults, younger adults more frequently participate in the workforce or pursue formal education, and have obligations to care for children and parents; this may shape how they engage in health-related behaviors, including walking.[11] Life stage-related factors have known associations with walking such as those related to commute-related demands and having less time for participation in leisure walking.[12] At the same time, decline in physical activity and increases in sedentary behaviors correlate with increases in age, contributing to increased risk, and potentially severity of disability, including mobility disability, and poor overall health.[13] Researchers have studied connections between leisure-time walking and active transportation (e.g., walking, cycling) for commuting, linking both types of walking to improvements in mental and physical health among younger adults.[14–17] However these studies often exclude disabled participants from their samples or fail to disambiguate types of disabilities.[18] Evidence suggests that disabled and non-disabled younger adults having unique mobility preferences and that different types of disability (e.g., physical, cognitive, mobility-specific) affect young adults' health and overall mobility patterns in distinct ways.[19–21] Further, participation in walking gets siloed by purpose (e.g., for transportation or for exercise), despite evidence that walking across different domains can influence health outcomes.[16,22,23] Unique patterns of walking purposes driven by lifestyle factors, like the mechanisms driving disability's causes and effects also vary, by age even within the working age adult category.[24–26] With limited population-level understanding of whether and how younger US adults, especially those with disabilities, engage in total walking, public health and transportation experts may lack necessary insights to implement interventions and policies to effectively preserve and enhance their health and mobility through encouraging walking.

By addressing three interrelated research questions, the present study sought to provide insight into the associations between overall walking, disability status, and health status among non-elderly US adults (i.e., those aged 18-64.) The first question examined the association between disability status and weekly walking behaviors, considering whether people with mobility disabilities (PWMD) report different patterns in adoption and overall participation in walking compared to those without mobility disabilities. The second research question evaluated how overall health status modifies associations between PWMD status and total walking, determining whether overall health status and disability status among non-elderly US adults' independently correlate with walking outcomes. Finally, the third question determined the effect of disability-specific factors on walking behaviors among PWMD, emphasizing the need to consider associations between different experiences or types of disability (e.g., whether one relies on mobility aids, whether a condition is chronic) and overall ability to participate in walking at any level.

All analyses used data from the 2017 National Household Travel Survey (NHTS,) a cross-sectional study that gathered an inventory of short- and longer-term travel practices through reports from a travel diary corresponding to a randomly assigned travel day and a questionnaire completed through an online or phone interview format.[27] Data were collected from all household members aged 5 and older and are designed to be nationally representative with the use of survey weights provided in the publicly available data files.[27] I provide additional information about NHTS data collection and compilation protocols in Chapter 1 of this dissertation. Through identifying factors that potentially promote and hinder walking among the often-overlooked population of non-elderly adults with mobility-related disabilities, findings from this study can inform the future design and implementation of public health and transportation-related interventions to promote walking and overall health.

Background and Literature Review

Public health scholars have traditionally relied on specific measures of individual-level physical functionality such as the activities of daily living (ADL) scale for understanding mobility in the context of health outcomes.[28,29] However, growing recognition of the influence of built and social environments on health has prompted increased interest in and use of expanded conceptualizations and operationalization of mobility in conjunction with studying transportation and health.[30] Alternatives or additions to using ADL may include assessing whether and how individuals can travel outside the home to access necessary goods, services, and environments through transportation-related measures. These can include whether one has a driver's license and/or access to a personal vehicle, uses public transportation or other motorized (e.g., taxis, on demand ridesharing services or paratransit) or non-motorized forms of transit (e.g., walking alone or with the assistance of another person or mobility device, cycling.)[31–33] Previous research has linked these forms of transportation access to various health outcomes, including improved access to health care services in the general US adult population and among specific subpopulations (e.g., residents of rural areas, individuals with serious mental illness).[30,34,35] Though walking plays an essential role in many types of transportation, few studies have focused on understanding the connections between mobility disability, walking, and health, especially among working-age adults. This reflects a deficit in the literature that translates to limited understanding of the unique mobility-related challenges affecting the daily lives of people with disabilities. The challenges may include a limited ability to access health promoting goods and services and to in engaging in healthy behaviors like sufficient physical activity.[19,36] Additional knowledge related to current patterns in walking behaviors among this population could help inform more effective policies and programs to improve mobility and health.

An estimated 25.5 million adults in the US live with mobility-related disabilities; among these disabled individuals, 3.6 million describe themselves as homebound.[37] These individuals make up the largest subset of US adults with disabilities and are among one of the largest groups facing marginalization globally.[18] People with mobility disabilities (PWMD) are defined as those who self-identify as having physical or cognitive limitations that result in challenges in using transportation that includes, but is not limited to walking. Mobility disability results from “mismatch between the goals and abilities of an individual and the demands of both the social and physical environment,” rather than an inherent, negative individual trait.[38, p.111] This definition encompasses and extends beyond the definition used by the US Centers for Disease Control and Prevention, who estimate that 11% of Americans live with a mobility disability that causes “serious difficulty walking or climbing stairs.[3]” The CDC measure may exclude some PWMD who, for example, have cognitive or visual impairments that may require alternative mobility accommodations for their daily travel but who do not meet criteria set by the CDC or through ADL-type measures. Individuals with all types of mobility disability may need additional supports for safe mobility, including walking, as demonstrated by several recent studies that also call for further research on these often-overlooked populations.[39–41]

Previous studies using NHTS data have found that disability affects travel behaviors, with effects that vary by disability-specific characteristics. For example, a 2018 report by the US Department of Transportation found that most individuals with mobility-disability self-reported reductions in their overall trip-making because of their disabilities, per their responses to questions asking whether they have “any handicap or condition” that affects their typical travel behaviors and how this condition affects their typical travel behaviors.[37] When examining data from the travel diary portion of the NHTS, findings indicated that PWMD make fewer average daily trips compared to non-disabled people in the same age categories, and that overall trip-making by disabled individuals has declined over time.[37] Additionally, findings indicated that people with disabilities less frequently used emerging technologies including app-based ridesharing compared to those without disabilities.[37] A 2022 study corroborated these trends and found that ridesharing use frequency and adoption among people using mobility devices was lowest among wheelchair users.[37,42] Henning-Smith et al found that overall travel participation among rural US adults is reduced among those with disabilities, likely affecting overall health by limiting their already reduced access to necessary goods and services.[43] These studies highlight that while some PWMD have relatively high levels of independent transportation mobility, which may include engaging in at least some walking, others may rely on assistance from devices (e.g., canes, walkers, wheelchairs), built environment modifications (e.g., rails, ramps, elevators,) or the help of other people. Like unassisted walking, modified forms of walking also confer health benefits associated with walking as a contributor to physical activity.[19,44,45] Further, all forms of walking may enable a higher degree of overall transportation access.[46] Previous qualitative studies related to the transportation needs of older adults in the US have found that engaging in some level of walking helps to preserve a sense of independence and connectivity to needed physical and social environments.[47] Walking may prove similarly vital in preserving and maintaining health through enabling access to essential goods, services, and environments among other populations, including PWMD.

Adults with disabilities are more likely to experience obesity, heart disease, diabetes and engage in smoking compared to non-disabled, non-elderly adults in the US.[3] Those with intellectual and physical disabilities have historically faced reduced life expectancy.[48,49] Mobility disability may contribute to these negative health outcomes through mechanisms such as reduced participation in adequate physical activity or through reduced access to healthy foods, safe workplaces, or appropriate healthcare. However, many of these specific health outcomes and behaviors are, like disability status itself, unevenly distributed across sociodemographic categories. Compared to men, White individuals, and individuals with higher incomes, women, people of color, and individuals with lower income, respectively, more often report experiencing disability.[3,48] When accounting for socioeconomic and demographic factors (e.g., age, sex, income), people with disabilities tend to describe their overall health as better on average compared to those without disabilities, yet a higher proportion of people with disabilities report being in poor health compared to those without disabilities.[38] Better understanding of these trends requires consideration of disability as a factor distinct from overall health status rather than as a proxy for poor current or future health.[38,50] Considering socioeconomic status and baseline health status, along with a more expansive definition of disability status may help clarify the mobility needs of disabled individuals, allowing for improved policy and programmatic interventions.[51,52]

Associations between disability status, overall health, and walking behavior remain underexplored, especially when accounting for socioeconomic status factors, many of which have known associations with overall mobility. Regardless of health status, some PWMD may, like non-disabled individuals, rely on walking as part of their transportation routine, either using walking as a standalone mode of transportation or as a first/last mile- mode after using other modes.[53,54] Among non-disabled individuals, use of non-driving forms of transportation likely occurs among those with lower household incomes unable to afford personal vehicle access (need driven transportation users) and among those who choose alternative modes (choice transportation users) despite their having access to personal vehicles.[54,55] Need-driven transportation users may engage in more walking compared to PWMD with alternative forms of transportation to meet their community mobility needs, regardless of health status.[56,57] In contrast, PWMD of higher socioeconomic status may also have different transportation mobility needs overall due to factors including: having other high socioeconomic status social network members who can provide them with rides, having the ability to work from home, having access to delivery services for needed goods, and being willing and able to use virtual rather than in-person health services.[58,59] Individuals with access to these substitutes for transportation often hold socioeconomic advantages; more socioeconomic advantage similarly predicts lower rates of disability.[60,61] People of lower socioeconomic status and people without personal vehicle access tend to report more transportation-focused walking and less leisure walking, especially outside of select metropolitan areas in the US.[62,63] Research assessing patterns in walking behaviors should therefore consider how a range of individual and extra-individual-level factors may independently and jointly affect the links between walking, health, and disability status. Previous studies investigating the links between walking and health using the 2017 NHTS did not consider how disability status may alter total walking patterns.[64–66] This study sought to yield novel insight into factors influencing walking patterns among non-elderly adults in the US with a specific consideration of PWMD status.

Methods

Figure 2-1 depicts hypothesized and tested connections between walking behavior, disability status, and overall health tested in these analyses. Research question 1 (RQ1) aimed to assess correlation between mobility disability status and walking in the past week among the general population of non-elderly US adults. The bold arrow linking disability status to walking outcomes represents this proposed association. Initial analyses measured its directionality and strength while later analyses explored how walking patterns varied when statistical models accounted for additional individual-, household-, and community-level factors.

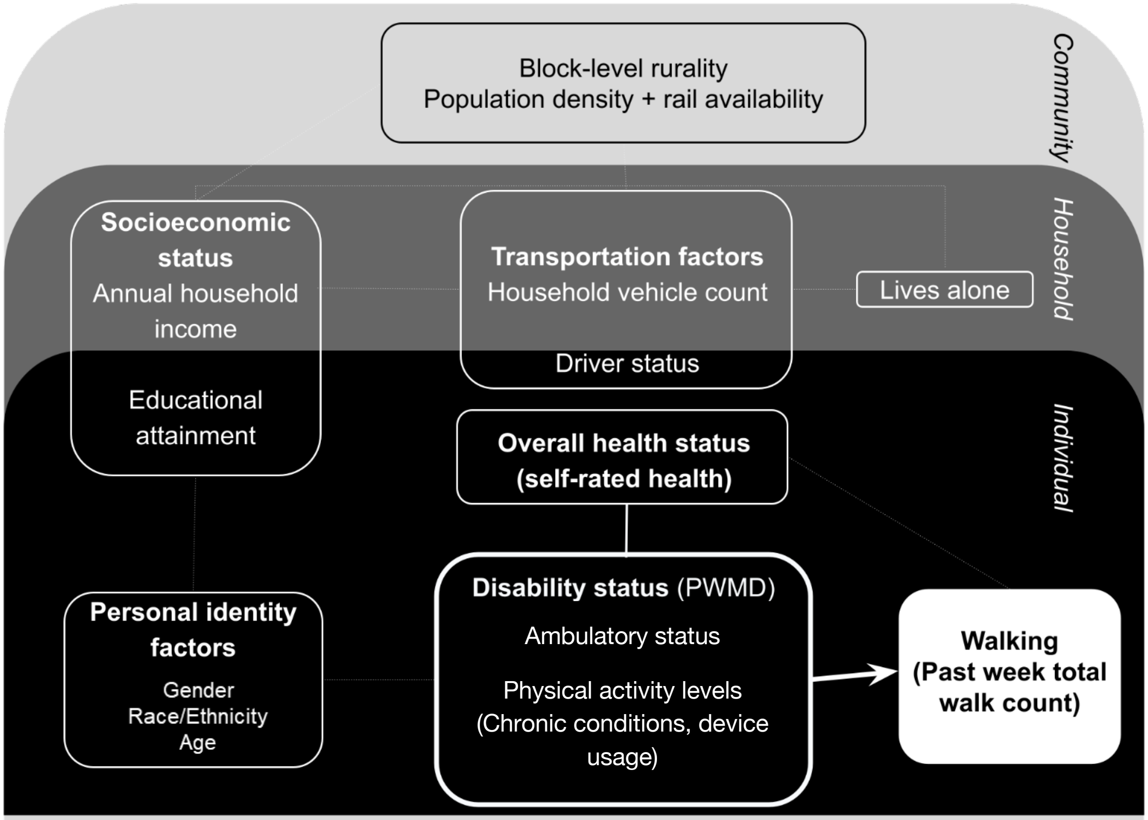


Figure 2-1: Conceptual model

Results of these analyses identified correlates of weekly walking and explored how these vary based on disability status, as proxied by self-identification as a person with mobility disability (PWMD.) RQ2 tested whether and how overall health status modifies the relationship between disability status and walking. Although previous research confirms covariance between overall health status and disability status, these factors represent distinct life stages and associated implications for overall wellbeing at the population level. Subsequent sections elaborate on distinctions between these constructs and the extant evidence informing the hypothesis that both health and disability statuses independently and jointly influence walking behaviors. RQ3 investigated weekly walking patterns among PWMD with an emphasis on quantifying correlations between specific aspects of disability (i.e., whether disability is due to a chronic condition, whether disability likely precludes walking, whether individuals use mobility devices, and if any travel practices are impacted by disability status.) Overall, analyses expanded current understanding of associations between disability status, health, and walking with the goal of advancing public health understanding of community mobility. A key contribution of this study is the framing of disability as proxied by mobility disability status as a predictor of walking. This conceptualization was informed by the recognition of walking as a component of transportation mobility and as a contributor to overall physical activity levels.[1,2,46] This framing contrasts to studies where walking is framed as a predictor of health outcomes, which may include presence or severity of disability, or of health status overall.[67] In this type of framing, readers may interpret disability as an inherent, individual-level trait with causes and consequences at least partially within an individual's control. In contrast, this study frames disability as a more nuanced condition resulting from a mismatch between an individual's physical or cognitive state and the social and environmental conditions in which they live.[38,68]

The variables representing additional individual-, household-, and community-level factors inform these conditions, although they serve as imperfect proxies for overall social and environmental context determining how disability affects daily life, including potentially through walking. Another distinctive contribution of my analyses includes treatment of general health status, proxied by self-rated health as a separate construct from disability status.

This conceptual model does not depict a bidirectional association between walking and disability status although one likely exists. Hypotheses explored in this study frame disability status as a predictor of walking, yet individuals who walk more may experience less disability because of the health benefits associated with walking. The cross-sectional nature of these data precluded definitive identification of causal linkages between walking and disability status and instead preliminarily described associations between disability, walking, and health status. I first measured these associations among all non-elderly adults in this sample (RQ 1, 2), then among only those with mobility-related disabilities (RQ 3.) Knowledge generated may inform future research and practice relevant to advancing health through promoting community mobility.

Data

Data for these analyses was sourced from public use files of the US Federal Highway Administration's 2017 National Household Travel Survey (NHTS.) The data collection involved an initial recruitment questionnaire featuring questions about travel behaviors of adult members of selected households. Questionnaires gathered contextual information about participants' individual- and household-level socioeconomic and demographic status and matching addresses to American Communities Survey data described additional characteristics about their residential area. Additional data come from a travel diary where all household members over 5 years old report detailed information about trips taken on a randomly assigned day intended to capture a daily snapshot of travel behavior. Additional details related to the NHTS 2017 data methodologies can be found in Chapter 1, publicly available reports, and the official online portal for the survey.[27,69]

Key variables

Focal predictor variable: disability status. I used mobility disability status, indicated through self-identification as a person with mobility disability (PWMD), as the central independent variable in these analyses. NHTS participants 16 or older addressed the question "[do you have] a[ny] condition or handicap that makes it difficult to travel outside of the home" with response options of "yes" and "no." [27] I grouped individuals who selected the "yes" option together as mobility disabled. I grouped those replying "no" into the non-disabled category. This binary variable comprises the PWMD category used throughout analyses.

Focal outcome variable: total walking. The key outcome variable for these analyses describes walking behaviors among NHTS participants through quantifying number of walk trips reported in the past week. This was assessed through the question "in the past 7 days, how many times did you take a walk outside, including walks to exercise, go somewhere, or to walk the dog (e.g., walk to a friend's house, walk around the neighborhood, walk to the store, etc.)?" [27] Participants responded to this question with a number ranging from 0 to 200 walks in the NHTS public use files. I topcoded responses to 40 after identifying likely outliers in the data using the Tukey fence method, resulting in a count variable with responses ranging from 0-40. I used these data to examine two forms of walking behavior: walking participation (i.e., whether a participant reported at least one walk (coded as 1) or no walks (0),) and walk frequency proxied by walk count (i.e., the number of walks reported, ranging from 0-40.)

Additional covariates

Covariates for these analyses represent elements of three levels of context, as depicted in the conceptual model: individual-, household-, and community-level factors. The first level includes a grouping of personal identity factors of gender (male=0, female=1), race & ethnicity (US Census Bureau categories, with non-Hispanic White as the reference group,) and age (categorical, 18-24=0, 25-34=2, 35-49=3, 50-64=4). Highest level of educational attainment (less than high school=0, high school diploma=1, some college =2, college degree=3, professional or graduate degree=4,) and worker status (binary, 1= reported working or temporary absence from work as one's primary activity in the past week, 0=reported another primary activity, including unemployment) represented socioeconomic status at the individual-level. The remaining individual-level covariate category includes health- and disability-relevant factors. To proxy overall health status, a focal effect modifier, I used self-rated health. This involved creating a binary variable from the original five categories participants could select to describe their health. I coded those reporting "poor" or "fair" health into one group (0) and those who reported "good," "very good," or "excellent" health into another (1.) This category also included data representing physical activity levels reported by participants. I grouped together those reporting that they did at least 30 minutes of physical activity at any exertion level in the past 7 days into one category (1) and all others into another (0.)

The final category of covariates represents the social and built environments in which participants live. These included a binary indicator of whether one lives alone, a categorical indicator of the number of vehicles available in the home (1, 2, or 3 or more), residential address-based measures of population density and availability of heavy rail infrastructure (6-level categorical variable designating residential address being in areas with populations of

"<50,000," "50,000-199,999," "200,000-499,999," "500,000-999,999," "1 million + without heavy rail," "1 million + with heavy rail.")[67]

Disability status details. Participants reporting that they had a disability or condition affecting how they travel (whom I categorized as PWMD,) also responded to follow-up questions relevant to their disability status.[27] Questions asked how their condition(s) affect their travel behaviors, whether condition(s) result in use of assistive devices, and about the duration or chronicity of the condition.[27] Disabled respondents selected all that applied from a list describing potential community mobility-related consequences of their disability including: "limiting driving to daytime," "using bus or subway less frequently," "asking others for rides," "giving up driving," "using special transportation services," "using reduced fare taxi," and "reducing day-to-day travel overall."[27] Binary variables indicate whether each item of this list was selected. Using these binary variables, I generated a separate count variable, totaling the number of results selected by each participant with a maximum possible value of 7. The question about disability duration asks whether the specific condition reported has affected the participant for: "6 months or less," "more than 6 months," or "all [their] life," which I coded into a binary variable indicating whether the person has had the condition for 6 months or less, or longer.[27] Finally, a question regarding assistive devices asks the participant to select all that apply in response to the question about whether they "use any of the following" from the list of "cane," "walker," "white cane," "seeing eye dog or other K-9 assistance," "crutches," "motorized scooter," "manual wheelchair," "motorized wheelchair," "something else," or "none of the above."[27] Another binary variable indicated whether participants used any assistive devices (0 for "none of the above" selected" and 1 for at least one device indicated.[27]) A final category captures use of multiple devices builds on the previous variables by further separating out those in the device-user category who reported use of more than one device (coded as 2.)

Ambulatory status. I used responses from a question asked of those who reported no travel on their assigned travel day to create a binary variable identifying individuals who are likely to be unable to leave their home (i.e., those most likely to be "homebound," with the limited capacity for independent community mobility via walking or other modes.) [27] Those who reported either not leaving their home in the past 30 days for any reason, and those who reported not leaving in the past 7 days due to being "homebound or disabled," per a question independent of the question determining PWMD status, were coded as 1.[27] I coded all others coded as 0 to create a reference group representing those mostly likely to have necessary physical and mental capacity for independent mobility *or* the necessary physical (e.g., mobility devices) or other support (e.g., family, friends, and public or private shared mobility services) available to them such that they *can* be mobile within the community.

Analytic Plan

Research question 1 asked whether and how walking behavior varied among PWMD compared to non-disabled people. I first assessed this using weighted tests of bivariate associations assessing potential differences in reported walking behaviors. Given previous studies' findings that those with disabilities may be less mobile overall, I hypothesized that a lower proportion of PWMD would report any total walking, compared to those without mobility disabilities.[70,71] Additionally, factors associated with reporting no walking and with lower walk counts among walkers would include: variables indicating lower socioeconomic status (i.e., lower educational attainment, lower household income, occupational statuses other than worker, no household vehicles), mirroring findings underscoring lower SES as a predictor of limited physical activity and indicative of transportation disadvantage.[72–74] Bivariate analyses assessed differences in proportions of disability status by individual- and community-level covariates dictated by literature review findings. I hypothesized that significant correlates of PWMD status would include female gender, older age, and lower socioeconomic status proxied by lower household income, lower educational attainment, and non-working occupational status.[75,76]

Subsequent analyses for RQ1 fit multivariable regression models to assess whether differences in walking outcomes remain when factors previously established to be associated with walking and disability status are taken into consideration. The model selection process for this and later analyses depended on both theory and data limitations. Specifically, preliminary findings demonstrating a high proportion of PWMD and non-disabled individuals reporting no walking in the past week indicated that assumptions of linear regression would be violated by these data. I used the Stata command countfit to assess whether alternative regression methods (e.g., Poisson, negative binomial, and zero-inflated negative binomial modeling) would provide better fitting models for the data. Per my literature review, individuals reporting no walking in the past week may fall into distinct categories—those who truly do not walk in a typical week and those whose self-reported walking may reflect misreporting or accurate reporting of an anomalous week.[6,77] Some participants who reported no walking may have limited abilities that influence or determine this while others may have the capacity to walk but choose not to. In the latter category, the lack of walking may reflect a choice driven by mutable circumstances like weather conditions, temporary illness, injury, or competing demands for their time whereas "true zeroes" represent those who truly never walk due to more permanent inability to walk. A zero-inflated regression model would thus help disambiguate these groups of non-walkers in the data.[42,78] This type of model has the distinct advantage of simultaneously identifying predictors of two related yet distinct processes: (1) whether one engages in any walking (walking participation) and among those who reported at least one walk, and (2) how many walks one reported taking in the past week (walking frequency.) Testing models of interrelated processes simultaneously allows for more accurate estimates of standard errors.[79]

Given evidence of key differences in walking behaviors when comparing disabled and non-disabled individuals, I hypothesized that PWMD and non-disabled individuals would have different patterns in walking behaviors when considering both walking adoption and walk count. Using the appropriate regression methods, I tested the assumption that this would hold true when controlling for: individual-level sociodemographic factors (age, sex, race and ethnicity), and SES (household income, educational attainment, occupational status). I also considered that additional household- and community-level factors such as: household composition, number of household vehicles, and residential population density could alter these associations.[80,81] Any variables significant in the part of the model describing decision to adopt any weekly walking may reflect factors that influence typical walking patterns, which I proxy using the measure of total walking reported in the past week. At the same time, factors significant in the walk count portion of the model may not completely overlap with this first part of the model, and further, may differ among those reporting no disability and PWMD.

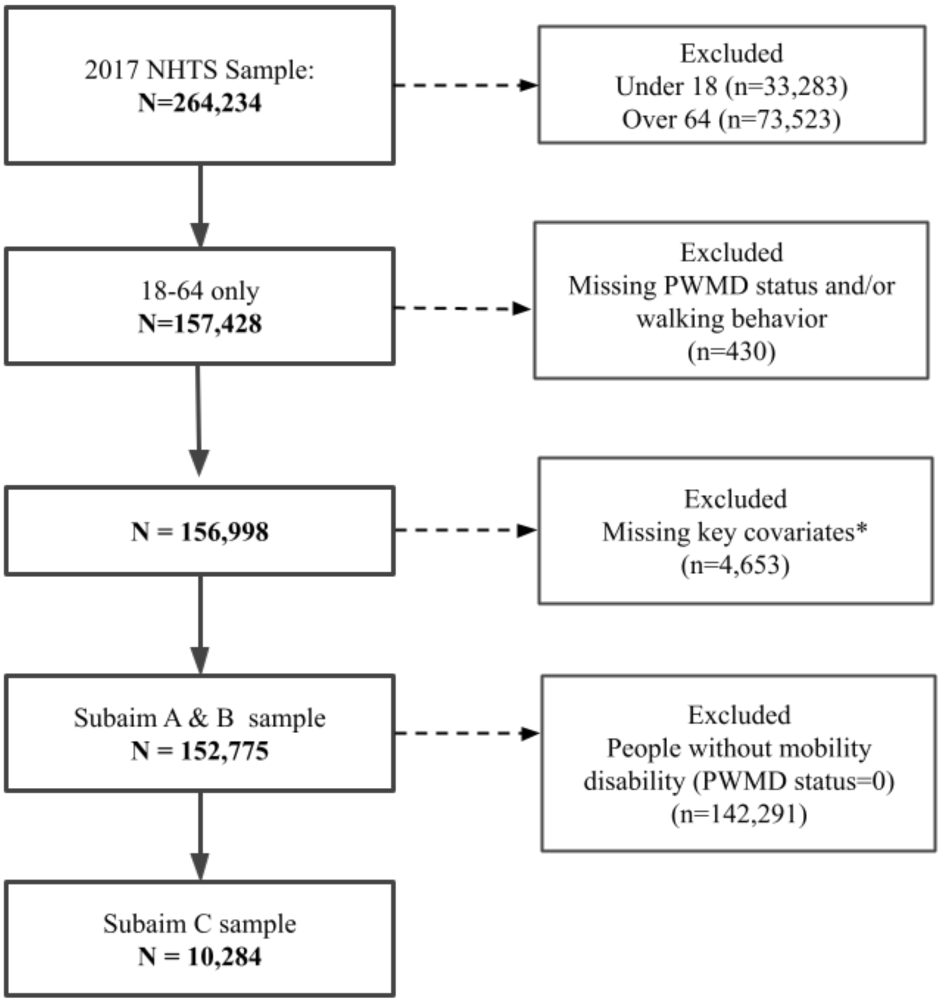
Research question 2 further analyzed patterns in total walking among the population of those with and without mobility disabilities with the additional consideration of general health status treated as an effect modifier. This required an expansion of previous models to test hypothesized effect modification of disability status by overall health status. Using an interaction term (overall health status x PWMD status), models assessed whether worse self-rated health interacted with disability status changes the strength and direction of the association between disability status and participation in weekly neighborhood walking and overall health status and walking behaviors more generally. I hypothesized that poor health status would associate with higher odds of reporting no walking (i.e., lower SRH predicting lower walk participation) and with lower odds of high walking frequency among those with and without disabilities.

Research question 3 examined correlates of walking among PWMD only. Models identified influences on walking behaviors among PWMD and clarified how these vary among those reporting no walks compared to those who reported at least one walk. The simplest of these models tested the assumption that the likely "homebound" or unlikely to walk without assistance more frequently reported lower rates of engaging in any walking. The two-part nature of regression models used also allowed testing of the hypothesis that when they do report walking, weekly counts would be lower among the non-ambulatory when controlling for other individual- and household-level characteristics. Further testing assessed the hypotheses that patterns of engaging in walking may change among PWMD with different types of disability and in different types of social and built environments. I hypothesized that individuals who have multiple specific disability-driven limitations, who do not use assistive devices, who live in more dense residential areas and who do not live alone would be less likely to report no walking and more likely to report higher walk counts when holding all other factors equal.[42,43,45] All analyses were carried out using Stata 17.

Results

Analytic samples

The samples for these analyses represent a subset of participants in the 2017 NHTS who met eligibility criteria for this study. For these analyses, participants included only non-elderly adults (those aged 18-64) who reported complete data on key analytic variables of past week walk



*Missing data on: household income, educational attainment, occupational status, self-rated health, race/ethnicity, driver status, last travel date, household urbanicity, activity levels, and/or mobility device use & disability's effect on travel (if applicable.)
** Missing data on: all of the above + self-reported annual walking behaviors

Figure 2-2: Analytic sample creation

count and mobility disability status. I also excluded participants with missing data for additional covariates as described in Figure 2-2. The sample used to address research questions 1 and 2 includes 152,775 individuals. The subsample used in analyses for research question 3 included only individuals from the first sample who reported having a mobility-related disability (PWMD), 10,285 individuals.

Descriptive analyses

Analytic sample for RQ 1 and 2. The complete NHTS 2017 sample and associated weights were designed to reflect the US population. Given these analyses focus on only a subset of this population, I elected not to use sample weights. Instead, I conducted careful bivariate and univariate analyses of this subsample, and accepted differences between this sample and the population-level distribution of selected attributes as a limitation of these data. As an initial step in understanding associations between disability status and walking behaviors, I assessed distributions of the key outcome of weekly walking behaviors and the key predictor of mobility disability status. Overall, approximately 7% of the sample reported having some kind of mobility-related disability; I classified these individuals as people with mobility disabilities (PWMD.) This portion of the sample is described in the specified column of Table 2-1, which also presents descriptive statistics for non-disabled participants and for the total sample.

Among PWMD, 35.4% reported no total walking in the past 7 days while 24.4% of those without disabilities reported 0 walks, a statistically significant difference. Among this sample, the mean count of total walking trips reported was 5.36 (95% CI: 5.44- 5.67, SD 7.06,) and 7.17 (SD 7.33) among the 74.87% of the sample reporting at least one walk trip in the past week.

Table 2-1: Descriptive analyses of non-elderly adults with and without mobility disabilities, 2017 NHTS (N=152,775)

		Non-disabled (n=142,491)		People with mobility disability (n=10,284)		Total	
		n	%	n	%	n	%
Gender	male	66,955	46.99	4,399	42.78	71,354	46.71
	female	75,536	53.01	5,885	57.22	81,421	53.29
Age (years)	18-24	12,491	8.77	455	4.42	12,946	8.47
	25-33	23,601	16.56	737	7.17	24,338	15.93
	34-49	44,716	31.38	2,069	20.12	46,785	30.62
	50-64	61,683	43.29	7,023	68.29	68,706	44.97
Race/ethnicity	White (non-Hispanic)	105,026	73.71	7,165	69.67	112,191	73.44
	Black/African-American (non-Hispanic)	10,365	7.27	1,333	12.96	11,698	7.66
	Hispanic)	7,995	5.61	192	1.87	8,187	5.36
	Asian / Pacific Islander (non-	4,966	3.49	612	5.95	5,578	3.65
	Hispanic or Latino (any race)	14,139	9.92	982	9.55	15,121	9.9
Highest level of educational attainment	Less than high school	4,190	2.94	1,074	10.44	5,264	3.45
	High school diploma	25,049	17.58	3,289	31.98	28,338	18.55
	Some college	42,651	29.93	3,713	36.1	46,364	30.35
	College degree	39,241	27.54	1,292	12.56	40,533	26.53
	Graduate/professional degree	31,360	22.01	916	8.91	32,276	21.13
Self-rated health	Good-Excellent	134,698	94.53	4,385	42.64	139,083	91.04
	Poor-Fair	7,793	5.47	5,899	57.36	13,692	8.96
Non-ambulatory status	Ambulatory	141,792	99.51	9,755	94.86	151,547	99.2
	Likely non-ambulatory	699	0.49	529	5.14	1,228	0.8
Physical activity	< 30 minutes in past 7 days	20,051	14.07	4,163	40.48	24,214	15.85
	30 or more minutes in past 7 days	122,440	85.93	6,121	59.52	128,561	84.15
Household income (annual)	$0-24,999	16,418	11.52	4,531	44.06	20,949	13.71
	$25k-49,999	24,310	17.06	2,381	23.15	26,691	17.47
	$50-74,999	25,177	17.67	1,290	12.54	26,467	17.32
	$75k-99,999	22,180	15.57	842	8.19	23,022	15.07
	$100k-149,999	30,360	21.31	816	7.93	31,176	20.41
	$150k+	24,046	16.88	424	4.12	24,470	16.02
Rural block	Non-rural	111,983	78.66	7,672	74.67	119,655	78.39
	Rural	30,385	21.34	2,602	25.33	32,987	21.61
Population density of residental address	50,000-199,999	20,352	14.28	1,657	16.11	22,009	14.41
	200,000-499,999	17,089	11.99	1,151	11.19	18,240	11.94
	500,000-999,999	10,717	7.52	729	7.09	11,446	7.49
	1 million or more, with heavy rail	32,025	22.48	1,859	18.08	33,884	22.18
	1 million or more, without heavy rail	18,278	12.83	949	9.23	19,227	12.59
	<50,000	44,030	30.9	3,939	38.3	47,969	31.4
Household composition	1 person	18,963	13.31	2,580	25.09	21,543	14.1
	2+ people	123,528	86.69	7,704	74.91	131,232	85.9
Household vehicle count	0	3,501	2.46	1,400	13.61	4,901	3.21
	1	25,957	18.22	3,370	32.77	29,327	19.2
	2	60,108	42.18	3,124	30.38	63,232	41.39
	3+	52,925	37.14	2,390	23.24	55,315	36.21
Driver status	Licensed driver	136,205	95.59	7,346	71.43	143,551	93.96
	Non-driver	6,286	4.41	2,938	28.57	9,224	6.04
Past week walk count	0	34,756	24.39	3,635	35.35	38,391	25.13
	1-2	22,135	15.53	1,401	13.62	23,536	15.41
	3-5	43,470	30.51	2,549	24.79	46,019	30.12
	7+	42,130	29.57	2,699	26.24	44,829	29.34

In $\chi 2$ tests at the .05 significance level, PWMD and non-disabled groups were statistically significantly different.

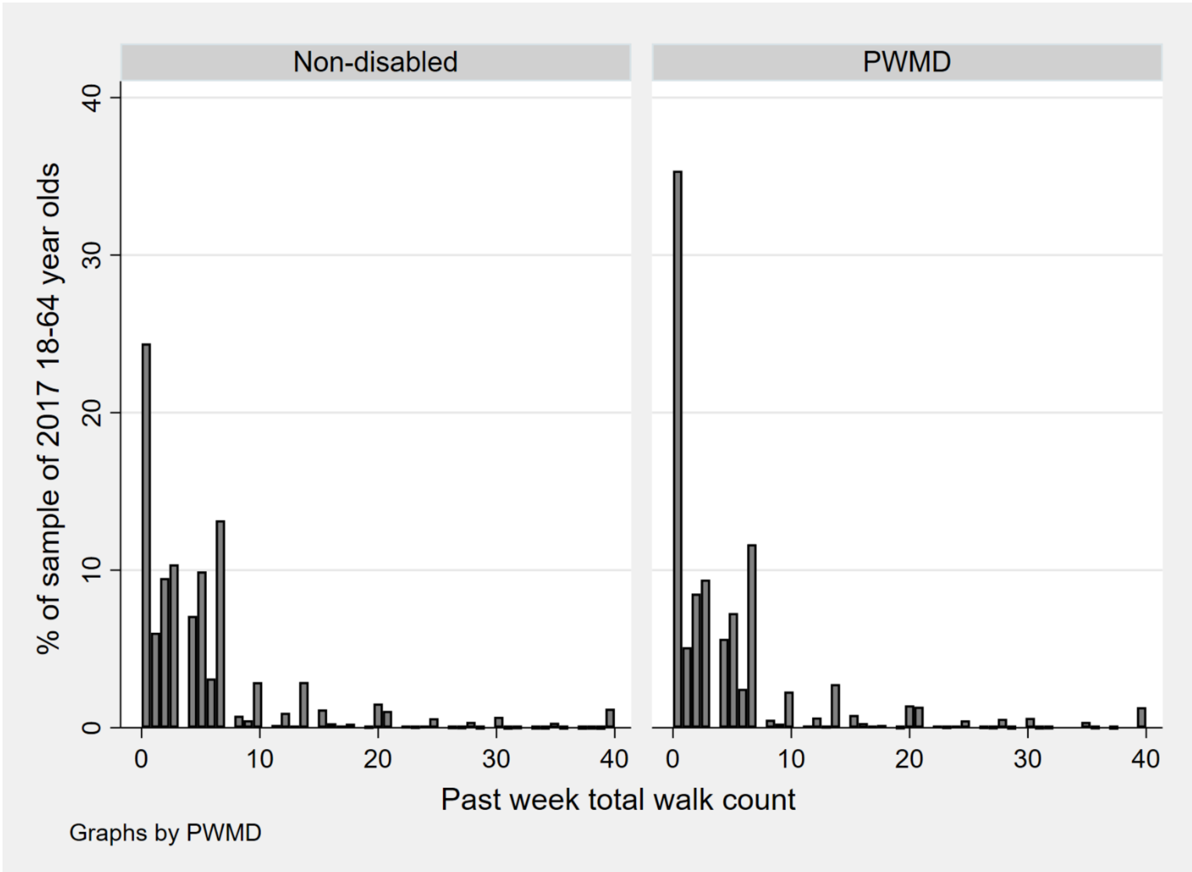


Figure 2-3. Histograms of weekly walk counts among disabled, non-disabled adults

Figure 2-3 shows the distribution of weekly walk counts among the total sample and among those with and without mobility disabilities. It further illustrates the decision-making process behind model selection as previously described. These histograms illustrate that relative to those without disabilities, those with disabilities more frequently reported 0 total walking in the past week. Further, the histogram shows spikes in overall proportion of those reporting counts at intervals of 7 potentially reflecting those who estimated their number of walks in the past week by approximating daily walks. The noticeable increase at 40 reflects the proportion of those in the sample reporting 40 or more walks in the past week and is an artifact of the coding process that consolidated less than 1% of the participants into this top category. The distribution of weekly walk counts is strongly right skewed, confirming that neither linear nor logistic regression models would suit this data, at least without significant transformation of the data. Given the practical challenges of interpreting transformed data in a way that suits real world applications, I elected to work with untransformed data, and to instead use an established model comparison method to identify an alternative appropriate modeling approach.[82] Appendix 2-A includes results of this method.

Analytic sample for research question 3. To better understand the interplay between disability status and various health factors, bivariate analyses for RQ3 focused on the subpopulation of people with mobility disabilities. Compared to PWMD who are likely to be non-ambulatory, those likely to be ambulatory more frequently reported: being in better overall health, engaging in more physical activity, using most types of assistive devices less frequently, and less frequently reporting specific travel limitations. In bivariate analyses, ambulatory PWMD have a higher mean number of weekly walks at an estimated 5.00 (SD 7.35) compared to non-ambulatory PWMD who reported a mean 1.92 walks (SD 4.72.) When comparing the count of specific travel limitations reported, non-ambulatory PWMD reported a mean of 1.41 (SD 0.72) compared to ambulatory PWMD's 1.29 (SD 0.73.) Results of these analyses (reported in more detail in Appendix 2-B) and previous findings related to RQs 1 and 2 informed selection of covariates for multivariable analyses.

Multivariable modeling

RQ1. Given the results of descriptive and bivariate analyses of the distribution of self-reported past week walk count data and the goal of describing overall patterns of walking rather than separate patterns of walking participation (i.e., any walking vs. none,) and walk counts, I used zero-inflated negative binomial regress (ZINB) models. Table 2-2 presents the best-fitting 2-part models of the multivariable modeling carried out for RQ1, which looked at the associations between of disability status on both participation in weekly walking and number of walks reported in the past week. The model simultaneously estimates the count of past week walks among those who reported at least one walk using a count model (upper portion of Table 2-2), and the odds of participating in no walking in the past week using a logit model.

Across all models, those with mobility-related disabilities were more likely to report no walking in the past week compared to those without mobility-related disabilities. Even when models accounted for individual and household level indicators of socioeconomic status and general health status (i.e., Models 2-4), PWMD had over 1.5 times higher odds than non-disabled individuals of reporting no walking. Factors most strongly associated with reporting no walking included: living in a household with at least one car and especially more than 3 cars, reporting being in fair or poor health, reporting likely non-ambulatory status, and being a worker. In contrast, the only factor consistently associated with decreased odds of reporting no walking in the past week included female gender; higher age (over 50) was sometimes associated with lower odds of reporting no walking as well.

In the portion of the model predicting reported walk counts, PWMD status influences walking in more nuanced ways. Factors associated with increased walk count were reporting 30 or more minutes of physical activity in the past week and living in a non-urbanized *or* highly urbanized environment with rail. In a pattern that mimics results from walk participation section of the model, an increased number of household vehicles was inversely associated with walk count such that those living in households with the most cars were more likely to report the fewer walks.

RQ2. To further examine the role of disability status in shaping walking behaviors, RQ2 investigated how health status acts as an effect modifier in the association between PWMD status and walking behaviors. Additional multivariable ZINB models including a health status and PWMD interaction term built on previous findings from RQ1, and elaboration of the best fitting model to include extra-individual factors that were significant predictors in previous results. Results of models with the additional health status-PWMD interaction term are reported in Table 2-3. Factors predicting increased walk counts include having a college degree or higher level of educational attainment and reporting at least 30 minutes of physical activity per week while a decreased walk count is associated with being a worker and living in a household reporting less than $50,000 income annually. For the portion of the model predicting adoption of any walking, factors associated with increased odds of reporting no walking include working and living in a household with at least one vehicle. Factors associated with decreased odds of no walking, otherwise understood as factors that may be associated with walk adoption include female gender and ages 50 and above.

Table 2-2: Best fitting zero-inflated negative binomial models predicting total walk participation and frequency among non-elderly adult NHTS 2017 sample

Count: negative binomial model predicting past week		Model 1	Model 2	Model 3	Model 4
Disability Status	PWMD	1.06* [1.01,1.11]	1.04 [0.99,1.09]	1.06* [1.00,1.12]	0.98 [0.93,1.03]
Age	50+		1.04** [1.01,1.07]	1.03* [1.01,1.06]	1.03** [1.01,1.05]
Sex	Female		0.94*** [0.93,0.96]	0.94*** [0.93,0.96]	0.94*** [0.92,0.95]
Race/Ethnicity	White		REF	REF	REF
	Non-Hispanic Black		1.01 [0.96,1.05]	1.03 [0.99,1.07]	0.93** [0.89,0.98]
	Non-Hispanic Asian		0.86*** [0.81,0.91]	0.87*** [0.82,0.93]	0.85*** [0.80,0.89]
	Non-Hispanic Other		1.07** [1.03,1.12]	1.08*** [1.03,1.13]	1.05* [1.00,1.10]
	Hispanic/Latino of any race		0.81*** [0.76,0.87]	0.83*** [0.77,0.89]	0.82*** [0.78,0.86]
Educational Attainment	College degree +			1.05 [0.99,1.11]	1.08*** [1.04,1.11]
Working status	Worker			0.93*** [0.91,0.95]	0.96*** [0.94,0.98]
SRH	Fair-Poor health			1.11*** [1.06,1.16]	1.04 [1.00,1.09]
Ambulatory status	Likely non-ambulatory			0.92 [0.82,1.04]	0.91 [0.82,1.02]
Physical activity level	30+ minutes in average week			1.57*** [1.49,1.65]	1.56*** [1.49,1.63]
Annual household income	$0-24k				REF
	$25k-49,999				0.93*** [0.89,0.96]
	$50k-74,999				0.88*** [0.85,0.92]
	$74-99,999				0.86*** [0.82,0.90]
	$100k-149,999				0.87*** [0.84,0.91]
	$150k+				0.91* [0.84,0.98]
Population Density	heavy rail				REF
	heavy rail				1.22*** [1.09,1.38]
	500,000-999,999				1.02 [0.94,1.11]
	200,000-499,999				1.03 [0.94,1.13]
	50,000-199,999				1.04 [0.96,1.11]
	<50,000				1.21*** [1.14,1.28]
Household vehicle count	0 vehicles				REF
	1				0.70*** [0.64,0.77]
	2				0.60*** [0.51,0.70]
	3+				0.61*** [0.51,0.73]
Household composition	Lives alone				0.98 [0.95,1.02]
Zero-inflation: binomial model (logit link) predicting participation in NO walking in past week		Model 1	Model 2	Model 3	Model 4
Disability status	PWMD	2.27*** [2.14,2.40]	2.33*** [2.19,2.48]	1.69*** [1.53,1.85]	1.87*** [1.70,2.06]
Age	50+		0.93* [0.87,1.00]	0.94 [0.87,1.02]	0.86*** [0.80,0.92]
Sex	Female		0.71*** [0.68,0.75]	0.69*** [0.65,0.72]	0.70*** [0.67,0.74]
Working status	Worker			1.29*** [1.20,1.37]	1.21*** [1.14,1.30]
Self-rated health	Fair-poor health			2.12*** [1.92,2.33]	2.27*** [2.06,2.49]
Ambulatory status	Likely non-ambulatory			4.89*** [4.08,5.87]	5.18*** [4.33,6.21]
Population density	heavy rail				REF
	heavy rail				0.77 [0.52,1.15]
	500,000-999,999				1.16 [0.79,1.71]
	200,000-499,999				1.07 [0.79,1.45]
	50,000-199,999				1.13 [0.80,1.58]
	<50,000				1.2 [0.93,1.55]
Household vehicle count	0 vehicles				REF
	1				3.89*** [3.04,4.97]
	2				5.14*** [3.82,6.92]
	3+				7.35*** [5.37,10.07
	lnalpha	0.89*** [0.86,0.93]	0.89*** [0.85,0.92]	0.93*** [0.89,0.97]	0.88*** [0.84,0.92]
	AIC	834077.5	833157.3	830111.9	825733.5
	BIC	834127.2	833286.4	830320.6	826071.3
	N	152,775	152,775	152,775	152,775

*=p<0.05,**= p<0.01,***= p<0.001; exponentiated coefficients in top portions represent IRRs, bottom, Ors

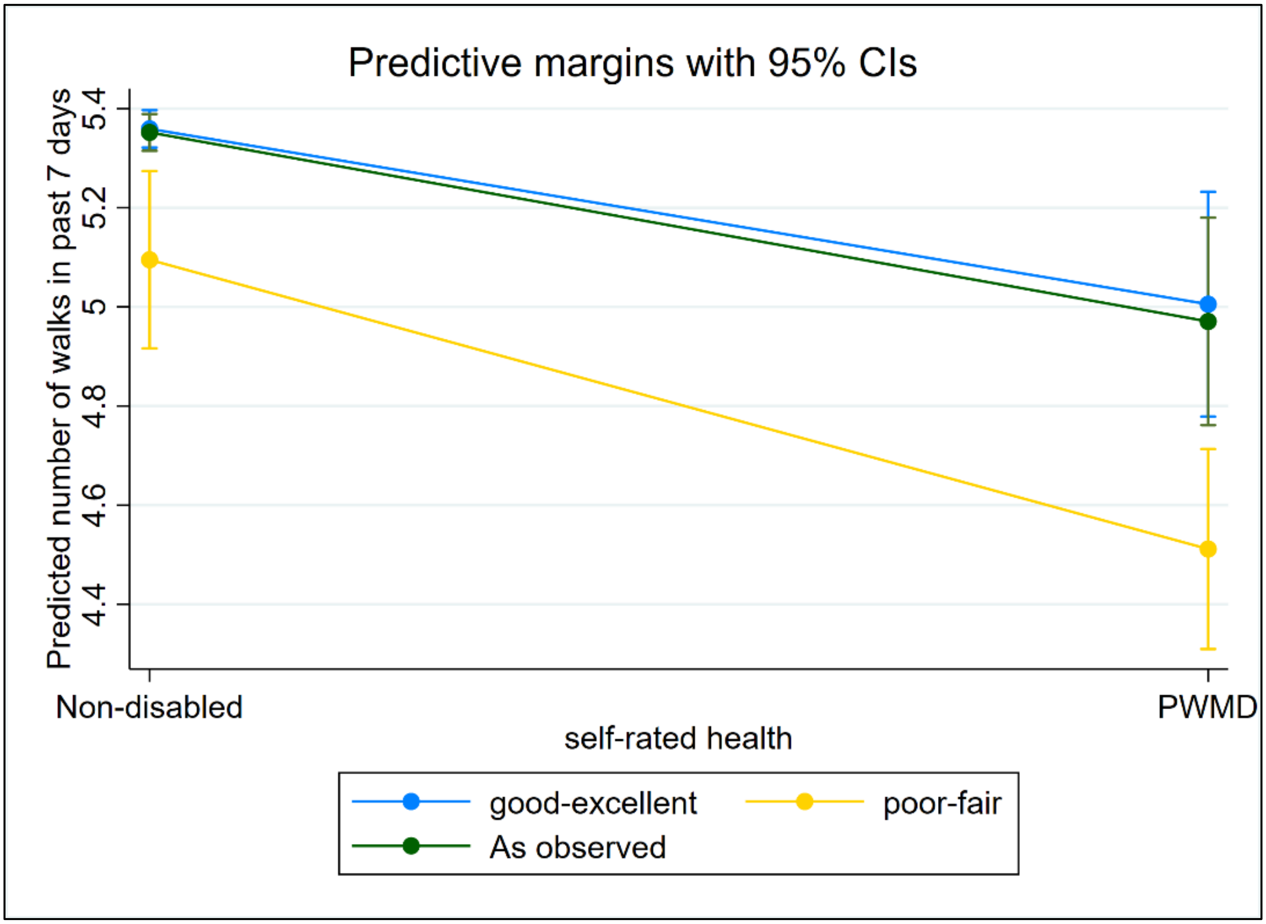
Table 2-3: Best fitting zero-inflated negative binomial model predicting total walk participation and frequency among non-elderly adults in NHTS 2017 sample, with interaction term

Count model predicting past week walk count (Exponentiated coefficients = IRRs)							
		Model 5		Model 6		Model 7	
Disability status	non-disabled	REF		REF		REF	
	PWMD	1.09***	[1.05,1.14]	1.12***	[1.07,1.18]	1.07**	[1.03,1.12]
SRH	Excellent-good health	REF		REF		REF	
	Fair-poor health	1.07***	[1.03,1.11]	1.15***	[1.11,1.19]	1.11***	[1.07,1.15]
SRH*Disability status	Poor-fair health & PWMD	0.88***	[0.82,0.94]	0.88***	[0.82,0.95]	0.89***	[0.83,0.95]
Age	50+			1.03***	[1.02,1.05]	1.02**	[1.01,1.04]
Sex	Female			0.94***	[0.93,0.95]	0.94***	[0.93,0.95]
Race/ethnicity	Non-Hispanic White	REF		REF		REF	
	Non-Hispanic Black			1.03*	[1.00,1.06]		0.99 [0.96,1.02]
	Non-Hispanic Asian			0.87***	[0.85,0.90]	0.86***	[0.83,0.88]
	Non-Hispanic Other			1.08***	[1.04,1.12]	1.07***	[1.03,1.10]
	Hispanic/Latino of any race			0.83***	[0.80,0.85]	0.83***	[0.81,0.85]
Educational Attainment	College degree +			1.05***	[1.04,1.07]	1.07***	[1.05,1.08]
Working status	Worker			0.93***	[0.92,0.95]	0.95***	[0.93,0.97]
Ambulatory status	Likely non-ambulatory				0.93 [0.84,1.03]	0.88*	[0.80,0.98]
Physical activity level	30+ minutes in average week			1.57***	[1.52,1.61]	1.55***	[1.50,1.59]
Household income	<$50,000 annually					0.79***	[0.77,0.81]
Population Density	1 million or more, with heavy rail					REF	
	1 million or more, without heavy rail					1.30***	[1.27,1.33]
	500,000-999,999						1.03 [1.00,1.06]
	200,000-499,999					1.04**	[1.01,1.06]
	50,000-199,999					1.04***	[1.02,1.07]
	<50,000					1.19***	[1.17,1.22]
Zero-inflated logit model predicting participation in NO walking in past week (Exponentiated coefficients=ORs)							
Disability status	non-disabled	REF		REF		REF	
	PWMD	2.03***	[1.85,2.23]	2.38***	[2.14,2.65]	2.65***	[2.38,2.95]
SRH	Excellent-good health		1 [1.00,1.00]		1 [1.00,1.00]		1 [1.00,1.00]
	Fair-poor health	2.24***	[2.09,2.40]	2.51***	[2.32,2.72]	2.73***	[2.53,2.96]
SRH*Disability status	Poor-fair health & PWMD	0.59***	[0.52,0.67]	0.52***	[0.45,0.61]	0.53***	[0.46,0.62]
Age	50+			0.94*	[0.90,0.99]	0.84***	[0.80,0.88]
Sex	Female			0.69***	[0.65,0.72]	0.71***	[0.67,0.74]
Working status	Worker			1.29***	[1.22,1.37]	1.19***	[1.13,1.26]
Ambulatory status	Likely non-ambulatory			4.94***	[4.25,5.75]	5.05***	[4.27,5.97]
Population Density	1 million or more, with heavy rail					REF	
	1 million or more, without heavy rail					0.84***	[0.77,0.92]
	500,000-999,999					1.17**	[1.06,1.28]
	200,000-499,999						1.07 [0.98,1.16]
	50,000-199,999					1.13**	[1.04,1.22]
	<50,000					1.16***	[1.09,1.24]
Household vehicle count	0 vehicles					REF	
	1					6.54***	[4.61,9.29]
	2					10.28***	[7.26,14.55]
	3+					14.44***	[10.19,20.46]
N		152,775		152,775		152,775	
lnalpha		0.89***	[0.88,0.91]	0.93***	[0.92,0.95]	0.89***	[0.88,0.91]
AIC		833,634.70		830,040.80		827,014.60	
BIC		833,734.10		830,269.40		826,382.20	

The effects of disability status and overall health status as proxied by self-rated health jointly influence both adoption of any walking and frequency of walking. As indicated by postestimation analyses illustrated in Figure 2-4 the model including additional individual- and extra-individual factors, similarly to the more parsimonious models that control for fewer covariates, provides evidence to support the hypothesis that the combination of health status and disability status influences walking patterns in a way that differs from the independent effects of each of these factors on walking. Specifically, people without disabilities are predicted to report more walks in the past week, particularly if they also reported good to excellent health status. However, among PWMD, those who reported good to excellent health were predicted to report only a slightly lower walk count (approximately 5 walks in the past week) than non-disabled individuals in poor to fair health (approximately 5.1 walks.)

RQ 3. The last collection of multivariable models focused on addressing the final research question about whether and how specific health related factors affect walking adoption and walk counts among only those with mobility disabilities (PWMD). Analyses also relied on ZINB models given the distribution of walk counts with excess zeroes among those reporting having a condition that affects their travel. As indicated in Table 2-4*,* in all the ZINB models tested, statistically significant predictors of reporting engaging in no walking included: reporting being non-ambulatory (especially after controlling for additional indicators of socioeconomic status), reporting being in poor to fair health, and reporting living in a household with one or more vehicles. In contrast to the general population, working status and female sex were *not* associated with increased odds of no walking adoption. In the portion of the models predicting walk counts, factors linked to lower walk counts included: likely non-ambulatory status, living in

Figure 2-4. Predictive margins of past week walking, health x PWMD status (full model results shown)



a household with an income of less than $50,000 annually, and reporting using multiple assistive mobility devices. Factors predictive of higher walk counts were: identifying as non-Hispanic “other” race, including multiple races, living in a non-urbanized (<50,000 people) or highly urbanized (1 million or more population size) area without heavy rail (compared to a highly urbanized area with heavy rail), having a chronic mobility disability (when compared to those who have had the condition that categorizes them as a person with mobility-related disability for less than six months), and reporting 30 or more minutes of physical activity in an average week. Living in a household with access to 1 or more personal vehicles was not significantly predictive of higher walk counts, nor was living alone, having a college degree or higher level of education.

Table 2-4: Weekly walk counts among working age adults with mobility disabilities, NHTS 2017

		Model 8	Model 9	Model 10	Model 11
Count model: predicting weekly walk count					
		IRR 95% CI	IRR 95% CI	IRR 95% CI	IRR 95% CI
Ambulatory status	Likely non-amb	0.76** [0.62, 0.93]	0.79* [0.64,0.97]	0.81* [0.66,0.99]	0.79* [0.64,0.97]
Age	50+		0.99 [0.93,1.05]	1 [0.94,1.07]	0.98 [0.92,1.05]
Sex	Female		0.98 [0.92,1.04]	0.97 [0.92,1.03]	0.97 [0.91,1.02]
Race/ethnicity	White		1 [1.00,1.00]	1 [1.00,1.00]	1 [1.00,1.00]
	Non-Hispanic Black		1.05 [0.96,1.13]	1.06 [0.98,1.15]	1.02 [0.94,1.11]
	Non-Hispanic Asian		0.87 [0.68,1.11]	0.88 [0.70,1.12]	0.91 [0.72,1.14]
	Non-Hispanic Other		1.14* [1.02,1.28]	1.16* [1.03,1.30]	1.14* [1.01,1.28]
	Hispanic/Latino of any race		0.89* [0.81,0.98]	0.90* [0.82,1.00]	0.92 [0.84,1.02]
Educational attainment	College degree+		0.98 [0.91,1.05]	0.98 [0.92,1.06]	1.04 [0.97,1.12]
Working status	Worker		1.04 [0.96,1.12]	1.06 [0.98,1.15]	1.09* [1.01,1.18]
SRH	Fair-poor health		1 [0.94,1.07]	1 [0.94,1.07]	0.98 [0.92,1.05]
Physical activity level	30+ minutes in an average week		1.36*** [1.27,1.47]	1.37*** [1.27,1.47]	1.34*** [1.25,1.44]
Condition duration[1]	Chronic			1.29*** [1.15,1.44]	1.24*** [1.11,1.39]
Specific travel limitation	1+			1.08 [0.99,1.17]	1.04 [0.95,1.13]
Assistive device use	2+			0.93** [0.89,0.97]	0.92*** [0.88,0.96]
Household income	<$50,000				1 [1.00,1.00]
	$50,000+				0.88*** [0.81,0.94]
Population density	1 million or				1 [1.00,1.00]
	1 million or				1.16* [1.03,1.30]
	500,000-				1 [0.87,1.15]
	200,000-				1.11 [0.99,1.25]
	50,000-				1.11 [1.00,1.23]
	<50,000				1.28*** [1.17,1.40]
Household vehicle count	0				1 [1.00,1.00]
	1				0.99 [0.90,1.08]
	2				0.94 [0.85,1.05]
	3+				0.91 [0.81,1.02]
Household composition	Lives alone				1.06 [0.99,1.14]
Zero-inflated model predicting no walking in past week					
		OR 95% CI	OR 95% CI	OR 95% CI	OR 95% CI
Ambulatory status	Likely non-amb	1.66*** [1.44, 1.88]	5.40*** [4.28,6.82]	5.47*** [4.33,6.93]	5.63*** [4.37,7.26]
Sex	Female		1.07 [0.94,1.23]		
Worker status	Worker		1.11 [0.94,1.31]	1.11 [0.94,1.32]	0.99 [0.84,1.17]
SRH	Fair-poor health		1.30*** [1.13,1.50]	1.32*** [1.14,1.52]	1.37*** [1.19,1.58]
Population density	1 million or				1 [1.00,1.00]
	1 million or				1.03 [0.81,1.33]
	500,000-				0.9 [0.66,1.22]
	200,000-				0.89 [0.71,1.12]
	50,000-				0.73* [0.54,0.97]
	<50,000				0.88 [0.73,1.07]
Household vehicle count	0				1 [1.00,1.00]
	1				4.00*** [2.83,5.67]
	2				5.46*** [3.86,7.74]
	3+				5.98*** [4.20,8.52]
	N	10,284	10,284	10,284	10,284
	AIC	52,270.89	52,138.60	52,105.20	51,787.59
	BIC	52307.08	52,268.89	52,249.97	52,062.65

*=p<0.05,**= p<0.01,***= p<0.001; [1] Participant responded that they have had the specific condition or limitation indicating PWMD status for 6 months or longer [2] Participant reported at least 1 specific way in which condition affects their day to day travel (e.g., reduced travel overall, limiting night time driving, etc.)

Discussion

Overall, results of this study suggest that walking behaviors, including participation in any total walking and patterns in past week total walking counts, differ among PWMD compared to people without disabilities. Specifically, having a mobility-related disability was associated with higher likelihood of reporting no walks in the past 7 days when controlling for socioeconomic status factors. This potentially aligns with perceptions of disability as a key contributor to limited community mobility and a contributing factor toward either current or future poor health and limited engagement in health-protecting behaviors.[6,18,64] However, in models predicting walk counts, PWMD status was statistically significantly associated with more walking (as measured through counts*)* compared to non-disabled individuals, even when overall health status and household-level factors including socioeconomic status indicators were considered. This seemingly paradoxical result may be partially attributable to the broad definition of mobility-disability used here. Further, when examining the actual predicted probabilities of walks when simultaneously modeling the process yielding no walks and more than one walk, practical differences in walk counts become less apparent. A potential reason for this is that some travel limiting conditions resulting in someone falling into the PWMD category in this study may have little bearing on walking. For example, someone with a visual or cognitive impairment that prevents safe driving may be capable of safe walking. This draws attention to the importance of disaggregating disability types when assessing the effects of disability of health-related behaviors including walking and transportation mobility.

RQ2 analyses, which explored the dual effects of health and disability statuses, also highlight the need to treat health and disability as distinctive factors when it comes to designing interventions to facilitate or promote walking. Findings suggested that general health status and mobility-disability status have both independent and joint effects on walking adoption and count of walks reported, even when socioeconomic status is held constant. In parallel with findings from previous studies suggesting that disability does not necessarily predict poor health status, neither poor health nor broad disability status alone have as much of an impact on predicting no walking and low walk count as does poor health status in conjunction with having a disability. Overall, these results underline the need for future research and interventions that approach disability and interventions for disabled individuals with more nuance. Rather than viewing disabled individuals as monolithically unwell or incapable of walking, it is important to recognize that some disabled people wish to, would be able to, or do already participate in walking in ways that advance their community mobility.

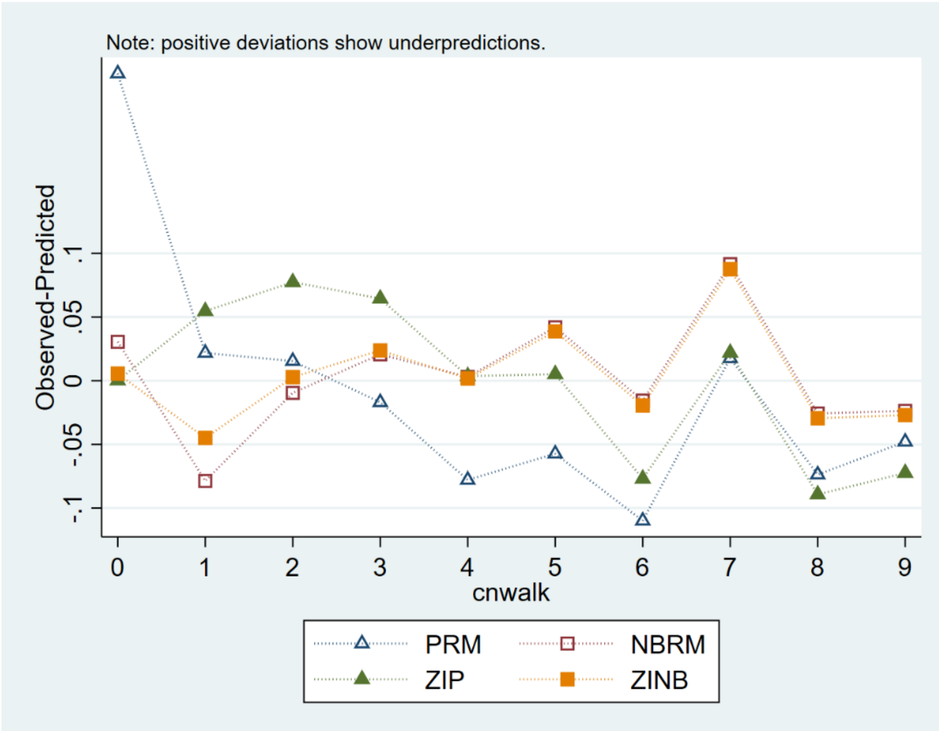
Adding further nuance to the conversation, the models in RQ3 show intragroup differences within the population of non-elderly US adults with mobility disabilities. Among PWMD, being in poor or fair health is associated with lower participation in any walking and fewer walks among walkers, as is having limited capacity to leave one's home (likely non-ambulatory status). Women, Latinos, and people living in non-urbanized areas compared to men and non-Hispanic Whites, and those living in urban areas respectively, were more likely to report higher walk counts among PWMD. Among all groups, reporting higher levels of physical activity was associated with higher likelihood of reporting any walking and higher walk counts. Similarly, living in a zero-car household was associated with more walking except for PWMD in zero-car households reporting 1 or more walks. As other scholars have noted, the effects of (lack of) vehicle ownership on physical activity, which cannot be fully disentangled from walking in this study, can be complex to interpret due to the potential for residential selection bias. Some respondents living in zero-car households may choose to live in neighborhoods with copious non-car transportation options and may choose to walk whereas others may be unable to afford to own a vehicle and/or live somewhere with fewer non-walking and non-driving transportation options. Aside from this more difficult to interpret vehicle ownership pattern, taken together, the results seem to parallel findings from previous studies' suggesting that transportation disadvantage – potentially also including engagement in walking – is most concentrated among those with the fewest socioeconomic resources.

The study findings are limited by a few elements. Data from NHTS is cross-sectional, reflecting only a snapshot of time in participants' lives that may not capture typical behavior. Further, the data relies on participant self-report which may introduce recall and social desirability bias. While the latter bias may contribute to overreporting participation in physical activity and walking, the phrasing of the walking question may have resulted in individuals underreporting walks that would still be contributing to participants' overall community mobility (e.g., short trips between other transportation modes may have been overlooked, those using assistive devices may have discounted their walks.[83,84]) Additionally, even if the survey accurately captured and recorded walking data, the challenge of interpreting what degree of participation in walking or number of walks has real world or clinical significance remains. For example, would a single short walk per week likely affect health differently compared to those who take 0 walks? Identifying a threshold for health benefits of walking may continue to prove an elusive goal, especially when the effects of disability—and especially the intersection of health and disability—are considered.[82,85] Encouraging walking may not be a desirable goal for some with severe disabilities or those in poor health who may experience adverse effects related to exposure to harsh weather, poor air quality, or fall risk.[86,87] Finally, the NHTS included relatively few health-specific questions, limiting my ability to disaggregate types of disability beyond the broadest categories. Moreover, reliance on assumptions about ambulatory status may misrepresent participants who fell into the “excess 0’s” part of the ZINB model.

Despite these limitations, this study has several strengths that advance understanding of the associations between walking, health, and disability among non-elderly US adults in a way that may inform future research and practice. For example, by using data from a large and nationally representative population-based sample, this study expands previous findings related to community mobility and experiences of disability conducted in more limited populations. Using ZINB models also expands understanding of the two interrelated outcomes of any past week walk participation and past week walk count by modeling them simultaneously. The relatively broad definition of disability used in this study draws attention to the potentially unique needs of individuals who may otherwise be considered non-disabled, but who still have challenges engaging in transportation not faced by the non-disabled population. Further, the analyses considered the interaction effects of health status and disability status, drawing attention to the need to consider these as separate but interrelated factors that influence community mobility. Finally, this study attempted to further contextualize experiences of disability and how it is associated with participation in walking in multiple levels of context by accounting for both individual-level factors (e.g., demographic covariates, self-rated health status, disability-related factors considered in RQ3) and extra-individual factors including household- (e.g., vehicle availability, income) and preliminary community- or geography-level factors (e.g., population density and availability of heavy rail.) While understanding built- and social-environment related mechanisms as contributing causes of participation in walking among PWMD and non-disabled individuals is beyond the scope of this study, findings laid a descriptive foundation for future analyses of this nature.

Overall, this study generated evidence that walking behaviors differ among PWMD and are influenced by individual- and extra-individual factors including health status and disability-specific characteristics. Increasing participation in walking among PWMD and the general population may help maintain and promote transportation mobility. In turn, health and disability status, both independently and jointly, are associated with walking behaviors. While further investigation may help clarify what specific factors may promote walking among PWMD, a key takeaway is that disability status alone is insufficient for predicting mobility patterns. This finding should inform future research and interventions aiming to promote walking. Other factors such as overall physical activity levels, vehicle ownership, gender, workers status, and a combination of disability and health are likely also useful for predicting patterns of walking participation in the overall US population. Future researchers may wish to examine how disability-related factors such as type and severity of disability, available and used supports for community mobility, and built environment factors further influence participation in walking. Additionally, researchers and practitioners attempting to provide guidance to the public related to how walking may benefit health may wish to disaggregate findings and recommendations based on disability status. Finally, the connections between both any adoption of walking and degree of participation in walking among people with and without mobility disability should be further explored in relation to overall community mobility and health. By challenging assumptions about how disability status, health, and walking patterns manifest among non-elderly US adults, findings from this study expand understanding of how an understudied population may experience community mobility.

Appendix 2-A: Model selection process for data with excessive zeroes



To confirm that the selected ZINB model generated the most accurate predictions for whether individuals in the sample adopted any weekly walking and if so, the count of weekly walks, I ran the countfit command created by Long and Freese.[88] As shown in the figure above, over the negative binomial model (NBRM) and the standard (PRM) and zero- inflated Poisson (ZIP) models, the ZINB model yielded the smallest deviations between predicted and observed values. This validates the decision to use this model in the multivariable analyses for these data.

Appendix 2-B: health-related statistics for PWMD by non-ambulatory status

Health-related descriptive statistics for People with Mobility Disabilities (PWMD) by non-ambulatory status (N=10,284)

		Likely ambulatory (n=9,755)		Likely non-ambulatory (n=529)		Total	
		n	%	n	%	n	%
Any walking in past 7 days	0 walks	3,276	33.58	359	67.86	3,635	35.35
	1+ walk	6,479	66.42	170	32.14	6,649	64.65
Self-rated health	Poor	1,745	17.89	210	39.70	1,955	19.01
	Fair	3,766	38.61	178	33.65	3,944	38.35
	Good	2,959	30.33	88	16.64	3,047	29.63
	very good	1,010	10.35	39	7.37	1,049	10.2
	excellent	275	2.82	14	2.65	289	2.81
Physical activity	30 or more minutes in past week	5,945	60.94	176	33.27	6,121	59.52
Chronicity of condition	<=6 months	733	7.51	44	8.32	777	7.56
	>6 months	7,617	78.08	391	73.91	8,008	77.87
	lifelong	1,405	14.4	94	17.77	1,499	14.58
Specific travel limitations	Limits driving to daytime	2,495	25.58	87	16.45	2,582	25.11
	Reduced use of public transportation	980	10.05	40	7.56	1,020	9.92
	Asks others for rides	4,059	41.61	227	42.91	4,286	41.68
	Given up driving	1,678	17.2	214	40.45	1,892	18.4
	Uses special transportation services (c)	823	8.44	44	8.32	867	8.43
	Uses reduced fare taxi	346	3.55	13	2.46	359	3.49
	Reduced day-to-day travel overall	7,111	72.9	368	69.57	7,479	72.72
Count of limitations reported	0	1,578	16.18	73	13.80	1,651	16.05
	1	3,793	38.88	166	31.38	3,959	38.5
	2 or more	4,384	44.94	290	54.82	4,674	45.45
Assistive device use	Cane*	3,182	32.62	157	29.68	3,339	32.47
	Wheelchair	771	7.9	87	16.45	858	8.34
	Crutch	356	3.65	29	5.48	385	3.74
	Service dog	129	1.32	2	0.38	131	1.27
	Motorized wheelchair	322	3.3	37	6.99	359	3.49
	Scooter	399	4.09	23	4.35	422	4.1
	White cane	107	1.1	4	0.76	111	1.08
	Walker	1,360	13.94	126	23.82	1,486	14.45
Count of devices	0	5,343	54.77	235	44.42	5,578	54.24
	1	2,835	29.06	161	30.43	2,996	29.13
	2 or more	1,577	16.17	133	25.14	1,199	11.66
Walk count in past 7 days	0	3,276	33.58	359	67.86	3,635	35.35
	1-2	1,340	13.74	61	11.53	1,401	13.62
	3-6	2,499	25.62	50	9.45	2,549	24.79
	7 or more	2,640	27.06	59	11.15	2,699	26.24

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Chapter 4: Aim 3 - Assessing the role of immigrant status on total walking among young Adults (18-25) in the United States

Introduction

Research across health and transportation fields has demonstrated that walking influences overall health and wellbeing at all ages and throughout the life course.[1–6] Immigrant status, health status, and socioeconomic indicators associated with both may influence walking behaviors among young adults in the United States (US.) Investigations of health disparities between and among immigrants and US-born individuals have often focused on the potential influence of acculturation processes, especially as they relate to childhood and later life health outcomes.[7–11] Yet few studies have sought to understand the connections between immigrant status and walking behaviors[12–15]; specifically, none to my knowledge have focused on adults at the transition period between childhood and young adulthood in the US at the national level.[16–18] This results in gaps in knowledge that, if addressed, would provide valuable insight for the promotion of population health. Habits established during young adulthood have known effects on later life engagement in physical activity that may help mitigate observed health disparities in chronic disease, functional disability, and mental health status among immigrants in later life.[19–21] A clearer understanding of associations between health status, immigrant status, and walking behavior could help public health practitioners generate more effective interventions to promote walking as a means of advancing health equity among a growing and economically important segment of the US population. To this end, this study uses data from the 2017 National Household Travel Study (NHTS) to address key research questions including: Do total walking patterns differ among immigrants compared to non-immigrant young adults in the United States? How might age of arrival in the US alter these patterns? And finally, what additional individual-, household-, and community-level characteristics may further influence total walking patterns among young adults? Factors examined will include health and disability status, household poverty status, personal vehicle access, and neighborhood rurality. I used descriptive statistical approaches and multivariable regression models to preliminarily address these questions. The results are intended to inform the design and implementation of programs and policies designed to increase engagement in walking among a growing population in the US, potentially advancing overall health equity.

Background

Young adult immigrants represent a substantial proportion of the US population. In 2010, an estimated 4.8 million people between the ages of 16 and 26 living in the US – approximately 1 in 11 of the entire young adult population—were born outside of the US.[22] According to American Community Survey estimates, between 2015 and 2019, approximately 22% of the population between the ages of 14-24 were either born outside the US or lived with at least one foreign-born parent.[22] Demographic trends in the US suggest that these groups, alongside those of current and future second- and third- generation immigrants will make up an increasing share of the population.[23] This has significant implications for economic and health trends and motivates this works' goal of understanding current health-relevant behaviors in service of identifying potential areas for intervention. Many health-focused studies of immigrant population groups in the US and socioeconomically comparable countries use an acculturation model to examine whether and how immigrants' health behaviors and related health statuses change throughout the life course. Through the process of acculturation, foreign-born individuals' behaviors and characteristics are thought to change over time to become more like those born in their receiving country.[24] To my knowledge, this study is the first to assess patterns in walking for combined utilitarian and leisure purposes (referred to hereafter as total walking.)[7–10,25,26]

For immigrants to the US, concretely measured factors such as duration of time in the US and English language proficiency often serve as a proxy for degree of acculturation, especially in studies not explicitly designed to measure acculturation.[7,24,27] Some research seeking to understand connections between immigrant acculturation and changes in health outcomes or risks have found that differences between immigrants and US-born individuals narrow in tandem with increased acculturation.[25,28] For example one review of studies evaluating health concerns among recently arrived immigrants found that increased time since arrival corresponded to worse access to health care and higher morbidity burden from communicable respiratory, gastrointestinal, and dermatologic conditions comparable to non-immigrants.[28] Another review of recent works studying acculturation effects among Latino immigrants to the US identified over a dozen studies providing evidence that increased acculturation predicts increased behaviors with known negative health consequences including smoking, alcohol use, and decreased consumption of low-fat foods.[25]

Other assessments of acculturation effects on health have found mixed associations. Liu, et al. found that among Hispanic adolescents, those reporting more acculturation as assessed using generational status and language spoken at home had similar obesity outcomes as their less acculturated peers, but that acculturation measures did predict lower rates of vigorous exercise.[8] Guerra et al.'s evaluation of physical activity participation in group of Latino adults found that some dimensions of acculturation including language proficiency predicted higher rates of overweight and obesity, while another measure of acculturation, including nativity and identification with American culture only predicted weight outcomes among some immigrants.[29] Mikell, Snethen, and Kelber's 2020 analysis of physical activity among adult immigrants found that low acculturation predicted lower physical activity levels, though this outcome also varied by gender and age.[30] Whether acculturation results in positive or negative overall health outcomes, especially in later adulthood remains less clear and may depend on cumulative levels of risk exposure and resource access.[19,25,31,32]

Differences in socioeconomic status at arrival and after residence in the US partially explain some health disparities between US- and foreign-born individuals, yet trends vary by immigrant subgroup and health outcome.[25,33–35] Worse health outcomes among immigrants with longer periods of US residency, and of higher generational status (e.g., second- and third-generation immigrants) compared to more recent arrivals and to US-born individuals may result from cumulative exposure to conditions that may intensify risk of chronic illness over time, such as limited participation in physical activity.[18,36] Other immigration-related factors such as stresses introduced by anti-immigrant social climate can also intensify health disparities, especially among immigrants without US citizenship.[37,38] Evidence suggests that some immigrants in these situations have worse access to and lower utilization of needed health care.[39–41] Exposure to traumatic events during immigration may affect mental and physical health of immigrants and their families, even as acculturation measures increase.[42–45] Recognizing the barriers to positive health outcomes many immigrants face, this study primarily seeks to measure if and how frequency of total walking, one behavior that can modify immigrants' immediate- and long-term health risk exposure, varies among immigrants compared to non-immigrant young adults in the

US. I will also assess how patterns vary when accounting for age of arrival to the US, a proxy measure for acculturation. Consideration of an interrelated series of individual-, household-, and community-level factors with theoretical and empirically supported links to both immigrant status and overall walking will help clarify the strength and directionality of these associations. Total walking patterns may significantly influence health and act as an immediate health outcome given the influence of walking on health through contributions to physical activity levels and transportation mobility as previously mentioned.[2,19,31,46]

Motivated by the importance of understanding whether differences in daily activity may appear in earlier life stages as a precursor to potential health disparities in later life, this study will seek to assess potential links between immigrant status and total walking. An acculturation informed framework guides the hypothesis that immigrants who arrived in the US at an earlier age may report more frequent participation in total walking compared to those with longer exposure to US context, including those born in the US. Though walking is a commonly practiced form of exercise among some groups of adults in the US, questions remain about whether younger adults regularly engage in walking, and whether they do so in a way that positively affects health, both at the individual, and population-level.[47–50] Decreased walking participation tying into less overall physical activity may encompass one pathway through which some immigrants may experience different long-term health outcomes compared to US-born counterparts.[7,19,31,33] Past studies have found that newer immigrants to the US may more frequently walk for transportation compared to those who have been in the US for longer times, even if they live in areas with limited walkability, likely due to limited access to alternative forms of transportation.[51–53] However, few studies have assessed total walking patterns—those inclusive of utilitarian and leisure or physical activity-focused walking alongside transportation walking— patterns among young adults in the US especially using national-level samples.

Among both immigrants and non-immigrants, young adulthood (defined as ages 18 to 25) represents a pivotal time in psychosocial and physical development.[54] Young adults tend to have good overall health, with those following normative life stages requiring little intervention.[55] This contributes to limited research dedicated to understanding day-to-day health patterns outside of those associated with immediate or long-term harm such as substance use, serious and persistent physical or mental health conditions, or engaging in risky sexual behavior.[56–58] Yet like these factors, engagement in walking related to active transportation or physical activity can carry forward into later adulthood to influence long-term health.[59,60] Physical activity and transportation walking represent the two most common domains examined by researchers studying walking among young adults in the US and comparable countries. The following section briefly reviews the literature relevant to young adults' walking behaviors in relation to their immigrant and health statuses.

Physical activity-focused walking

Meeting physical activity targets has a known positive effect on current and future health among adults in the United States, yet a high proportion of the population does not currently meet recommended levels of weekly physical activity.[47] Public health researchers have explored this pattern among various immigrant subgroups. Lacoste et al.'s 2020 systematic review on immigrant physical activity found that children (6-12 years of age) residing in the US and Canada born outside of these countries tend to have lower participation in group sports compared to non-immigrant children, and that obesity rates tend to increase with increased time in arrival countries.[31] US-specific studies including Singh, et al.'s 2008 analysis of data from the National Survey of Children's Health and Ross, et al.'s 2014 longitudinal analysis of the Minnesota Student Survey also found that immigrant children tend to have lower rates of physical activity compared to non-immigrants, and that rates of engagement in physical activity have fallen over time while sedentary behaviors have increased.[18,19] These studies cite challenges in knowing how overall physical activity levels among immigrant children may differ from those of non-immigrant children given difficulties including relying on parent reports of specific types of activity and recognizing heterogeneity of immigrants and immigration experiences. [18,19] At the same time, they note that disparities in physical activity in adulthood likely begin in childhood and the importance of measuring them for improving interventions to disrupt these patterns.[18,19]

Studies among adults have similar findings and arguments regarding disparities in physical activity and implications for long-term health. One California-based 2018 study found that compared to non-Latina adults in the sample, those in the ethnic minority group more frequently reported activity levels below recommended targets.[61] These disparities likely have a bidirectional influence on health; limited physical activity elevates risk for future health problems while current poor health has been associated with decreased participation in physical activity.[62] A 2012 systematic review by Gerber et al. found that a majority of the 44 studies relevant to child immigrants' physical activity levels yielded results supporting the idea that immigrant status has an independent effect on patterns in leisure time physical activity among adults in high income countries.[7] Since both utilitarian and recreational walking can contribute to total physical activity, questions remain about whether including non-exercise-specific walking was considered in these studies, how such inclusion could alter findings and how to interpret and apply these finding to promote more physical activity and better overall health.[7,63] Shi et al investigated key predictors of physical inactivity among a sample of adults living in Los Angeles County in 2004 and 2007, finding that compared to those who were born in the US, the most recent immigrants who arrived in the US within 0 and 4 years of the survey were significantly more likely to engage in physical activity.[9] This may reflect a process of gradual acculturation to US norms of limited walking. Women, those in older age groups, and Black and Asian (compared to White) individuals were also more likely to report increased physical activity.[9] Personal identity factors such as race, ethnicity, and gender reflect heterogeneity among immigrants should be accounted for and assessed in analyses seeking to understand connections between immigrant status and physical activity, including walking. This, alongside findings from other individual studies, encourage consideration of race and ethnicity in research seeking to understand how socioeconomic factors may influence physical activity levels, including those informed by walking behaviors.[7,13,33] Racial and ethnic differences tend to dissipate when models consider other socioeconomic factors such as individual or household-level poverty and educational attainment status.[33,37] This suggests that differences are not inherent to these racialized groups, but instead reflect shared exposure to structural inequities. Taken together, these studies provide evidence to suggest that immigration and characteristics associated with a family history of immigration may represent one under-explored factor that shape racial and ethnic disparities in physical activity among younger adults. Understanding connections between immigrant health and transportation-focused walking represented another area of research informing the present study.

Transportation walking

Some transportation scholars have sought to understand immigrants' mobility patterns, in part, to inform the future of transportation design and implementation in response to increasing immigrant population in the US, shifting norms in transportation use, and changes to where immigrants settle.[51,52,64,65] Some differences between immigrant and non-immigrant transportation patterns relate to population-level sociodemographic differences. For example, immigrants tend to be younger and less wealthy than non-immigrants, and these factors influence residential location, occupational trends, and related transportation mode preferences.[66,67] Immigrants make up a larger share of younger adults, who compared to older adults, walk for transportation more frequently.[68] Drivers of increased transportation walking include living in areas with adequate infrastructure to support walking for transportation or leisure, and those who do not own personal vehicle and therefore use walking as a standalone transportation mode or as a component of other modes.[69] Research demonstrates that patterns of car ownership and subsequent engagement in transportation-related physical activity among millennials commonly reflects either a lifestyle choice or a result of limited economic means.[70,71] The sample represented in the present study, born between 1990 and 1998, likely encompasses a blend of these circumstances, therefore including some who choose not to own a vehicle and some who cannot afford to do so and therefore rely on alternative means of transportation. Both groups likely participate in more transportation walking compared to those who own a personal vehicle or otherwise report having regular access to one.[72,73] In alignment with studies related to immigrants' exercise walking, Tal and Handy found that most immigrants' transportation behaviors become assimilated to resemble non-immigrants' in their settlement region within 5 years of arrival.[51] Xu's more recent analysis of repeated cross-sectional data from the American Community Survey from 1980-2010 adds evidence to support the conclusion that immigrants reduce their public transportation ridership, and thus, associated transportation walking (e.g., first-/last-mile transit involving getting to and from transportation stops and destinations,) as they reside in the US for longer.[53,74]

More directly connecting transportation and health, some transportation scholars have quantified how social factors and health factors shape active transportation behaviors, citing the need to identify how factors including, but also extending beyond infrastructure and other built environment factors, shape decisions to walk or bike.[75–77]For example, Barajas' 2019 examination of 2017 NHTS data found that consistent with past findings of immigrants' transportation use patterns, those born outside the US are more likely to receive and give rides to others using personal vehicles, less likely to drive alone, and more likely to walk and use public transportation options compared to US born counterparts with similar socioeconomic backgrounds.[78] Additionally, they determined that in US states where non-citizens can obtain drivers licenses compared to states without this option, immigrants reported modest increases in frequency of driving alone and larger increases in reporting carpooling. [78] These, alongside further findings that immigrants' decisions to more frequently engage in active transportation when they live in areas with immigrant support services and businesses friendly to immigrants, suggest that differences in social and political contexts may influence immigrants' travel mode choices.[75,79] In their 2021 study using NHTS data, Barajas and Braun found that self-rated health and proportion of those reporting any walking and cycling trips in the past week were positively correlated, though this trend did not hold for walking trips only for transportation.[79] This study framed walking as a predictor of positive health perceptions while recognizing a likely bidirectional association between health outcomes and walking. [79] Altogether these findings further encourage consideration of built environment and social factors when modeling outcomes relevant to transportation-related physical activity, including walking; these factors may include vehicle availability, driver's licensure, and health status.

As a final area of connection between immigrant transportation and physical activity, some research has focused on active transportation in relation to educational and occupational status, especially among younger individuals. Among children and adolescents, engaging in active transportation through walking to school could satisfy a significant portion of daily activity targets, but this practice has declined precipitously over the past decades in the United States and comparable countries.[80] Only an estimated 30% of those under 18 years old in the US currently meet physical activity guidelines.[81] Research into these trends attributes these changes to a mix of social and built environment factors including increasing concerns about safety, suburbanization, and reliance on personal vehicle transportation.[16,82,83] Scholars have called for further investigation into the transitional period between childhood and adulthood to understand what factors may help preserve health-promoting walking behaviors.[16,80] Limited research investigates how these factors shape walking in aggregate (compared to walking in one context, e.g., walking to school, walking for exercise,) and no studies, to my knowledge, quantifying active transportation to school specifically focused on understanding differences between immigrant and non-immigrant behaviors. This supplies additional motivation for the present study.

Methods

Alongside findings from past research, theories of immigrant acculturation and the Social Ecological Model inform the conceptual model guiding analysis of the central research questions for this study.[24,84] As illustrated in Figure 1 below, the central association to be assessed connects total walking, the focal outcome, to immigrant status, the focal predictor. I grouped together covariates representing similar overall constructs and located them within three nested contextual levels: individual, household, and community. The individual level includes constructs operationalized using data gathered for each NHTS participant, including all health indicators. These health factors consist of 1) general health status operationalized using self-rated health, 2) mobility-disability status, and 3) physical activity level. Three additional individual level factors include occupational or educational status, and the two personal identity factors of race and ethnicity and gender. I also included driver status as an individual-level transportation factor.

Within the household level, I constructed an indicator of poverty status to complete the socioeconomic status factors group, and with transportation factors, I included a ratio of household vehicles per person. The household level also includes proxy status, representing those whose responses were submitted by another household member. Among community factors, the most distal level encompassing households and individuals within those households, I included indicators of neighborhood characteristics: block-level rurality, proportion of renter-occupied housing, and census region. Dotted lines indicate likely bidirectional associations between these variables. These connections will not be assessed empirically in this study due to the limited sample size included in this subsample and study's focus on the association between immigrant status and walking outcomes, but linkages informed by literature reviewed for these analyses may guide interpretation of results. The two solid lines depicted correspond to two central research questions. Specifically, the line linking immigrant status and walking represents the first hypothesis that US and foreign-born individuals will report differences in total walking patterns. The second solid line indicates socioeconomic status as an effect modifier of the association between immigrant status and walking. It represents the hypothesis that the addition

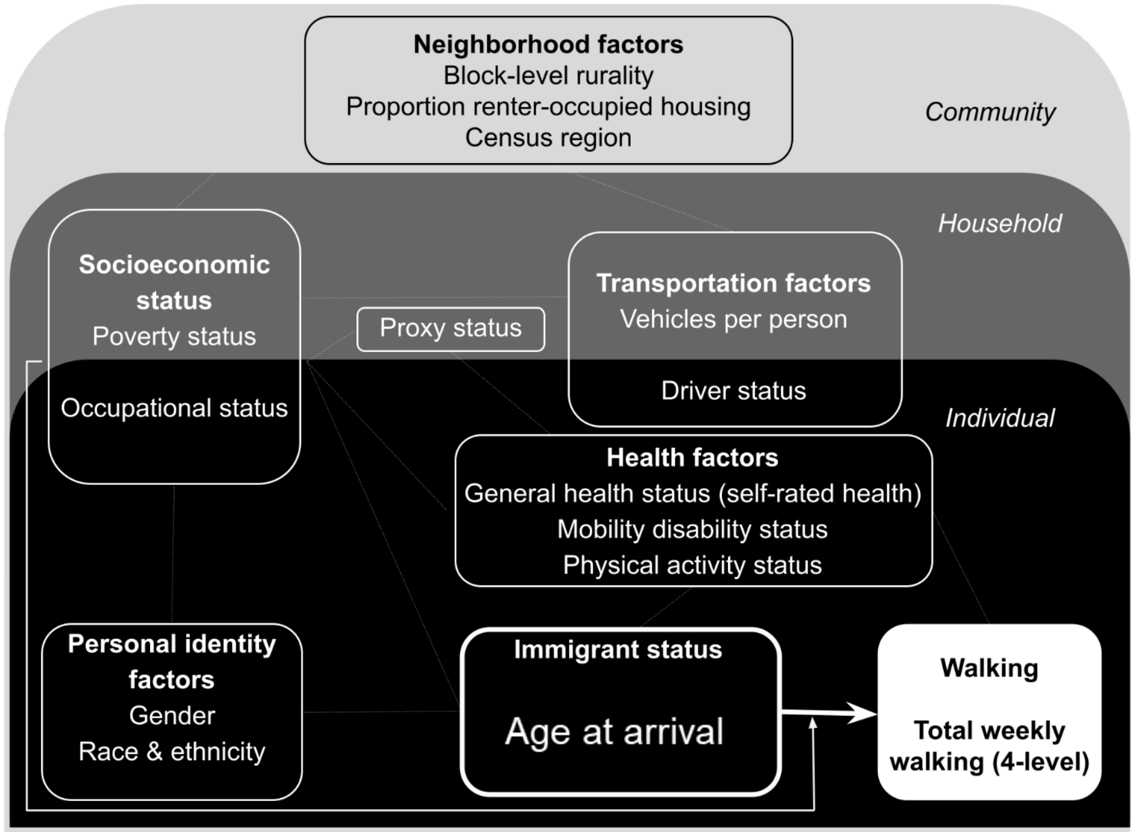


Figure 3-1: Conceptual model, Aim 3

of socioeconomic indicators, which collectively link to the additional groupings of variables (i.e., personal identity, transportation factors, health factors, neighborhood factors,) that may alter the focal association. The following section provides more information related to the inclusion of selected indicators, and hypotheses connecting all covariates to central research questions.

Key outcome: total weekly walking frequency

The key outcome for these analyses is total walking as reported by NHTS participants during the week prior to completing the survey. All NHTS participants, or proxies representing household members unable to complete the questionnaire, were asked to report how often they walked in the past seven days. Specifically, they responded with an integer ranging from 0-99 in response to the question "[i]n the past 7 days, how many times did you take a walk outside, including walks to exercise, go somewhere, or to walk the dog (e.g., walk to a friend's house, walk around the neighborhood, walk to the store, etc.)?"[85] The examples provided by NHTS do not constrain walking to a specific category of recreational or utilitarian walking, nor do they require a specified minimum duration nor distance to count as a walk. Thus, I interpret responses as a proxy for all types of walking and operationalized this variable categorically to reflect different frequencies of total. I anticipate that generating these categories will provide a buffer for the likely imprecision and inaccuracies introduced through self-report and recall biases, which may especially affect reporting among younger individuals, such as those included in this sample.[86] Compared to patterns in walking observed in previous analyses of this data, I expected to see a high proportion of younger adults reporting at least one walk in the past week. This likely relates to younger participants' lower levels of functional disability and likelihood of more incidental walking among students and those in more physically intensive careers who skew younger and in better physical health and older adults.[87,88]

Key predictor: Age at time of arrival in the US

I used participants' age of arrival in the US as a proxy for degree of acculturation, my key predictor of walking outcomes. All NHTS 2017 participants were asked if "[they were] born in the United States?" As a follow-up, all individuals who indicated that they were foreign-born were asked to report the year in which they arrived in the United States. The NHTS instrument, in both web and phone forms then asked participants to confirm their age of arrival, although this was not reported in the NHTS public use files.[85] Instead, I used participants' age and year of arrival to calculate their age upon arrival. I then grouped individuals into five levels: US born, those who arrived in the US at or below the age of 5, those who arrived between the ages of 6 and 12, 13 and 17, and 18 or older. I used these groupings to represent key developmental periods throughout childhood and into emerging adulthood. The relatively narrow age inclusion criteria for this study informed my decision to exclude age, given that aside from likelihood of predicting student status, which is accounted for in another covariate, informed my decision to not include age itself as a covariate. The immigration status variable reflects physiological changes and social changes in norms around school attendance (i.e., not yet attending school, attending elementary, middle, high school, and college) in the age groupings described by the immigration status variable, in parallel with the groupings included in the occupational status variable. These stages also parallel commonly used 5-year interval groupings of elapsed time since arrival in the US used by acculturation researchers.[9,27,30]To mirror their findings, I hypothesized that individuals who arrived in the US as younger children would have walking patterns most like US born younger adults, and that those with less time in the US would have the highest dissimilarity.

While I hypothesized that I would see some differences between walking frequency levels by time in the US, given the inclusion of all types of walking in the total measure, I did not hypothesize a directional association (e.g., more frequent total compared to US-born adults corresponding to increased age of arrival in the US.) Some acculturation focused studies have found that immigrants decrease their initially higher levels of physical activity such that their exercise-specific activity levels become more sedentary (and thus, more like most US-born adults,) while others have found that activity levels increase among younger immigrants with increasing levels of acculturation.[7,19,21]Additionally, among all young adults, leisure time activity levels tend to decrease as working hours increase, although commuting-related transportation activity may offset declines for some.[73,81,89] How these patterns change among immigrants when accounting for both leisure- and utilitarian walking levels remains unclear. Patterns may also vary within immigrant groups in alignment with age of arrival because those ages may correspond with reasons for immigration. For example, those who arrived in the US at older ages may more often represent individuals who immigrated for work or educational opportunities, whereas those who arrived at younger ages may have accompanied parents seeking similar opportunities. These motivations may influence total walking patterns through pathways such as influencing residential location, student status, health and/or perception of health status, and poverty levels. I account for some of these factors in remaining covariates.

Covariates: socioeconomic status indicators

Socioeconomic factors commonly drive immigration to the United States and studies have identified links between higher socioeconomic status and more engagement in physical activity, including walking, among immigrant populations in the US.[3,15,61] However, patterns related to total walking may exhibit more nuance than simply higher socioeconomic status predicting higher walking frequency due to the inclusion of both incidental and utilitarian instances of walking. For example, individuals with lower incomes who lack access to personal vehicles may report more utilitarian walking, but less leisure time walking compared to those with higher incomes, a finding consistent with past studies looking at overall walking among adults represented in samples other than the 2017 NHTS.[13,90,91] I hypothesized that socioeconomic indicators would alter the association between immigrant status and total frequency. I constructed two primary indicators of socioeconomic status to include in models testing this hypothesis.

I grouped participants into one of four categories based on their employment and student status based on three interrelated NHTS questions. Specifically, I grouped individuals who reported working or a temporary absence from work as their primary activity in the past week into the “worker” category. A follow-up NHTS survey item inquired whether all participants who reported not working participated in any work for pay in the past week. I grouped together those who indicated student status and work for pay in the past week as “working students,” students who did not work for pay as “students,” and others who reported receiving paid work as “workers.” Those who reported being unemployed without pay in the past week were grouped together as “unemployed,” and all others were categorized as “other,” if they did not receive pay in the past week. I hypothesized that these groups would demonstrate different total patterns since evidence supports different patterns in active transportation use and physical activity by occupational status and educational attainment.[3,17] I choose this indicator of occupational status rather than educational attainment for this group given the high likelihood that participants in this sample, especially among reporting the youngest ages, would not yet have achieved their final level of educational attainment given norms around completion of high school and college degrees during this age window in the US. I hypothesized that student and occupational statuses would be significantly associated with different levels of walking given past studies' findings showing these correlations, including within the entire NHTS sample.[17,85]

The NHTS question measuring income at the household level informed my second socioeconomic indicator. To generate a binary poverty status indicator, I combined this self-reported data collected at the household level with self-reported household size data, and federal guidelines for 2017 poverty levels (FPL.)[92] I used these data to calculate whether NHTS participants belonged to households with annual incomes above or below the FPL in a similar manner as other studies that focused on similar immigrant populations, especially among younger populations who may more frequently rely on forms of public assistance, eligibility for which may depend on FPL guidelines.[93]

Covariates: social identity factors

While few studies related to walking or other physical activity engagement conducted by public health scholars collect detailed information related to household- and community-level characteristics that may affect total, all population-level studies I reviewed collected individual-level social identity information. This informed my decision to include gender, race and ethnicity, and individual-level health and mobility factors in these analyses. I hypothesized that I would see variation in total walking by gender and race and ethnicity based on prior evidence in the literature demonstrating different patterns in physical activity by these factors.[29,30] For example, in an analysis comparing rates of engagement in various behaviors associated with positive future health outcomes among adolescents in California, Allen et al., found that Latino adolescents participated in less physical activity over time compared to White adolescents.[94] Further, they found that among those living in Asian and Latino immigrant families, first generation immigrants (i.e., those born outside the US) reported more physical activity than those of second and third generations (i.e., those born in the US to immigrant parents or grandparents). [94] In their examination of National Health Interview Survey data, Paul, et al. found that prevalence of any walking for transportation and any walking for leisure different by gender and racial and ethnic categorization.[90]

With respect to health status indicators, factors including self-rated health, functional limitations, and overall participation in physical activity, have all shown significant associations with respect to immigrant status and walking behaviors.[95–97] I hypothesized that higher activity levels would predict higher total walking. Although few studies included measures of disability when assessing walking patterns, especially among younger adults, I hypothesized that those reporting mobility disabilities in the analytic sample per the NHTS question asking whether participants "have any condition or handicap that make it difficult to travel outside the home," would report lower levels of total walking. Evidence for potential challenges engaging in exercise and non-driving transportation modes among adults with disabilities in the NHTS sample in past studies informed this hypothesis.[96] Although disability and physical activity levels link to general health status in US adult populations, the limited variation in young adults' self-rated health informed my decision to group together most young adults who reported having excellent or very good health, and the minority who reported having good, fair, or poor health. I hypothesized that self-rated health operationalized in this way would exhibit weak, if any, correlation with total walking.

Covariates: transportation mobility indicators

As I note in the literature review, individual ownership of or access to a personal vehicle represents one of the strongest predictors of reduced transportation-related walking among adults in the US.[15,27,72] Thus, I hypothesized that my two proxies for the construct of personal vehicle access – drivers' licensure at the individual level, and ratio of vehicles to household members—would predict total walking outcomes. The strength of this association could vary for many reasons. First, in accordance with findings from past literature on transportation patterns in emerging adulthood and across different generational cohorts, this specific subpopulation could occupy a range of life stages and a correspondingly wide range of need and access to cars and drivers' licenses. For example, a high school or college student living near the school they attend full time may find car ownership and drivers licensure less important than someone with a longer commute to work or school. The practicality of car ownership and driver's licensure also varies with community-level factors such as affordability of parking and access to alternatives to driving, and further, is not necessarily predictive of non-transportation walking. Some studies suggest that individuals who can afford vehicle ownership may still experience time poverty that prevents leisure-time physical activity due to the time demands of working, commuting, or other obligations.[13,73]

Covariates: additional factors – individual-, household-, and community-level

In contrast with public health studies focused on family or household and some community-level factors, transportation-focused studies have more often included indicators of household-level and community-level mobility and built environment when considering how immigrants and non-immigrants engage in walking. Guided by these findings, I constructed indicators for a handful of additional covariates which primarily describe extra-individual factors that relate to both immigrant status and total walking in this study. These include block level rurality, which describes urbanicity at the block group level for participants' home address. I hypothesized that more urban environments would correlate with higher total walking. This aligns with findings showing that those living in more densely urbanized areas tend to report more frequent transportation walking. For example, an analysis of all adult participants in the 2017 NHTS found that over 20% of all trips reported by urban residents involved walking while those living in rural areas reported walking on 13.6% of trips.[68] As a second indicator or population density, I created a measure of proportion of renter-occupied housing at the block group level and grouped together those living in areas where 45% or more and 55% or less of housing is occupied by those who rent their homes. These groups represent the upper and lower half of the distribution of proportion of renter occupied residences in the analytic sample. To reflect another component of regional variation, I included a census region indicator specifying whether individuals live in the South, Northeast, Midwest, or West portions of the US as dictated by the US Census Bureau.[98] Although these measures group together potentially disparate states and regions within states, prior studies have found variation in walking patterns among NHTS participants by these regions.[47,99] I hypothesized that proportion of renter-occupied housing and census region would predict different total patterns but did not specify a direction given limited evidence for how these broader indicators of geography might affect health and transportation behaviors among this population.

Whether a proxy respondent generated NHTS participant's data reflects the final covariate included. I contextualized it within the household level since proxy responses were supplied by a household member. Previous research examining differences between proxy and non-proxy responses in trip diary data from household travel surveys across groups from different geographic locations in the US found that women under 55 had the largest discrepancies with proxies likely underreporting trip counts, especially among households with students.[86] Thus, I hypothesized that individuals with proxy responses would have a lower total and recognize this as a limitation of the data.

Data - 2017 National Household Travel Survey

Data for these analyses come from the 2017 National Household Travel Survey (NHTS), a population-based survey assessing travel behaviors among US residents comprising of a household-level recruitment survey and an individual-level retrieval survey with a travel diary component. I have provided additional details relating to methods employed to gather and refine NHTS data in previous chapters. Since this analysis focuses on young adults, I used a subsample of the NHTS data and did not apply the provided weights, which reflect characteristics of the total US population and are intended for use with the full sample.[100]

Analytic plan

As a first step to addressing the central research questions, I examined univariate distribution of key predictor and outcome variables and potential covariates, confirming that operationalizations would suit planned analyses. I next quantified bivariate associations between key predictor and each covariate, and between covariates, preliminarily testing hypotheses using chi-square analyses. I further tested for collinearity between interrelated covariates (e.g., age of arrival in the US, age, and occupational status). The results helped me develop a strategy for model-building guided by the theoretical and empirical evidence synthesized in this section.

Finally, I fit a series of nested regression models to first estimate how age of arrival in the US predicted frequency of engaging in total walking, and then to assess how this association varied when I included nested groupings of covariates. The following section describes the outcomes of these protocols, presents the best fitting models, and offers preliminary results of sensitivity analyses. I used Stata software to complete all analyses.

Results

Analytic Sample

To generate an analytic sample, I assessed the 2017 NHTS public use file sample and restricted inclusion to those with complete data which resulted in a final analytic sample size of 15,205 individuals aged 18-25. Of the full NHTS sample that met age-specific inclusion criteria, I excluded less than 3% of participants due to missing data. Most participants with missing data lacked responses to the NHTS question related to annual household income; Appendix 3-A shows further details regarding the sample construction.

Within the analytic sample, demographics appear to somewhat represent the US population. For example, the sample was roughly evenly split between male and female genders (48.83% male, 51.17% female) and approximately 35.43% of the sample reported falling into a race and ethnicity category other than non-Hispanic White. The mean age was 21.62 years, and approximately one quarter of households reported incomes below the federal poverty line. In other ways, the sample may not reflect the population of the US within this age category. For example, over 44% of participants live in the South US Census region and less than 15% in the Midwest compared to 38.1% and 20.8% of the total US population living in these regions, respectively.[105] Total columns of Table 1 illustrate further detail regarding overall sample characteristics. Within the analytic sample, 7.64% were born outside of the US. Among these immigrants, approximately 25.5% reported being Hispanic or Latino; 37.3% were non-Hispanic Asian only, 23.8% were non-Hispanic White only, and the remaining roughly 13% identified as non-Hispanic Black or African America, non-Hispanic Native American, non-Hispanic Pacific Islander, or multiracial. Over 70% of the sample reported having some form of employment and nearly one in three reported being a student (28.33%.)

Descriptive analyses

To preliminarily assess patterns of walking among the analytic sample, I studied the distributions of key variables and determined the most suitable operationalizations for planned analyses. As shown in Table 1, I generated categorical variables to described weekly walking. Among participants in the analytic sample, 69.52% reported taking 1 or more walks in the past week; the median walk count was 3 and mean walk count was 5.18, reflecting a right skewed distribution of walk counts, as shown in Appendix 3-B. The distribution of walks showed peaks at intervals suggesting some rounding or reporting of numbers consistent with a specific count of walks per day (5, 7, 14, 15, 20, 21, etc.,) supporting my decision to treat this self-reported data with some degree of caution, interpreting responses as general indicators of total walking in an average week rather than exact count of walking in the past 7 days. This also simplifies intergroup comparison and interpretation of results. Informed by past categorizations of walkers into groups (see Aim 2,) I divided participants into three groups; non-walkers (0 walks reported,) low total walking (those reporting 1 or 2 walks in the past 7 days), medium total walking (those reporting between 3 and 6 walks in the past 7 days) and high total walks for those reporting 7 or

Table 3-1: Sample characteristics by total weekly walking frequency, 2017 NHTS Young adults 18-25 (N=15,205)

	Walk count in past week	None		Low (1-2)		Med. (3-6)		High (7+)		Total		Chi2
		No.	%	No.	%	No.	%	No.	%	No.	%	P-value
Age of arrival in US	US-born	4302	30.63	1965	13.99	3940	28.06	3836	27.32	14043	100	10.037
	<=5	101	24.94	60	14.81	125	30.86	119	29.38	405	100	0.613
	6-12	87	32.71	36	13.53	68	25.56	75	28.2	266	100	
	13-17	58	27.62	26	12.38	62	29.52	64	30.48	210	100	
	18-25	86	30.6	35	12.46	77	27.4	83	29.54	281	100	
Race/ethnicity	Black/AfAm, non-Hispanic	413	30.75	157	11.69	337	25.09	436	32.46	1343	100	86.538
	White, non-Hispanic	2902	29.56	1405	14.31	2775	28.26	2736	27.87	9818	100	0
	White, Hispanic	510	36.07	209	14.78	400	28.29	295	20.86	1414	100	
	Hispanic/Latino, non-White	280	33.21	109	12.93	254	30.13	200	23.72	843	100	
	Asian	292	32.27	114	12.6	252	27.85	247	27.29	905	100	
	Native/PI	49	25.65	18	9.42	64	33.51	60	31.41	191	100	
	Multi-racial/other	188	27.21	110	15.92	190	27.5	203	29.38	691	100	
Gender	male	2474	33.32	928	12.5	1984	26.72	2038	27.45	7424	100	70.353
	female	2160	27.76	1194	15.35	2288	29.4	2139	27.49	7781	100	0
Working/student status	Working	2617	31.53	1283	15.46	2296	27.66	2105	25.36	8301	100	112.73
	Student	706	26.17	315	11.68	780	28.91	897	33.25	2698	100	0
	Working student	497	30.87	180	11.18	443	27.52	490	30.43	1610	100	
	Unemployed	336	29.73	143	12.65	333	29.47	318	28.14	1130	100	
	Other	478	32.61	201	13.71	420	28.65	367	25.03	1466	100	
Driver status	Non-driver	585	25.66	254	11.14	660	28.95	781	34.25	2280	100	81.289
	Driver	4049	31.33	1868	14.45	3612	27.95	3396	26.27	12925	100	0
Self-rated health	poor-good	1111	35.55	475	15.2	796	25.47	743	23.78	3125	100	66.796
	v.good-excellent	3523	29.16	1647	13.63	3476	28.77	3434	28.43	12080	100	0
Disability status	Non-mobility-disabled	4432	30.21	2041	13.91	4135	28.18	4064	27.7	14672	100	19.624
	Mobility-disabled	202	37.9	81	15.2	137	25.7	113	21.2	533	100	0
Proxy responses	no	3032	28.94	1530	14.6	2956	28.22	2958	28.24	10476	100	43.531
	yes	1602	33.88	592	12.52	1316	27.83	1219	25.78	4729	100	0
Poverty level	below fed. pov. lvl	965	27.14	445	12.52	946	26.61	1199	33.73	3555	100	93.525
	above fed. pov. lvl.	3669	31.49	1677	14.39	3326	28.55	2978	25.56	11650	100	0
Home owenership	Rent or another arrangement	1382	23.48	792	13.46	1684	28.61	2028	34.45	5886	100	328.113
	Own home	3252	34.9	1330	14.27	2588	27.78	2147	23.04	9317	100	0
Household vehicle count	0 veh. HH	46	8.35	36	6.53	147	26.68	322	58.44	551	100	329.388
	Fewer than 1 veh. pc	2018	32.14	821	13.08	1749	27.85	1691	26.93	6279	100	0
	1+ veh/person	2570	30.69	1265	15.1	2376	28.37	2164	25.84	8375	100	
Block rurality	rural	934	32.62	397	13.87	725	25.32	807	28.19	2863	100	128.232
	small town	1086	33	492	14.95	933	28.35	780	23.7	3291	100	0
	suburban	1080	31.18	524	15.13	992	28.64	868	25.06	3464	100	
	second city	1015	28.59	485	13.66	1038	29.24	1012	28.51	3550	100	
	urban	519	25.48	224	11	584	28.67	710	34.86	2037	100	
% renter-occupied housing	<45%	4092	33.28	1756	14.28	3436	27.94	3012	24.5	12296	100	378.125
	45%+	542	18.63	366	12.58	836	28.74	1165	40.05	2909	100	0
Census region	Northeast	694	28.05	291	11.76	669	27.04	820	33.14	2474	100	71.956
	Midwest	693	31.37	354	16.03	607	27.48	555	25.12	2209	100	0
	South	2101	31.32	933	13.91	1838	27.4	1836	27.37	6708	100	
	West	1146	30.05	544	14.26	1158	30.36	966	25.33	3814	100	

more walks in the past 7 days. These groups also reflect quartiles of walking frequency in the analytic sample.

Initial tests of my first research question asking whether US young adult immigrants and non-immigrants would exhibit differences in total patterns included other analyses to understand associations between the focal predictor and outcome variables. Simplified preliminary analyses used binary immigrant status (0=US born, 1= foreign-born,) and binary engagement in any walking in the past week (0= no total reported, 1= 1+ total reported). Upon initial inspection, there did not seem to be clear discrepancies in walking participation by immigrant status. A majority – approximately 70% – of both US-born and foreign-born young adults in this sample reported walking at least once in the past week. In terms of mean count of past week total walking among young adults, the mean was 5.18 for US-born individuals (95% CI 5.05-5.53) and 5.28 for foreign-born young adults (CI 4.87-5.69) Similarly, comparing those reporting at least one walk in the past week, the mean number of walks for non-immigrants was 7.40 (95% CI 6.89-7.89,) and 7.46 for (CI 7.31-7.62) for US born individuals. I found a similar lack of support for the hypothesis that total walking patterns would vary by age of arrival in the US, which corresponded to my second research question related to the potential role of acculturation. Figure 2 illustrates this. The most notable differences seem to be between US-born individuals and those who arrived in the US before the age of 5, who had the lowest proportion of individuals reporting no walking (24.94%) in the past week. A test of bivariate association did not yield statistically significant results, however. Overall, these results suggested that if differences between immigrant and non-immigrant walking trends were present in this sample, underlying population differences, such as socioeconomic status, might obscure them. The

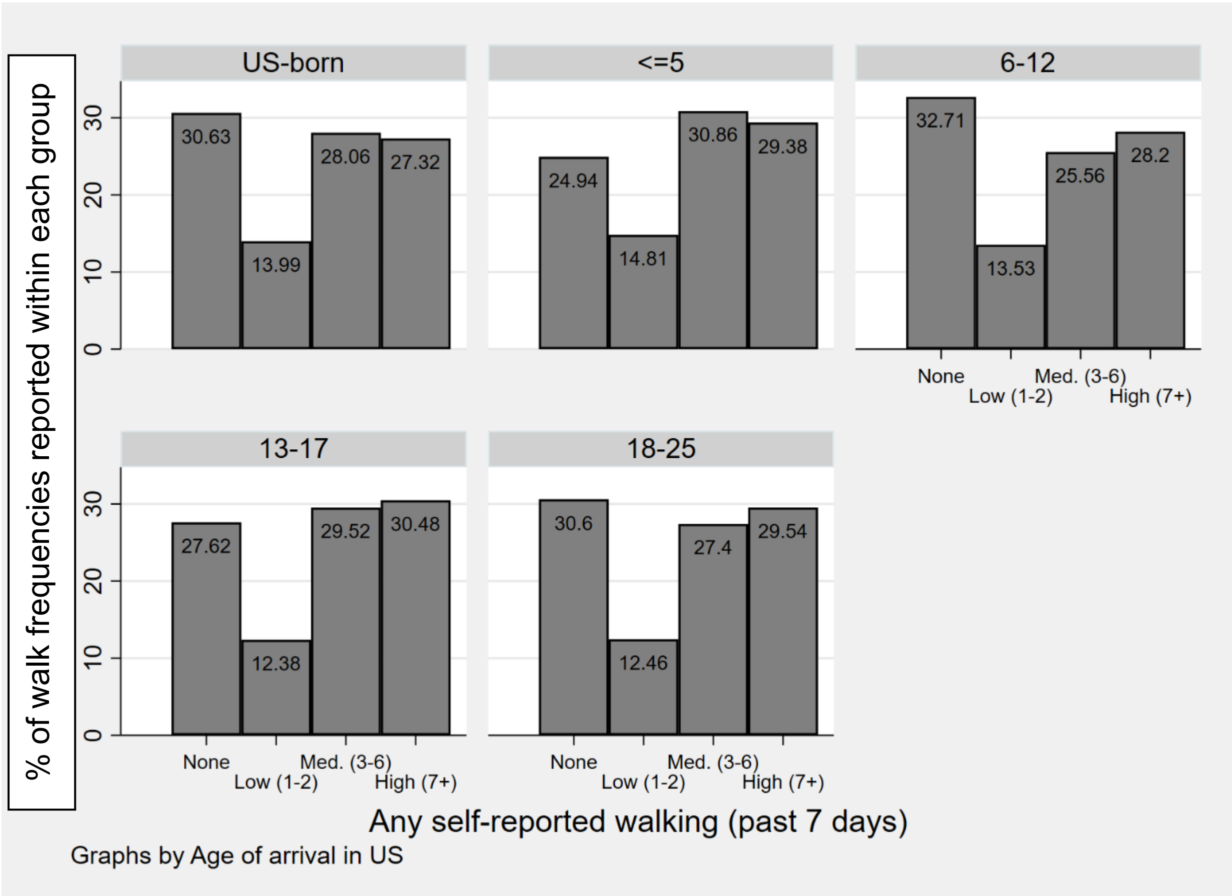


Figure 3-2: Distribution of total walking among US-born young adults and among immigrants (by age of arrival in the US), 2017 NHTS (N=15,205)

general distribution of total walking, along with trends including statistically significant differences in total walking patterns by all other covariates and the univariate distribution of walk counts informed the next analytic steps.

Multivariable modeling results

Consolidation of weekly walk counts into ordered categories informed the decision to fit a series of nested ordered logistic regression models to test all remaining hypotheses. In specifying each model, I used robust standard error calculations to help account for clustering in the sample.[96] Table 3-2 presents the models and covariates contained within each. To guide selection of the best fitting model, I used the Stata function linktest to confirm correct model specification and assessed overall model fit using information criteria (Akaike and Bayesian, AIC and BIC, presented at the bottom of Table 3-2) and tests for collinearity between variables included.[106] Ultimately, model 5, which included the individual-, household-, and community level indicators described in the methods section provided the best fitting estimates. With respect to the first research question about whether young adults born outside of the US have distinctive total walking patterns compared to those born in the US, multivariable modeling results affirm the hypothesis of an immigration-status related difference. Specifically, in the best fitting model which includes all covariates, those who arrived in the US before the age of 5 had 1.36 times the adjusted odds of those born within the US of walking at a higher frequency in the past week (95% OR 1.15-1.62). This difference shifted as I considered additional covariates in adjusted models. As I included more covariates, and thus, represented more fully the context in which walking may occur, the role of age of arrival among immigrants seemingly intensified. With respect to occupational status, model results corroborate the hypothesis that students, including working students who engaged in paid work in the past week, report more walking compared to those who reported their primary activity as working exclusively. Personal identity factors of race, ethnicity and gender also predicted different trends in total walking, with women having higher odds of walking compared to men, and those identifying as White and non-Hispanic having higher total frequencies than non-Hispanic/Latino Black individuals. Conversely, individuals who identified as Latino or Hispanic, whether White or non-White, had lower odds of reporting higher total walking compared to their Black counterparts in the fully adjusted model.

Some health and mobility factors seemingly influence total weekly walking patterns among US young adults. Those with higher overall activity levels tended to report higher total walking. Those who reported at least some vigorous and some low to moderate intensity activity in the past week reported having 5.35 and 3.27 times the odds of higher total walking (?) compared to inactive young adults, respectively (95% OR 4.82-5.93, 2.99-3.59.) Those who reported having mobility disabilities had reduced odds of falling into higher total walking frequency categories compared to non-disabled individuals. However, those who reported being in poor, fair, or good health did not report statistically significantly different levels of total walking compared to those with excellent or very good health. Having a driver's license, the final individual-level characteristic in the best fitting model, predicted reporting less frequent total walking compared to those not having a driver's license in the fully adjusted model. The household level factor of higher vehicle to person ratio predicted less total walking; odds ratios among those living in households with 1 vehicle shared among multiple household members and with more than 1 vehicle per person had nearly identical odds ratio about 0.30 times the odds of those living in zero-car households.

With respect to the remaining household- and community-level factors, having proxy responses, household poverty level, and indicators of community characteristics all yielded significant odds ratios. Specifically, individuals with proxies responding on their behalf had significantly lower odds of reporting higher weekly total walking compared to those who submitted their own responses. Living in a household with income below the federal poverty line also predicted decreased odds of higher total walking, as did living in a small town, compared to living in a rural area. Differences between rural, suburban, and second cities were not significant. The fully adjusted model indicated statistically significant differences by census region in predicting total walking, with those living in the Northeast region reporting the highest odds of falling into a higher category of total frequency compared to those living in the remaining three regions. The next section describes preliminary efforts to confirm the accuracy of these results and aid in their interpretation.

Table 3-2: Ordered logistic regression models for weekly walking frequency, NHTS 2017 18-25 year olds (N=15,205)

			1: Immigrant status only		2: + indiv. identity factors		3: + health & mobility factors		4: + household factors		5: + community factors	
Individual level	Age at time of arrival in US	US-born	Ref		Ref		Ref		Ref		Ref	
		<=5	1.20*	[1.01,1.42]	1.31**	[1.10,1.55]	1.38***	[1.16,1.63]	1.38***	[1.17,1.64]	1.36***	[1.15,1.62]
		6-12	0.96	[0.77,1.21]	1.04	[0.83,1.32]	1.11	[0.88,1.40]	1.1	[0.87,1.39]	1.1	[0.87,1.39]
		13-17	1.18	[0.92,1.51]	1.23	[0.95,1.58]	1.36*	[1.04,1.76]	1.31*	[1.01,1.71]	1.27	[0.98,1.64]
		18-25	1.06	[0.85,1.33]	1.16	[0.92,1.46]	1.09	[0.86,1.37]	0.89	[0.70,1.13]	0.85	[0.67,1.08]
	Occupational status	Working			Ref		Ref		Ref		Ref	
		Student			1.45***	[1.34,1.57]	1.40***	[1.29,1.52]	1.40***	[1.29,1.53]	1.44***	[1.33,1.57]
		Working student			1.19***	[1.08,1.32]	1.18**	[1.07,1.31]	1.18**	[1.06,1.30]	1.21***	[1.09,1.33]
		Unemployed			1.18**	[1.05,1.32]	1.25***	[1.12,1.41]	1.20**	[1.07,1.35]	1.22***	[1.09,1.38]
		Other			0.99	[0.89,1.09]	1.01	[0.91,1.13]	1	[0.89,1.11]	1.03	[0.93,1.15]
	Race/ethnicity	Black, non-Hispanic/Latino			Ref		Ref		Ref		Ref	
		White, non-Hispanic/Latino			0.92	[0.82,1.03]	0.94	[0.84,1.06]	1.07	[0.95,1.20]	1.13*	[1.00,1.27]
		White, Hispanic/Latino			0.66***	[0.57,0.76]	0.71***	[0.62,0.82]	0.79**	[0.69,0.92]	0.80**	[0.69,0.93]
		Hispanic/Latino (any non-White race)			0.77**	[0.66,0.91]	0.77**	[0.65,0.90]	0.81*	[0.69,0.95]	0.80*	[0.68,0.95]
		Asian			0.75***	[0.63,0.89]	0.81*	[0.68,0.96]	0.88	[0.74,1.04]	0.87	[0.73,1.04]
		American Indian/Alaska Native/Pacifc Islander			1.18	[0.90,1.55]	1.19	[0.90,1.56]	1.24	[0.94,1.64]	1.31	[0.99,1.73]
		Multi-racial/other			0.97	[0.82,1.15]	0.98	[0.83,1.17]	1.08	[0.90,1.28]	1.11	[0.93,1.32]
	Gender	Female			1.13***	[1.07,1.20]	1.25***	[1.18,1.33]	1.25***	[1.18,1.32]	1.23***	[1.16,1.31]
	Proxy	proxy responses			0.85***	[0.80,0.91]	0.82***	[0.77,0.87]	0.83***	[0.78,0.89]	0.86***	[0.80,0.92]
	Disability status	Mobility disabled					0.69***	[0.58,0.83]	0.73***	[0.62,0.88]	0.75**	[0.63,0.90]
	Self-rated health	Self-rated health					1	[0.93,1.09]	1.06	[0.98,1.15]	1.07	[0.99,1.16]
	Weekly physical activity level	None, or rarely engages in exercise					Ref		Ref		Ref	
		Some light-moderate exercise					3.31***	[3.02,3.63]	3.28***	[2.99,3.59]	3.27***	[2.99,3.59]
		At least some vigorous activity					5.35***	[4.82,5.94]	5.34***	[4.82,5.92]	5.35***	[4.82,5.93]
	Driver status	Licensed driver					0.54***	[0.50,0.60]	0.68***	[0.61,0.75]	0.70***	[0.63,0.77]
Household level	Household poverty status	Annual household income below federal poverty line							0.78***	[0.72,0.84]	0.83***	[0.77,0.90]
	Household vehicle availability	0 vehicle household							Ref		Ref	
		Fewer than 1 veh. pc							0.28***	[0.23,0.34]	0.32***	[0.27,0.39]
		1+ veh/person							0.28***	[0.23,0.33]	0.32***	[0.27,0.39]
Community level		45% or more homes in block group renter-occupied									1.37***	[1.28,1.47]
	Block-level rurality	rural									Ref	
		small town									0.84***	[0.77,0.93]
		suburban									0.92	[0.83,1.01]
		second city									0.96	[0.87,1.06]
		urban									1.18**	[1.04,1.33]
	Census region	Northeast									Ref	
		Midwest									0.80***	[0.72,0.90]
		South									0.90*	[0.82,0.98]
		West									0.85**	[0.77,0.94]
		cut1	0.44***	[0.43,0.46]	0.43***	[0.38,0.49]	0.84*	[0.71,0.99]	0.27***	[0.22,0.34]	0.36***	[0.28,0.45]
		cut2	0.81***	[0.78,0.83]	0.80***	[0.71,0.90]	1.61***	[1.37,1.90]	0.53***	[0.42,0.66]	0.69**	[0.54,0.88]
		cut3	2.66***	[2.57,2.76]	2.66***	[2.36,2.99]	5.79***	[4.90,6.84]	1.93***	[1.55,2.41]	2.56***	[2.01,3.27]
		Observations	15205		15205		15205		15205		15205	
		aic	41018.33		40850.62		39552.51		39278.69		39124.52	
		bic	41071.74		40995.58		39735.62		39484.68		39391.54	

* p<0.05, ** p<0.01, ***p<0.001

Sensitivity analyses

Although guided by theory and empirical considerations, specification of the ordered logistic regression above still merited additional scrutiny in relation to inclusion of focal variables and covariates, and appropriateness of the model. Collinearity and challenges in practical interpretation of results of certain variables encompassed two interrelated concerns. These variables included occupational status and arrival in the US, which both exhibit theoretical ties to age in years. This informed my decision to exclude age in years from the model alongside occupational status and age at arrival in the US. I ran variance inflation factor (VIF) tests for collinearity for the best fitting model described in the previous section, and for additional combinations of variables including the model as specified with the addition of age as a quasi-continuous variable (i.e., in integer years between 18 and 25.) In analyses where I included age alongside occupational status and age at arrival in the US for immigrants, all variance inflation factors were below 1.4. I generated an alternative version of Model 5, including both age and age of arrival. In these results, only immigrants who reported arriving in the US before the age of 5 exhibited statistically significant differences in higher total frequency odds compared to those born in the US (not shown.) The age covariate yielded a statistically significant odds ratio, indicating a small age effect, wherein each additional year results in 1.05 times greater odds of falling into the next highest walk category. This corroborates that I correctly specified these models, using appropriate operationalizations to begin to address the research questions as planned, *Appendix 3-C* shows the results of a stratified analysis restricted to only those participants who responded to NHTS for themselves rather than through a proxy. As with the original sample, in this subsample, the model containing all covariates provided the best fit to the data according to AIC and BIC. Magnitude of associations change somewhat slightly for household and community level variables, strengthening the evidence for validity of observed associations.

Larger differences, shown by changes in significance levels indicate slight mismatch between the populations with and without proxy responses included. For example, in the models without proxy responses, the South census region no longer predicted statistically significantly lower odds of higher total walking frequency compared to the Northeast region in the original sample. Belonging to American Indian, Alaska Native, and Pacific Islander groups significant predicts higher odds of walking compared to non-Hispanic Black group membership in the proxy model while the lower odds among those of Hispanic identity of any race compared to non-Hispanic Blacks are no longer statistically significant. Additionally, while students still reported having higher odds of higher total frequency compared to workers, unemployed individuals no longer fall into that category with statistical significance. Most notably, in the best fitting model without proxy responses, age of arrival between 13 and 17 remains statistically significantly predictive of higher odds of higher total walking compared to US-born groups. As with the original modeling results, these results may have some actionable public health implications, but ultimately point to the need for more interrogation of these patterns. The next section delves into analyses of all results, contextualizing them within the literature reviewed and proposing next steps for research and application of walking patterns among immigrant and US-born young adults.

Discussion

In response to the first research question, these results support the hypothesis that total weekly walking patterns differ when comparing US-born young adults to immigrant young adults born outside of the US. In bivariate analyses, differences between US-born and immigrant young adults did not exhibit statistical significance. However, multivariable analyses motivated by the knowledge that factors with known associations to exercise and transportation walking outcomes such as gender, socioeconomic status, overall activity levels, and vehicle access likely masked true associations. Additional bivariate tests of association as presented in Table 1 confirmed that all other covariates included in multivariable models yielded differences with respect to proportion of sample participants' weekly total walking patterns. Results of my simplest ordered logistic regression model, which used only age of arrival in the US to predict frequency of total walking, provided the first instance of support that at least one category of immigrants divided by age of arrival to the US exhibited unique total walking patterns compared to US-born young adults. As I added potential confounders into the multivariable model, the strength and statistical significance of this association increased, suggesting that age of arrival influences total walking, at least among this segment of young adult immigrants as represented in this sample. Better fitting models considered additional individual-, household-, and community-level factors while maintaining similar directionality and significance across models as they included more robust descriptions of walking environments and the social, health, and mobility factors that likely influence walking behaviors among young adults in the US. These results only partially align with those from studies where duration of time in the US seems to influence the extent to which immigrants adopt less walking for exercise and transportation, more closely matching behaviors most exhibited by their US-born counterparts.[53,78,101,102]

Adjusted model results suggest differences in whether and how age of arrival links to total walking outcomes, yet patterns exhibited do not have a clear direction aligning with the duration of time for which immigrants have lived in US. These results provide inconclusive responses to the second research question, which asked whether increased acculturation, as proxied by earlier age of arrival in the US, would link to walking behaviors. Though I did not hypothesize that I would see a gradient effect in a specific direction within the immigrant subgroups (i.e., that earlier age of immigration would exhibit the least or most amount of total walking compared to those who arrived at later ages), this type of effect would have been partially supported by the literature linking increased time in US to changes in walking behaviors.[7,89] In other words, if adaptation to walking behaviors followed these patterns, those who have lived in the US the longest, in this case, those who arrived in the US at youngest ages, would have reported patterns of total walking most like US-born young adults. However, the best fitting model suggests that compared to US-born young adults, immigrant young adults with the longest histories of living in the US rather than the newest arrivals, differ the most from US-born young adults in their total walking patterns, all other factors considered. Results do not support a gradient effect hypothesis, nor do they support my original hypothesis that those with the least time in the US would exhibit behaviors most unlike US-born individuals. Excluding those who arrived at age 5 or below, the three remaining categories of arrival ages exhibited decreasing odds of engaging in higher amounts of total walking, which would support the opposite trend from this hypothesis, that those who have spent the least time in the US exhibit patterns most like their US-born counterparts. However, these odds ratios were not statistically significant, suggesting that walking patterns among those arriving in the US after the age of 5 do not differ from those born in the US.

One potential interpretation of these results is that young adult immigrants, regardless of acculturation status and proxy used to assess acculturation status, exhibit trends parallel to those observed among US-born young adults, whose physical activity decreases during adulthood, especially during the transition from adolescence to adulthood.[18,18] Higher age was associated with a slight, but statistically significant difference in odds of total walking frequency levels among both US-born and immigrant young adults in sensitivity analyses including age in years as a separate variable. However, these results suggested that increasing age corresponds with slightly higher odds of more total walking with each additional year of age in this sample. This could relate to the narrow span of ages included. Future analyses may wish to consider a broader age range among young adults – perhaps encompassing adolescents under 18 and adults over 25 to better gauge the effects of transitioning more fully into walking patterns that will likely carry forward to later adulthood. Additionally, data used for these analyses came from a 2017 cross-sectional survey, which does not reflect the full range of possible immigrant experiences, even among this age-restricted sample. To understand effects of shared types of immigrant experiences and how these may affect acculturation processes and associated health behaviors, including walking trends, future researchers may wish to utilize qualitative or longitudinal quantitative methods.

Interpretation of results indicating that young adults who arrived in the US at the earliest ages, this study's proxy for higher degrees of acculturation, reported engaging in more total walking than do US-born individuals may relate to other aspects of immigrants' experiences not accounted for in this data. The differences in this age group could reflect a type of period effect reflecting events in the US or in sending countries that would influence whether this age cohort of individuals experience acculturation relevant to total walking. Specific examples could include periods of extreme poverty in sending countries, or of limited instrumental support for immigrants in specific US locations where these immigrant families choose to settle. Immigrant health scholars have long posited that reasons for immigration may explain health disparities observed among immigrants, though empirical evidence has varied in its support of this hypothesis.[25,103] With respect to the outcome at hand, context of immigration could affect immigrant families' ability to afford a car upon arrival to the US, their willingness or ability to obtain drivers licenses, and thus, the habits their children develop with respect to transportation walking. Patterns of walking associated with early life walking to school or choosing alternative forms of transportation to driving could carry forward into young adulthood. setting this group apart from other immigrants who arrived in the US at older ages. Alternatively, immigrants who arrive at younger ages may differ in their legal authority to reside in the US compared to those who arrived later. A growing literature has determined that legal status affects overall wellbeing of immigrants in the US through mechanisms including affecting access to and willingness to engage with care services for physical and mental health and differential workplace safety.[104–106] Policies relevant to travel behaviors also affect immigrant's driving and active transportation use.[78,107] With these studies in mind, future research may wish to further evaluate the role of legal status on walking behaviors, with expanded focus to this age group.

Each of these scenarios relates to the life course and social ecological models' perspectives that community and even global-level political events can create conditions that translate into health-determining practices, especially if they occur during critical periods of children's psychosocial development.[108] Drivers of total walking differences among the group of earliest arrivals to the US could also overlap with patterns driven by where immigrant families choose to settle and how built and social environments at the neighborhood level may encourage increased walking among cohorts of arrivals. Perhaps immigrants in this age of arrival group were more likely to settle in immigrant enclaves, another area of interest in both health and transportation research. Immigrant enclave effects could promote walking through a number of mechanisms including through increasing neighborhood trust, a known predictor of increased walking for leisure among adults or through promoting carpooling or use of other shared transportation modes, which may involve some degree of walking (i.e., walking to or from a neighbor's house or a transit stop.)[109–111]

Finally, these differences may relate to other family-level differences which I was unable to ascertain in this data. For example, immigrants who arrive in the US at younger ages likely accompanied parents coming to the US for different reasons compared to those who arrive at older ages, perhaps seeking their own work or educational opportunities. Research has demonstrated that immigrants of different generations, including those who come to the US as adults compared to "1.5 generation" immigrants, who are born abroad but spend most of their lives in the US, exhibit different health behaviors.[94,112] Future research may wish to specifically compare immigrants by these more precise generational categories to understand whether intermediate groups may experience acculturation processes differently. Emerging research related to immigrant acculturation and obesity, another health outcome often studied in conjunction with physical activity, found that parent (or other caregiver's) degree of acculturation significantly predicted rates of child obesity, one outcome with known links to walking patterns, among a longitudinal and nationally representative sample of immigrant parent-child dyads.[113] Future research may also wish to consider relational factors, such as whether young adults live or regularly engage with family and how their transportation and leisure walking habits may act as a potential effect modifiers of the association between immigrants' own total walking. These explanations speak to some limitations of this study including lack of data that could better proxy acculturation and specific neighborhood contexts;

other limitations and potential ways to mitigate these future analyses are discussed in a subsequent section.

Results corresponding to my final research question, how individual-, household-, and community-level factors accounted for among this sample may alter associations between immigrant status and walking mostly aligned with extant literature on these factors. The associations between age of arrival in the US and levels of total walking remained somewhat consistent as models were adjusted for selected individual-, household-, and community level factors. As anticipated, I observed statistically significant differences in total walking by most individual-level factors including gender, most racial and ethnic groups, and occupational status. As I hypothesized, disability status predicted reduced odds of higher total walking levels, likely reflecting the barriers to transportation and physical activity walking reported by disabled individuals in prior studies. Self-rated health was not significantly predictive of total walking levels, which may reflect the overall low levels of poor through good health in this age group. With respect to mobility factors, indicators associated with more frequent driving and less frequent use of transportation walking as a standalone mode or in conjunction with use of other non-driving modes predicted reduced odds of total walking. This suggests that transportation walking patterns observed in past studies indicating that increased driving corresponds to reduced walking, are unlikely to be altered by non-transportation walking. Though proxy status was significantly associated with higher total walking, stratified sensitivity analyses yielded similar overall results. Variables operating at more distal contextual levels seemed to influence the association between immigrant age of arrival and total walking the least, which echoes findings that while factors including census region and neighborhood seem to influence walking patterns among adult populations of broader age ranges, individual-level characteristics seem to have characteristics have stronger influences.[47,99] Indeed, the highest odds ratios generated corresponded to overall physical activity levels, which underscores the argument posited by Singh, et al, that assessment of physical activity, regardless of type of physical activity (i.e., incidental vs. utilitarian), likely corresponds to how physically active individuals are overall.[18,19]

Study limitations

In addition to the challenges associated with using age of arrival in the US as previously described, this study had some additional limitations which influenced the study outcomes and interpretation of results. One series of limitations relates to use of NHTS 2017 data. While they provide estimates for a large sample of the young adult population, the 2017 NHTS data do not represent all young adults in the US. Because the data represent a cross-sectional snapshot of self-reported behaviors during a narrow time frame, they are limited in their ability to identify true causal relationships. It is possible that total walking has bidirectional effects on factors included as covariates including disability status and self-rated health, alongside overall physical activity levels. A longitudinal study design, following the same individuals over many years, could help clarify these relationships.

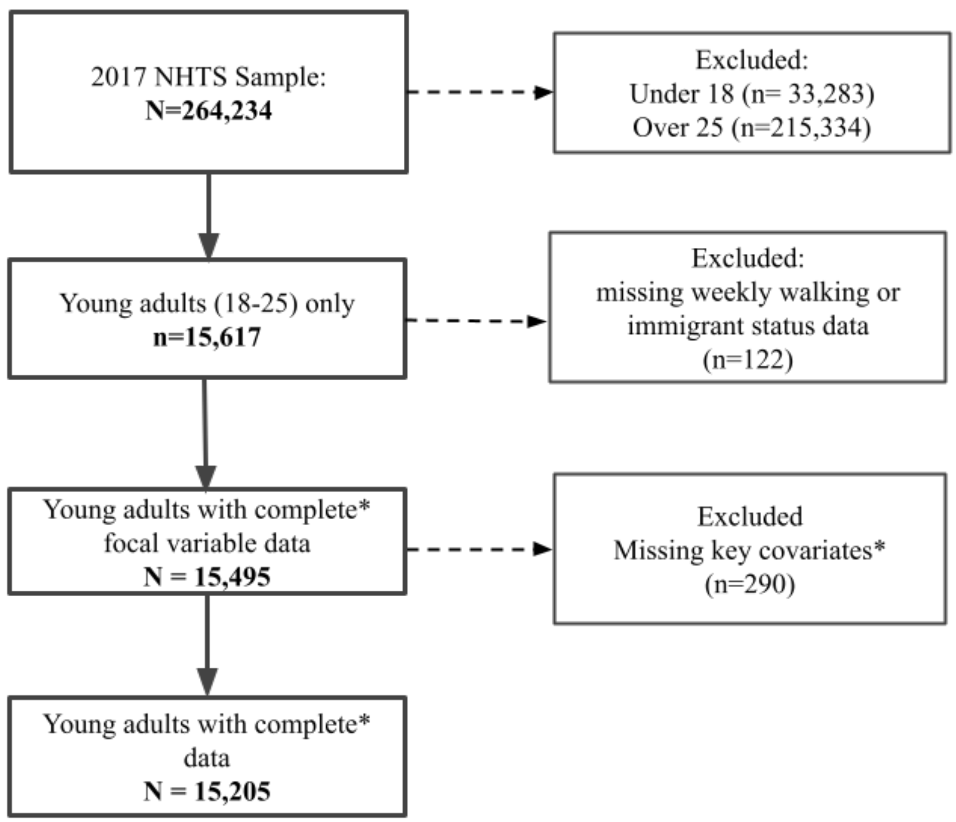
Self-reported physical activity data are subject to several biases including overreporting due to social desirability bias and underreporting due to recall bias. In addition to these potential sources of error, relative to the proportion of proxy responses in other age groups within this data source, the young adult subsample represented here had a higher proportion of proxy responses. In analyses of proxy status by 1-year ages, I noted that proxy responses were most common among those in the youngest age categories, potentially suggesting that parents could be responding on behalf of their children who may be temporarily absent from the household where they officially reside to attend school or to work. In an analysis comparing responses supplied by proxies and those directly recruited into a different travel diary study, a team of researchers found that while some types of responses such as demographic information and responses related to vehicle ownership showed little evidence of bias, other responses such as travel diary data showed signs of proxy underreporting.[86] These patterns were more prevalent among younger groups, and women. Future analyses of these data could employ appropriate multiple imputation or other approaches to generate responses for missing behavioral questions and adjust values for measures thought to be under- or over-reported.

Study contributions

Despite its limitations, this study advances understanding of total walking, a daily activity with significant health implications for current and future health outcomes.[2,5] In particular, this study investigated total walking among a unique, growing, and economically significant population of young adult immigrants in the US. Analyses of children's physical activity and transportation behaviors and analyses of broader age ranges of adults informed the design of this study and interpretation of its outcomes, but this study also benefits the literature by focusing on a transitional age range with unique health behaviors and characteristics. Further, this study assessed behaviors of young adults from a national-level population with significant heterogeneity, which addresses shortcomings of previous studies assessing walking behaviors among samples restricted to specific geographic regions and/or ethnic or racial backgrounds.[13,61] This study used a distinctive measure of walking, incorporating both walking for leisure and transportation, which have historically been studied in a siloed manner, potentially masking the true influence of walking on overall health.[95,101]

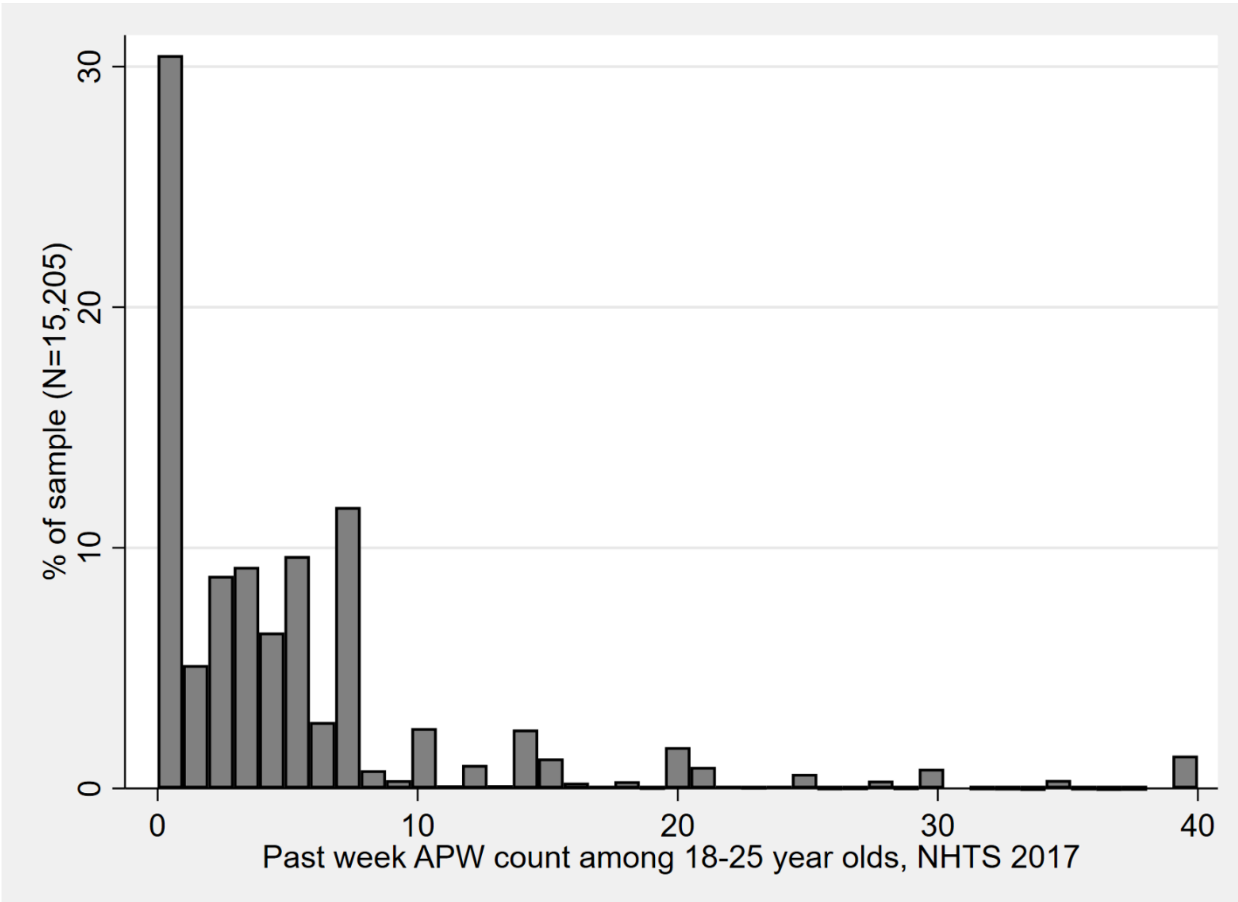
Results supported the hypotheses that immigrant status affects patterns in total walking among young adults in the US and that these patterns vary among young adults who arrived in the US at different ages. My final hypothesis, that contextual factors likely influence this association was somewhat supported but should be further explored in studies that consider additional immigration-related factors such as the context of arrival in the US and more detailed data on the built and social environment contexts in which walking occurs. Future analyses may wish to consider whether individuals live in neighborhoods with high concentration of immigrants and services that cater to immigrants, whether regular walking is supported by public transportation infrastructure, and norms around transportation and leisure walking. That those who arrived in the US at the earliest ages exhibited highest likelihood of reporting more total walking compared to US-born individuals points to a promising direction for public health interventions promoting walking among populations that are often assumed to exhibit worse health outcomes with increased time in the US. Health-promoting walking behaviors may already be occurring at a life stage where physical activity tends to decline. Programs and policies to promote walking may help preserve or further enhance this behavior, mitigating future health disparities among immigrant populations that relate to overall physical activity levels.

Appendix 3-A: analytic sample creation, Aim 3



* Key covariates included: race & ethnicity, gender, age, educational attainment, weekly physical activity level, self-rated health status, use of mobility devices, disability status, driver status, household size, household income, block rurality, and census region

Appendix 3-B: Distribution of walk counts



Appendix 3-C: total by age at time of arrival in the US, no proxy responses NHTS 2017 18–25-year-olds (N= 10, 476)

			1: Immigrant status only		2: + indiv. identity factors		3: + health & mobility factors		4: + household factors		5: + community factors	
Individual level	Age at time of arrival in US	US-born	1	[1.00,1.00]	1	[1.00,1.00]	1	[1.00,1.00]	1	[1.00,1.00]	1	[1.00,1.00]
		<=5	1.46***	[1.17,1.81]	1.54***	[1.24,1.92]	1.61***	[1.29,2.00]	1.60***	[1.28,2.00]	1.54***	[1.23,1.93]
		6-12	1.02	[0.77,1.34]	1.11	[0.83,1.48]	1.18	[0.89,1.57]	1.17	[0.89,1.55]	1.15	[0.87,1.52]
		13-17	1.38*	[1.03,1.84]	1.42*	[1.05,1.92]	1.53*	[1.10,2.12]	1.49*	[1.07,2.07]	1.40*	[1.02,1.94]
		18-25	1.22	[0.95,1.55]	1.32*	[1.02,1.71]	1.2	[0.92,1.56]	0.93	[0.71,1.21]	0.89	[0.68,1.17]
	Occupational status	Working			1	[1.00,1.00]	1	[1.00,1.00]	1	[1.00,1.00]	1	[1.00,1.00]
		Student			1.35***	[1.22,1.49]	1.31***	[1.19,1.45]	1.33***	[1.20,1.47]	1.38***	[1.24,1.52]
		Working student			1.19**	[1.05,1.34]	1.19**	[1.05,1.35]	1.18**	[1.05,1.34]	1.23**	[1.09,1.39]
		Unemployed			1.1	[0.96,1.27]	1.18*	[1.02,1.36]	1.12	[0.97,1.30]	1.16	[1.00,1.34]
		Other			0.98	[0.87,1.10]	0.97	[0.86,1.11]	0.96	[0.84,1.09]	1	[0.88,1.14]
	Race/ethnicity	Black, non-Hispanic/Latino			1	[1.00,1.00]	1	[1.00,1.00]	1	[1.00,1.00]	1	[1.00,1.00]
		White, non-Hispanic/Latino			1.01	[0.87,1.16]	1.02	[0.88,1.18]	1.18*	[1.02,1.38]	1.25**	[1.07,1.47]
		White, Hispanic/Latino			0.70***	[0.59,0.84]	0.77**	[0.64,0.92]	0.88	[0.73,1.06]	0.88	[0.73,1.06]
		Hispanic/Latino (any non-White race)			0.87	[0.71,1.07]	0.85	[0.69,1.04]	0.92	[0.75,1.14]	0.89	[0.71,1.11]
		Asian			0.86	[0.70,1.06]	0.93	[0.75,1.16]	1.02	[0.82,1.26]	0.98	[0.78,1.21]
		American Indian/Alaska Native/Pacifc Isla			1.34	[0.95,1.89]	1.37	[0.98,1.91]	1.44*	[1.03,2.03]	1.49*	[1.06,2.10]
		Multi-racial/other			1.04	[0.85,1.28]	1.07	[0.86,1.32]	1.19	[0.96,1.47]	1.21	[0.98,1.51]
	Gender	Female			1.18***	[1.10,1.27]	1.31***	[1.22,1.41]	1.29***	[1.21,1.39]	1.27***	[1.18,1.37]
	Disability status	Mobility disabled					0.78*	[0.62,0.98]	0.81	[0.65,1.02]	0.83	[0.66,1.05]
	Self-rated health	Self-rated health					0.99	[0.90,1.08]	1.05	[0.95,1.15]	1.06	[0.97,1.17]
	Weekly physical activity level	None, or rarely engages in exercise					1	[1.00,1.00]	1	[1.00,1.00]	1	[1.00,1.00]
		Some light-moderate exercise					3.64***	[3.26,4.07]	3.59***	[3.21,4.01]	3.56***	[3.19,3.98]
		At least some vigorous activity					5.53***	[4.87,6.27]	5.49***	[4.84,6.23]	5.46***	[4.81,6.19]
	Driver status	Licensed driver					0.53***	[0.47,0.60]	0.69***	[0.60,0.78]	0.71***	[0.63,0.80]
Household level	Household pover	Annual household income below federal poverty line							0.73***	[0.66,0.80]	0.78***	[0.71,0.86]
	Household vehicle availability	0 vehicle household							1	[1.00,1.00]	1	[1.00,1.00]
		Fewer than 1 veh. pc							0.25***	[0.20,0.31]	0.29***	[0.24,0.37]
		1+ veh/person							0.25***	[0.20,0.32]	0.30***	[0.24,0.38]
Community level		45% or more homes in block group renter-occupied									1.37***	[1.26,1.48]
	Block-level rurality	rural									1	[1.00,1.00]
		small town									0.83**	[0.74,0.93]
		suburban									0.95	[0.84,1.07]
		second city									1.05	[0.93,1.19]
		urban									1.29***	[1.12,1.49]
	Census region	Northeast									1	[1.00,1.00]
		Midwest									0.83**	[0.73,0.94]
		South									0.91	[0.82,1.01]
		West									0.9	[0.80,1.01]
		cut1	0.41***	[0.40,0.43]	0.47***	[0.40,0.54]	0.92	[0.75,1.13]	0.27***	[0.21,0.36]	0.39***	[0.29,0.52]
		cut2	0.79***	[0.75,0.82]	0.89	[0.77,1.04]	1.85***	[1.51,2.26]	0.55***	[0.42,0.72]	0.79	[0.59,1.05]
		cut3	2.59***	[2.48,2.71]	2.97***	[2.55,3.45]	6.62***	[5.38,8.14]	2.02***	[1.55,2.64]	2.92***	[2.17,3.92]
		Observations	10476		10476		10476		10476		10476	
		aic	28363.47		28282.98		27379.9		27137.79		27004.63	
		bic	28414.27		28413.6		27546.81		27326.47		27251.36	

* p<0.05, ** p<0.01, ***p<0.001

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Chapter 5: Conclusions

This dissertation quantified associations between total walking and health-related factors across the life course among three distinct samples drawn from the 2017 National Household Travel Survey (NHTS.) The specific health-related factors examined included overall health status, mobility disability status, age, and immigrant status. The samples I focused on included (Aim 1) older adults, (Aim 2,) working age adults with and without mobility disabilities, and (Aim 3) young adults born in and outside of the United States (US.) The results provide a baseline understanding of patterns in total walking (i.e., walking for both utilitarian and recreational purposes) among relatively large and diverse samples of these population groups. This research builds on prior evidence suggesting that participation in exercise and transportation walking varies across different populations embedded in different social and built environment contexts by assessing self-reported walking, inclusive of exercise, transportation, and other forms of walking.[1–5] The findings provide a starting point for future research and interventions to promote more total walking participation and frequency among members of these groups as one strategy to increasing overall health and wellbeing. Public health theory including the social ecological model and life course perspectives informed the conceptual models that guided analyses for each study.[6,7] The models presented illustrate my inclusion of a broad range of individual-, household-, and community-level factors to better isolate associations between the focal predictor variables and the focal outcomes of total walking examined in each study. The results may further discussions across public health and transportation scholarship. In the remainder of this chapter, I briefly revisit and expand upon central findings of my three aims, touching strengths and limitations shared across and distinct to each study. I then highlight how analyses presented in this dissertation may contribute to the overall narrative of this interdisciplinary topic, and finally, suggest how results may inform future public health research and practice.

Key findings: Aim 1

In the first study, I quantified correlations between total walking participation and frequency among older adults in the 2017 National Household Travel Survey using zero-inflated ordered logistic regression modeling. In alignment with the hypotheses I presented, compared to mobility-disabled older adults, those without mobility disabilities had higher odds of reporting engaging in one or more walk for any purpose in the past week and higher odds of reporting higher total walking counts, placing them into higher frequency categories (e.g., low- vs. medium-, or medim vs. high counts.) In models considering several key individual-level social identity, household- and community-level contextual factors, female gender predicted lower odds of total walking participation and frequency compared to male gender among this sample of older adults. Since these findings relate to total walking, they expand on evidence from studies with smaller samples of women in the US and socioeconomically comparable countries which found a need to specifically engage older women in transportation- and leisure-specific walking.[1,8,9] Additionally findings from my analyses suggested that race, ethnicity, and age more were more strongly associated with the outcome of walking participation compared to the outcome of walking frequency. In the samples I examined, older adults who had driver’s licenses reported higher counts of past week total walking and higher odds of walking participation in the past week; household vehicle access had the inverse association. These surprising findings suggest a need for closer analyses of walking behaviors which could potentially include disaggregation of type of walks taken (e.g., by purpose, duration, or distance) among members of specific older adult groups. This could potentially identify facilitators and barriers of total walking to clarify these patterns. Further, lack of evidence for associations between total walking frequency and total walking participation with community-level covariates could motivate investigation of older adults' walking behaviors with more specific descriptors of local environments. Descriptors of the local built and natural environment could have been obscured by the type of community-level factors I included in my models; greater attention to these factors could potentially yield insight into modifications that could affect outcomes of walking and thus, potentially improve older adult population health.

Key findings: Aim 2

In the second study from this dissertation, I used zero-inflated negative binomial regression models to analyze patterns in walking adoption and frequency among both disabled and non-disabled US working-aged adults (18-64) using data from the 2017 NHTS. My findings suggest that as hypothesized, people with mobility disabilities more frequently report no total walking in the past week compared to their non-disabled counterparts. This aligned with past public health and transportation scholarship demonstrating that people with disabilities, including those related to transportation mobility, often face challenges engaging in walking, whether for transportation, physical activity, or other purposes, and thus report reduced frequencies of walking compared to non-disabled individuals.[10–14] However, in the models I generated, mobility disability status was not statistically significantly associated with total weekly walk counts. This finding suggests that frequency of total walking may have a potentially more complex association with mobility disability status due to the influence of overall health and socioeconomic status, among other factors. Further, many studies examining the role of disability in walking behaviors have focused on older adults, those with specific types of disabilities requiring use of mobility aids, or only certain types of walking.[3,11,15,16] My analyses of younger individuals in these analyses may have yielded unexpected results due to the different distribution of disability among this sample compared to the samples previously mentioned. In my analyses, the factors most closely associated with walking count included overall physical activity levels and household vehicle counts. Those who engaged in at least 30 minutes of physical activity of some type in a typical week reported higher walk counts, suggesting that leisure time walking may make up a significant portion of total walking among this sample. While including both walking and physical activity in the same models could introduce collinearity, the lack of evidence for collinearity in my preliminary analyses suggests that the measure of physical activity used in my analyses represents a distinct set of behaviors. Phrasing of the question I used to operationalize total walking suggests that participants in NHTS may have reported instances of walking in their walk counts that to them did not quantify as physical activity; perhaps their interpretation of physical activity as requires a specific amount of effort, duration, or intensity. Living in a household with zero vehicles strongly predicted high walk counts compared to those with access to one or more household vehicles among this sample in fully adjusted models. In the future researchers should examine a subsample of carless working-age adults to assess the relationship between transportation walking and motivations for not having a personal vehicle.

With respect to walking participation, health status modifies the association between mobility disability and total walking, suggesting that mobility-disabled working-age adults with fewer health concerns may be amenable to total walking promotion efforts. Overall, future research and practitioners may wish to consider mobility disability status, health status, and their joint and independent effects should when designing and evaluating policies and programs to promote walking. Interventions promoting total walking may help facilitate health and transportation behaviors that may correlate with improved overall wellbeing among both disabled and non-disabled adults in the US.

Key findings: Aim 3

My third aim sought to measure associations between immigrant status and total walking participation and frequency among young adults between the ages of 18 and 25 among 2017 NHTS participants. Informed by past analyses' findings that immigrants tend to engage in more transportation walking but potentially less exercise walking than non-immigrants, I hypothesized that immigrants and non-immigrants would differ in their self-reported total weekly walking behaviors.[17–19] I also anticipated that results would indicate differences dependent on immigrants' age of arrival in the US, as studies guided by acculturation models have suggested that degree of acculturation predicts several health behaviors among immigrants in the US.[17,20] Finally, I hypothesized that consideration of individual-, household-, and community-level factors would affect the strength of these associations. Results provided partial support for each of these hypotheses, but also inspire further questions. Specifically, my best fitting ordered logistic regression models suggested that among immigrants, those who arrived in the US at the age of 5 or below had the highest odds of reporting more weekly total walking compared to US-born individuals and immigrants with different arrival ages. Accounting for covariates with known associations with both immigrant status and walking behaviors did not alter the direction of this association or attenuate the strength of the correlation. Future analyses may wish to assess how other acculturation-related factors such as immigrant population density in initial arrival location and current residential area may contribute to these unexpected patterns. Overall, challenges related to assessing acculturation and health behaviors in general were exacerbated by the limited amount of information included in the NHTS questions, by the limited sample size among this age group, and by the high degree of proxy responses. Future analyses may wish to integrate the additional factors previously identified as relevant to these factors by drawing on external data sets and the confidential version of this and future NHTS data.

Conclusions

Shared limitations

Although the dissertation findings summarized above address gaps in the public health, transportation, aging, and immigrant health literatures, limitations of the NHTS data, and analytic and theoretical approaches used still affected my three studies. Sampling bias is one limitation related to the baseline NHTS sample and the specific subsamples I analyzed. While the NHTS sampling frame and data collection processes are designed to capture the general US population, new residential construction or demolition of houses likely resulted in some sampling bias.[21] Further, the subpopulations I assess may experience particularly high risk of exclusion from residential surveys due to factors associated with advanced age and associated higher prevalence poor health, and/or disability status.[22–24] The NHTS excluded institutionalized and unhoused individuals because mailings were only sent to residential addresses. The population of institutionalized and unhoused older adults is relatively low compared to those with residential addresses, but may increase in the near future due to population aging.[25,26] People 55 or older are among the fastest growing age category of those incarcerated in the US and make up between 7.8% (Minnesota) to 17.3% (Montana) of the incarcerated population in each state.[26,27] Additionally, an estimated 1.3 million people aged 65 and older live in long-term care settings, representing over 90% of the individuals in facilities such as assisted living facilities and rehabilitation centers.[28] Another potentially undersampled population includes recent immigrants and those residing in the US without legal authorization, who face disproportionately high burdens in accessing necessary services in the US including legal documents such as drivers licenses, and health care, both of which may affect walking behaviors.[29–32] While a strength of these studies is my focus subpopulations often overlooked in physical activity and transportation mobility-related literature including immigrants, older adults and disabled individuals, it is likely that the NHTS sampling methods excluded non-negligible segments of these communities who live outside of residential spaces and in institutions or otherwise marginalized spaces.

Additionally, as a cross-sectional survey, analyses reflect only one point in time. Although total walking measures used throughout these analyses were drawn from a question asking about experiences over the last seven days and thus expand on previous findings in the literature using these data that only assess travel diary data capturing an even narrower period in participants' daily lives, limitations apply to all self-reported data. Recall and reporting biases likely affect the accuracy of weekly walking reports due to individuals' limited ability to remember and accurately report their behaviors and characteristics.[33] These errors might be of particular concern for those whose responses were reported by a proxy respondent.[23,24] To my knowledge, few studies relevant to adult's walking behaviors seeking to understand them in a health-relevant context contain data from proxy responses at rates similar to those present in subsamples used for these analyses. Alternatively, relatively high levels of proxy reporting may represent a strength in the data in that information about adults who might otherwise not be reflected in research findings. Research comparing proxy responses to self-report data among older adults suggest that proxy responses more often replace participation by individuals with health and disability challenges.[24,34] The same factors that make responding to surveys directly likely also affect overall health and mobility. Proxy reporting may also introduce biases driven by social desirability (i.e. in communicating with a proxy rather than with the survey instrument directly, individuals and/or their proxy respondents may not feel comfortable sharing responses they feel are socially undesirable and may edit responses to reflect more acceptable answers.) Overall, biases related to self-reporting and use of proxies can result in misclassification errors that could have skewed these analyses. Future analyses of these data may wish to include additional sensitivity analyses and use of statistical control methods to explore the potential influence of proxy reporting on outcomes reported.

Additional caveats may apply to interpretation of findings related to self-reported total walking data. In a 2019 report assessing accuracy of reporting travel behaviors in a state-level travel survey in the US, researchers concluded that self-reporting walking, even when constrained to a relatively narrow time window, may lead to skewed results in a way that varies by age and by geography.[33,35] Other previous studies have concluded that individuals with physical disabilities, who may more often overlap with older adults, tend to underreport their physical activity.[36] These findings call into question the reliability of the findings related to walking counts and suggest that they ought to be de-emphasized – not only because a single walk may not have a clinically relevant effect on health—but also because patterns describing overall walking participation (whether one walked at all) are likely to be more accurate than those describing extent of participation.

Other limitations relate to data collection methods for the NHTS. For example, while research recognizes that online survey methods improve response rates among many US demographic groups, they may do so at the detriment of others. This approach may result in underrepresentation of specific subsets of the population, including people with limited internet access or limited computer literacy who may more often include older individuals, people with disabilities (including those with visual or cognitive impairments that may overlap with mobility disabilities), and immigrants to the US. As a result, despite careful sampling methods used in the design and participant recruitment, NHTS 2017 data may not capture all population-wide trends. However, the size of the sample who did participate still adds credibility and valuable baseline estimates of trends upon which future research can build.

Few health-related national-level studies measure walking behavior. Some that have in the past have include NHIS cancer supplements, using survey questions like those included in the 2017 NHTS, and NHANES pilot studies.[37,382] The latter have recently piloted use of GPS-enabled smart phone apps to track activity though due to privacy laws, researchers are unable to collect such data at the national level currently.[39,40] Further, while data collection using cell phones aims to reduce biases introduced through recall, gaps in data can occur when people do not carry their phones with them or when reliable cellular data or internet access is limited. Analyses have found that older adults, people with disabilities, and immigrants are less likely to regularly use internet-enabled devices and less likely to use travel modes that rely on smartphones.[41,42] Although these patterns may change in the future, at the time in which these data were collected, self-reported data likely represented a practical solution to these shortcomings. Future research may wish to collect data on walking behaviors using both objectively recorded data and self-report to assess the validity of both methods, particularly among the populations examined in these studies.

Overall, shortcomings in the NHTS data and difficulties in interpreting my findings speak to the lack of quality data on physical activity behaviors at the population-level. Should public health researchers wish to better understand how health and transportation factors are linked, they should advocate for continued inclusion of transportation variables in population-level health-focused surveys. Similarly, transportation researchers should consult with their counterparts in health-related fields to ensure that variables related to health included in transportation-focused surveys provide adequate context for health-related analyses. For example, in addition to continuing to inquire about self-rated health, future NHTS and state or local travel surveys could also include more specific questions related to disability. Questions such as whether individuals are independently ambulatory, what devices they use, and how their disability or condition could be categorized (e.g., mobility, sight, hearing, behavioral/emotional.) Recent analyses of data from the US Behavior Risk Factor Surveillance System data suggest that disaggregation of disability data may help reduce conflation of health and disability and result in higher quality data to inform targeted programs and policies.[43] Overall, the limitations described above merit attention when it comes to interpreting and putting into practice results from this dissertation and future work relevant to total walking and health.

Shared strengths

Despite shortcomings described in the previous section, this dissertation features several key strengths that speak to its contributions to interdisciplinary scholarship in this topic area. For example, one strength of my analyses includes my consideration of both walking participation and walking frequency in two-part models and in interpretation of findings in general. These outcomes, while likely related, do not receive separate consideration in many analyses focusing on understanding walking for various purposes among adults in the US.[44–46] Yet as my results from each study presented in this dissertation suggest, correlates of walk participation and walking frequency may differ within and across specific population groups. This suggests that interventions designed to promote walking may wish to establish whether their goals are to promote walking among those who may already engage in some walking, or whether they wish to help those who do not currently walk begin to walk. Findings also suggest that if interventions desire to meet the latter goal, assessing whether participants can walk at all, and under what circumstances, may be a valuable first step. In terms of research, future analyses may wish to distinguish between subpopulations of current walkers and potential future walkers when assessing the role of walking in health or transportation mobility.

Another strength of this research includes the consideration of connections between various health factors and walking when total walking is assessed, rather than only walking associated with exercise or transportation. Some scholars have argued for studying types of walking separately to better identify what factors can be modified to encourage the types of walking with the most benefits.[47] However, walking practices do not occur in isolation; physical activity focused studies, including those assessing activity with wearable devices suggest that step counts and intensity of physical activity differ among those with different exercise and transportation habits.[24,34,35] This understanding guided my approach of assessing total walking while also considering overall health status, disability status, physical activity levels, and to a rudimentary degree, whether individuals had access to alternatives to transportation walking. By assessing how interlinked walking behaviors occur in the context of other health factors among a national sample, that while imperfect, still provides a more complete picture than some previous studies, this dissertation contributes to reducing a gap in the public health literature.

A final strength of this study relates to expansion of discussion across public health and transportation literatures, alongside consideration and relevance to the work of other interdisciplinary scholars. Analyses in Aim 1 was informed by and may be informative to the future work of gerontologists. Aim 2 parallels this for disability scholars, and Aim 3, for scholars working in immigrant health. Overall, increased interdisciplinary collaboration could help yield data that avoids some of the potential issues described in this chapter and throughout the dissertation. Further, it could help guide applications of existing research into more effective solutions to limited total walking and interrelated health problems.

Many existing questions remain, and new questions have arisen through these analyses regarding how health-relevant factors including overall health status, disability status, age, and immigration status influence walking behaviors. However, the findings have helped to bridge connections across scholarship from multiple disciplines and have highlighted the need for continued attention from current and future researchers. By reducing barriers and boosting facilitators of total walking for the specific populations examined in this dissertation, public health practitioners can help ensure better engagement in physical activity and transportation mobility, key inputs to overall health.

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