Investigating the Link between Active Transportation Use and Cardiometabolic Health

by

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ABSTRACT

This dissertation was guided by the Ecological Model of Physical Activity and Ecological Model of Obesity and sought to determine the relationship between active transportation (AT), physical activity, and cardiometabolic health among adults and ethnic minority women. Chapter 2 presents an investigation into the relationship between walking for AT and cardiometabolic health among adults through systematic review. Chapter 3 presents an exploration of the cross-sectional relationships of AT and moderate-to-vigorous physical activity (MVPA) with cardiometabolic health among African American (AA) and Hispanic/Latina (HL) women from Texas. Chapter 4 presents an investigation into the cross-sectional relationship of AT on cardiometabolic health and physical activity among primarily HL women.

In Chapter 2, walking for AT was found to be related to smaller waist circumference, lower blood pressure, and lower prevalence of abdominal obesity and hypertension, and that differences may exist based on sex. Walking for AT was not clearly defined, and criteria used to determine the presence of cardiometabolic outcomes were inconsistent. No significant relationships between AT and cardiometabolic health were found in Chapter 3 or 4; however, AT users had slightly better cardiometabolic health. AT users had significantly higher levels of self-reported total physical activity compared to those who did not use AT in Chapter 3. Furthermore, a significant relationship was found between MVPA and diastolic blood pressure. Associations differed by ethnicity, with MVPA being inversely related to body fat in both AA and HL women, but to body mass index only in AA women. AT users were found to be seven times more likely to meet 2018 national MVPA recommendations than non-AT users in

Chapter 4. Across all studies, measures of AT were subjective and of low quality, potentially limiting the ability to detect significant findings.

High quality randomized controlled studies should be conducted using clearly defined, objective measures of AT, and analyzed based on sex and race/ethnicity. Clinicians should recommend AT use to promote meeting MVPA recommendations where appropriate, potentially resulting in improved cardiometabolic health. Policymakers should advocate for changes to the built environment to encourage AT use and MVPA to improve public health.

DEDICATION

I would like to dedicate this dissertation to my daughter and husband, Josie and Joshua Lorenzo. You both provided unconditional love, patience, humor, and understanding throughout the past five and a half years, and I could not have succeeded without your support. The sacrifices you both made means more than you will ever know, especially of Josie, who was only six years old when this journey began.

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CHAPTER 1

INTRODUCTION

It is estimated that approximately 25% of the world population has cardiometabolic syndrome with a global economic burden into the trillions of dollars (Saklayen, 2018). Cardiometabolic syndrome is a preventable medical condition indicated by a combination of three or more of five recognized risk factors that, together, increases risks for coronary artery disease, stroke, type 2 diabetes mellitus, and cardiovascular disease, and resulting in significantly increased morbidity and mortality (Alberti et al., 2009; National Heart Lung and Blood Institute, n.d.). Cardiometabolic syndrome risk factors include: a) abdominal obesity (≥88 cm for women), b) low high-density lipoproteins (<50 mg/dL for women) or taking medication for low high density lipoproteins, c) high triglycerides (≥150 mg/dL) or taking medication to lower triglycerides, d) elevated fasting blood glucose (≥100 mg/dL) or taking medication to lower blood sugar, and e) hypertension (≥130 mmHg systolic and/or ≥85 mmHg diastolic) or taking medication to treat high blood pressure (Alberti et al., 2009; National Heart Lung and Blood Institute, n.d.). These risk factors are the same as some cardiovascular disease risk factors, which contribute to numerous cardiovascular diseases (Saklayen, 2018) and are responsible for the largest cause of death across the globe (World Health Organization, 2017).

The prevalence of cardiometabolic syndrome for adults in the United States is approximately 33% overall, with women having a higher rate (36%) than men (30%) (Aguilar, Bhuket, Torres, Liu, & Wong, 2015). Further disaggregation the rates for women by ethnicity and age group shows that Hispanic (10.9%, age 18-29; 24.5%, age

30-49; 56.9%, age 50-69, and 69% ≥ 70) and non-Hispanic black (9.1%, 27%, 52.7%, and 63.7%) women are disproportionally affected by cardiometabolic syndrome, compared to non-Hispanic white women (7.8%, 21.9%, 42.5%, and 62.1%) across the life span (Moore, Chaudhary, & Akinyemiju, 2017). The upward trend in the incidence of cardiometabolic syndrome as women age demonstrates the need to intervene in early adulthood to prevent, delay, and/or treat cardiometabolic syndrome. According to these projections, women with cardiometabolic syndrome could drive significantly higher health care costs in an already overstressed U.S. health care system, demonstrating the need for innovative and sustainable solutions to prevent and reduce this health disparity.

Physical activity participation is an effective method to prevent, treat, or delay cardiometabolic syndrome, type 2 diabetes mellitus, obesity, hypertension, and cardiovascular diseases in adults (Physical Activity Guidelines Advisory Committee, 2018). The evidence for improving cardiometabolic syndrome with physical activity has been conducted primarily investigating leisure-time physical activity and includes epidemiological studies, randomized controlled trials, systematic reviews, meta-analyses, and cross-sectional studies (Pedersen & Saltin, 2015; Physical Activity Guidelines Advisory Committee, 2018). The impact of physical activity on each of the cardiometabolic syndrome risk factors can vary depending on the “dose” or frequency, duration, intensity, and type of physical activity; however, benefits can be found for participation at frequencies ranging from one to five days per week (Physical Activity Guidelines Advisory Committee, 2018).

The literature investigating abdominal obesity found that it can take at least three months of regular moderate physical activity to demonstrate any improvements, without reference to duration (Pedersen & Saltin, 2015). High-density lipoproteins appear to be the cardiometabolic syndrome risk factor that takes longer bouts of physical activity to change. In a meta-analysis, the duration of exercise needed to increase high-density lipoproteins was greater than 120 minutes per week, with larger improvements seen with longer bouts regardless of intensity; however, these effects were very modest (Kodama et al., 2007). According to Pedersen & Saltin (2015), lengthy bout durations of at least 60 minutes were needed to impact high-density lipoproteins. Similarly, triglycerides were also found to be more influenced by the duration of physical activity, independent of intensity.

Low intensity and moderate intensity breaks in sedentary behavior have shown to improve glucose responses, with multiple moderate intensity breaks more effective than one long bout (Chastin, Egerton, Leask, & Stamatakis, 2015). Furthermore, taking 2-minute breaks of light intensity physical activity during sedentary behavior every 20 minutes (totaling 28 minutes for the day) reduced blood glucose (Dunstan et al., 2012). According to Kraus & Slentz (2009), with stronger improvements in insulin sensitivity for moderate intensity physical activity than vigorous. There is a strong body of evidence indicating that replacing sedentary time with light physical activity can prevent type 2 diabetes mellitus (Physical Activity Guidelines Advisory Committee, 2018).

Moderate intensity physical activity in accumulated amounts totaling at least 30 minutes per day with the goal of 150 minutes per week can decrease blood pressure chronically, after approximately 3 months of regular participation (Brook et al., 2013). Physical activity improves blood pressure, but effects are even more significant at higher intensities (Cornelissen & Smart, 2013). Three ten-minute bouts of vigorous physical activity throughout the day can be more effective at lowering blood pressure than one 30-minute bout (Angadi et al., 2010; Bhammar, Angadi, & Gaesser, 2011).

Even though the duration, frequency, and intensity required to improve cardiometabolic health outcomes differ depending on which outcome, the Physical Activity Advisory Committee (2018) determined that participating in at least 150 minutes of moderate intensity aerobic physical activity per week can improve cardiometabolic health risk factors. However, they also found that replacing sedentary behavior with any amount or intensity of physical activity has health promoting effects. The vast majority of the research from which these recommendations were drawn were based on aerobic physical activity and did not provide evidence based on sex. Some of the research gaps identified in the report included the inability to provide specific physical activity recommendations based on sex or race/ethnicity and recommendations for transportation related physical activity participation to improve health. Recommendations for future research include investigating these variables.

The 2018 national physical activity recommendations include at least 150 minutes of moderate intensity aerobic physical activity per week combined with two days of weight training of all major muscle groups to provide the best opportunity to improve cardiometabolic health (Physical Activity Guidelines Advisory Committee, 2018). Unfortunately, even with the multiple health benefits, only 21% of Americans met these recommendations in 2014, with substantial differences by gender and race. About one fourth (25.4%) of men met recommendations compared to 17.6% of women. Men of all races/ethnicities met recommendations at higher levels than the corresponding women, including Hispanics (19.1% vs. 11.5%), non-Hispanic black (27.8% vs. 13.4%), and non-

Hispanic whites (26.8% vs. 20.6%), respectively. When looking at percentages of those who met only the aerobic recommendations, men for each race/ethnicity also met aerobic recommendations at higher levels among Hispanic (47.0% vs. 38.2%), non-Hispanic black (47.5% vs. 35.5%), and non-Hispanic white (56.4% vs. 50.9%) women, respectively (Blackwell, Lucas, & Clarke, 2014). This demonstrates a significant disparity among women for meeting either minimum physical activity recommendations; however, this was highest in Hispanic and non-Hispanic black women.

There are a number of barriers experienced by minority women that inhibit participation in physical activity. One of the most common barriers cited by both Hispanic and non-Hispanic black women was lack of time (Bautista, Reininger, Gay, Barroso, & McCormick, 2011; Im et al., 2010; Joseph, Ainsworth, Keller, & Dodgson, 2015; Mama et al., 2015), with Hispanic women viewing physical activity as a "waste of time," because it takes away family time (Im et al., 2010). Family obligations, motivation, social support, and neighborhood safety all influence participation in physical activity by Hispanic and non-Hispanic black women (Joseph et al., 2015; Mama et al., 2015).

A potential physical activity intervention that could provide a sustainable and contextually appropriate physical activity strategy for Hispanic and non-Hispanic black women is active transportation. Active transportation is defined as walking or bicycling for part or all of a commute to school, work, public transit stops, or any other destination. Active transportation use is related to improved cardiovascular outcomes (Hamer & Chida, 2008), increase levels of physical activity, and decrease body weight in U.S. adults (Wanner, Götschi, Martin-Diener, Kahlmeier, & Martin, 2012; Xu, Wen, & Rissel, 2013); however, the evidence investigating health benefits of active transportation among Hispanic or non-Hispanic black women is absent from the literature.

Walking is the most common method of active transportation (Reynolds, McKenzie, Allender, Brown, & Foulkes, 2014), the preferred form of physical activity in all adults (Centers for Disease Control and Prevention [CDC], 2013), and has been the main component of successful interventions to increase physical activity participation among Hispanic and non-Hispanic black women (Bland & Sharma, 2017; Ickes & Sharma, 2012). Furthermore, walking provides an opportunity to be physically active while overcoming barriers to physical activity because it has no cost and can be a social endeavor (Bland & Sharma, 2017; Ickes & Sharma, 2012). Walking for active transportation could provide an opportunity to provide a culturally relevant physical activity intervention, while including friends and/or family members.

Unfortunately, physical activity interventions have not demonstrated sustainability over time among Hispanic or non-Hispanic black women, possibly due to the multiple roles and cultural expectations they experience, which limits their ability to set aside time for physical activity. Interventions should include the family, be pragmatic to promote adaptation, and provide the opportunity for mothers to model the behavior to their children to develop healthy lifestyle habits and promote use across the lifespan. Incorporating active transportation into a daily routine is an innovative, culturally appropriate way to increase physical activity levels of an entire family, (e.g., commute to work, take children to school, run errands), can maximize time spent with family, and decrease the need for additional time to be set aside for physical activity.

Importance of the Problem

Cardiometabolic syndrome disproportionately affects Hispanic and non-Hispanic black women, and regular participation in physical activity can improve many aspects of health, including preventing, delaying, and treating cardiometabolic syndrome and risk factors (Physical Activity Guidelines Advisory Committee, 2018). Physical inactivity is a modifiable risk factor for cardiometabolic syndrome, which provides an opportunity for active transportation interventions to be developed and evaluated to increase physical activity. The discipline of nursing is concerned with maximizing health and advocating for health equity, and nurses are provided a unique platform to promote and educate patients and the public on a variety of health topics. They interact with patients of all ages, across the continuum of health and disease, providing multiple opportunities to advocate for increased physical activity participation through active transportation use to improve individual and/or family health, and mortality. The expansive reach of nursing demonstrates the significance for nursing scholarship to advance the science of public health nursing in the area of active transportation use among adults, and Hispanic and non-Hispanic black women.

There have been multiple studies, mostly observational, that have assessed the health benefits of active transportation among primarily white adults (Hamer & Chida, 2008; Wanner et al., 2012; Xu et al., 2013). The association between active transportation use and cardiometabolic risk factors has not been investigated among Hispanic or non-Hispanic black women. Further, most active transportation research combines walking and cycling, preventing specific benefits to be attributed to either method of active transportation. This limits the ability for healthcare providers to recommend walking for active transportation as an effective intervention to prevent, delay, or treat decrease cardiometabolic syndrome in these women and their families. Furthermore, research has not demonstrated adequate evidence to provide recommendations for the method, dose, or intensity of physical activity or active transportation needed to maintain or improve health outcomes for Hispanic and non-Hispanic black women. This indicates there is a gap in the scientific literature regarding the use of active transportation among Hispanic and non-Hispanic black women and cardiometabolic outcomes, and the need for exploration, which aligns with the National Institute of Nursing Research's mission to promote wellness and improve the health of families of diverse populations (National Institute of Nursing Research, 2016).

Theoretical Foundation

This study is guided by the Ecological Model of Physical Activity (EMPA) (Lee & Cubbin, 2009; Spence & Lee, 2003) and the Ecological Model of Obesity (EMO) (Lee et al., 2015). These models posits how variables at environmental levels in which an individual is situated can directly and indirectly impact physical activity behavior (Lee & Cubbin, 2009; Spence & Lee, 2003) and obesity (Lee et al., 2015) through dynamic linkages, while also accounting for intra-individual factors and influences. The EMPA and EMO can be used to guide investigation into correlates of physical activity and/or obesity, and in descriptive research to determine and describe the relationships between variables at multiple levels of the models and how they interact to influence physical activity levels or obesity (Lee et al., 2015; Lee & Cubbin, 2009; Spence & Lee, 2003).

The *micro*-level environment is the most proximal level of the EMPA/EMO and is defined as the social and physical space where an individual exists. The *meso*-level environment describes the interaction between people in two or more *micro*-level environments and how they influence physical activity or obesity. The *exo*-level environment is the third distal level, and similar to the *meso*-level in that this level also includes two or more *micro*-level environments. However, one of the levels is external to the person whose behavior/outcome is being investigated. The most distal level to the individual is the *macro*-level environment, which encompasses the *micro*-, *meso*-, and *exo*-level environments, and is the sociocultural context of an individual. This level includes many broad level influences that can affect multiple individuals. Local policies, cultural background and/or socioeconomic status are examples of the *macro*-level environment (Lee et al., 2015; Lee & Cubbin, 2009; Spence & Lee, 2003).

The *intra*-personal factors encompassed in the EMPA/EMO include biological and genetic factors, behaviors, and psychological factors. Biological and genetic factors are more limiting because they are not typically amenable to change by choice and typically moderate effects between extra-individual factors and outcomes; however, must be accounted for when investigating these outcomes (Lee et al., 2015; Lee & Cubbin, 2009; Spence & Lee, 2003). Behaviors can include sedentary behavior, physical activity, and active transportation. The psychological factors are the personal traits and cognitive processes that impact physical activity participation, such as self-efficacy, attitudes, and perceptions (e.g., environment, available time, level of difficulty) that mediate the relationship between extra-individual factors and an individual's physical activity level or obesity. These are the higher-level mediators that can have a direct, causal effect on physical activity behavior (Lee et al., 2015; Lee & Cubbin, 2009; Spence & Lee, 2003). When designing interventions to positively change human behavior, these intrapersonal factors, such as psychological factors, are the mediators that are the underlying process that must be targeted for a change in outcomes (Sidani, 2014). The concept of pressure for macrosystem change include globalization, modernization, and urbanization. These pressures have been found to both positively and negatively impact physical activity levels and obesity (Lee et al., 2015; Lee & Cubbin, 2009; Spence & Lee, 2003).

The EMPA and EMO were extended in this investigation to test relationships among AT use (physical activity), total physical activity, and the presence or absence of CMS risk factors (health outcome) among adults. The EMPA/EMO provided the framework to guide the selection of intra-individual variables and at multiple environmental levels and are found in **Figure 1.1**. The *micro*-level environmental variables included in this collective body of research include research site and early care and education center. *Macro*-level environmental variables included race/ethnicity and socioeconomic status. The intra-individual factors include biological variables (age, sex, body mass index), educational level, and behavioral factors of the participants, which include physical activity, active transportation, and walking for active transportation. The outcome variables of interest include CMS risk factors, CMS, and total physical activity.

Specific Aims and Research Hypotheses

Specific Aim 1: Determine the extent to which walking as a method of AT is related to improved CMS risk factors and/or CMS among adults.

- Hypothesis 1a: Adults who walk for AT have better cardiometabolic health than those who use passive modes of transportation.

- Hypothesis 1b: It is expected that those engaging in more minutes of walking for AT increase will have fewer CMS risk factors; be less likely to have CMS; have lower waist circumference, triglycerides, fasting blood sugar, and blood pressure; and higher high-density lipoproteins.

Specific Aim 2: Examine associations among active transportation, physical activity, and CMS risk factors in a sample of African American and Hispanic/Latina women from two metropolitan cities in Texas, and examine these associations separately by ethnicity.

- Hypothesis 2a: Women who use active transportation will have lower body mass index, systolic and diastolic blood pressure, resting heart rate, and body fat percentage than women who do not use active transportation.
- Hypothesis 2b: Individuals who spend more time in active transportation and MVPA will have lower BMI, SBP, DBP, RHR, and BF.

Specific Aim 3: Examine associations of AT behaviors with CMS risk factors, CMS, and physical activity levels among urban, primarily Hispanic women from Arizona.

- Hypothesis 3a: Hispanic women who participate in AT will have a lower prevalence of abdominal obesity, hypertension, elevated fasting blood glucose and triglycerides, low high-density lipoproteins, and CMS, and will more frequently meet weekly MVPA recommendations than women who do not use active transportation.
- Hypothesis 3b: There are beneficial dose-response relationships between weekly minutes of AT use and waist circumference, systolic and diastolic blood pressures, fasting blood glucose, triglycerides, high-density

lipoproteins, CMS risk factor counts, minutes of MVPA per week, and total physical activity minutes per day.

Relationship among Chapters

Guided by the EMPA/EMO, specific variables were chosen to address each aim for this dissertation. Aim 1 is addressed in Chapter 2, and was completed to establish the state of the science on the association between walking for active transportation, the most common method of active transportation, and cardiometabolic health among adults. The desire was to investigate the relationship among women; however, the body of research was too limited to include only women, necessitating the inclusion of all adults. Chapter 3 provides a secondary analysis to answer Aim 2 and add to the limited active transportation research by investigating the relationship between active transportation, physical activity, and cardiometabolic health among Hispanic and non-Hispanic black women in Texas. Finally, in Chapter 4 we address Aim 3 through an investigation into the association of active transportation with objective measures of cardiometabolic health and physical activity, including blood markers among primarily Hispanic women.

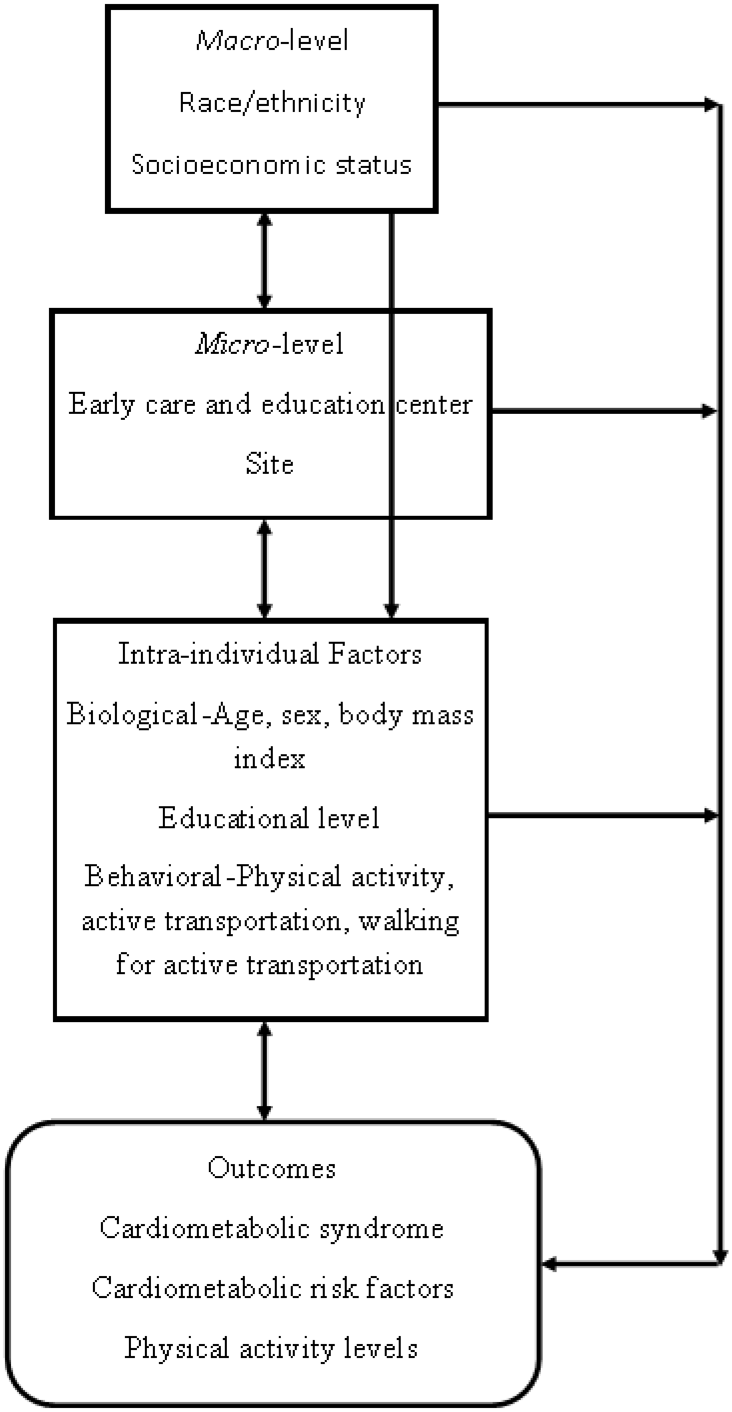

Figure 1.1. Model of hypothesized relationships of the Ecological Model of Physical Activity/Ecological Model of Obesity being tested.

CHAPTER 2

RELATIONSHIP BETWEEN WALKING FOR ACTIVE TRANSPORTATION AND CARDIOMETABOLIC HEALTH AMONG ADULTS: A SYSTEMATIC REVIEW

It is estimated that over one billion people in the world have cardiometabolic syndrome, with total costs into the trillions of dollars (Saklayen, 2018). Cardiometabolic syndrome is a clustering of three of five risk factors, including abdominal obesity, low levels of high density lipoproteins, hypertriglyceridemia, elevated fasting blood glucose, and hypertension, based on specified diagnostic criteria (Alberti et al., 2009), and can increase risks for cancer, cardiovascular disease, stroke, and non-insulin dependent diabetes (T2DM) (National Heart Lung and Blood Institute, n.d.). Cardiovascular disease is the number one cause of death across the world with three cardiometabolic risk factors, hypertension, T2DM, and dyslipidemia, and physical inactivity identified as the major contributing factors (World Health Organization, 2017).

Moderate to vigorous physical activity participation has numerous health benefits documented in the literature, including preventing cardiovascular disease and events, preventing, delaying, and treating cardiometabolic syndrome, and decreasing risks for T2DM and some cancers (CDC, 2019a; Physical Activity Guidelines Advisory Committee, 2018). Approximately 28% of the global adult population did not meet the recommended aerobic guidelines in 2016, with more women (31.7%) than men (23.4%) failing to meet guidelines (Guthold, Stevens, Riley, & Bull, 2018). There are several factors that have contributed to high physical inactivity levels, including increased sedentary occupations, lack of public space to be active, and increased traffic, air pollution, and use of passive methods of travel (World Health Organization, 2019).

The World Health Organization recommends active transportation, walking or cycling to or from any destination, as a method to increase physical activity for all communities (World Health Organization, 2018). Active transportation has been found to positively be related to decreased risks for diabetes and hypertension (Saunders, Green, Petticrew, Steinbach, & Roberts, 2013). Active transportation to work or school has also been found to be associated with better cardiometabolic health, but the review combined several cardiovascular outcomes into the synthesis and included both children and adults (Xu et al., 2013). A systematic review with meta-analysis found a significant association between active transportation and cardiovascular risk factors; however, when analyzing by sex only women had a significant relationship (Hamer & Chida, 2008). Furthermore, hypertension and diabetes were combined with other cardiovascular events and coronary heart disease, and were not investigated as individual health outcomes. In the most recent systematic review and meta-analysis conducted by Dinu, Pagliai, Macchi, & Sofi (2019), active transportation was found to be related to a significant decrease in diabetes, cardiovascular disease incidence, all-cause mortality, but not cardiovascular disease or cancer mortality. In subgroup analyses, cycling and walking for active transportation were compared and cycling was related to reduced risks for diabetes, cardiovascular disease incidence, all-cause and cancer mortality compared to walking. However, only three studies were included with diabetes as the outcome (Dinu et al., 2019), limiting interpretability of the findings.

Walking for active transportation is more common than cycling (Reynolds et al., 2014), and walking for physical activity is preferred over any other method among adults (CDC, 2013). The previous systematic reviews and meta-analyses on active transportation combined walking and cycling as a single behavior (Hamer & Chida, 2008; Saunders et al., 2013; Xu et al., 2013), except one (Dinu et al., 2019), making it difficult to draw conclusions or make recommendations for walking for active transportation alone. Furthermore, children were included with adults (Xu et al., 2013), and none included all five cardiometabolic risk factors separately or cardiometabolic syndrome as an outcome. This demonstrates the need to determine the extent to which walking for active transportation is related to improved cardiometabolic risk factors and cardiometabolic syndrome among adults, separate from cycling. It is hypothesized that adults who walk for active transportation have better cardiometabolic health than those who use passive modes of transportation. It is expected that as minutes of walking for active transportation increase, there will be lower prevalence of cardiometabolic risk factors and cardiometabolic syndrome, and/or lower waist circumference, triglycerides, fasting blood sugar, blood pressure, number of cardiometabolic risk factors, and higher high density lipoproteins.

Methods

Protocol

This systematic review was conducted and reported according to the Preferred Reporting Items of Systematic Reviews and Meta-Analyses (PRISMA) (Moher, Liberati, Tetzlaff, Altman, & PRISMA Group, 2009) and the protocol has been registered with the International prospective register of systematic reviews (PROSPERO); registration number CRD42019143081 (https://www.crd.york.ac.uk/prospero/).

Data Sources and Search Strategy

The literature searches for this review were conducted in March of 2019 using PubMed, Social Sciences Citation Index, Cochrane Library Trials, CINAHL, and PsycInfo. Databases were searched using advanced-search options, when applicable, with an identical search string entered into each, which was active transportation OR active commut* OR utilitarian walking OR active travel OR walk* for transportation OR walk commut*. In addition, key terms specific to each database were searched (e.g. Transportation/manpower[MeSH Terms]) for PubMed). The PubMed search was restricted by using NOT biological transport, active[MeSH Terms], due to the excessive number of studies that were related to biological active transport. Searches were limited to English, but there were no restrictions used for date or country. Initial searches were conducted by one author (EL) and citations were entered into an Excel spreadsheet. All duplicates were removed, and two authors (EL, JS) independently reviewed the final list of titles to determine study eligibility for inclusion into the systematic review. Both reviewers also identified previously conducted systematic reviews and meta-analyses related to the topic. The two reviewers compared the selected studies for inclusion and discussed any discrepancies. Additional studies were identified by reviewing the reference lists for all studies that met inclusion criteria and any previously conducted systematic reviews, and through searches completed for a dissertation literature review.

Eligibility Criteria

The inclusion criteria for this review were research studies (a) published in English in a peer-reviewed journal, (b) used a randomized-controlled trial, quasi-experimental, cohort, or cross-sectional research design, (c) investigated and analyzed walking as a method of active transportation in apparently healthy adults (≥ 18 years) separately from bicycling, and (d) reported any of the outcomes related to cardiometabolic syndrome and/or cardiometabolic risk factors (i.e., blood glucose, blood pressure, high density lipoproteins, triglycerides, waist circumference). All conference abstracts and studies that analyzed bicycling and walking active transportation together or only bicycling for active transportation were excluded.

Data Extraction

All research studies were reviewed multiple times with study characteristics extracted and recorded. The information extracted included (a) study setting, including city, state, country (if reported), (b) sample characteristics (size, race, ethnicity, sex, mean age), (c) study design, (d) follow-up time period and/or data collection time points, (e) measurement of walking for active transportation, (f) dependent variables with methods of measurement, (g) covariates (e.g. education, income, physical activity levels), (h) description of study findings, and (i) information necessary to conduct a quality assessment.

Quality Assessment

The instrument used to assess the quality of included studies was adapted from two previously adapted versions of the Strengthening the Reporting of Observational Studies in Epidemiology (STROBE) (Lubans, Boreham, Kelly, & Foster, 2011; Wanner et al., 2012). Two reviewers (EL, JS) independently completed the nine-item quality assessment for each study to determine a quality score ranging from 0-12, displayed in **Table 2.1**. Discrepancies between the two reviewers were discussed and disputes were resolved with a third reviewer (REL) when necessary.

Data Synthesis

The overall study characteristics and results were synthesized in aggregate. This included (a) study setting, including city, state, country (if reported), (b) sample characteristics (size, age, sex, race/ethnicity, socioeconomic status), (c) study design, (d) major variables and covariates with methods of measurements, (e) measurement of walking for active transportation, (f) follow-up time period and/or data collection time points, if applicable, (g) description of significant study findings for each outcome, (h) quality assessment rating, (i) strengths, and (j) limitations.

Results

Sample

A total of 13,161 study titles were screened after duplicates were removed. The full text of all studies that included active transportation (or other related term) and any health outcome in the title were assessed for eligibility, resulting in 13 studies that met inclusion and exclusion criteria and were included in this review. The flow diagram describing study selection can be found in **Figure 1**. Of the 13 studies, the designs included one pilot randomized controlled trial (Oja et al., 2007), four cohort studies (Hayashi et al., 1999; Honda et al., 2015; Kuwahara et al., 2016; Sato et al., 2007), and eight cross-sectional studies (Boone-Heinonen et al., 2009; García-Hermoso et al., 2018; Larouche, Faulkner, & Tremblay, 2016; Millett et al., 2013; Riiser, Solbraa, Jenum, Birkeland, & Andersen, 2018; Tajalli & Hajbabaie, 2017; Tao et al., 2019; Xiao et al., 2016). The data collection time points included for the pilot randomized controlled trial were at baseline and post 10-week intervention and the range of follow-up for the cohort studies was between 4 and 16 years. The significance level was set a 0.05 for all included studies except one, which was 0.10 (Tajalli & Hajbabaie, 2017).

Demographic Characteristics

The studies were published between 1991 and 2019, with sample sizes ranging from 65 to 26,628 and participants aged 18 to 79 years old. Only one study had fewer than 500 participants (Oja et al., 2007). Eleven studies included samples with both males and females (Boone-Heinonen et al., 2009; García-Hermoso et al., 2018; Honda et al., 2015; Kuwahara et al., 2016; Larouche et al., 2016; Millett et al., 2013; P. Oja et al., 2007; Riiser et al., 2018; Tajalli & Hajbabaie, 2017; Tao et al., 2019; Xiao et al., 2016) and two were only men (Hayashi et al., 1999; Sato et al., 2007). Of the studies with samples that included both males and females, only three analyzed the data by sex (Boone-Heinonen et al., 2009; García-Hermoso et al., 2018; Xiao et al., 2016).

Eight different countries were represented in this review. Four were conducted in Japan (Hayashi et al., 1999; Honda et al., 2015; Kuwahara et al., 2016; Sato et al., 2007), two each in China (Tao et al., 2019; Xiao et al., 2016) and the United States (Boone-Heinonen et al., 2009; Tajalli & Hajbabaie, 2017), and one each in Columbia (García-Hermoso et al., 2018), Canada (Larouche et al., 2016), India (Millett et al., 2013), Finland (Oja et al., 2007), and Norway (Riiser et al., 2018). One study from the United States included a sample of white and black participants (Boone-Heinonen et al., 2009), and the other did not include race/ethnicity characteristics (Tajalli & Hajbabaie, 2017). See **Table 2.2** for sample sociodemographic characteristics of each study.

Quality Assessment

The mean quality score for the included studies was 7.08±1.04 with a range of scores from 5 to 8. The highest possible quality score was 13, demonstrating that the included studies were of fairly low quality. Individual study quality assessment scores are found in **Table 2.2**.

Over half of the studies were cross-sectional (*n* = 8) with only 5 longitudinal. All studies included some details related to inclusion/exclusion criteria and/or cited studies that provided this information. Almost 40% of the studies (*n* = 5) included participants that were either randomly selected or population based (Boone-Heinonen et al., 2009; García-Hermoso et al., 2018; Larouche et al., 2016; Oja et al., 2007; Tajalli & Hajbabaie, 2017). The use and reporting of reliable measures of walking for active transportation was only found in four studies (Millett et al., 2013; Riiser et al., 2018; Sato et al., 2007; Xiao et al., 2016). Approximately 46% (*n* = 6) investigated walking for active transportation as a dichotomous variable (Boone-Heinonen et al., 2009; García-Hermoso et al., 2018; Oja et al., 2007; Riiser et al., 2018; Tajalli & Hajbabaie, 2017; Xiao et al., 2016), 46% (*n* = 6) as a categorical variable (Honda et al., 2015; Kuwahara et al., 2016; Larouche et al., 2016; Millett et al., 2013; Sato et al., 2007; Tao et al., 2019), and only 8% (*n* = 1) as a continuous (Hayashi et al., 1999) as the highest level of measurement of walking for active transportation in the study. For example, Hayashi et al. (1999) investigated walking for active transportation as a continuous variable, but also analyzed it as a categorical variable. Approximately 92% of studies (*n* = 12) included objective measures of outcome variables except for one (Tajalli & Hajbabaie, 2017). No study reported a power analysis; however, 69% of studies (*n* = 9) had sample sizes ranging from 500-10,000 (Boone-Heinonen et al., 2009; García-Hermoso et al., 2018; Hayashi et al., 1999; Larouche et al., 2016; Millett et al., 2013; Riiser et al., 2018; Sato et al., 2007; Tajalli & Hajbabaie, 2017; Tao et al., 2019) and almost a quarter (*n* = 3) had samples >10,000 (Honda et al., 2015; Kuwahara et al., 2016; Xiao et al., 2016). Only 38% of studies (*n* = 5) controlled for age, sex, where applicable, and socioeconomic status (Boone-Heinonen et al., 2009; Larouche et al., 2016; Millett et al., 2013; Riiser et al., 2018; Tajalli & Hajbabaie, 2017).

Covariates

Age (*n* = 12), other physical activity (*n* = 11), and smoking (*n* = 11) were the most common covariates found throughout the studies. There were a total of 58 different covariates that were controlled for in the statistical analyses across studies, with a mean of 10.15±6.23 covariates per study, which ranged from 0 to 27. Only five studies controlled for age, sex, if applicable, and socioeconomic status. **Table 2.3** includes a detailed description of covariates for each study.

Walking for Active Transportation Measurement

The levels of measurement and operational definitions for walking active transportation can be found for all studies according to outcome in **Table 2.4**. Only four studies reported the validity and/or reliability for the measure of walking for active transportation used in the study (Millett et al., 2013; Riiser et al., 2018; Sato et al., 2007; Xiao et al., 2016). A total of seven studies included a dichotomous variable for walking for active transportation with a total of four different operational definitions. This included walking to amenities (Boone-Heinonen et al., 2009), walking to campus (García-Hermoso et al., 2018), walking for any active transportation (Riiser et al., 2018) and walking to work (Millett et al., 2013; Tajalli & Hajbabaie, 2017; Tao et al., 2019; Xiao et al., 2016). The comparators included using a car to amenities (Boone-Heinonen et al., 2009), non/infrequent walk to campus (García-Hermoso et al., 2018), not working or being a farmer (Xiao et al., 2016), no active transportation use (Riiser et al., 2018), cycling active transportation (Oja et al., 2007), and using a car (Tajalli & Hajbabaie, 2017), car/taxi (Tao et al., 2019), or private transport to get to work (Millett et al., 2013).

In the seven studies that investigated walking for active transportation as a categorical variable (Hayashi et al., 1999; Honda et al., 2015; Kuwahara et al., 2016; Larouche et al., 2016; Millett et al., 2013; Sato et al., 2007; Tao et al., 2019), there were seven different ways that this was operationalized, and these can be found in **Table 2.4**. The reference groups also differed between studies, which included four different comparators. The one study that investigated walking for active transportation as a continuous variable defined it as 10 minute increments in walking to work (Hayashi et al., 1999).

Cardiometabolic Health Outcomes

Data extracted from the studies can be found in **Table 2.2**, which includes significant results. Details of study characteristics by subgroup can be found in **Table 2.5**. This includes the total number of studies and number significant for walking for active transportation measure (dichotomous, categorical, continuous), sex (both, female, male), and continent (North America, South America, Europe, Asia) by outcome variable.

Waist circumference/abdominal obesity. A total of 30.7% (n = 4) of studies investigated the association between walking for active transportation and waist circumference/abdominal obesity (Boone-Heinonen et al., 2009; García-Hermoso et al., 2018; Larouche et al., 2016; Xiao et al., 2016). Significant associations in the expected direction were found in 75% (*n* = 3) of studies, in which walking for active transportation was measured as a dichotomous variable (Boone-Heinonen et al., 2009; García-Hermoso et al., 2018; Xiao et al., 2016). One study found a significant relationship only for men (Boone-Heinonen et al., 2009) and another only for women (Xiao et al., 2016). No dose-response relationship between walking active transportation and waist circumference/abdominal obesity was found (Larouche et al., 2016).

High density lipoproteins/low levels of high-density lipoproteins. Forty-six percent (*n* = 6) of the studies investigated walking active transportation and high density lipoproteins/low levels of high density lipoproteins (García-Hermoso et al., 2018; Larouche et al., 2016; Oja et al., 2007; Riiser et al., 2018; Tao et al., 2019; Xiao et al., 2016). Two found significant relationships in the expected direction (García-Hermoso et al., 2018; Tao et al., 2019), with walking for active transportation as a dichotomous variable in both. A significant relationship was found for the entire sample in one study (Tao et al., 2019) and only for men in the other (García-Hermoso et al., 2018). A significant dose-response relationship was found for participants who had greater than 30 minutes of walking active transportation to work compared to car/taxi (Tao et al., 2019).

Triglycerides/hypertriglyceridemia. A total of 46% (*n* = 6) of included studies investigated the relationship between walking for active transportation and high triglycerides/hypertriglycerides (García-Hermoso et al., 2018; Larouche et al., 2016; Oja et al., 2007; Riiser et al., 2018; Tao et al., 2019; Xiao et al., 2016). Two studies found an association in the expected direction (García-Hermoso et al., 2018; Tao et al., 2019), which investigated walking active transportation as a dichotomous variable. There were no significant relationships when analyzing by sex (García-Hermoso et al., 2018; Xiao et al., 2016). One of two studies (Larouche et al., 2016; Tao et al., 2019) found a significant dose-response relationship, where those with greater than 30 minutes of walking active transportation to work were less likely to have hypertriglyceridemia compared to those who took car/taxi to work (Tao et al., 2019).

Fasting glucose/type 2 diabetes mellitus. Almost 62% (*n* = 8) of studies investigated fasting glucose/T2DM (García-Hermoso et al., 2018; Honda et al., 2015; Larouche et al., 2016; Millett et al., 2013; Riiser et al., 2018; Sato et al., 2007; Tajalli & Hajbabaie, 2017; Xiao et al., 2016). Three studies found significant associations in the expected direction (Millett et al., 2013; Sato et al., 2007; Tajalli & Hajbabaie, 2017), with one only significant for urban compared to rural dwellers (Millett et al., 2013). Two of those studies measured walking active transportation as a dichotomous variable (Millett et al., 2013; Tajalli & Hajbabaie, 2017). One significant relationship was found for men, which also found those who used walking for active transportation at least 21 minutes to work had lower odds of T2DM compared to 10 minutes or fewer (Sato et al., 2007).

Blood pressure/hypertension. A little more than half (*n* = 7) of the studies investigated walking active transportation and blood pressure/hypertension (García-Hermoso et al., 2018; Hayashi et al., 1999; Larouche et al., 2016; Millett et al., 2013; Riiser et al., 2018; Tajalli & Hajbabaie, 2017; Xiao et al., 2016). Just over 57% (*n* = 4) of the studies found a significant relationship in the expected direction (García-Hermoso et al., 2018; Hayashi et al., 1999; Riiser et al., 2018; Tajalli & Hajbabaie, 2017), three of which the exposure variable was dichotomous (García-Hermoso et al., 2018; Riiser et al., 2018; Tajalli & Hajbabaie, 2017). Riiser et al. (2018) and Tajalli & Hajbabaie (2017) found significant relationships for the entire sample and of those that analyzed by sex, only men were found to have a significant relationship (García-Hermoso et al., 2018). Only Hayashi et al. (1999), with a sample of only men, found a significant dose-response relationship where men who walked for active transportation at least 21 minutes to work had significantly lower odds of hypertension compared to men who walked for 10 minutes or less. Furthermore, for every additional 10 minutes of walking for active transportation, the risk of hypertension decreased (Hayashi et al., 1999).

Cardiometabolic syndrome. There was 23% (n = 3) of the studies that investigated walking for active transportation and cardiometabolic syndrome (García-Hermoso et al., 2018; Kuwahara et al., 2016; Xiao et al., 2016). None of the studies demonstrated a significant relationship, either by sex (García-Hermoso et al., 2018; Xiao et al., 2016) or for a dose-response (Kuwahara et al., 2016).

Discussion

The purpose of this review was to determine the relationship between walking for active transportation with cardiometabolic syndrome risk factors and cardiometabolic syndrome among adults. Walking for active transportation was found to be related to smaller waist circumference and/or risk of abdominal obesity (Boone-Heinonen et al., 2009; García-Hermoso et al., 2018; Xiao et al., 2016) and lower blood pressure and/or hypertension prevalence (García-Hermoso et al., 2018; Hayashi et al., 1999; Riiser et al., 2018; Tajalli & Hajbabaie, 2017); however, this evidence was of fairly low quality. Minimal to no evidence was found to suggest a relationship between walking for active transportation and high density lipoproteins, triglycerides and/or hypertriglyceridemia, fasting glucose and/or T2DM, or cardiometabolic syndrome. This review failed to demonstrate evidence for dose-response relationships between walking for active transportation and any cardiometabolic risk factor.

The findings of this review were somewhat unexpected, but not surprising. There were a number of measurement issues revealed among the studies that may have limited significant findings, which have been previously identified (Dinu et al., 2019; Hamer & Chida, 2008; Saunders et al., 2013; Wanner et al., 2012). Walking for active transportation was inconsistently operationalized, including as a dichotomous, categorical, and/or continuous variable. Walking for active transportation included walking to work (Hayashi et al., 1999; Honda et al., 2015; Kuwahara et al., 2016; Millett et al., 2013; Tajalli & Hajbabaie, 2017; Tao et al., 2019; Xiao et al., 2016), school (García-Hermoso et al., 2018), any neighborhood amenity (Boone-Heinonen et al., 2009), and any destination (Larouche et al., 2016; Riiser et al., 2018), with durations ranging from zero to 10-minutes, to greater than five hours. All studies except one (Larouche et al., 2016) failed to provide the frequency participants engaged in walking for active transportation. These methodological issues were further compounded by measures of walking for active transportation that were self-report and did not report adequate validity and/or reliability (Boone-Heinonen et al., 2009; García-Hermoso et al., 2018; Hayashi et al., 1999; Honda et al., 2015; Kuwahara et al., 2016; Larouche et al., 2016; Oja et al., 2007; Tajalli & Hajbabaie, 2017; Tao et al., 2019).

These rudimentary measures of active transportation are consistent throughout the literature and have been recognized as a methodological issue for over a decade (Hamer & Chida, 2008; Shephard, 2008), yet the use of flawed measures persist in the most current research conducted (García-Hermoso et al., 2018; Larouche et al., 2016; Tajalli & Hajbabaie, 2017; Tao et al., 2019). The inconsistency between measures and issues inherent with subjective measures making it difficult to detect significant relationships, draw conclusions, and/or conduct a quantitative analysis. It is vital that future research incorporate valid and reliable objective measures of walking for active transportation that can delineate destination, mode of transportation/activity, frequency, and duration. This could include using a combination of accelerometers and global positioning systems (Carlson et al., 2015); however, these measures are somewhat prohibitive due to cost, skills to analyze these types of data, and the perception of an invasion of privacy by research participants. Further research should be conducted to develop an objective measure of walking for active transportation that is affordable that can be analyzed easily to maximize use.

There were significant design and statistical heterogeneity investigating each cardiometabolic health outcome among the included studies, which can be found in **Table 2.4**. This demonstrated the wide range of exposure criteria for active transportation, comparators, abnormal cut-points for outcome variables, and statistical tests between studies (Althuis, Weed, & Frankenfeld, 2014). It was determined that the interpretability of any meta-analysis would have been difficult and inappropriate; therefore, was not conducted (Borenstein, Hedges, Higgins, & Rothstein, 2009).

Physiological responses, or lack thereof, between walking for active transportation and cardiometabolic health may partially explain the findings in this review, especially because the included studies failed to quantify the duration or intensity of walking for active transportation. Previous research has demonstrated that longer durations of physical activity may be needed to significantly improve high density lipoproteins and triglycerides in adults (Kodama et al., 2007; Pedersen & Saltin, 2015), suggesting that it takes a minimum of 120 minutes of physical activity per week to improve high density lipoproteins (Pedersen & Saltin, 2015). A systematic review with meta-analysis and meta-regression analysis of walking interventions found that walking significantly improved fasting glucose and blood pressure, but not waist circumference, high density lipoproteins, or triglycerides. Furthermore, the only dose-response improvements found for any cardiometabolic risk factor was between session duration and systolic blood pressure (Oja et al., 2018), suggesting that walking for active transportation may not be long or intense enough to impact cardiometabolic risk factors, especially the blood markers.

There may also be physiological differences based on sex. We found a significant association in the expected direction found for women only 7.7% of the time (Xiao et al., 2016) compared to 33.3% for men (Boone-Heinonen et al., 2009; García-Hermoso et al., 2018; Hayashi et al., 1999; Sato et al., 2007). Only a few studies in this review were analyzed by sex, which could obscure significant relationships if there different physiological responses to walking for active transportation based on sex. Contrary to our findings, Hamer & Chida (2008) found more protective effects between active transportation and cardiovascular risk for women than men; however, Dinu et al. (2019) and Wanner et al., (2012) found no differences in any outcome by sex. Research investigating the effects of physical activity on cardiometabolic outcomes has been unable to draw sex-specific conclusions, because the literature is either inconsistent and/or inconclusive (Oja et al., 2018; Physical Activity Guidelines Advisory Committee, 2018; Zhang et al., 2017).

Finally, few studies exist that investigate walking for active transportation and cardiometabolic risk factors and syndrome. Most of the research found included cross-sectional and cohort designs, with only one experimental study. Considering the limited quantity of studies combined with the extensive methodological quality issues, it is difficult to draw firm conclusions. It is imperative that future research be conducted with experimental designs to determine the presence of any causal relationships between walking for active transportation and cardiometabolic health, using objective exposure and outcome measures. This should include large samples of diverse populations and be analyzed by sex to determine any differences in effects.

Strengths and Limitations

To our knowledge, this is the first systematic review specifically investigating walking for active transportation and cardiometabolic health among adults. We identified measurement and methodological issues, as well as gaps in the literature that provide direction for future research to improve study quality. The main limitation to this review was the inability to conduct a meta-analysis for each cardiometabolic outcome.

Conclusion

The evidence-base for walking for active transportation is of low quality and primarily cross-sectional and cohort designs, with weak measures of walking for active transportation. Future research should include randomized controlled trials using objective measures of walking for active transportation to determine the causal effects on cardiometabolic health. Study designs need to include consistent definitions and measurements of walking for active transportation, with analyses conducted by sex. Walking for active transportation may influence waist circumference and blood pressure among adults warranting further investigation. Policymakers and city planners should incorporate pedestrian friendly options into existing and proposed zoning and infrastructure designs, and health practitioners should encourage patients to participate in walking active transportation, when appropriate.

Table 2.1. Quality assessment

Quality criteria	Specification	Score
1. Study type	Cross-sectional	0
	Longitudinal	1
2. Included a description of participant eligibility criteria	No	0
	Yes	1
3. Participants randomly selected or a population based sample	No	0
	Yes	1
4. Measure of AT includes description with adequate reliability	No	0
	Yes	1
5. Assessment of walking AT	Dichotomous	1
	Categorical	2
	Continuous	3
6. Measurement of outcomes	Self-report, not validated	0
	Self-report, validated	1
	Objective measurement	2
7. Power calculation reported and study was adequately powered to detect hypothesized relationships	No	0
	Yes	1
8. Sample size	<500 (too small for meaningful results)	0
	500-10,000	1
	>10,000	2
9. Controlled for confounding (at least age, sex (if applicable), and SES (income, education, and/or social class)	No	0
	Yes	1
Total score	Min	0
	Max	13

Note. AT = active transportation; SES = socioeconomic status.

Table 2.2. Studies that examine walking AT, CMS risk factors and CMS among adults.

Author Year	Sample characteristics	Analyzed by sex	Exposure	Outcomes	Significant Findings	Quality Score
Boone-Heinonen et al. 2009	*N* = 2717 Age range = 38-50 56.8% female, 43.1% male Female mean age = 45.1 52.6% white, 47.4% black females 36.9% females with income ≤$42,500 Male mean age = 45.2 60.2% white, 39.8% black males 27.6% males with income ≤$42,500 *n* = 2490 walk or car only 42% female, 58% male Birmingham, AL; Chicago, IL; Minneapolis, MN; Oakland, CA United States	Only by sex	Walk vs. car to work	WC	Walking to amenities was significantly associated with WC for men, β = **1.63 (95% CI, -3.18, 0.09)**	7
Garcia-Hermoso et al. 2018	N = 784 Mean age = 20.1 78.6% female, 21.4% male	Only by sex	Walk vs. non/ infrequent walk to campus	Abdominal obesity, low HDL, high TG, high	Men who walked to campus had significantly lower risks for HTN, OR =	6

	No race/ethnicity or income data Tunja, Columbia			FG, HTN, CMS	**0.26 (95% CI, 0.13, 0.55)** and low HDL, OR = **0.29 (95% CI 0.14, 0.59)** than those who were non/ infrequent walkers to campus	
Hayashi et al. 1999	N = 6017 males Age range = 35-60 Mean age=41.7 No race/ethnicity or income data Follow-up 6-16 years Osaka, Japan	NA	0-10 minute vs. 11-20 minute walk to work 0-10 minute vs. ≥21 minute walk to work Walk to work per 10 minutes	HTN	The relative risk for HTN was significantly lower in men who walked to work for ≥21 minutes compared to those who walked 0-10 minutes, RR = **0.71 (95% CI, 0.52, 0.97)** When the duration of walking to work was increased by 10 minutes, the risk for HTN decreased by 12%, RR = **0.88 (95% CI, 0.79, 0.98)**	8
Honda et al. 2015	N = 26,628 Age range = 30-64 Mean age = 45.3 12.8% female, 87.2% male No race/ethnicity or income data	No	<20 minute vs. 20 40 minute walk to work <20 minute vs. ≥41 minute walk to work	T2DM	Walking to and from work was not associated with risk for T2DM in any model	8

	Mean follow-up = 5.2 years Japan					
Kuwahara et al. 2015	N = 22,383 Age range = 30-64 Mean age = 45.2 15.1% female, 84.9% male No race/ethnicity or income data Mean follow-up = 4.1 years Japan	No	<20 minute vs. 20 40 minute walk to work <20 minute vs. ≥41 minute walk to work	CMS	There was no significant difference in risk for CMS between any groups of walking to and from work	8
Larouche et al. 2016	N=7160 Age range = 20-79 Mean age = 45.7 50.5% female, 49.5% male No race/ethnicity data 25.2% < $40,000 Canada	No	1-5 vs. <1 hour utilitarian walking >5 vs. 1-5 hour utilitarian walking >5 vs. <1 hour utilitarian Walking	WC, HDL, TG, HbA1c, SBP, DBP	There were no significant differences between the groups of utilitarian walking for any outcome	8
Millett et al. 2013	N = 3,902 Mean age = 42.2 12.8% female, 87.2% male 35.3% low SES 35% rural, 65% urban n = 1,779 walked only	No	Walk to work vs. private transport 0-29 minute walk to work vs. no active travel ≥30 minute walk to work vs. no active	Self-reported HTN, self-reported T2DM, undiagnosed HTN,	There were no significant differences in risk of any outcome for those who walked to work compared to those who used private transport, or for any	8

	or private transport 5.9% female, 94.1% male Lucknow, Nagpur, Hyperabad, & Bangalore, India		travel 0-19 minute walk to work vs. no active travel ≥20 minute walk to work vs. no active travel 0-39 minute walk to work vs. no active travel ≥40 minute walk to work vs. no active travel	undiagnosed T2DM	dose response The urban dwellers who walked to work had lower risk for self-reported T2DM than those who used private transport, RR = **0.21 (95% CI, 0.04, 0.93**) When separating participants by rural compared to urban dwellers, there were no significant differences in risk for any other outcome for those who walked to work compared to those who used private transport	
Oja et al. 1991	N = 68 Age range = 20-65 44.1 % female, 55.9 male No race/ethnicity or income data *n* = 39 walking intervention Finland	No	Walking active transportation intervention vs. cycling active transportation intervention Those who lived 2 4.9 km from work were randomly assigned into walking treatment and control group	HDL, TG	No statistically significant differences in HDL or TG pre/post walking AT intervention	6

			Those who lived 5-6.9 km from work had the choice of walking or cycling treatment group and then were randomized into treatment and control group			
Riiser et al. 2018	N = 2445 Age range = 30-67 Mean age = 48 56.4% female, 43.6% male No race/ethnicity data Low SES Oslo, Norway	No	≥1 ten-minute bout per week vs. no walk for travel	Low HDL, elevated TG, undiagnosed and self-reported T2DM, systolic HTN, diastolic HTN, self-reported HTN, all HTN	Those who walked for travel had lower odds of systolic HTN compared to those that did walk for travel, OR = **0.718 (95% CI, 0.554, 0.931)** Walking for travel was Not associated with low HDL, elevated TG, undiagnosed/ self-reported T2DM, diastolic HTN, self reported HTN, all HTN	7
Sato et al. 2007	N = 8576 males Mean age = 47.8 No race/ethnicity or income data Follow-up = 4 years Kansai, Japan	NA	0-10 vs. 11-20 minute walk to work 0-10 vs. ≥21 minute walk to work	T2DM	Men who walked to work for ≥21 minutes were less likely to have T2DM than those who walked to work for 0-10 minutes, OR	8

					= 0.73 (95% CI, 0.58, 0.92) There were no significant differences in risk for T2DM for those with a 0-10 vs. 11-20 minute walk to work	
Tajalli et al. 2019	N = 2650 Mean age = 46.5 55% female, 45% male No race/ethnicity data Mean income = 200-400% FPL n = 1010 walking or private commuters New York City, NY United States	No	Walking commute to work vs. private mode	Self-reported, T2DM, self-reported HTN	Walking commute was significantly associated with less likelihood of self reported diabetes, coefficient = **-0.47, *p* = .004**, and self-reported HTN, coefficient = **-0.17, *p* = .097**; α = .10	5
Tao et al. 2019	N = 8090 Age range = 18-65 Mean age = 38.36 43.9% female, 56.1% male 11.9% high school or lower n = 3282 walked or car/taxi to/from work 40.2% female, 59.8% male Beijing, China	No	Walk vs. car/taxi to/from work ≤30 minute walk to work vs. car/taxi >30 minute walk to work vs. car/taxi	Elevated TG, low HDL	Those who walked to/from work were less likely to have low HDL, OR = **0.69 (95% CI, 0.54, 0.88)**, and elevated TG, OR **= 0.64 (95% CI, 0.48, 0.86)**, compared to those who took a car/taxi to work Those who walked >30 minute to work were	6

					less likely to have low HDL, OR = **0.64 (95% CI, 0.47, 0.86)** and elevated TG, OR = **0.53 (95% CI, 0.38, 0.75)** compared to those who took car/taxi to work There were no differences in risk for low HDL or elevated TG for those who walked ≤30 minute walk to work compared to those who took car/taxi to work	
Xiao et al. 2016	N = 20,502 Age range = 18-74 65.9% female, 34.1% male No race/ethnicity data 65.4% females with income ≤500 Yuan, 62.7% males with Income ≤500 Yuan n = 3,600 walked to work, did not work, or were farmers 77.2% female, 22.8% male	Only by sex	Walk to/from work vs. no work/farmer	Abdominal obesity, low HDL, elevated TG, elevated FG, systolic HTN, diastolic HTN, CMS	Women who walked to work were significantly less likely to have abdominal obesity than women who did not work or were farmers, OR = **0.71 (95% CI, 0.60, 0.82)** There were no significant differences in risk for any other CMS risk factor or CMS for women who	7

Nantong, China		walked to work compared to those who did not work or were farmers There were no significant differences in any CMS risk factor or CMS for men who walked to/from work compared to men who did not work or were farmers

Note. AT = active transportation; CMS = cardiometabolic syndrome; vs. = versus; WC = waist circumference; β = beta coefficient; CI = confidence interval; HDL = high-density lipoproteins; TG = triglycerides; FG = fasting glucose; HTN = hypertension; OR = odds ratio; NA = not applicable; RR = relative risk; T2DM = type 2 diabetes mellitus; HbA1c = hemoglobin A1c; SBP = systolic blood pressure; DBP = diastolic blood pressure; SES = socioeconomic status; FPL = Federal poverty level.
Boldface = significant finding.

Table 2.3. Covariates by study.

Reference	Total covariates	Age	Other PA	Smoking	Alcohol	Sex	BMI	Education	Additional covariates
Boone-Heinonen et al. (2009)	8	√	√	√	√			√	Income, race, site
Garcia-Hermoso et al. (2018)	7	√	√	√	√		√		Diet, commute distance
Hayashi et al. (1999)	8	√	√	√	√		√		FG, SBP, DBP
Honda et al. (2015)	11	√	√	√	√	√	√		Shift work, sleep, HTN, FH DM, OPA
Kuwahara et al. (2015)	9	√	√	√	√	√	√		Shift work, sleep, OPA
Larouche et al. (2016)	8	√	√			√		√	Income, complex design, social class, place of residence
Millett et al. (2013)	10	√	√	√	√	√			Social class, standard of living, occupation, factory location, fat intake
Oja et al. (1991)	0								
Riiser et al. (2018)	8	√	√	√		√		√	Cycling AT, employment, country
Sato et al. (2007)	7	√	√	√	√		√		FG, FH DM

Tajalli et al. 2019	14	√	√	√	√	√		√	Income, diet, marital status, neighborhood SES, children, household size, FV, soda
Tao et al. (2019)	27	√		√	√	√	√	√	Commute time, FG, sleep, fat intake, work pressure, PA frequency, PA intensity, vegetable diet, excessive salt, sugar, and meat, medication for HTN, DM, and dyslipidemia, MAP, $PM_{2.5}$, PM_{10}, NO_2, SO_2, CO, O_3
Xiao et al. (2016)	15	√	√	√	√		√	√	Income, OPA, marital status, FV, tea, red meat, white meat, fish, soy
Totals		12	11	11	10	7	7	6	

Note. PA = physical activity; BMI = body mass index; FG = fasting glucose; SBP = systolic blood pressure; DBP = diastolic blood pressure; HTN = hypertension; FH DM = family history diabetes mellitus; OPA = occupational physical activity; AT = active transportation; FV = fruit and vegetable consumption; DM = diabetes mellitus; MAP = mean arterial pressure; PM = particulate matter; NO2 = nitrogen dioxide; SO2 = sulfur dioxide; CO = carbon monoxide; O3 = ozone.

Table 2.4. Study design heterogeneity by outcome

Design	Walking AT exposure/comparison	Outcome measurements (abnormal cut points)	Statistical test	Author Year
Waist circumference/abdominal obesity				
Cross-sectional	Dichotomous Walk vs. car to any neighborhood amenity	Continuous-cm	Linear regression	Boone-Heinonen et al. 2009
Cross-sectional	Dichotomous Walk vs. non/infrequent walk to campus	Dichotomous (men ≥90 cm, women ≥80 cm)	OR	Garcia-Hermoso et al. 2018
Cross-sectional	Dichotomous Walk to/from work vs. no work/farmer	Dichotomous (men ≥85 cm, women ≥80 cm)	OR	Xiao et al. 2016
Cross-sectional	Categorical/dose response <1 hour vs. 1-5 hours vs. >5 hours utilitarian walking	Continuous-cm	ANCOVA	Larouche et al. 2016
High density lipoproteins/low levels of high density lipoproteins				
Pilot RCT Crossover	Dichotomous Walking vs. cycling AT intervention	Continuous-mmol/L	RM-ANOVA	Oja et al. 1991
Cross-sectional	Dichotomous Walk vs. non/infrequent walk to campus	Dichotomous (men <40 mg/dL, women <50 mg/dL)	OR	Garcia-Hermoso et al. 2018
Cross-sectional	Dichotomous ≥1 ten-minute bout/week vs. no active travel	Dichotomous (<1.3 mmol/L)	OR	Riiser et al. 2018
Cross-sectional	Dichotomous Walk to/from work vs.	Dichotomous	OR	Xiao et al. 2016

	no work/farmer	(men <1.0 mmol/L, women <1.3 mmol/L, or self-reported treatment for HDL)		
Cross-sectional	Dichotomous Walking to/from work vs. car/taxi Categorical/dose response ≤30 minute walk to work vs. car/taxi >30 minute walk to work vs. car/taxi	Dichotomous (<1.0 mmol/L, 40 mg/dL)	OR	Tao et al. 2019
Cross-sectional	Categorical/dose response <1 hour vs. 1-5 hours vs. >5 hours utilitarian walking	Continuous-mmol/L	ANCOVA	Larouche et al. 2016
Triglycerides/hypertriglyceridemia				
Pilot RCT Crossover	Dichotomous Walking vs. cycling AT intervention	Continuous-mmol/L	RM-ANOVA	Oja et al. 1991
Cross-sectional	Dichotomous Walk vs. non/infrequent walk to campus	Dichotomous (≥150 mg/dL)	OR	Garcia-Hermoso et al. 2018
Cross-sectional	Dichotomous ≥1 ten-minute bout/week vs. no walk for travel	Dichotomous (>1.7 mmol/L)	OR	Riiser et al. 2018
Cross-sectional	Dichotomous Walk to/from work vs. no work/farmer	Dichotomous (≥1.7 mmol/L or self-reported lipid medication)	OR	Xiao et al. 2016
Cross-sectional	Dichotomous Walk to/from work vs. car/taxi Categorical/dose response	Dichotomous (≥2.3 mmol/L, 200 mg/dL)	OR	Tao et al. 2019

	≤30 minute walk to work vs. car/taxi >30 minute walk to work vs. car/taxi			
Cross-sectional	Categorical/dose response <1 hour vs. 1-5 hours vs. >5 hours utilitarian walking	Continuous-mmol/L	ANCOVA	Larouche et al. 2016
Fasting glucose/type 2 diabetes mellitus				
Cross-sectional	Dichotomous Walk vs. non/infrequent walk to campus	Dichotomous (FG ≥100 mg/dL)	OR	Garcia-Hermoso et al. 2018
Cross-sectional	Dichotomous ≥1 ten-minute bout/week vs. no walk for travel	Dichotomous (combined undiagnosed based on elevated non-FG, FG, and/or HbA1C and self-reported diabetes)[a] Dichotomous (self-reported diabetes)	OR	Riiser et al. 2018
Cross-sectional	Dichotomous Walk to work vs. private mode	Dichotomous (self-reported diabetes)	Binary probit model	Tajalli et al. 2019
Cross-sectional	Dichotomous Walk to/from work vs. no work/farmer	Dichotomous (FG ≥5.6 mmol/L or self-reported medication)	OR	Xiao et al. 2016
Cross-sectional	Dichotomous Walk to work vs. private transport Categorical/dose response 1 0-19 minute walk to work vs. no active travel ≥20 minute walk to work vs.	Dichotomous (self-reported diabetes) Dichotomous (undiagnosed=FG >7.0 mmol/L) Dose response Dichotomous	RR	Millett et al. 2013

	no active travel Categorical/dose response 2 0-29 minute walk to work vs. no active travel ≥30 minute walk to work vs. no active travel Categorical/dose response 3 0-39 minute walk to work vs. no active travel ≥40 minute walk to work vs. no active travel	(self-reported diabetes)		
Cross-sectional	Categorical/dose response <1 hour vs. 1-5 hours vs. >5 hours utilitarian walking	Continuous-HbA1C	ANCOVA	Larouche et al. 2016
Cohort	Categorical/dose response <20 minutes vs. 20-40 minute walk to work <20 minute vs. ≥41 minute walk to work	Dichotomous (FG ≥126 mg/dL (7.0 mmol/L), HbA1C ≥6.5% (44 mmol/L), random glucose ≥200 mg/dL (11.1 mmol/L), or self-reported medication)	HR	Honda et al. 2015
Cohort	Categorical/dose response 0-10 minute vs. 11-20 minute walk to work 0-10 min vs. ≥21 minute walk to work	Dichotomous (FG ≥126 mg/dL or self-reported medication)	OR	Sato et al. 2007
Blood pressure/hypertension				
Cross-sectional	Dichotomous Walk vs. non/infrequent walk to campus	Dichotomous (SBP ≥130, DBP ≥ 85 mmHg)	OR	Garcia-Hermoso et al. 2018
Cross-sectional	Dichotomous ≥1 ten-minute bout/week vs.	Dichotomous (SBP >140 mmHg)	OR	Riiser et al. 2018

	no walk AT	Dichotomous (DBP >90 mmHg) Dichotomous (self-reported medication) Dichotomous (SBP, DBP and/or self-reported medication)		
Cross-sectional	Dichotomous Walking commute to work vs. private mode	Dichotomous (self-reported HTN)	Binary probit model	Tajalli et al. 2019
Cross-sectional	Dichotomous Walking to/from work vs. no work/farmer	Dichotomous (SBP ≥130 mmHg or self-reported medication) Dichotomous (DBP ≥ 85 mmHg or self-reported medication)	OR	Xiao et al. 2016
Cross-sectional	Dichotomous Walk to work vs. private transport Categorical/dose response 1 0-19 minute walk to work vs. no active travel ≥20 minute walk to work vs. no active travel Categorical/dose response 2 0-29 minute walk to work vs. no active travel ≥30 minute walk to work vs. no active travel Categorical/dose response 3 0-39 minute walk to work vs. no active travel ≥40 minute walk to work vs.	Dichotomous (self-reported HTN) Dichotomous (undiagnosed SBP ≥140 mmHg or DBP ≥90 mmHg) Dose response Dichotomous (self-reported HTN)	RR	Millett et al. 2013

	no active travel			
Cross-sectional	Categorical/dose response <1 hour vs. 1-5 hours vs. >5 hours utilitarian walking	Continuous-SBP mmHg and DBP mmHg	ANCOVA	Larouche et al. 2016
Cohort	Categorical/dose response 1 0-10 minute vs. 11-20 minute walk to work 0-10 minute vs. ≥21 minute walk to work Continuous/dose response 2 Per 10 minutes increments	Dichotomous (SBP ≥160 mmHg, DBP ≥95 mmHg, or self-reported medication)	HR	Hayashi et al. 1999
Cardiometabolic syndrome				
Cross-sectional	Dichotomous Walk vs. non/infrequent walk to campus	Dichotomous (≥3 risk factors: WC men ≥90 cm, women ≥80 cm; HDL men <40 mg/dL, women <50 mg/dL; TG ≥150 mg/dL; FG ≥100 mg/dL; SBP ≥130 or DBP ≥ 85 mmHg)[b]	OR	Garcia-Hermoso et al. 2018
Cross-sectional	Dichotomous Walk to/from work vs. no work/farmer	Dichotomous (≥3 risk factors: WC men ≥85 cm, women ≥80 cm; HDL men <1.0 mmol/L, women <1.3 mmol/L, or self-reported treatment for HDL; TG ≥1.7 mmol/L or self-reported lipid medication; FG ≥5.6 mmol/L or self-reported medication; SBP ≥130 mmHg or DBP ≥85 mmHg or self-reported medication)	OR	Xiao et al. 2016
Cohort	Categorical/dose response <20 minutes vs. 20-40 minute walk to work <20 minute vs. ≥41 minute walk to work	Dichotomous (≥3 risk factors: WC men ≥90 cm, women ≥80 cm; HDL men <40 mg/dL, women <50 mg/dL; TG ≥150 mg/dL or self-reported medication; FG ≥100 mg/dL or self-reported	HR	Kuwahara et al. 2015

	medication; SBP ≥130 mmHg or DBP ≥85 mmHg or self-reported medication)

Note. AT = active transportation; OR = odds ratio; ANCOVA = analysis of covariance; RM-ANOVA; repeated measures analysis of variance; HDL = high-density lipoproteins; RR = risk ratio; FG = fasting glucose; HbA1C = hemoglobin A1C; HR = hazard ratio; SBP = systolic blood pressure; DBP = systolic blood pressure; HTN = hypertension; WC = waist circumference; TG = triglyceride.

[a]Did not provide cut points.

[b]Did not include self-report diagnoses or medication.

Table 2.5. Subgrouping of associations between walking AT and CMS outcomes.

	WC		HDL		TG		FG/T2DM		BP/HTN		CMS	
	n	*n* significant	*n*	*n* significant	*n*	*n* significant	*n*	*n* significant	*n*	*n* significant	*n*	*n* significant
WAT Exposure												
Dichotomous	3	**2**	5	**2**	5	**1**	5	**2**	5	**3**	2	0
Categorical	1	0	2	**1**	2	**1**	4	**1**	3	**1**	1	0
Continuous	-	-	-	-	-	-	-	-	1	**1**	-	-
Sex												
Both	1	**1**	4	**1**	3	**1**	5	**2**	4	**2**	1	0
Female	3	**1**	2	0	2	0	2	0	2	0	2	0
Male	3	**1**	2	**1**	2	0	3	**1**	3	**2**	2	0
Continent												
N. America	2	**1**	1	0	1	0	2	**1**	2	**1**	-	-
S. America	1	0	1	**1**	1	0	1	0	1	**1**	1	0
Europe	-	-	2	0	2	0	1	0	1	**1**	-	-
Asia	1	**1**	2	**1**	2	**1**	4	**2**	3	**1**	2	0

Note. AT = active transportation; CMS = cardiometabolic syndrome; n = number of studies; WC = waist circumference/abdominal obesity; HDL = high-density lipoproteins/low levels of high-density lipoproteins; TG = triglycerides/hypertriglyceridemia; FG = fasting glucose; T2DM = type 2 diabetes mellitus; BP = blood pressure; HTN = hypertension; WAT = walking for active transportation; N = North; S = South.
Boldface = significant.

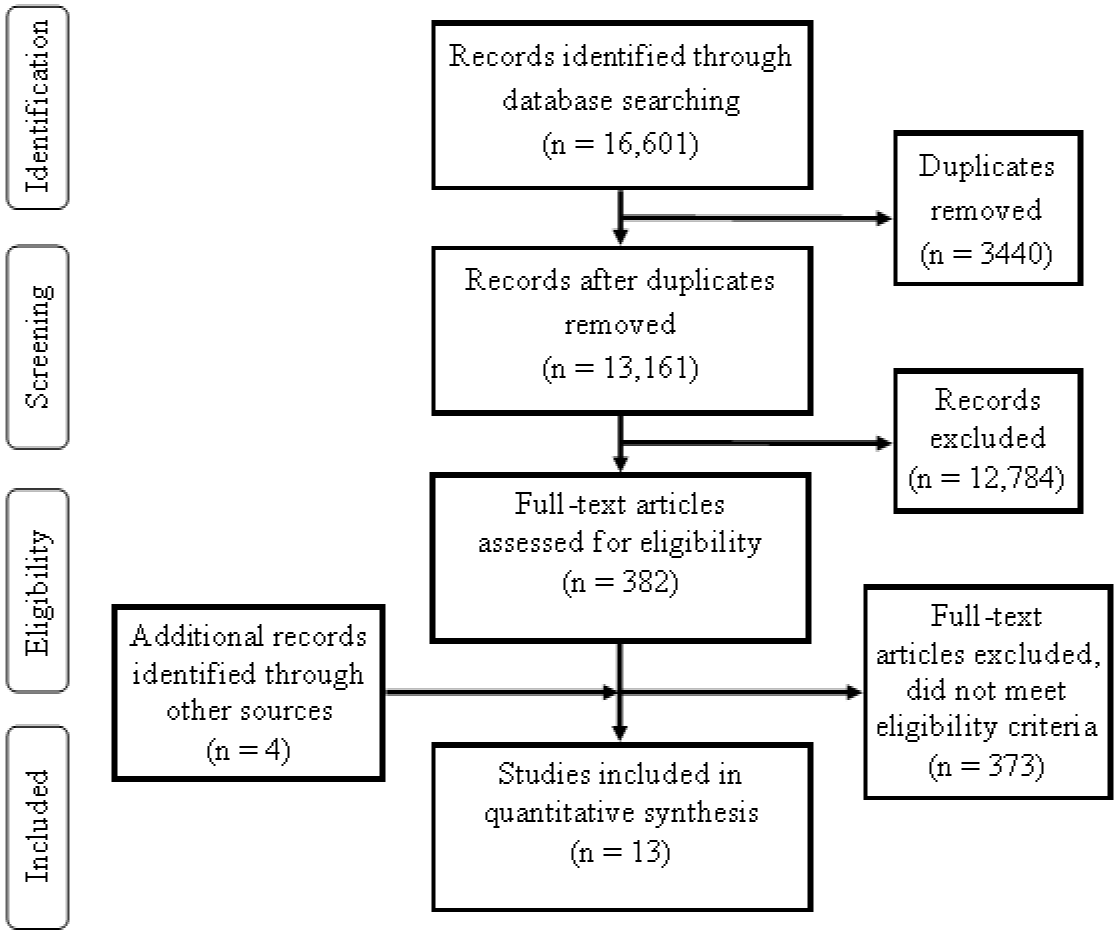

Figure 2.1. Flow diagram of study selection.

CHAPTER 3

HEALTH IS POWER (HIP): ACTIVE TRANSPORTATION, PHYSICAL ACTIVITY, AND CARDIOMETABOLIC HEALTH AMONG ETHNIC MINORITY WOMEN

Abstract

Background: Active transportation (AT) increases physical activity (PA), reducing cardiometabolic risk among non-Hispanic white adults; however, research on these linkages in racial/ethnic minority women is sparse. This study explored these associations in 327 African American (AA) and Hispanic/Latina (HL) women. **Methods:** This analysis used sociodemographics, self-reported AT via the International Physical Activity Questionnaire, accelerometer-measured moderate to vigorous PA (MVPA), body mass index (BMI), systolic (SBP) and diastolic blood pressures (DBP), resting heart rate (RHR), and body fat percentage (BF). Unadjusted bivariate associations and associations adjusted for sociodemographic demographic factors were examined. **Results:** AT users had higher levels of objective MVPA, but this was not statistically significant. AT was not associated with cardiometabolic risk factors in adjusted models (*ps*>.05); however, SBP was lower for AT users. MVPA was negatively associated with DBP and BF overall, negatively associated with BMI and BF in AA women, and negatively associated with BF in HL women (*ps*<.05). **Conclusions:** MVPA was associated with improvements in BMI, DBP, and BF among minority women, and these relationships may vary by race/ethnicity. Practitioners should recommend increased participation in MVPA. Future research, using longitudinal designs, should investigate AT's potential for increasing MVPA and improving cardiometabolic health along with the role of race/ethnicity in these associations.

In 2017, only 24% of adults in the United States met the 2008 physical activity recommendations (Blackwell & Villarroel M.A., 2018). African American and Hispanic/Latina women were less likely (13.9% and 13.8%, respectively) to have met recommendations than non-Hispanic white women (23.7%) were. Despite the many health promoting benefits physical activity has for adults, including prevention and control of excessive weight gain, type 2 diabetes mellitus, hypertension, dyslipidemia, and/or cardiometabolic syndrome (Physical Activity Guidelines Advisory Committee, 2018), low rates of physical activity participation persist among women of color.

In the United States, healthcare costs for an individual with cardiometabolic syndrome are approximately $4,000 per year higher than costs for an individual without cardiometabolic syndrome (McQueen et al., 2016). A cardiometabolic syndrome diagnosis includes having been diagnosed with at least three of the following risk factors: hypertension, abdominal obesity, low levels of high-density lipoproteins, hypertriglyceridemia, and pre-diabetes (National Heart Lung and Blood Institute, n.d.). Across all adult age groups, racial/ethnic minority women are disproportionately affected by cardiometabolic syndrome compared to non-Hispanic white women, with prevalence of cardiometabolic syndrome exceeding 50% among African American and Hispanic/Latina women age 50 or older (Moore et al., 2017).

Active transportation is walking or bicycling for all or part of a commute to any destination (CDC, 2011). Systematic reviews conducted to evaluate active transportation use and health have found active transportation to be associated with a lower risk of diabetes and high blood pressure (Berger, Qian, & Pereira, 2017; Furie & Desai, 2012; Saunders et al., 2013; Xu et al., 2013) and lower body weight in adults (Wanner et al., 2012; Xu et al., 2013). Furthermore, active transportation users have been found to have better cardiovascular health than those who do not use active transportation (Xu et al., 2013), suggesting that promotion of active transportation may be an effective physical activity intervention. Active transportation may provide a sustainable method to improve health and reduce cardiometabolic syndrome in racial/ethnic minority women, because it is accessible (low cost, not requiring additional equipment) and does not require taking time away from family, which has been found to be a barrier to physical activity (Bautista et al., 2011; Im et al., 2010). Incorporating active transportation into a daily trip to work, school, or other destination can add numerous opportunities to be active every day and allows members of the family to participate in the activity together.

Participation in health promoting behaviors, such as physical activity and active transportation, is complex and multiply determined. The Ecological Model of Physical Activity (EMPA) is a dynamic systems framework used to guide investigation into how factors at multiple (e.g., micro and macro) environmental levels can act directly and indirectly, and interact within and across people and places to influence individual-level physical activity (including active transportation) and health outcomes (Lee et al., 2015; Lee & Cubbin, 2009; Spence & Lee, 2003). This framework allows for exploration of how social and economic factors, such as income, education, and cultural context may influence individual participation in health promoting behaviors and, in turn, health outcomes.

Although numerous studies have investigated the health promoting benefits of active transportation in samples of primarily white adults (Furie & Desai, 2012; Laverty, Mindell, Webb, & Millett, 2013; Saunders et al., 2013; Wanner et al., 2012; Xu et al., 2013), these associations have not been well-studied in African American or Hispanic/Latina women. Furthermore, the current literature on how best to provide effective physical activity interventions and recommendations for different social groups and minority women is still sparse (Ball, Carver, Downing, Jackson, & O'Rourke, 2015; Physical Activity Guidelines Advisory Committee, 2018). Guided by the EMPA, this exploratory study addresses this gap in the literature by investigating associations among active transportation, physical activity, and cardiometabolic risk factors in a sample of African American and Hispanic/Latina women from two large cities in Texas, and examines these associations by race/ethnicity. We hypothesized that women who used active transportation would have lower body mass index (BMI), systolic (SBP) and diastolic blood pressure (DBP), resting heart rate (RHR), and body fat percentage (BF) than women who did not use active transportation. It was also expected that time spent in active transportation and MVPA, would be negatively associated with BMI, SBP, DBP, RHR, and BF.

Methods

Data Source

This study was a secondary analysis of data collected as part of the Health is Power (HIP) study, a longitudinal, multi-site, randomized controlled trial conducted in Houston and Austin, Texas between 2006-2008 to increase physical activity or fruit and vegetable consumption among racial/ethnic minority women (1R01CA109403). Participants completed interviewer-administered surveys at baseline health assessments (Lee et al., 2011; Lee et al., 2011) Study assessments, measures, and procedures were approved by the Committee for the Protection of Human Subjects at the University of

Houston and the Institutional Review Board at the University of Texas, Austin and informed consent was obtained by all study participants.

Participants

Physically inactive, non-pregnant women who identified as African American or Hispanic/Latina, aged 25 to 60 years old, and who were able to read and write in English or Spanish were recruited to participate in the study. Details of study eligibility, recruitment, and intervention have been previously published (Lee et al., 2011; Lee et al., 2011). A total of 410 participants provided written informed consent and were enrolled in the study. Only participants who completed the self-reported measure of active transportation at baseline were included in this secondary analysis.

Individual Measures

Sociodemographic variables. Sociodemographic variables included race/ethnicity, age, educational attainment, and household income adjusted for number of family members. These were collected using an adapted version of the *Maternal Infant Health Assessment* survey, which has been previously used with diverse populations (California Department of Public Health, 2010).

Active transportation and physical activity. Active transportation and physical activity were measured using items from the long form of the *International Physical Activity Questionnaire* (IPAQ). The IPAQ has established reliability (0.80) but fairly low validity (0.30), consistent with other self-reported measures of physical activity (Craig et al., 2003). The IPAQ questionnaire allows for calculation of total physical activity in MET-minutes per week, a measure of frequency and intensity of exercise, and time spent in different domains of physical activity, including transportation, work, domestic, and leisure-time activity, as well as time spent engaging in moderate and vigorous intensity physical activity across all domains (Craig et al., 2003; Sjöström, Bull, & Craig, 2002). Active transportation was operationalized using two methods to answer our hypotheses. Time spent in active transportation was dichotomized into active transportation user (any IPAQ transportation-related physical activity) versus no active transportation use (no IPAQ transportation-related physical activity). In addition, IPAQ transport-related MET-minutes per week were used as a continuous variable for active transportation. MET-minutes per week spent in (a) moderate physical activity, (b) vigorous physical activity, (c) combined moderate-to-vigorous physical activity (MVPA), (d) total physical activity, (e) total physical activity minus active transportation, and (f) MET-minutes per day of MVPA were used in the analyses. Self-reported total IPAQ physical activity values of greater than 960 MET-minutes per day were excluded from the analyses based on the IPAQ scoring protocol's data processing rules (IPAQ Research Committee, 2005).

Objective moderate vigorous physical activity. Objective MVPA was measured using unidirectional ActiGraph GT1M accelerometers (ActiGraph, Pensacola, Florida) (ActiGraph, n.d.), which has demonstrated reliability with an intraclass correlation of 0.87 (Welk, 2005). During baseline health assessments, a subsample of participants from the Houston site was asked to wear the accelerometer for seven days, taking it off for sleeping or bathing, and to record daily wear times on an accelerometer log. Accelerometers were not available at the Austin site. After seven days, participants returned accelerometers, and all data were downloaded and processed as previously described (Layne, Mama, Banda, & Lee, 2011), with MVPA minutes per day used in the analyses.

Cardiometabolic risk factors. BMI, SBP, DBP, RHR, and BF were measured or derived from measures collected at baseline**.** Each anthropometric feature (height, weight, and BF) was measured twice using established protocols by trained research staff, and the average of the two measurements was computed (Lee et al., 2011). Height was measured in inches using a stadiometer for use in the calculation of BMI. Weight and BF were measured using the Tanita Body Fat 310 scale (Tanita, Arlington Heights, IL) in pounds (Kueht, McFarlin, & Lee, 2009; Lee et al., 2011). RHR was measured by palpating the radial pulse and counting for one full minute, after the participant had sat quietly in a chair for two minutes. SBP and DBP were also measured twice and averaged using a manual aneroid sphygmomanometer on the left arm with two minutes between measurements, following detailed protocols previously published (Lee, Mama, & Adamus-Leach, 2012; Lee, Mama, & Lopez III, 2012).

Statistical Analyses

Descriptive analyses were used to summarize sociodemographic characteristics (race/ethnicity, site, education, household income adjusted for family size, age). Chi-square tests, Fisher's exact tests (for expected frequencies less than 5), and independent samples *t*-tests were used to examine bivariate associations of active transportation use (any/none) and race/ethnicity (African American and Hispanic/Latina) with sociodemographic variables, cardiometabolic risk factors (BMI, BF, RHR, SBP, and DBP), and physical activity measures (IPAQ-measured moderate, vigorous, and total physical activity and MVPA; accelerometer-measured MVPA). Bivariate correlations among active transportation use, physical activity measures, and cardiometabolic risk factors were computed for the full sample and separately by race/ethnicity.

Separate linear regression models were used to estimate the association between active transportation use and each cardiometabolic risk factor, and the relationship between MET-minutes of active transportation each cardiometabolic risk factor, adjusting for covariates (sociodemographic variables and total IPAQ physical activity minus active transportation). Associations between accelerometer-measured MVPA and cardiometabolic risk factors were also estimated, adjusting for sociodemographic variables. Finally, regression models were used to examine associations of dichotomous active transportation use, MET-minutes of active transportation, and accelerometer-measured MVPA with each of the cardiometabolic risk factors separately by race/ethnicity (African American and Hispanic/Latina), adjusting for income, education and age. Site was not included as a covariate as it was perfectly collinear with race/ethnicity. All analyses were conducted using SPSS version 23.0 with the significance level set at 0.05.

Results

Of the 410 participants enrolled in the study, 367 completed the IPAQ. Of those, 40 participants reported greater than 960 minutes per day of total physical activity and were excluded from analyses (IPAQ Research Committee, 2005), yielding a total analytic sample of 327 participants. Participants excluded from analyses were significantly more likely to be African American (vs. Hispanic/Latina) than those whose data were retained for analysis, χ^2 (1, N = 410) = 6.49, $p < .05$. Exclusion (vs. inclusion) was not significantly related to site, income, education level, age, or any cardiometabolic risk factor ($ps > .05$). Due to accelerometry data only being collected at the Houston site, a higher proportion of participants with valid accelerometer data (n = 159) were African

American (n = 103) compared to Hispanic/Latina (n = 56), but sociodemographic characteristics or outcome variables from participants with accelerometer data were not significantly different from those without (n = 168).

Participant Characteristics

Demographic characteristics for the entire sample, and by active transportation use and race/ethnicity are described in Table 3.1. The means and standard deviations of cardiometabolic risk factors and physical activity measures for the total sample, active transportation users versus non-users, and African American versus Hispanic/Latina women are presented in Table 3.2.

There were no significant differences in cardiometabolic risk factors or physical activity measures by education. Women who reported an income of 101-200% of the federal poverty level (FPL) self-reported significantly higher amounts of total IPAQ physical activity compared to women with an income of 201-300% of the FPL (M = 2173.29, SD = 1873.25 vs. M = 1203.03, SD = 1325.58, respectively; $F[4, 302] = 2.62$, $p < .05$). There were no differences in outcome variables by income or site.

Meeting Physical Activity Guidelines

Self-reported physical activity for the overall sample was high, with the majority (62.4%) reporting achieving the minimum recommended guidelines of at least 500 MET-minutes per week of total physical activity. Active transportation users were significantly more likely to report meeting physical activity guidelines than were non-users (88.2% vs. 69.6%; χ^2 (1, n = 327) = 15.70, $p < .001$). There were no significant differences in meeting weekly IPAQ physical activity recommendations for African American women compared to Hispanic/Latina women (60.0% vs. 67.0%; χ^2 (1, n = 327) = 1.52, $p > .05$).

Of the 159 participants with accelerometer-measured MVPA, 32.1% (n = 51) met the national MVPA recommendation of 150 minutes per week. A higher percentage of active transportation users also met MVPA recommendations than non-users (35.8% vs. 29.3%); however, this difference was not significant (χ^2 (1, n = 159) = 0.746, $p > .05$). Significantly more African American women (44.7%) met the recommendation compared to Hispanic/Latina women (8.9%; χ^2 (1, n = 159) = 21.26, $p < .001$).

Bivariate Correlations

Age was significantly correlated with SBP (r = .33; $p < .001$), DBP (r = .23; $p < .001$), BF (r = .18; $p < .01$), moderate IPAQ physical activity (r = .13; $p < .05$), and total IPAQ physical activity (r = .11; $p < .05$) for the sample. Table 3.3 presents bivariate correlations of active transportation use, physical activity measures, and cardiometabolic risk factors. Tables 3.4 and 3.5 present bivariate correlations of active transportation use, physical activity measures, and cardiometabolic risk factors for African American and Hispanic/Latina women in the sample, respectively.

Linear Regression Models

Active transportation predicting cardiometabolic risk. In linear regression models adjusting for demographic variables (race/ethnicity, site, income, education, age) and non-active transportation physical activity, active transportation use (any/none) and MET-minutes of active transportation were not significantly associated with BMI, SBP, DBP, RHR, or BF (*ps* > .05) for the full sample. Likewise, in analyses conducted separately in African American-only and Hispanic/Latina-only subsamples, active transportation use and MET-minutes of active transportation were not associated with BMI, SBP, DBP, RHR, or BF for either group (*ps* > .05).

Accelerometer-measured MVPA predicting cardiometabolic risk. In models of linear associations between accelerometer-measured MVPA and individual cardiometabolic risk factors (adjusting for race/ethnicity, site, income, education, and age), MVPA was negatively associated with DBP (b = -0.074, t = -1.98, p = .052) and BF (b = -0.094, t = -3.22, p < .01). Associations between accelerometer-measured MVPA and BMI, SBP, and RHR were not significant (*ps* > .05).

For African American women, accelerometer-measured MVPA was significantly inversely associated to BMI (b = -0.097, t = -2.65, p < .05) and BF (b = -0.081, t = -2.69, p < .01), but not SBP, DBP, or RHR (*ps* > .05). Among Hispanic/Latina women, BF was the only risk factor significantly related to accelerometer-measured MVPA (b = -0.292, t = -2.79, p < .01) after controlling for income, education, and age.

Discussion

The purpose of this study was to investigate relationships among active transportation, MVPA, and cardiometabolic risk factors among African American and Hispanic/Latina women. This is the first observational study to examine the relationship between active transportation use and cardiometabolic risk factors among racial/ethnic minority women, while also investigating outcomes based on race/ethnicity. The results of this secondary analysis did not provide support for the hypothesis that active transportation use is associated with better cardiometabolic health in this sample of women; however, SBP was found to be slightly lower, albeit not significantly so, among the women using active transportation compared to those who did not. Analyses showed no relationship between active transportation use and cardiometabolic risk factors by race/ethnicity. Accelerometer-measured MVPA was found to be inversely related to

DBP and BF for the entire sample, consistent with current literature (Physical Activity Guidelines Advisory Committee, 2018), but not related to BMI, SBP, or RHR. Further analyses by race/ethnicity revealed that accelerometer-measured MVPA was only associated with lower BMI and BF among African American women, and lower BF for Hispanic/Latina women.

The findings of this study are contrary to systematic reviews, which found active transportation use to be inversely associated with body weight (Wanner et al., 2012; Xu et al., 2013) and blood pressure (Furie & Desai, 2012; Saunders et al., 2013) among adults. Additionally, walking and cycling as modes of active transportation have been found to be related to improved cardiovascular health including lower total cholesterol, and low-density lipoproteins, increased high-density lipoproteins, and improved blood glucose levels (Xu et al., 2013). According to one review (Saunders et al., 2013), those who used active transportation for relatively longer distances had a lower risk of type 2 diabetes mellitus and hypertension; however, an actual dose-response relationship could not be clearly ascertained due to the inconsistencies across the studies in the measurement of time spent in, and intensity of, active transportation. For example, studies differed in how they classified an individual as an active transportation user versus non-active transportation user, with an active transportation user defined as someone spending greater than 20 minutes, greater than 30 minutes, 3 MET-hours, or 8 MET-hours in active transportation per day. Furthermore, the intensity of active transportation, as influenced by factors such as terrain, climate, or traffic congestion, was not reported in any of the papers reviewed (Saunders et al., 2013). Given that the typical intensity level of AT-related physical activity in previous studies is unknown and that there is no way of determining intensity level in the data reported herein, directly comparing our findings to those of previous studies is impossible. This could also explain the absence of a significant relationship between active transportation and cardiometabolic health.

The active transportation users in this sample of African American and Hispanic/Latina women reported significantly more self-reported total physical activity per week compared to non-active transportation users, suggesting that active transportation may help women increase their weekly physical activity, as others have also suggested (Physical Activity Guidelines Advisory Committee, 2018; Whitfield, Paul, & Wendel, 2015). Women reported participating in just over 300 MET-minutes of active transportation per week, meeting over half the minimum weekly physical activity recommendations with active transportation alone. The overall sample self-reported participating in large amounts of weekly physical activity (1,718 MET-minutes) and MVPA (1,211 MET-minutes), which is higher than national trends for this population (Blackwell & Villarroel M.A., 2018). This discrepancy may reflect overestimation of physical activity, a bias commonly found in self-reported physical activity data. Interestingly, Hispanic/Latina women self-reported higher levels of moderate and vigorous physical activity than African American; however, accelerometry demonstrated African American women actually had significantly higher levels of MVPA. This is consistent with literature that suggests age may moderate self-report bias in Hispanic/Latina women (Nicaise, Marshall, & Ainsworth, 2011). Overall, objectively measured MVPA levels were lower than self-reported MVPA levels. Nevertheless, the objectively measured MVPA was somewhat higher for active transportation users than non- active transportation users, lending some support to findings from the self-reported data showing higher rates of physical activity among active transportation users.

This sample engaged in approximately 133 minutes of accelerometer-measured MVPA per week, which is just below the weekly aerobic recommendation of 150 minutes of MVPA to maintain and/or improve health (Physical Activity Guidelines Advisory Committee, 2018); however, greater MVPA minutes were only related to improvements in DBP and BF in this sample. When examining associations by race/ethnicity, accelerometer-measured MVPA and DBP were no longer significantly related, but associations with BMI became significant. African American women achieved a mean of 177 minutes of objective MVPA per week, surpassing the recommended weekly MVPA guidelines. This was associated with BMI and BF, but not SBP, DBP, or RHR. Hispanic/Latina women participated in only approximately 66 minutes of MVPA per week, and for them, MVPA was negatively related to BF.

When considering the findings of the study through the lens of the EMPA, the linkages between race/ethnicity, education, MVPA participation, and cardiometabolic outcomes are complex. The African American women in this sample had significantly more education than the Hispanic/Latina women and, as expected, the African American women participated in significantly more accelerometer-measured MVPA. It was also expected that the higher levels of MVPA would have translated to better health outcomes, though this was only consistent with BMI and BF. Furthermore, African American women actually had higher SBP, DBP, and BF than the Hispanic/Latina women in this sample, and, although this difference was not statistically significant, it is clinically significant, especially related to SBP. The sample mean for SBP of the African

American women was 126.08 mmHg compared to 123.18 for Hispanic/Latina women, increasing their risks for all-cause and cardiovascular disease mortality, coronary heart disease, and cardiovascular disease (Bundy et al., 2017). Consistent with the EMPA, this may suggest there are other cultural and/or biological factors that may moderate the effects of MVPA on cardiometabolic health in racial/ethnic minority women necessitating further investigation (Lee et al., 2015; Lee & Cubbin, 2009; Spence & Lee, 2003).

Strengths and Limitations

This is the first study investigating the associations between active transportation use and cardiometabolic risk factors in a large sample of racial/ethnic minority women, a population that has been underrepresented in active transportation and physical activity research (Furie & Desai, 2012; Physical Activity Guidelines Advisory Committee, 2018; Saunders et al., 2013; Wanner et al., 2012; Xu et al., 2013). The IPAQ has been shown to be reliable in diverse populations (Craig et al., 2003), and the addition of accelerometer-measured physical activity is a strength of this study. All cardiometabolic measures were objectively measured by trained research staff. History of hypertension or antihypertensive medication status was not recorded at the time of measurement; however, women with untreated hypertension were excluded from the study following the PAR-Q protocol. One caveat of this study is that the education and income levels of the study participants were quite high, limiting generalizability and negatively influencing active transportation participation rates (Lee, Lorenzo, Heck, Kohl III, & Cubbin, 2017). A majority of the sample was obese with elevated SBP, which could potentially limit the ability to detect differences and associations related to those outcomes. Self-report measures may have been biased by overestimation or social desirability. As these data were collected using correlational cross-sectional design; causation may not be inferred.

Future research should continue to examine this relationship using objectively measured active transportation and physical activity, as well as active transportation intensity, using longitudinal designs to determine the presence and magnitude of a potential dose-response relationship between active transportation use and MVPA on cardiometabolic risk factors among racial/ethnic minority women. Further investigation into the relationship between active transportation use and additional cardiometabolic risk outcomes, including fasting blood glucose, triglycerides, and high-density lipoproteins is recommended. Health practitioners should, when appropriate, encourage patients to substitute active transportation for any daily motorized transport to increase levels of MVPA. Policymakers should develop and pass policies that increase safe and pleasant routes to destinations for active commuters and walkability of the built environment to promote active transportation use to potentially increase overall MVPA levels.

Conclusion

Active transportation use has been found to be associated with improved cardiometabolic health in the literature; however, this investigation did not show a significant relationship between active transportation and cardiometabolic risk factors in this sample of women. Objectively measured MVPA was associated with more favorable DBP, BMI, and BF values; therefore, health practitioners should recommend to their African American and Hispanic/Latina women patients that they increase overall MVPA levels to improve cardiometabolic risk factors and promote health. Active transportation appears to be a good strategy for racial/ethnic minority women to increase their daily physical activity levels; however, more research is needed to determine the cardiometabolic health benefits of active transportation, including at different intensity levels. African American women who meet national weekly aerobic physical activity recommendations may not see improvements in health outcomes, necessitating research to determine the amount and types (e.g., aerobic, strength training, flexibility) of physical activity needed to result in improved health outcomes in this population.

Table 3.1. Demographic characteristics for sample, by AT use and race/ethnicity.

Variable	Sample	AT User	Non-AT User	*p*-value	African American	Hispanic/ Latina	*p*-value
Race/ethnicity (%)				0.891			
African American	65.7	41.9	58.1		100.0	--	
Hispanic Latina	34.3	41.1	58.9		--	100.0	
Site (%)				0.893			**< 0.001**
Houston	74.6	41.8	58.2		88.1	11.9	
Austin	25.4	41.0	59.0		--	100.0	
Income (% FPL)				0.376			0.071
≤100%	2.3	2.4	2.2		1.0	4.7	
101-200%	12.1	15.7	9.4		11.9	12.3	
201-300%	19.5	15.7	22.2		18.4	21.7	
301-400%	15.0	14.2	15.6		12.9	18.9	
>400%	51.1	52.0	50.6		55.7	42.5	
Education (%)				0.349			**< 0.001**
Less than high school	3.1	1.5	4.3		0.5	8.1	
High school (or GED)	6.8	8.9	5.3		1.4	17.1	
Some college	44.6	44.4	44.7		43.4	46.8	
College graduate	44.5	45.2	45.7		54.7	27.9	
Age (M [SD])	45.07 (9.47)	45.30 (9.39)	44.9 (9.55)	0.713	44.64 (9.48)	45.87 (9.44)	0.266

Note. AT = active transportation; FPL = Federal poverty level; M = mean; SD = standard deviation.
Boldface indicates significant.

Table 3.2. Outcome variables for sample, and by AT use and race/ethnicity.

Variable	Sample Mean (SD)	AT User	Non-AT User	*t*	*p*-value	African American	Hispanic/ Latina	*t*	*p*-value
CMS risk factors									
BMI (kg/m^2)	34.43 (7.75)	34.94 (7.80)	34.07 (7.71)	-1.00	0.320	34.42 (8.08)	34.44 (7.10)	-0.02	0.985
SBP (mmHg)	125.08 (13.22)	124.51 (12.95)	125.48 (13.43)	0.65	0.520	126.08 (13.43)	123.18 (12.66)	1.89	0.060
DBP (mmHg)	78.71 (9.58)	78.91 (8.93)	78.57 (10.03)	-0.32	0.750	79.32 (9.54)	77.54 (9.59)	1.59	0.113
RHR (bpm)	73.72 (8.92)	74.41 (9.19)	73.23 (8.72)	-1.18	0.237	73.10 (8.68)	74.91 (9.30)	-1.74	0.082
BF (%)	42.81 (7.14)	42.97 (7.23)	42.70 (7.10)	-0.33	0.738	42.90 (7.57)	42.65 (6.29)	0.30	0.763
Physical activity									
IPAQ transport (MET-min/wk)	134.04 (317.19)	322.29 (426.43)	--	-8.81	**<0.001**	133.54 (314.56)	134.99 (323.61)	-0.04	0.969
IPAQ MVPA (MET-min/wk)	1210.96 (1288.20)	1356.71 (1325.66)	1107.19 (1254.03)	-1.73	0.084	1144.22 (1292.91)	1339.08 (1275.06)	-1.30	0.195
IPAQ moderate (MET-min/wk)	965.33 (1114.50)	1046.71 (1015.61)	907.40 (1179.08)	-1.11	0.266	937.71 (1136.51)	1018.37 (1074.02)	-0.62	0.535
IPAQ vigorous (MET-min/wk)	245.63 (581.12)	310.00 (737.78)	199.79 (433.12)	-1.56	0.120	206.51 (496.86)	320.71 (712.19)	-1.52	0.131
IPAQ non-transport (MET-min/wk)	1583.51 (1507.66)	1721.57 (1549.83)	1485.20 (1473.10)	-1.40	0.163	1534.35 (1526.17)	1677.87 (1473.63)	-0.82	0.415
IPAQ total (MET-min/wk)	1717.55 (1544.40)	2043.86 (1588.09)	1485.20 (1473.10)	-3.27	**0.001**	1667.89 (1572.77)	1812.87 (1490.72)	-0.81	0.421
Accel MVPA (min/day)	19.72 (19.78)	21.66 (20.25)	18.31 (19.42)	-1.06	0.293	25.29 (21.88)	9.48 (8.45)	5.20	**<0.001**

Note. AT – active transportation; SD – standard deviation; CMS = cardiometabolic syndrome; BMI = body mass index; kg/m^2 – kilograms per meters squared; SBP = systolic blood pressure; mmHg – millimeters of mercury; DBP = diastolic blood pressure; RHR = resting heart rate; bpm – beats per minute; IPAQ – International Physical Activity Questionnaire; MET – metabolic equivalents; MVPA – moderate to vigorous physical activity; accel = accelerometry-measured.
Boldface indicates significant.

Table 3.3. Bivariate correlations among cardiometabolic risk factors and physical activity variables for sample.

	AT (Any/None)	IPAQ Transport	IPAQ Moderate	IPAQ Vigorous	IPAQ Total	IPAQ MVPA	Accelerometer MVPA
Body mass index	.056	.019	.014	-.085	-.027	-.026	**-.199***
Systolic blood pressure	-.036	.004	.087	-.021	.031	.066	-.098
Diastolic blood pressure	.018	.018	.033	**-.116***	-.039	-.024	-.132
Resting heart rate	.066	.205	.037	-.077	-.017	-.003	-.111
Body fat	.019	.036	.053	-.103	.009	-.002	**-.186***
Accelerometer MVPA	.084	.096	.098	.061	.136	.112	--

Note. AT – active transportation; IPAQ – International Physical Activity Questionnaire; MVPA – moderate to vigorous physical activity.
*$p < .05$. Boldface indicates significant.

Table 3.4. Bivariate correlations among cardiometabolic risk factors and physical activity variables for African American women.

	AT (Any/None)	IPAQ Transport	IPAQ Moderate	IPAQ Vigorous	IPAQ Total	IPAQ MVPA	Accelerometer MVPA
Body mass index	.091	.034	.013	-.054	-.030	-.010	**-.233***
Systolic blood pressure	-.060	.007	.098	-.003	.044	.084	-.154
Diastolic blood pressure	.008	.056	.035	-.111	-.033	-.012	-.194
Resting heart rate	.062	.095	.050	-.044	.040	.027	-.091
Body fat	.052	.057	.058	-.072	.015	.021	**-.198***
Accelerometer MVPA	.126	.087	.150	.164	**.202***	**.201***	--

Note. AT–active transportation; IPAQ – International Physical Activity Questionnaire; MVPA – moderate to vigorous physical activity.
*$p < .05$. Boldface indicates significant.

Table 3.5. Bivariate correlations among cardiometabolic risk factors and physical activity variables for Hispanic/Latina women.

	AT (Any/None)	**IPAQ Transport**	**IPAQ Moderate**	**IPAQ Vigorous**	**IPAQ Total**	**IPAQ MVPA**	**Accelerometer MVPA**
Body mass index	-.021	-.011	.017	-.139	-.020	-.063	**-.297***
Systolic blood pressure	-.060	.002	.079	-.023	.017	.054	-.040
Diastolic blood pressure	.011	-.049	.037	-.109	-.039	-.029	-.161
Resting heart rate	.036	.027	.004	-.143	-.038	-.076	.071
Body fat	-.058	-.011	.046	-.159	-.001	-.050	**-.318***
Accelerometer MVPA	-.156	-.041	.027	-.101	-.045	-.034	--

Note. AT–active transportation; IPAQ – International Physical Activity Questionnaire; MVPA – moderate to vigorous physical activity.
*$p < .05$. Boldface indicates significant.

CHAPTER 4

LINKING ACTIVE TRANSPORTATION USE AND CARDIOMETABOLIC RISK FACTORS AMONG PRIMARILY HISPANIC AND LATINA MOTHERS

Physical inactivity has an economic impact of approximately 117 billion dollars per year in the United States (CDC, 2019a). The benefits of regular participation in moderate to vigorous physical activity (MVPA) have been well documented in the literature, including decreasing risks for cancer, non-insulin dependent diabetes (T2DM), cardiovascular disease, and stroke. MVPA is also an effective method to prevent, treat, and/or delay cardiometabolic syndrome (CMS) among adults (CDC, 2019a; Physical Activity Guidelines Advisory Committee, 2018).

CMS consists of a cluster of preventable risk factors that significantly increases morbidity and mortality. According to the National Cholesterol Education Program Adult Treatment Panel III (ATP III) diagnostic criteria, CMS is defined as having three of five risk factors, which include hypertension (HTN), abdominal obesity, elevated fasting blood glucose (FG), high triglycerides (TG), or low high-density lipoproteins (HDL) (Expert Panel on Detection, Evaluation, and Treatment of High Blood Cholesterol in Adults, 2001; Grundy et al., 2005). CMS increases risks for T2DM, cancer, coronary heart disease, and stroke, which can have a detrimental effect on quality of life and healthcare costs (National Heart Lung and Blood Institute, n.d.).

Hispanic/Latina (HL) women are disproportionally affected by negative health outcomes and low participation in physical activity compared to non-HL white women. Across all age groups, HL women have a higher prevalence of CMS than non-HL white women (Moore et al., 2017). Additionally, HL women have much lower rates of meeting the recommended physical activity guidelines (13.8%) than non-HL white women (23.7%). Cultural family obligations (D'Alonzo, 2012; Gil & Vazquez, 2014) and limited time available often prevent HL women from regularly participating in physical activity away from their families (Bautista et al., 2011; Mama et al., 2015).

Active transportation, walking or cycling as a mode of transport, may provide a sustainable solution for HL women to participate in physical activity because family members can participate in active transportation together. This would allow HL women to overcome some of the barriers that keep them from regular physical activity. Active transportation has been found to be associated with better cardiovascular health (Dinu et al., 2019; Hamer & Chida, 2008), lower risks for T2DM (Dinu et al., 2019; Furie & Desai, 2012; Saunders et al., 2013), lower body weight (Xu et al., 2013), and higher overall levels of physical activity (Wanner et al., 2012). Studies investigating the relationship between active transportation and cardiometabolic health and/or physical activity have been conducted primarily with non-HL white adults and have not consistently conducted subgroup analyses based on gender and/or ethnicity.

The purpose of this study is to examine associations of active transportation with CMS risk factors, CMS, and physical activity levels among urban-dwelling, primarily HL women from Arizona. We hypothesized that women who use active transportation will have lower prevalence rates of HTN, abdominal obesity, elevated FG, high TG, low HDL, and CMS, and will more frequently meet weekly MVPA recommendations than women who do not use active transportation. Additionally, those engaging in more minutes of active transportation per week will have relatively lower systolic (SBP) and diastolic blood pressure (DBP), waist circumference (WC), FG, TG, and CMS risk factor counts, while their HDL, minutes of MVPA per week, and minutes of total physical activity per day will be relatively higher.

Methods

Participants

Participants were recruited from nine early care and education centers (ECEC) that were enrolled in cohort two of the *"Partnering for Early Childhood Physical Activity: Sustainability via Active Garden Education (SAGE)"* cooperative agreement research project (PI: Lee; U01MD010667) in Phoenix, Arizona. SAGE is a cluster-randomized controlled, crossover trial to determine the efficacy of a garden-based curriculum developed to increase physical activity and fruit and vegetable consumption of children aged 3-4 years. Details of the SAGE intervention and ECEC recruitment procedures have been published elsewhere (Lee et al., 2019).

Female guardians who enrolled in SAGE and provided informed consent were asked to participate in this study if they met inclusion and exclusion criteria. The inclusion criteria were being able to speak, read, and write in English or Spanish. Exclusion criteria were being pregnant, fewer than 3 months postpartum, or diagnosed with type 1 diabetes mellitus. All eligible participants were asked to provide a fasting blood sample with point of care testing (POCT) at the time of informed consent at morning recruitment, if fasting for at least eight hours, or at a scheduled morning appointment at their child's ECEC. All participants were given a $10 incentive after completion. The Institutional Review Board at Arizona State University approved all procedures of the study.

Individual Measures

The data presented here were collected at the SAGE Cohort 2 baseline assessment and at the time of POCT, between August and October 2018, via questionnaires provided in either English or Spanish and in either paper or online format, depending on participant's preferences. The survey questions completed at POCT were interviewer-administered and asked in either English or Spanish. These additional questions were used to verify exclusion criteria and active transportation use at the time of POCT, due to lower than expected rates of return for baseline data and to ensure active transportation was captured for all participants that underwent point of care testing, which was the primary aim of the study.

Sociodemographic variables. Items from the from the Behavioral Risk Factor Surveillance System questionnaire were used to collect information on age, race/ethnicity (CDC, 2010), and items from the Maternal Infant Health Assessment were used to assess education level and household income (Braveman, Cubbin, Marchi, Egerter, & Chavez, 2001). Responses to the race/ethnicity measure were collapsed into two categories, HL vs. non-HL.

Active transportation. The four transport-related physical activity questions from the *International Physical Activity Questionnaire* (IPAQ) long form were used to measure active transportation. Two questions were asked for both bicycling and walking, including how many days in the past seven did you walk (cycle) to go from place to place for at least 10 minutes and how much time in hours and minutes did you usually spend on those days walking (cycling) from place to place. Total minutes per week of active transportation were calculated and used in the analyses as a continuous variable. All active transportation users reported walking in the past week, but only six reported cycling. The IPAQ has established reliability (r_s = 0.80) but somewhat low criterion validity (Craig et al., 2003; Lee et al., 2011; Lee et al., 2011). The additional measure of active transportation used at the time of POCT included six questions from the 2009 National Household Travel Survey (NHTS) (Federal Highway Administration, 2009). A participant was classified as an active transportation user if she self-reported active transportation use on either the IPAQ or the NHTS questionnaire.

Cardiometabolic syndrome risk factors. Each CMS risk factor in the study was analyzed as both a continuous (i.e., each risk factor in its original physical metric) and dichotomous (i.e., absence vs. presence of risk factor) measure. Variables were objectively measured by trained research assistants using a detailed protocol. Cut points to determine the presence or absence of each CMS risk factor were based on ATP III criteria (Expert Panel on Detection, Evaluation, and Treatment of High Blood Cholesterol in Adults, 2001; Grundy et al., 2005). Each participant was provided with a copy of her results, and anyone with abnormal results was advised to seek medical care and provided with a list of local clinics where they could obtain free or reduced-cost health care.

SBP and DBP were measured twice after participants sat quietly with both feet on the floor for 2 minutes using an automatic sphygmomanometer. Assessments were separated by one minute, and if either of the two measurements differed by at least 10 mmHg, a third was obtained. The two measurements were averaged and used as the continuous variable in the analyses, and if a third measurement was necessary, the two closest measurements were used. Blood pressure was transformed into a dichotomous variable with participants having a SBP ≥ 130 mmHg, a DBP ≥ 85 mmHg, and/or self-reported medication for or diagnosis of high blood pressure/HTN classified as having HTN (Grundy et al., 2005; International Diabetes Federation, 2006).

WC was measured twice to the nearest 0.1 cm at the level of the umbilicus with a tape measure using a modified CDC protocol. If the measures differed by at ≥ 1 cm, a third measurement was obtained. The two closest measurements were averaged and used in the analysis as the continuous variable. The presence of abdominal obesity was determined by a WC ≥ 88 centimeters (Grundy et al., 2005; International Diabetes Federation, 2006).

FG, TG, and HDL values, assessed using the POCT CardioChek Plus (Polymer Technology Systems Inc., Indianapolis, Indiana), were collected according to manufacturer's directions (Polymer Technology Systems Inc., 2018), after the participant had fasted for at least eight hours. Testing using capillary blood via POCT is less invasive than venous blood draws, and meets industry standards for accuracy (Bastianelli, Ledin, & Chen, 2016). Participants were asked to place the hand of their choosing in a dependent position while materials were arranged. The third or fourth finger was prepped with an alcohol and allowed to dry before puncturing the skin with a sterile lancet. The blood sample was directly applied to the eGLU strip and then wiped with gauze. The finger was then milked until a large drop was obtained and drawn into a collection pipette to the amount indicated. The sample was then expressed onto the lipid panel test strip for analyzing. The resulting values were used in the analyses as continuous variables. Participants were classified as having elevated FG if their FG value was ≥ 100 mg/dL, they had been diagnosed with T2DM, or were taking medication for elevated blood sugar, prediabetes, or T2DM. Participants with TG values ≥150 mg/dL were classified as having high TG, and those with HDL values < 50 mg/dL were classified as having low (vs. normal) HDL (Grundy et al., 2005; International Diabetes Federation, 2006).

Cardiometabolic syndrome. The presence of CMS was operationalized according to ATP III criteria. CMS was defined as having the presence of at least three of the five cardiometabolic risk factors described above (Grundy et al., 2005).

Physical activity. Participants were instructed to wear Actigraph GT3X+ accelerometers, the gold standard to measure physical activity, at the right hip for 7 days, except when exposed to water (ActiGraph, 2018; Welk, 2005). Participants were given written instructions for the accelerometer and asked to complete a daily log (provided in either English or Spanish) to document wear time. Accelerometers were preset and data were downloaded at 60-second epochs (Layne et al., 2015; Ward, Evenson, Vaughn, Rodgers, & Troiano, 2005).

Accelerometer data tracings were visually inspected to determine sleep and wake times and compared to self-reported wear time that participants documented on their daily logs. Wear time was validated using the Choi 2011 algorithm in the ActiLife software (Choi, Liu, Matthews, & Buchowski, 2011) and Freedson 1998 physical activity cut points were used (Freedson, Melanson, & Sirard, 1998). Only participants with ≥ 10 valid hours of wear time per day for ≥ three days within a seven-day period were included in the analysis (Welk, 2005). Moderate and vigorous minutes per day were summed and multiplied by seven to determine moderate to vigorous physical activity (MVPA) minutes per week. MVPA was dichotomized into yes/no for participants based on whether they met national MVPA recommendations of ≥ 150 minutes per week (Physical Activity Guidelines Advisory Committee, 2018). Light, moderate, vigorous, and very vigorous minutes per day were summed to determine total daily physical activity and used in the analyses.

Body mass index. Trained research assistants measured participants' height to the nearest 0.25 inch using a Stadiometer for use in the calculation of body mass index (BMI). The Tanita total body composition analyzer model TBF- 310 (Tanita, Arlington Heights, IL) was used to measure BMI. The average of two BMI values was used as a continuous covariate in the analyses. BMI was transformed into underweight, normal weight, overweight and obese according to CDC criteria (CDC, 2017) for descriptive analyses.

Statistical Analyses

Univariate analyses, plots, standardized residuals, leverage, and Cook's Distance were used to assess distributions, outliers, and influential data. Intra-class correlations were calculated for each CMS risk factor, total physical activity, and MVPA to determine the strength of within-ECEC clustering (non-independence) of outcome scores. Descriptive analyses using means, standard deviations, and/or percentages were conducted for sociodemographic variables (age, race/ethnicity, education level, household income), BMI, minutes of active transportation, continuous outcomes (SBP, DBP, WC, FG, TG, HDL, CMS risk factor counts (0-5), weekly MVPA minutes, and total physical activity minutes per day), and dichotomous outcomes (HTN, abdominal obesity, prediabetes/T2DM, high TG, low HDL, CMS, met MVPA recommendations) for the sample, and by active transportation use (any vs. none). Chi-square and two-sample t-tests were used to examine associations between active transportation versus no active transportation groups with covariates (age, HL/non-HL, BMI), CMS outcomes, and physical activity variables. Covariates, CMS outcomes, and physical activity variables were also compared across race/ethnicity (HL vs. non-HL). Bivariate correlations for sociodemographic variables (age, race/ethnicity, education level, household income), minutes of active transportation, active transportation use (any vs. none), CMS outcomes, physical activity variables, and BMI were conducted.

Separate multivariable logistic regression models were used to determine the association between the dichotomous measure of active transportation use (any vs. none) and each of the dependent variables (presence vs. absence of each CMS risk factor, presence vs. absence of CMS, and meeting MVPA recommendations), while adjusting for age and HL/non-HL (all outcomes) and BMI (CMS outcomes only). Multivariable linear regression analyses were conducted to examine associations of active transportation use (any vs, none) and minutes of active transportation use with each of the continuous cardiometabolic outcome and physical activity variables, adjusting for age, and race/ethnicity (for all outcomes) and BMI (for CMS outcomes only). Participants were only included in an analysis if they had complete data on all variables used in the analysis. Analyses were conducted using SPSS version 23.0 with a significance level set at 0.05.

Results

Sample Characteristics and Bivariate Associations

The total sample consisted of 64 women, 42 (66%) of whom reported using active transportation. Of the 46 women who self-reported that they were not previously diagnosed with or prescribed medication for prediabetes/T2DM, 12 (26%) had elevated FG. Of 48 women who denied a previous diagnosis of or medication for HTN, 3 (6%) had HTN by objective measure.

Table 4.1 presents descriptive characteristics for the entire sample and by active transportation use (any/none), including means and standard deviations for age, BMI, active transportation minutes per week, walking active transportation, and cycling active transportation. The sample prevalence of dichotomous variable outcomes (CMS risk factors, CMS, and met MVPA guidelines) and the means with standard deviations of continuous variable outcomes (CMS risk factors, weekly MVPA minutes, and total physical activity minutes per day) and by active transportation use are presented in **Table 4.2**.

Preliminary Regression Diagnostics

In preliminary linear regression analyses, one participant's value for minutes of active transportation from the IPAQ was found to be highly influential based on high standardized residual, leverage, and Cook's Distance values in models for all outcomes. Linear regression models estimated with and without the data point showed no difference in patterns of significant associations for any outcome. Accordingly, this participant was excluded from all statistical analyses, including descriptive and bivariate analyses, involving minutes of active transportation, but classified as an active transportation user for and included in logistic regression analyses. Three participants had a single outlier value, one for FG, TG, and HDL. Linear regression models were conducted with and without these data points and there were no changes in patterns of significant associations for any of the three outcomes. Each data point was excluded from the descriptive and bivariate analyses when using continuous values, and respective linear regression models due to ±3 standard deviations from the mean. These participants' raw values were transformed into their corresponding dichotomous outcomes and included in descriptive and bivariate analyses, and logistic regression models as dichotomous values. Intraclass correlations were conducted for each continuous outcome (SBP, DBP, WC, FG, TG, HDL, MVPA, and total physical activity) with little evidence of clustering (ICC = -0.08 to 0.18).

Bivariate Associations

HL women had lower SBP (*M*=106.91, *SD*=11.89) and DBP (*M*=71.83, *SD*=10.65) than non-HL women (*M* = 113.73, *SD* = 7.08; *M* = 76.15, *SD* = 5.79), both of which approached significance ($t(61) = 1.97$, $p = .053$, $d = .70$; $t(35.67) = 1.96$, $p = .057$, $d = .50$), respectively. There was a significant relationship between race/ethnicity and the presence of CMS, χ^2 (1, $N = 64$) = 4.31, $p = .038$, with HL women being more likely to meet criteria for CMS than non-HL women. There were no other significant associations between race/ethnicity and other variables.

Age was significantly positively correlated with SBP ($r = .30$, $p = .015$) and DBP ($r = .25$, $p =.044$). Income was positively correlated with education ($r = .30$, $p =.045$). No other sociodemographic variables were related to any of CMS risk factors and physical activity outcomes. BMI was significantly related to WC ($r = .90$, $p <.001$), FG ($r = .26$, $p =.044$), TG ($r = .36$, $p = .005$), and the number of CMS risk factors ($r = .49$, $p <.001$). Bivariate correlations between active transportation use, CMS outcomes, and physical activity variables are presented in **Table 4.3**.

Attrition Analyses

A significantly higher proportion of non-HL women (*n* = 11; 85%) had valid accelerometry data than HL women (*n* = 28; 55%), (χ^2 (1, *N* = 64) = 3.84, *p* = .050). Of those who did not have valid accelerometry data (*n* = 25), more were active transportation users (*n* = 20; 80%) than those who did not use active transportation (*n* = 5; 20%) (χ^2 (1, *N* = 64) = 3.76, *p* = .053), and this approached significance. Women who had accelerometry data had significantly lower FG (*M* = 92.79, *SD* = 12.49) and number of CMS risk factors (*M* = 1.89, *SD* = 1.10) than women who did not have accelerometry data (*M* = 102.83, *SD* = 26.89; *M* = 2.56, *SD* = 1.36; *t*(61) = 2.01, *p* = .049; *t*(62) = 2.15, *p* = .036), respectively. There were no other significant differences in women who had valid accelerometry data than those who did not.

There were significantly more women included in the linear regression analyses (i.e., women with data on self-reported active transportation minutes) that had accelerometry data (82%) than those who were excluded (i.e., did not have data for self-reported active transportation minutes) (18%), (χ^2 (1, *N* = 64) = 6.59, *p* = .010). There was a significantly lower proportion of women excluded from linear regression who had normal HDL (5%) compared to those included (95%), (χ^2 (1, *N* = 64) = 8.49, *p* = .007). The women included in the linear regression analyses had higher HDL (*M* = 44.47, *SD* = 11.27) than those excluded (*M* = 38.94, *SD* = 4.86; *t*(60.55) = -2.72, *p* = .009). There were no other differences in sociodemographic variables or CMS risk factors in women with and without valid accelerometry data or those who were excluded from the regression analyses.

Logistic Regression Models

In logistic regression models, adjusting for age, race/ethnicity, and BMI, active transportation use (none vs. any) was not related to HTN, abdominal obesity, elevated FG/T2DM, elevated TG, low HDL, or CMS (*p*s > .05). The odds of engaging in ≥ 150 minutes of MVPA per week was over seven times higher for women who used active transportation (OR = 7.174, 95% CI [1.50, 34.41]) than for those who do not use active transportation ($p = .014$, $Q = .66$), after adjusting for age and race/ethnicity.

Linear Regression Models

In linear regression models, between active transportation use was not significantly related to SBP, WC, FG, TG, HDL, or number of CMS risk factors (*p*s > .05), after adjusting for age, race/ethnicity, and BMI. There was some evidence that women who used active transportation had lower DBP, but this association was not significant at $p < .05$ ($B = -4.517$, $t = -1.735$, $p = .088$, $d = .52$). No associations were found between active transportation use and weekly MVPA minutes or total physical activity minutes per day, after adjusting for age and race/ethnicity (*p*s > .05). Minutes of active transportation use was not significantly related to SBP, DBP, WC, FG, TG, HDL, or number of CMS risk factors (*p*s > .05), when adjusting for age, race/ethnicity, and BMI. Similarly, minutes of active transportation use was not associated with weekly MVPA minutes ($p > .05$), when adjusting for age and race/ethnicity. Minutes of active transportation per week was positively related to total physical activity ($B = .197$, $t = 3.226$, $p = .003$), accounting for 29% of the variance in this outcome ($R^2 = .29$, $F[3, 28] = 3.866$, $p = .020$).

Discussion

The purpose of this study was to determine the association between active transportation and CMS risk factors, CMS, and physical activity levels among primarily HL women. This is the first study investigating the association between active transportation and objective measures of CMS risk factors. The results from this study failed to support a relationship between active transportation, CMS risk factors, or CMS although we did find limited support that DBP was lower among active transportation users than those who did not use active transportation.

This is contrary to what some previous studies have found. According to a meta-analysis by Hamer and Chida (2008), active transportation was significantly associated with cardiovascular health, with even larger protective benefits for women. Active transportation users were less likely to have T2DM (Dinu et al., 2019; Furie & Desai, 2012) and high blood pressure (Furie & Desai, 2012; Saunders et al., 2013) than non-users. In other previous research, similar to our findings, no relationships were found between active transportation and HDL (Furie & Desai, 2012) and CMS (Churilla & Fitzhugh, 2012; Kuwahara et al., 2016). Furthermore, the significant relationships found between active transportation and some CMS risk factors were only significant for high levels of active transportation (Furie & Desai, 2012; Saunders et al., 2013). This could suggest that use of active transportation in this sample was insufficient in duration or intensity to result in improvements in cardiometabolic health.

The active transportation users in our sample were more likely to meet the 2018 weekly aerobic recommendations of at least 150 minutes per week of MVPA than those who did not use active transportation; however, we did not find a dose response relationship between minutes of active transportation and MVPA. We did confirm a dose response relationship between minutes of active transportation and total physical activity among active transportation users. This provides some evidence that active transportation does have a beneficial relationship with total minutes of physical activity among these women, similar to the literature (Physical Activity Guidelines Advisory Committee, 2018; Wanner et al., 2012).

In a meta-analysis of physical activity interventions, the majority of included studies consisted of minority adults, predominantly women, participating in observed physical activity interventions lasting almost 40 minutes at moderate intensity, approximately three times per week for 11 weeks (Conn, Phillips, Ruppar, & Chase, 2012). These physical activity interventions did not significantly improve lipids or T2DM risk. Approximately 86% of the studies included in the meta-analysis had samples with more than half being overweight and/or obese (Conn et al., 2012). More than half of the women in our study who wore accelerometers met weekly MVPA recommendations; however, approximately 82% of our sample was either overweight or obese and had abdominal obesity. This could indicate that the MVPA recommendations to improve cardiometabolic health may be different for overweight or obese minority women. Future research should include experimental studies investigating active transportation interventions at different intensities and bout lengths among HL women of different BMI classifications.

Although we did not find statistically significant relationships between active transportation and CMS risk factors, our findings are clinically relevant. Approximately

6% of the sample met criteria for undiagnosed HTN. Untreated HTN increases risks for heart disease-, cerebrovascular-, and cardiovascular disease-related mortality, as well as all-cause mortality (Zhou, Xi, Zhao, Wang, & Veeranki, 2018). More than 25% of the sample met criteria for undiagnosed prediabetes or T2DM. Over time, uncontrolled blood sugar can cause blindness, renal disease, and cardiovascular disease (CDC, 2019b). Both of these conditions increase risks for early morbidity and mortality (Pratley, 2013; Zhou et al., 2018) demonstrating the need to screen and treat HL women with undiagnosed HTN and prediabetes/T2DM to improve health outcomes of this population.

The cardiometabolic health of active transportation users was better than those who did not use active transportation. The mean values for all CMS risk factors and CMS risk factor counts were in the expected direction except for FG, which could be explained by those women controlling their FG with medication for prediabetes/T2DM. For example, 31% of active transportation users met the criteria for prediabetes/T2DM compared to 31.8% on non-users, even though the mean FG was 97.62 for active transportation users and 94.62 for those who did not use active transportation. The mean BMI value for the present sample was considered obese; however, active transportation users' BMI was significantly lower than those who did not use active transportation, with the non-users approaching class 2 obesity (CDC, 2017). Thirty-six percent of the women who used active transportation had CMS compared to 50%, which places the women who do not use active transportation at even higher risks for cardiovascular disease, stroke, T2DM, and cancer (National Heart Lung and Blood Institute, n.d.) than active transportation users.

Strengths and Limitations

This was the first study investigating active transportation use with objective measures of SBP, DBP, WC, FG, TG, and HDL among primarily HL women, who are understudied in the active transportation literature (Dinu et al., 2019; Furie & Desai, 2012; Hamer & Chida, 2008; Saunders et al., 2013; Wanner et al., 2012; Xu et al., 2013) and disproportionately affected by CMS (Moore et al., 2017). Previous diagnosis of and medication prescribed for HTN and prediabetes/T2DM was measured and included in the assessment of CMS risk factors. Physical activity was measured objectively using Actigraph accelerometers, and the IPAQ has established reliability for HL women (Craig et al., 2003).

This study does include some limitations. The small sample size limits the power to detect statistical significance in associations, and makes the interpretation of results somewhat difficult. Subjective measure for active transportation use and minutes of active transportation use may be biased due to overestimation. The use of accelerometers alone does not allow for measurement of active transportation use. Due to the cross-sectional design, the ability to draw causal inferences is limited.

Conclusion

Active transportation use was not related to CMS risk factors or CMS in this group of primarily HL women; however, it was associated with meeting weekly MVPA recommendations and total physical activity levels. The HL women who used active transportation had better health outcomes compared to those who did not use active transportation, and even though this was not statistically significant, this has significant clinical relevance. Health practitioners should recommend active transportation use to HL women as a way to achieve the recommended MVPA guidelines and increase total physical activity when possible, while potentially improving cardiometabolic health. Additionally, HL women should be screened for HTN and prediabetes/T2DM when possible for early detection and treatment to improve health and prevent long-term sequelae. Policymakers should work with urban planners to improve the built environment to promote active transportation. Future research should investigate the relationship between active transportation use and CMS risk factors and CMS with large samples of HL women. This should include various intensities and durations using objective measures among HL women of different BMI classifications to determine more tailored MVPA recommendations to decrease SBP, DBP, WC, FG, and TG, and increase HDL. The findings of this study indicate there may be unidentified factors that influence the relationship of active transportation and physical activity with cardiometabolic health among primarily HL women that require further exploration.

Table 4.1. Descriptive characteristics of sample and by active transportation use

		Sample	AT user	No AT use		
	N	% (*n*)	% (*n*)	% (*n*)	t/χ^2	*p*-value
Hispanic ethnicity (%)	64	79.7 (51)	78.6 (33)	81.8 (18)	0.094	1.000
Household income (%)	46				4.603[a]	.292
$0-24,000		34.8 (16)	40.6 (13)	21.4 (3)		
$24,001-36,000		41.3 (19)	34.4 (11)	57.1 (8)		
$36,001-55,000		8.7 (4)	12.5 (4)	--		
$55,001-71,000		8.7 (4)	6.3 (2)	14.3 (2)		
≥71,001		6.5 (3)	6.3 (2)	7.1 (1)		
Education (%)	50				2.483[a]	.486
Less than high school		20.0 (10)	25.0 (9)	7.1 (1)		
High school (or GED)		26.0 (13)	22.2 (8)	35.7 (5)		
Some college		36.0 (18)	36.1 (13)	35.7 (5)		
Trade or college graduate		18.0 (9)	16.7 (6)	21.4 (3)		
Body composition	62				3.978[a]	.118
Underweight		--	--	--		
Normal weight		17.7 (11)	22.0 (9)	9.5 (2)		
Overweight		24.2 (15)	29.3 (12)	14.3 (3)		
Obese		58.1 (36)	48.8 (20)	76.2 (16)		
Mean (SD)						
Age	64	31.28 (7.70)	31.64 (8.26)	30.59 (6.62)	-0.516	.607
Body mass index	62	32.01 (6.93)	30.70 (6.78)	34.55 (6.64)	2.132	**.037**
AT (min/week)	45	143.00 (244.33)	207.58 (271.48)	--	-4.257	**.000**
Walking AT (min/week)	45	135.78 (239.43)	197.10 (267.56)	--	-4.101	**.000**
Cycling AT (min/week)	48	6.77 (27.36)	9.56 (32.22)	--	-1.730	.093

Note. AT = active transportation; M = mean; SD = standard deviation.
[a]Fisher's exact test statistic

Table 4.2. Descriptives for outcome variables for sample and by AT use

	N	Sample % (n)	AT user % (n)	No AT use % (n)	t/χ^2	p-value
CMS risk factors						
Hypertension	63	11.1 (7)	9.5 (4)	14.3 (3)	0.321[a]	.677
Abdominal obesity	62	82.3 (51)	76.2 (32)	95.0 (19)	3.284	.087
Prediabetes/type 2 diabetes	64	31.3 (20)	31.0 (13)	31.8 (7)	0.005	1.000
High triglycerides	62	25.8 (16)	22.5 (9)	31.8 (7)	0.644	.422
Low high density lipoproteins	64	68.8 (44)	64.3 (27)	77.3 (17)	1.133	.287
CMS	64	40.6 (26)	35.7 (15)	50.0 (11)	1.222	.269
Met 150 min/wk MVPA	39	56.4 (22)	72.7 (16)	35.3 (6)	5.465	**.019**
Mean (SD)						
CMS risk factors						
SBP (mmHg)	63	108.32 (11.37)	107.05 (11.55)	110.86 (10.82)	1.260	.213
DBP (mmHg)	63	72.72 (9.97)	71.05 (9.43)	76.07 (10.38)	1.927	.059
WC (cm)	62	103.09 (16.30)	100.86 (16.99)	107.76 (14.01)	1.577	.120
FG (mg/dL)	63	96.62 (19.70)	97.62 (23.02)	94.62 (10.49)	-0.567	.573
TG (mg/dL)	61	123.70 (46.76)	117.74 (39.47)	134.27 (56.96)	1.207	.236
HDL (mg/dL)	63	42.89 (10.14)	43.48 (10.78)	41.71 (8.84)	-0.647	.520
CMS risk factors present	64	2.16 (1.24)	2.02 (1.20)	2.41 (1.30)	1.187	.240
PA						
Total PA (min/day)	39	386.61 (83.04)	396.54 (91.37)	373.75 (71.46)	-.847	.402
MVPA (min/week)	39	189.53 (108.52)	211.334 (111.63)	161.31 (100.56)	-1.448	.156

Note. AT = active transportation; CMS = cardiometabolic syndrome; MVPA = moderate to vigorous physical activity; SD = standard deviation; SBP = systolic blood pressure; DBP = diastolic blood pressure; WC = waist circumference; FG = fasting glucose; TG = triglycerides; HDL = high density lipoproteins; PA = physical activity.

[a]Fisher's exact test statistic

Table 4.3. Bivariate correlations between study variables.

	1	2	3	4	5	6	7	8	9	10	11
1. SBP	1										
2. DBP	.864**	1									
3. WC	.143	.309*	1								
4. FG	.235	.279*	.246	1							
5. TG	.198	.353**	.348**	.145	1						
6. HDL	.106	.035	.007	-.081	-.436**	1					
7. CMS RF	.240	.403**	.458**	.515**	.611**	-.538**	1				
8. Total PA	-.057	-.047	.150	.096	-.052	.341*	.049	1			
9. MVPA min/wk	-.176	-.142	.057	.065	-.132	.336*	-.060	.459**	1		
10. MVPA rec	-.194	-.190	-.041	.015	-.105	.294	-.036	.324*	.763**	1	
11. AT min/wk	-.036	.000	-.188	.083	-.183	.016	.051	.494**	.356*	.383*	1
12. AT use	-.159	-.240	-.200	.072	-.171	.083	-.149	.138	.232	.374*	.398**

Note. SBP = systolic blood pressure; DBP = diastolic blood pressure; WC = waist circumference; FG = fasting glucose; TG = triglycerides; HDL = high-density lipoproteins; CMS RF = cardiometabolic syndrome risk factors; PA = physical activity; MVPA = moderate to vigorous physical activity; rec = met MVPA recommendations; AT = active transportation.
**Correlation is significant at the 0.01 level (2-tailed). *Correlation is significant at the 0.05 level (2-tailed).

CHAPTER 5

DISCUSSION

The purpose of this body of research was to investigate the existence of relationships between active transportation, walking active transportation, physical activity and cardiometabolic health among adults, including African American and Hispanic/Latina women. This was guided by the Ecological Model of Physical Activity (EMPA) and Ecological Model of Obesity (EMO), which was extended to include active transportation as the physical activity exposure and cardiometabolic risk factors and syndrome as the health outcomes, and physical activity as an additional outcome (see **Figure 1.1**). The EMPA and EMO are dynamic frameworks that were used to guide variable selection at multiple environmental levels that may directly and/or indirectly interact to influence active transportation, physical activity, and cardiometabolic health, while accounting for *intra*-individual factors (Lee et al., 2015; Lee & Cubbin, 2009; Spence & Lee, 2003).

In Chapter 2, a systematic review was conducted to determine the association between walking active transportation, the most common form of active transportation, and cardiometabolic syndrome and risk factors among adults. This systematic review indicated that adults who used walking active transportation had smaller waist circumference, lower presence of abdominal obesity, and lower blood pressure (presence of hypertension). Relationships between walking active transportation and high-density lipoproteins/low levels of high-density lipoproteins, triglycerides/hypertriglyceridemia, fasting glucose/type 2 diabetes mellitus, and/or cardiometabolic syndrome were found. None of the studies included in the systematic review found significant results in opposition to our hypothesis. The systematic review revealed significant design and statistical heterogeneity among active transportation studies, including definitions and measures of active transportation, comparators, and criteria to determine presence/absence of cardiometabolic risk factors (see **Table 2.4**). Studies tended to be of low quality, and the overall measurement of active transportation was crude, indicating the need for future research with objective measures of active transportation. The number of covariates adjusted for and the domains represented by them varied across studies, with variables drawn from the *micro*- (e.g., site, location of employment) and *macro*-environmental levels (e.g., socioeconomic status, race/ethnicity, air pollutants) of the EMPA/EMO, and *intra*-individual factors, including biological (e.g., sex, age, body mass index, family history) and behavioral (e.g., education diet, nicotine use) factors (see **Table 2.3**).

The purpose of Chapter 3 was to investigate the relationship between active transportation, physical activity, and cardiometabolic risk factors among African American and Hispanic/Latina women from two cities in Texas, and examine those associations by ethnicity (*macro*-environment). This investigation failed to find a significant relationship between active transportation use and cardiometabolic health for the sample of women or by race/ethnicity; however, systolic blood pressure was slightly lower and accelerometry-measured moderate to vigorous physical activity (MVPA) was higher for active transportation users, but not significantly so. MVPA was significantly inversely associated with diastolic blood pressure and body fat, but not body mass index, systolic blood pressure, or resting heart rate in the entire sample of women. When investigating this relationship within race/ethnicity groups, diastolic blood pressure was no longer significant, but the association with body mass index became significant in the expected direction for African American women, and MVPA remained inversely associated with body fat for both African American women and Hispanic/Latina women. Interestingly, accelerometry-measured mean minutes of MVPA for African American women was 177 minutes per week, while Hispanic/Latina women had, on average, only 66 minutes per week. Even though the African American women in this sample, on average, exceeded the 2018 recommendations for weekly MVPA minutes, higher MVPA was not significantly associated with lower systolic or diastolic blood pressure in this group. Furthermore, even though, on average, women in the sample participated in approximately 140 minutes of MVPA per week, the mean body mass index met the CDC criteria for obesity. These findings demonstrated the presence of significant differences in MVPA participation and cardiometabolic health outcomes by ethnicity, which is consistent with the EMPA/EMO (Lee et al., 2015; Lee & Cubbin, 2009; Spence & Lee, 2003).

Chapter 4 explored the relationship between active transportation and cardiometabolic risk factors, cardiometabolic syndrome, and physical activity levels among primarily Hispanic/Latina (*macro*-environment) women (biological factor) living in an urban city in Arizona. Active transportation use was not found to be significantly related to the presence of cardiometabolic syndrome or risk factors among the women in the sample. Minutes of active transportation was also not significantly related to lower systolic or diastolic blood pressure, waist circumference, fasting glucoses, triglycerides, number of cardiometabolic syndrome risk factors, or higher levels of high density lipoproteins; however, there was some evidence that women who used active transportation had lower diastolic blood pressure. Furthermore, active transportation users had less prevalence of cardiometabolic risk factors than non-users, even though these differences were not significant. A significant dose-response was found between minutes of active transportation use and minutes of total physical activity, and women who used active transportation were seven times more likely to meet the 2018 national aerobic recommendations of 150 minutes of MVPA per week than those who did not use active transportation. Although the mean minutes of accelerometry-measured MVPA was greater than the 2018 national weekly MVPA recommendations, this group of women met criteria for multiple cardiometabolic risk factors and most were obese based on CDC criteria. Furthermore, 6% of the women had undiagnosed hypertension and 25% had undiagnosed type two diabetes mellitus.

Integration of Studies

This dissertation provides some evidence that adults and ethnic minority women who used active transportation have lower blood pressure than those who did not, although this difference was not significant. Active transportation users had more minutes of physical activity using objective and subjective measures. Both of these findings have clinical significance for public health, especially because blood pressure contributes to early mortality and cardiovascular diseases (Bundy et al., 2017), which is the leading cause of death worldwide (World Health Organization, 2017). Replacing sedentary behavior with any amount of physical activity can improve cardiometabolic health (Physical Activity Guidelines Advisory Committee, 2018); therefore, active transportation should be encouraged to increase physical activity.

When looking at the findings through the lens of the EMPA/EMO, some themes become apparent. It emerged that biological difference based on sex may exist that moderate the relationship between walking for active transportation and cardiometabolic syndrome (Boone-Heinonen et al., 2009; García-Hermoso et al., 2018; Xiao et al., 2016). This has also been found in physical activity research (Zhang et al., 2017), but a large body of conclusive evidence to make active transportation or MVPA recommendations based on sex is lacking (Physical Activity Guidelines Advisory Committee, 2018). It is vital that future research investigating active transportation, physical activity, and cardiometabolic syndrome explore relationships based on sex. This should also include an exploration into how active transportation use may be influenced by neighborhood safety for women compared to men.

Interestingly, both samples of minority women had MVPA levels that are related to benefits to cardiometabolic health among adults (Physical Activity Guidelines Advisory Committee, 2018); however, the women in these studies were mostly obese with a number of cardiometabolic risk factors present. This may suggest that the amount of MVPA needed to translate to improved cardiometabolic health may be different for obese minority women, and may be explained by biological and cultural differences (*macro*-level), consistent with the EMPA/EMO (Lee et al., 2015; Lee & Cubbin, 2009; Spence & Lee, 2003).

The methods used to measure active transportation throughout the studies, both walking and cycling, are of low quality and fail to consistently demonstrate adequate validity and reliability. Without objective measures of active transportation that are able to adequately operationalize the concept of active transportation, it will be difficult, if not impossible, to determine the presence or absence of any relationships between active transportation and cardiometabolic syndrome. Criteria to define active transportation based on specific interval amounts (e.g., none, less than 30 minutes per day, greater than 30 minutes per day) should be established as an industry standard to allow for comparisons across studies. Collecting active transportation data with accelerometry, geographical positioning systems, and geographic information systems would allow for objective measure of active transportation, along with data collection from various levels of the EMPA/EMO. This would enable simultaneous investigation into the linkage between *intra*-individual factors and *extra*-individual environmental variables that influence active transportation use and cardiometabolic syndrome (Spence & Lee, 2003)

The EMPA and EMO hypothesize that there are numerous factors that directly and indirectly influence active transportation and cardiometabolic syndrome. The lack of significant associations could be attributed to the absence of critical contextual variables related to active transportation and cardiometabolic syndrome that were not included in this dissertation. For example, the relationship of dietary behavior (*intra*-individual factor) and cardiometabolic syndrome was not investigated or controlled for; however, diet and physical inactivity are the two largest lifestyle contributors to cardiometabolic syndrome (Saklayen, 2018) demonstrating the need to address this with future studies. The neighborhood (*micro*-level environment) and walkability indices (*macro*-level environment) of an individual's home, work, and/or school may interact with active transportation use and/or diet, which could influence cardiometabolic syndrome (Lee et al., 2015; Lee & Cubbin, 2009; Spence & Lee, 2003).

Strengths and Limitations

This body of research was the first to investigate walking active transportation and cardiometabolic risk factors and syndrome among adults and linkages between active transportation, cardiometabolic risk factors and syndrome, MVPA, and race/ethnicity among primarily Hispanic/Latina and/or African American women. The cardiometabolic outcome measures throughout the chapters were objectively measured, except for one study included in Chapter 2 (Tajalli & Hajbabaie, 2017). Furthermore, the sample sizes in Chapter 2 and 3 were quite large, and MVPA was objectively measured using accelerometers, which is the gold standard. Overall, this dissertation adds important findings to the literature that provide evidence-based recommendations to advance active transportation research.

There were also some limitations present in this dissertation, including the subjective methods used to measure active transportation throughout the studies. Limitations also exist with accelerometry-measured physical activity, including the inability to measure upper body, bicycling, and swimming activity (Al-Eisa, Alghadir, & Iqbal, 2016) and the physical activity domain (transport, occupational, household, leisure-time) one is engaged in. The placement of accelerometers at the hip should be secure and consistent to minimize measurement error, which can be difficult with obese research participants (Beechy, Galpern, Petrone, & Das, 2012). The mean body mass index for the samples from both Chapters 3 and 4 met the CDC criteria for obesity, potentially making it difficult to determine associations and differences in outcomes that are related to obesity. Chapter 4 had a small sample size limiting the potential to detect significant associations and ability to control for important contextual variables aligned with the

EMPA, such as income, education, number of children, and food insecurity that could influence cardiometabolic syndrome.

Implications

Research Implications

Future research should focus on developing and/or incorporating a combination of objective measures of walking for active transportation to allow for differentiation between domains of physical activity. This should include studies with consistent definitions and cut-off criteria for active transportation use with similar comparators to allow for findings to be quantitatively synthesized in meta-analysis. Published criteria to determine the presence/absence of cardiometabolic syndrome risk factors that was established through consensus within the international community should be used to allow for consistency across studies and to maximize external validity (Alberti et al., 2009).

This research has generated additional research questions to be explored through qualitative research methods. Guided by the EMPA, research should be conducted to investigate which contextual and/or psychological variables may be mediating and/or moderating the relationships between active transportation, physical activity, and cardiometabolic syndrome. This should include interviews with the Hispanic/Latina women that participated in the study from Chapter 4 that explore the context surrounding active transportation use and physical activity in hopes of developing multi-level interventions to target mediators and/or overcome moderators to improve cardiometabolic health. Additional qualitative research should include exploring the barriers these women experience that may prevent them from being screened, diagnosed, and/or treated for undiagnosed hypertension and type 2 diabetes mellitus.

Future research should investigate culturally specific mediators that influence walking for active transportation, physical activity, and cardiometabolic health among African American and Hispanic/Latina women. This could potentially provide an opportunity to develop multi-level interventions specific to race/ethnicity. Interventions that include *macro*-level environmental variables have the potential to affect larger numbers of individuals that could improve public health (Lee et al., 2015; Lee & Cubbin, 2009; Spence & Lee, 2003).

Large randomized controlled trials should be conducted to investigate the causal effects of walking for active transportation on cardiometabolic syndrome and accelerometry-measured physical activity among ethnic minority women. This should include objective measures of walking for active transportation at different frequencies, durations, and intensity levels among women of all body mass index classifications. This is necessary to determine prescriptive walking for active transportation recommendations to improve cardiometabolic syndrome risk factors based on race/ethnicity, sex, and body mass index classification. Biological factors, such as sex and body mass index, must be considered when making active transportation recommendations to maximize intervention effectiveness on cardiometabolic health.

Practice Implications

Healthcare providers should recommend walking active transportation to their patients, when appropriate, to increase MVPA and total physical activity, especially among African American and Hispanic/Latina women. Even though active transportation was only found to be related to lower risks for hypertension in one study in this dissertation, many cardiometabolic health outcomes were more normal for ethnic minority active transportation users compared to non-users, especially systolic blood pressure. This is relevant and important because high systolic blood pressure increases cardiovascular and all-cause mortality, and is a significant predictor for cardiovascular disease (Bundy et al., 2017), which is the leading cause of death in the world (World Health Organization, 2017).

It is important for health care providers to consider the context surrounding active transportation when recommending use, especially for ethnic minority women. One barrier to active transportation is the long commuting distances to work or school (Lee, Adamus-Leach, Cheung, et al., 2012). This could be ameliorated by health care providers recommending that any passive travel within walkable distances be replaced with active transportation. Unsafe neighborhoods have been identified as a barrier to physical activity among ethnic minority women (Joseph et al., 2015; Mama et al., 2015); however, poor, ethnic minority women have been found to be undeterred by unsafe neighborhoods when using active transportation (Lee, Kim, & Cubbin, 2018). Even so, to maximize safety, health care providers should encourage the inclusion of family and/or friends when using active transportation, which also would provide social support.

Healthcare providers should screen African American and Hispanic/Latina women for undiagnosed hypertension and type 2 diabetes mellitus based on incidental findings. This could allow for early diagnosis and treatment of these diseases among ethnic minority women. Undiagnosed hypertension and type 2 diabetes mellitus increases risks for cardiovascular disease and events, and contributes to early morbidity and mortality (Pratley, 2013; Zhou et al., 2018), which demonstrates the significance for early treatment.

Policy Implications

Policymakers should legislate for changes to existing and proposed built environment infrastructure and work with city planners to increase walkability for pedestrians to encourage participation in active transportation and physical activity. It is vital for policymakers to ensure women have access to affordable healthcare to screen, diagnosed, and treat cardiometabolic risk factors. This could include lobbying for healthcare for all, free health screenings, and/or affordable medications to treat cardiometabolic risk factors.

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APPENDIX A

HUMAN SUBJECTS

APPROVAL: MODIFICATION

Rebecca Lee
CONHI: Research Faculty and Staff
-
Rebecca.E.Lee@asu.edu

Dear Rebecca Lee:

On 6/28/2018 the ASU IRB reviewed the following protocol:

Type of Review:	Modification
Title:	Partnering for Physical Activity in Early Childhood: Sustainability via Active Garden Education
Investigator:	Rebecca Lee
IRB ID:	STUDY00003761
Funding:	Name: HHS: National Institutes of Health (NIH), Grant Office ID: FGS0440, Funding Source ID: U01MD010667 ; Name: HHS-NIH: National Institute for Nursing Research (NINR), Funding Source ID: 1f31nr017560
Grant Title:	None
Grant ID:	None
Documents Reviewed:	• ECEC Letter of Support, Category: Other (to reflect anything not captured above); • Sustainability Needs Checklist 5-17-18.pdf, Category: Measures (Survey questions/Interview questions /interview guides/focus group questions); • Marsiglia_FF CITI_142949669_112020.pdf, Category: Non-ASU human subjects training (if taken within last 3 years to grandfather in); • Community Partner Letter of Support, Category: Other (to reflect anything not captured above); • 24hr Diet Recall form, Category: Measures (Survey questions/Interview questions /interview guides/focus group questions); • Garden Build Protocol 5 27 14.pdf, Category: Other (to reflect anything not captured above);

	• O'Connor CITI reports.pdf, Category: Non-ASU human subjects training (if taken within last 3 years to grandfather in); • SAGE Curriculum Lesson Plan Example.pdf, Category: Measures (Survey questions/Interview questions /interview guides/focus group questions); • SAGE postcard 1-24-17 SPA aea.pub, Category: Recruitment Materials; • Backtranslation form for informed consent, Category: Other (to reflect anything not captured above); • Accelerometer Log ENG_7-18-2017.pdf, Category: Participant materials (specific directions for them); • Results Letter 6.22.18 FINAL (Spanish).pdf, Category: Participant materials (specific directions for them); • SAGE Brochure, Category: Recruitment Materials; • Accelerometer log SPA, Category: Participant materials (specific directions for them); • BrueningCITI_Refresher.pdf, Category: Non-ASU human subjects training (if taken within last 3 years to grandfather in); • SAGE Cirriculum Outline 3.14.14.pdf, Category: Participant materials (specific directions for them); • SAGE parent consent form 6-26-2018 ENG.pdf, Category: Consent Form; • Consent Form Protocol, Category: Other (to reflect anything not captured above); • SAGE Postcard eng, Category: Recruitment Materials; • ECEC Letter of Support, Category: Other (to reflect anything not captured above); • SAGE MOA ASU Washington Elem SD FE 6-21-18.pdf, Category: Off-site authorizations (school permission, other IRB approvals, Tribal permission etc); • SAGE FAQ, Category: Recruitment Materials; • HFI_Backtranslation Form.pdf, Category: Other (to reflect anything not captured above); • Eating in the Absence of Hunger Protocol, Category: Other (to reflect anything not captured above); • SAGE parent and child demographic survey T2-T3 - Control, Category: Measures (Survey questions/Interview questions /interview guides/focus group questions); • USDA Multiple Pass Method Protocol.pdf,

	Category: Measures (Survey questions/Interview questions /interview guides/focus group questions); • Preference Assessment Game.pdf, Category: Participant materials (specific directions for them); • Reminder Flyer 6-26-18 ENG.pub, Category: Recruitment Materials; • Home Food Inventory Spa, Category: Measures (Survey questions/Interview questions /interview guides/focus group questions); • Backtranslation Form.pdf, Category: Other (to reflect anything not captured above); • SAGE Newsletter Example ENG, Category: Participant materials (specific directions for them); • St.pdf, Category: Other (to reflect anything not captured above); • Director Program Sustainability Survey T1, Category: Measures (Survey questions/Interview questions /interview guides/focus group questions); • Parent SAGE Handout ENG 7-14-17.pub, Category: Recruitment Materials; • Safe Routes To School Community Organization Letter of Support, Category: Other (to reflect anything not captured above); • Shaibi-CITI-Renewal_2016.pdf, Category: Non-ASU human subjects training (if taken within last 3 years to grandfather in); • Community Partner Letter of Support, Category: Other (to reflect anything not captured above); • F31 application, Category: Grant application; • Phoenix Parks and Recreation Letter of Support, Category: Other (to reflect anything not captured above); • State of Arizona Department of Education Letter of Support, Category: Other (to reflect anything not captured above); • Community Advisory Board Meeting Agenda, Category: Other (to reflect anything not captured above); • Substudy recruitment script, Category: Recruitment Materials; • SAGE FAQ_1.21.17 SPA (1).pdf, Category: Recruitment Materials; • SAGE Safety Curriculum.pdf, Category: Measures (Survey questions/Interview questions /interview guides/focus group questions); • ECEC Letter of Support, Category: Other (to reflect

	anything not captured above); • ECEC MOa, Category: Off-site authorizations (school permission, other IRB approvals, Tribal permission etc); • Backtranslation-form_IC_handout_logs.pdf, Category: Other (to reflect anything not captured above); • Parent SAGE Handout SPA 7-14-17.pub, Category: Recruitment Materials; • MTodd_CITI_CompletionReport2952382-ASU-April-25-2016.pdf, Category: Non-ASU human subjects training (if taken within last 3 years to grandfather in); • Parent and Child Demographic Questionnaire_ENG.pdf, Category: Measures (Survey questions/Interview questions /interview guides/focus group questions); • SAGE blurb.pdf, Category: Recruitment Materials; • backtranslation-form_SAGE Parent Accelerometer Log Spa.pdf, Category: Other (to reflect anything not captured above); • SAGE parent and child demographic survey T1 ENG, Category: Measures (Survey questions/Interview questions /interview guides/focus group questions); • Results Letter 6-26-18 English.pdf, Category: Participant materials (specific directions for them); • Fruit and Vegetable Screener 6-26-18 ENG.pdf, Category: Measures (Survey questions/Interview questions /interview guides/focus group questions); • SAGE parent and child demographic survey T2-T3 (ENG) - Intervention, Category: Measures (Survey questions/Interview questions /interview guides/focus group questions); • Hill_CitiRefresher_IRB2016.pdf, Category: Non-ASU human subjects training (if taken within last 3 years to grandfather in); • Wilder Collaboration Factors Inventory.pdf, Category: Measures (Survey questions/Interview questions /interview guides/focus group questions); • ECEC Letter of Support, Category: Other (to reflect anything not captured above); • SAGE Environmental Assessment.pdf, Category: Measures (Survey questions/Interview questions /interview guides/focus group questions); • Substudy Recruitment Protocol, Category:

	Recruitment Materials; • Partnership Representativeness Survey.pdf, Category: Measures (Survey questions/Interview questions /interview guides/focus group questions); • Parent and Child Demographic Questionnaire_SPA.pdf, Category: Measures (Survey questions/Interview questions /interview guides/focus group questions); • ECEC Screening Form_1-22-18_aea.pdf, Category: Screening forms; • SAGE CAB Informed Consent_ShortForm-OralConsent 10 12 2017.pdf, Category: Consent Form; • Back-translation form - FV Screener, Category: Other (to reflect anything not captured above); • Eating in the Absence of Hunger Observation Form, Category: Measures (Survey questions/Interview questions /interview guides/focus group questions); • Silver Toten CITI Training, Category: Other (to reflect anything not captured above); • Sustainability Action Plan 6.5.17.pdf, Category: Measures (Survey questions/Interview questions /interview guides/focus group questions); • backtranslation-form_SAGE Parent Exit Survey Signed.pdf, Category: Other (to reflect anything not captured above); • Substudy POCT Questionnaire-Spanish, Category: Measures (Survey questions/Interview questions /interview guides/focus group questions); • SAGE Content Checklist_Lesson 1.pdf, Category: Measures (Survey questions/Interview questions /interview guides/focus group questions); • Protocol for Recruiting & Scheduling Childcare Director Interviews.pdf, Category: Recruitment materials/advertisements /verbal scripts/phone scripts; • SAGE Parent and Child Demographic Survey SPA T1 6-25-18.pdf, Category: Measures (Survey questions/Interview questions /interview guides/focus group questions); • Parent Accelerometer Log ENG.pdf, Category: Participant materials (specific directions for them); • Community Organization Letter of Support, Category: Other (to reflect anything not captured above); • Recruitment Call Script Example, Category: Recruitment Materials;

	• SAGE Self Efficacy Questionnaire (1).pdf, Category: Measures (Survey questions/Interview questions /interview guides/focus group questions); • PARA.pdf, Category: Measures (Survey questions/Interview questions /interview guides/focus group questions); • SAGE Parent and Child Demographic Survey SPA T4.pdf, Category: Measures (Survey questions/Interview questions /interview guides/focus group questions); • Fruit and Vegetable Screener 6-26-18 SPA.pdf, Category: Measures (Survey questions/Interview questions /interview guides/focus group questions); • Opportunity Reception Agenda.pdf, Category: Participant materials (specific directions for them); • SAGE Fasting Finger Stick Blood Sample Data Collection Form.pdf, Category: Measures (Survey questions/Interview questions /interview guides/focus group questions); • CAB Demographic Survey8.18.16 EL.pdf, Category: Measures (Survey questions/Interview questions /interview guides/focus group questions); • Maricopa Dept.pdf, Category: Other (to reflect anything not captured above); • Teacher Program Sustainability Survey T2-T4.pdf, Category: Measures (Survey questions/Interview questions /interview guides/focus group questions); • FriendlyHouse_SAGE_MOA.pdf, Category: Off-site authorizations (school permission, other IRB approvals, Tribal permission etc); • Home Food Inventory Eng, Category: Measures (Survey questions/Interview questions /interview guides/focus group questions); • C2 Parent Flyer_Eng (1).pub, Category: Recruitment Materials; • SAGE parent and child demographic survey T2-T3 (ENG)- Control, Category: Measures (Survey questions/Interview questions /interview guides/focus group questions); • UofA Agricultural Literacy and School Garden Food Safety LOS, Category: Other (to reflect anything not captured above); • Reminder Flyer 6-26-18 SPA.pub, Category: Recruitment Materials; • WSD_SAGE_MOA.pdf, Category: Off-site authorizations (school permission, other IRB

	approvals, Tribal permission etc); • Substudy transportation log, Category: Participant materials (specific directions for them); • Substudy POCT Questionnaire, Category: Measures (Survey questions/Interview questions /interview guides/focus group questions); • Parent Accelerometer Log SPA.pdf, Category: Participant materials (specific directions for them); • Hunger and Fullness Cues Protocol 5.29.14.pdf, Category: Participant materials (specific directions for them); • Active transportation log-Spanish.pdf, Category: Participant materials (specific directions for them); • Tiger Mountain Community Garden Organization Letete, Category: Other (to reflect anything not captured above); • Substudy CMS fact sheet, Category: Resource list; • Teacher Program Sustainability Survey T1 .pdf, Category: Measures (Survey questions/Interview questions /interview guides/focus group questions); • Teachers Interview Guide and Questions, Category: Measures (Survey questions/Interview questions /interview guides/focus group questions); • TiffanyDowling.pdf, Category: Non-ASU human subjects training (if taken within last 3 years to grandfather in); • SAGE Grant.pdf, Category: Grant application; • Estabrooks Citi Human Research 10_2014.pdf, Category: Non-ASU human subjects training (if taken within last 3 years to grandfather in); • Director Program Sustainability Survey T2-T4, Category: Measures (Survey questions/Interview questions /interview guides/focus group questions); • Teacher self evaluation.pdf, Category: Measures (Survey questions/Interview questions /interview guides/focus group questions); • C2 Parent Flyer_Spa (1).pub, Category: Recruitment Materials; • Lee_Soltero CITI Training Certificates.pdf, Category: Non-ASU human subjects training (if taken within last 3 years to grandfather in); • SAGE Postcard, Category: Recruitment Materials; • Directors and Teachers IC, Category: Consent Form; • SAGE PostIntervention Survey_Satisfaction_Communication_ENGLISH.pdf, Category: Measures (Survey questions/Interview

	questions /interview guides/focus group questions); • ECEC Letter of Support, Category: Other (to reflect anything not captured above); • backtranslation-form_SAGE Parent Exit Survey Signed.pdf, Category: Other (to reflect anything not captured above); • Petrov_CITI 2017.pdf, Category: Non-ASU human subjects training (if taken within last 3 years to grandfather in); • SAGE parent exit survey_SPA_7-13-17.pdf, Category: Measures (Survey questions/Interview questions /interview guides/focus group questions); • AZ Department of Health Services Letter of Support, Category: Other (to reflect anything not captured above); • SAGE parent and child demographic survey T2-T3 - Intervention SPA, Category: Measures (Survey questions/Interview questions /interview guides/focus group questions); • SAGE Social Behavioral IRB Application , Category: IRB Protocol; • Substudy fasting finger stick blood sample protocol, Category: Technical materials/diagrams; • SAGE parent consent form 6-26-2018 SPA.pdf, Category: Consent Form; • Open Forum Symposium_ Agenda.pdf, Category: Participant materials (specific directions for them); • SAGE Parent and Child Demographic Survey T4.pdf, Category: Measures (Survey questions/Interview questions /interview guides/focus group questions);

The IRB approved the modification.

When consent is appropriate, you must use final, watermarked versions available under the “Documents” tab in ERA-IRB.

In conducting this protocol you are required to follow the requirements listed in the INVESTIGATOR MANUAL (HRP-103).

Sincerely,

IRB Administrator

cc: Anel Arriola
Michael Todd

Megan Petrov
Nina Palermo
Jamielee Richardson
Meredith Bruening
Everly Inzunza
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