Walkability Around the Worksite and Physical Activity

by

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ABSTRACT

Features of the built environment (BE) are related to a wide range of health factors, including leisure-time physical activity (PA) and active forms of transportation. For working adults, worksite neighborhood is likely an important BE to better understand the impact of various factors on PA patterns. Compared to home neighborhood walkability research, worksite walkability has received relatively less attention. The objective of this project was to identify if worksite walkability was significantly associated with PA behavior.

Aims: to evaluate 1) the PA variation explained by work walkability, 2) the moderating effects of person-level characteristics to the relationship between PA and work walkability, and 3) the differences in the rate of change in PA over time by worksite walkability.

Methods: self-report and accelerometer measured PA at baseline (aim 1, 2); longitudinal accelerometer PA during the initial 56 days of a behavioral intervention (aim 3). Adults were generally healthy and reported part- or full-time employment with a geocodeable address outside the home. Geographic Information Systems (GIS) measured walkability followed established techniques (i.e., residential, intersection, and transit densities, and land-use-mix).

Results: On average, worksite walkability did not show direct relationships with PA (aim 1); yet certain person-level characteristics moderated the relationships: sex, race, and not having young children in the household (aim 2). During 56 days of intervention, the PA rate of change over time showed no evidence of a moderating effect by worksite walkability.

Discussion: Worksite walkability was generally not shown to relate to the overall PA. However, specific subgroups (women, those without young children)

appeared more responsive to their worksite neighborhood walkability. Prior literature shows certain demographics respond differently with various BE exposures, and this study adds a potentially novel moderator of interest regarding young children at home. Understanding who benefits from access to walkable BE may inform targeted interventions and policy to improve PA levels and foster health equity.

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CHAPTER 1

INTRODUCTION

Major deficits in physical activity (PA) engagement are a persistent public health concern.[1-3] The benefits of PA for reducing health risks have been established,[4] and greater attention to the influence of the environment on health, including PA adoption and maintenance, has garnered interest across disciplines.[5] How physical and built environments promote or constrain PA adoption have emerged as particularly important factors to address in a public health framework.[6] To combat insufficient PA, health and exercise scientists are collaborating with practitioners and policymakers in the fields of urban design, transportation, and city planning, with the common goal of increasing PA at a population level.

National guidelines encourage adults to achieve 150 minutes per week of moderate-intensity aerobic activity to improve health,[4,7] yet most in the US fall short of this goal. The percentage of American adults meeting the aerobic guidelines is suboptimal, ranging from <5%[2] at the low end, to 49% at best,[8] depending on objective or self-report assessment methods. Further, a meta-analysis by Conn and colleagues revealed that current intervention strategies to increase recreational or leisure time PA are largely unsatisfactory, indicating an average increase of only 14.7 minutes *per week* of PA.[9] In light of inadequate leisure-time interventions and a deeper understanding of the contextual factors influencing PA, attention has shifted to include the environment for enhancing PA behaviors.

Behavior is shaped by the environment,[10,11] and both individual and contextual elements hold important relationships to many health outcomes, including PA.[12] Ecological models establish a useful framework to investigate and intervene on human behavior and it’s interrelatedness to the environment. Spanning multiple levels of influence from within (e.g., physiological, psychological, demographic) to outside of the individual (e.g., interpersonal, physical environment, policy), this framework underscores how the physical environment can enable or inhibit behaviors. Moreover, the notion that any one level of influence may interact with another or multiple levels adds to the complexity of the models, but also provides a greater context in which to study the behavior and outcome of interest. Additional principles justifying the use of ecological models within intervention work include the importance of tailoring interventions to a specific behavior and the potential for multilevel interventions to increase the sustainability of change, see Chapter 2 and Figure 1 for an expanded review of ecological models. Empirical evaluations using ecological frameworks have led to a greater understanding of PA behaviors.[13,14]

The built environment (BE) – sometimes referred to as cultural features, or urban features when discussing cities and suburbs - is a broad term encompassing human-made features of the environment: all buildings, roadways, spaces, and objects.[15] Features of the BE are related to a wide range of health outcomes such as obesity, coronary heart disease, and diabetes,[5,16-18] but also relate to leisure-time PA and active forms of transportation.[14] Borrowed from the planning field, the notion of walkability is a term that has been adopted by health and PA researchers. Walkability is the design of a community that can either increase or decrease the likelihood of people walking to destinations. Although the concept of walkability is relatively new, the wide application in the health field shows strong and consistent relationships between walkability and PA engagement in the US and internationally.[19] However, there is a gap in the literature regarding the associations of context-specific (e.g., home vs. workplace) BEs and their influence on PA.[18]

Home neighborhood walkability has received the majority of attention in the literature,[20-22] presumably because people spend long periods in the area where they live. However, American workers typically spend 8.8 hours in work-related activities on the days they work, including the commute to and from work.[23] For the 146 million working adults,[24] the worksite may be leveraged to influence PA on a regular basis.

In contrast to home neighborhood walkability, considerably less research has been dedicated to the walkability of worksite neighborhoods;[25] places employed persons visit regularly and presumably spend long periods of time. Worksite health promotion efforts often include inventorying and experimentally manipulating factors such as education and programming (e.g., onsite PA classes), employer policies (e.g., incentives for active travel to work), and the internal physical environment (e.g., office gym equipment, stairway accessibility).[26,27] Notably, the research base of worksite health promotion often focuses on elements of the indoor environment, although some questionnaires developed explicitly for worksite health promotion do evaluate some outdoor environment features (i.e., the worksite neighborhood).[27] However, it is often not the focus of the worksite health promotion researcher to understand the role of the worksite neighborhood and it's relationship to PA behavior. Failure to evaluate non-residential environments (e.g., worksite neighborhoods) prolongs the lack of understanding in how important places contribute to health[28] and future research that includes places other than the home is warranted.[29]

In 2013, the vast majority of U.S. workers traveled alone to their worksite by automobile.[30] Recently, there has been a subtle yet declining trend in automobile use to travel to work, from almost 88 percent in 2000 to 85.8 percent in 2013. Moreover, younger workers have changed their reliance on driving as the primary commute choice. From 2006 to 2013, workers 25-29 years old increased use of public transportation commuting by 1.6 percent, and, among urban workers specifically, decreased their automobile commuting by 4 percent.[30] These early trends in declining auto-dominated transportation to work, coupled with more active forms of commuting seen in younger adult workers, supports exploring the worksite BE as a potentially important factor to understand PA patterns among adults working outside of the home.

The current state of literature regarding worksite neighborhoods and PA shows conflicting relationships. Schwartz et al. found no associations between pedometer-measured steps during reported work hours and self-reported presence or absence of BE features around the worksite in Maryland employees.[31] In contrast, Troped et al. found relationships between accelerometer measured-PA located within 1-km of the worksite and objective measures of the worksite BE in Massachusetts.[32] Recently, additional studies observed relationships between the BE around the worksite and PA. Adlakha and colleagues examined the domains of self-reported PA and perceptions of BE factors near the workplace; and reported significantly greater odds of meeting PA guidelines with the presence of several worksite BE features (e.g. nearby transit stop, sidewalks, facilities to bicycle).[33] Barrington et al., found that neighborhood socioeconomic status and objectively-measured residential density close to the worksite were related to changes in walking during a randomized trial to prevent employee weight gain.[34] And in a report published in 2018, Marquet and colleagues purposely recruited only females and discovered that accelerometer-assessed and GPS-located PA within 400-m of worksites, with correspondingly higher walkability values, were related to higher levels of MVPA.[35] Marquet, et al. also revealed a ‘synergistic’ result with a home and worksite neighborhood walkability interaction; this combination of neighborhood contexts related to a stronger relationship with PA.[35]

However, the literature on the BE around the worksite was limited in several ways. First, few studies of PA behavior (i.e., accelerometer, or self-report PA) and the neighborhood environment around the worksite exist.[31-35] Second, objective measures of worksite neighborhood are rarely considered[22,25,32,34,35] compared to studies of residential neighborhoods.[36-40] Third, with few exceptions, evaluations of the worksite neighborhood have not adjusted for the home environment.[31,34,35] Fourth, moderating analyses of individual level characteristics (e.g., age, sex) are limited.[22,32,35] To help determine for whom the worksite neighborhood environment is more or less influential on PA, demographic and other person-level characteristics must be considered important factors to better understand these relationships. Finally, there is no known longitudinal study with an objectively measured outcome, such as accelerometer measured PA, to evaluate variation in participant's PA over time. Exploring these questions can overcome some of the limitations of current research in the field of worksite neighborhood walkability and PA.

Given the scarcity and limitations of research to date, addressing these questions may advance the field of PA adoption and maintenance. Additionally, to the author's knowledge there have been no studies evaluating objective worksite neighborhood BE features utilizing a standardized method of BE evaluation. The walkability index, derived initially to evaluate home neighborhood walkability,[20] has been used extensively to evaluate PA in a range of cities within the U.S. and internationally[19] and may prove useful in evaluating worksite neighborhoods as well.

The overarching question this dissertation aimed to address: Is worksite neighborhood walkability associated with PA behavior? The purpose of this study was to examine the associations of walkability around worksite neighborhood to self-reported and objectively-measured PA behavior among adults in Maricopa County, Arizona aged 18-60 years old participating in the WalkIT Arizona study.

Aims are presented in brief here and with specific hypothesis in Chapter 3:

Aim 1 (A1) Title: the variation of PA explained by worksite walkability

To evaluate the relation of walkability around worksites on physical activity after accounting for home neighborhood walkability and socioeconomic status: a **cross-sectional** study used baseline data from the WalkIT AZ study.

Aim 2 (A2) Title: the moderating effects of individual-level characteristics to the relationship between PA and worksite walkability (see Chapter 3 for details).

To examine the relationship between walkability around the worksite and physical activity as moderated by individual-level demographics and characteristics (age, sex, SES, presence of children, ratio of cars to people in household): a cross-sectional study used baseline data from the WalkIT AZ study.

Aim 3 (A3) Title: differences in the rate of change over 56 days of a behavioral intervention by worksite walkability

Evaluate whether differences in worksite walkability at baseline explains the rate of change in PA through the first 56 days of a walking intervention. Does worksite walkability explain daily variation in participants' physical activity minutes (total MVPA bout minutes, sedentary-Light PA (SLPA) minutes) over the course of 56 days?

CHAPTER 2

REVIEW OF LITERATURE

Physical activity (PA) and Public Health

The accumulation of evidence on the benefits of a physically active lifestyle is extensive.[7,41,42] To improve the health of Americans, Healthy People 2020 objectives sets nationwide targets to improve physical activity (PA) engagement by increasing walking trips (PA-13), bicycling trips (PA-14), and enhancing community design through the built environment.[43] Yet, national surveillance of physical activity (PA) indicate many people are not sufficiently active[2,8] and most do not meet guidelines for aerobic PA whether assessed by self-report or objectively.[44] Researchers in this field have underscored the importance of PA as a public health priority[45,46] and urged collaborations between local governments and organizations to motivate health-promoting changes to the built environment (BE)[47] The report "Step it Up! The Surgeon General's Call to Action to Promote Walking and Walkable Communities" encourages people, cities and society as a whole to embrace PA, plus mentions worksites among several places as a promising location to promote PA.[43] Moreover, the Healthy People 2020 objectives of the Center for Disease Control further stress the importance of transdisciplinary approaches to increasing PA through environment and policy changes[48] These objectives include explicit targets to increase walking and bicycling trips by 10 and 1 percentage points, respectively.[48]

Physical Activity Guidelines for Americans

The Physical Activity Guidelines for Americans recommends adults achieve weekly aerobic and strength goals for considerable health benefits. Updated guidelines encourage the general ideas that any PA is better than none, and that reducing sitting time is good for health. For aerobic activity, specific recommendations include achieving 150-300 minutes per week of moderate-intensity activity, or 75-150 minutes per week of vigorous-intensity, or any equivalent combination thereof, for the greatest health benefits.[4,7] With regard for muscle-strengthening activity, working all major muscle groups at an intensity at least moderately higher than usual on a minimum of 2 days per week provides additional benefits to muscle and bone health. Adults are also encouraged to practice regular flexibility and balance training activities. While generally considered beneficial to joint health and fall-risk prevention, flexibility and balance exercises are not clearly related to improvements in widespread health outcomes.[7]

Domains of Physical Activity

Physical activity is generally classified into one of several types, forms or topographies. In this manuscript, PA is defined using the definition by Caspersen, Powell, and Christenson as bodily movement produced by skeletal muscles that results energy expenditure.[49] Domains of PA for the current project include leisure-time (recreational), occupational (work), transportation (utilitarian), and household (domestic). Precise definitions vary, but are based from Craig, et al. and presented as the following: **Leisure**: recreational or discretionary activities such as sports, hobbies, or purposeful exercise. **Occupational**: employment-related such as manual labor tasks, lifting or moving objects, or walking for work errands. **Transport**: to go from place to place by means of walking, bicycling or other human-powered transport; including going to or from transit stops. **Household**: domestic housework such as cleaning the home, childcare, routine yard work and gardening.[50] Another model using a time-budget framework adds sleep to complete a structure that can be thought of as a the 24-hour totality of behaviors,[51] but while the author acknowledges the importance of sleep to overall health and wellbeing, it was not considered an important topic of this project.

Domains of PA have differing relationships to reduction in morbidity and mortality. As Samitz, Egger, and Zwhalen (2011) demonstrate in a systematic review and meta-analysis, the relative risk (RR) of mortality is reduced across all domains with higher amounts of PA.[52] However there is notable variation of across domains, with RR = 0.64 (95% Confidence Interval [CI] 0.55–0.75) for activities of daily living (combined transport and household PA); 0.74 (95% CI 0.70–0.77) for leisure; and .83 (95% CI 0.71–0.97) for occupational activity when comparing the lowest to highest levels of activity in each domain.[52] This shows that domains of PA have specific and differing relationships to mortality. Because forms of PA vary by setting (e.g. transportation often occurs outdoors), context specific interventions to promote PA are an avenue to pursue for enhancing health.

Quantifying Physical Activity

Self-report Methods and METs.

Numerous options exist to capture free-living physical activity (PA) by subjective methods, often referred to as self-report. Most self-report measures are categorized into three broad categories: questionnaires, logs, and diaries. These methods are typically a mechanism to classify behavioral dimensions of intensity, duration, and frequency of free-living activities, and these dimensions can be used to estimate energy expenditure. Several tools incorporate domains of PA and determine a volume of PA over a given period of time or typical week (or day). Questionnaires have been a common method to assess PA,[53] but variety in the type of questionnaire applied impacts our understanding of PA.[53] In descriptive epidemiological studies, population surveillance, and behavioral interventions, a useful and commonly employed instrument is the International Physical Activity Questionnaire (IPAQ), which includes two forms, short and long.[50] A related tool constructed in a similar style to the IPAQ is the Neighborhood Physical Activity Questionnaire (NPAQ) and was used in this project as it can be self-administered to determine estimates of volume and intensity of PA in domain- and environment- contexts, see Chapter 3 for details.

Intensity, duration, and frequency of a given activity influence energy expenditure and require standardization to be useful in self-report methodology of PA assessment. The metric of Metabolic Equivalent of Task (MET) is a physiologic unit used to compare EE across activities that are captured in questionnaires such as the NPAQ. A MET is defined in terms of the amount of oxygen consumed each minute per kilogram body weight.[54] This reference value is set by convention as 1 MET equaling 3.5 milliliters of oxygen per minute of activity (3.5 mL/kg/min).[54,55] This value approximates the EE of a 70-kg person resting in a seated position for 1 minute.[54,55] Assigning a MET value to specific activities aids researchers in comparing types of activities based on laboratory measured EE at specified intensities and durations of activity. The "Compendium of Physical Activities" provides reference MET values (an intensity factor) for hundreds of physical activities.[56] This is often expressed in MET-minutes or MET-hours of activity per day or week. Multiplying the MET value by the duration (e.g., minutes, hours) and frequency (e.g., days per week) of a given self-reported activity allows the MET value to be totaled for comparison with other activities.

As with any measurement device, limitations exist in questionnaires of PA. Systematic and random error obscures the relationships between factors influential to PA behavior and the assessment of PA for empirical purposes. Systematic errors manifest in a variety of forms and are considered a threat to the validity of a questionnaire. Response bias includes topics such as recall bias, cognitive limitations in remembering events correctly, especially over longer time-spans,[57] and social desirability bias, the tendency to describe oneself in ways that align with perceived social or cultural norms.[58] The ability for a questionnaire to reflect behavioral change over time is known as responsiveness, however, lack of longitudinal follow-up to evaluate responsiveness of an instrument during intervention studies is threat to validity.[53] Ongoing evaluation of psychometric properties,[53] quality assessment,[53] inclusion of longitudinal designs[53] and following best practices for survey administration[57] aims to improve the science of self-report based PA research.

Accelerometer Methods and Counts.

Accelerometers are small electronic motion sensors that record acceleration counts over a unit of time.[55,59] The counts allow quantification of frequency, duration, and intensity for estimation of PA and sensors are arranged in at least one, but up to three, planes of movement: vertical, antero-posterior, and medio-lateral.[55,59] With triaxial accelerometers, in addition to data from individual axes, the opportunity to combine axes allows calculation of a vector magnitude (i.e., the square root sum of squares of two or more individual axis counts). Specific methods of accelerometer use in PA research are diverse and include require considerations of the type of unit used,[60] data processing techniques,[61] and analytical approaches.[61,62]

Activity monitors are often categorized as "research grade" or "commercial grade" though these classifications as not always distinct. Commercial devices are often used in research studies for various reasons (e.g., participant acceptance, lower relative cost, availability). While popular, commercial devices present issues to researchers such as rapid fluctuations in device availability whereas research devices may have somewhat less frequent technology updates or model changes. Commercial products frequently have additional features that are potential confounders when their use is outside the control of the investigator, such as device feedback, use history, social media integration, online nutrition trackers, and other web tools. Within the research grade category are devices from companies such as ActiGraph, LLC (Pensacola, FL, USA), PAL Technologies, Ltd (Glasgow, UK), SWA Body Media, Inc. (Pittsburg, PA, USA), and ActivInsights, Ltd (Cambs, UK) which include various devices and wear placements at the hip, upper arm, thigh and more recently, the wrist. In 2014, ActiGraph announced its release of a new device the GT9X Link, based their previous GT3X accelerometer technology, but which introduced features aligned with consumer preferences.[63] Features included a slimmer size for wear on the hip or wrist, an LCD display with time, date and other display options, and wireless upload features using a mobile app to better achieve the desirable features of commercial grade devices.[63] Major benefits of the GT9X Link over commercial devices are that it allows control of feedback, access to unmodified data, and extensive testing of its foundational platform, the GT3X device, for reliability[64,65] and validity,[66,67] which are often lacking in commercial devices. Especially for longitudinal and intervention research, given the longer spans of time that accelerometer wear is required, these commercial grade features become critical to maintain participant compliance with wear protocols.

Many difficulties in using accelerometers to capture physical activity are well documented. Limitations include inconsistencies in data analysis and processing[61,68] agreement across commercial and research monitors in free living contexts,[69] and determination of wear and non-wear time.[2,70] Particular trouble with compliance of wearing an accelerometer a minimum number of days and hours per day is apparent in the National Health and Nutrition Examination Survey (NHANES). When the NHANES protocol switched from a waist-worn protocol to wrist worn-protocol, they noted vast improvements in compliance.[71] Accelerometer wear protocols are typically

4 days or more to obtain a representative period to be used to estimate habitual PA.[2,19,29,37,62,68,69,72-74]

Physical activity by walking and active travel

Walking is the most common physical activity reported in both men and women. National surveys of US adults indicate 34% participate in some walking, with the next most frequent activities being cycling and yard work at 12% and 11%, respectively,[75] though sex differences exist.[75] Purposeful activity conducted at a moderate intensity (i.e., walking at 3 METs), such as walking for transportation,[6,76] has shown to benefit health, and the relationship holds independent of other more vigorous activities.[76] Widely accepted themes of health promotion messaging encourage walking in both home neighborhoods (e.g., "Start a walking club in your neighborhood") and in the worksite neighborhood (e.g., "Get off the bus early and walk the rest of the way") as prominent opportunities for PA.[77] These examples offer encouragement to use surrounding environments that people routinely spend much of their time in (i.e. home and worksite neighborhoods) as the basis for walking in routine ways. While walking is popular and encouraged in a variety of contexts, efforts to increase walking behavior have often been constructed within one domain, leisure time PA,[78] but lackluster results have shifted focus of the field of PA research.

Acknowledging the difficulties in achieving broad changes in population activities with leisure-time approaches, a shift in focus to active transportation, or active travel, (e.g. walking and cycling) has been underway for more than a decade linking features of the BE to health outcomes.[12] Features of neighborhood design show consistent associations to various physical activity domains and health factors.[6,12,19,39,79-83] Active travel, though widely encouraged as a means to improve health, still has limited evidence to link it to specific health outcomes in longitudinal designs that monitor or intervene to increase PA.[84] Sahlqvist and colleagues showed that those participating in active travel achieved more total PA over a week than those who do not engage in active travel.[79]

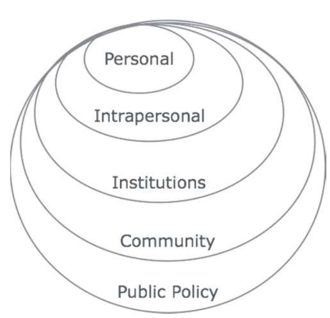
Ecological models of physical activity

The above description of domains of PA helps organize how aspects of life involve PA; however, one's settings and contexts may play a more precise role in determining where PA behaviors occur. Models and theories to explain and help evoke behavior change should be thought of as incomplete with ongoing conversations from numerous perspectives that are not always in agreement. While this ongoing conversation contributes to slow incremental advancements, it also complicates a thorough discussion of the matter and is beyond the scope of the current project. A few brief notes on the complexities include the diversity of frameworks that have emerged;[85,86] methodological advancements influencing the application of theories and models;[87] reinterpretation of and additions to previous models; and the incomplete testing of the theories, models and their constructs. The following is a brief history and progression of ecological models relevant to physical activity behavior.

Diligent inquiry of context was produced by R.G. Barker and colleagues with the dawning of ecological psychology and greater attention to behavioral settings.[88] From the field of human development, Bronfenbrenner described an ecological framework using a systems-models approach with the Ecological Framework for Human Development.[10] A highlighted feature of Bronfenbrenner's theory is the nested environments, termed systems: micro-, meso-, exo- and macro-systems with a notable emphasis on the bi-directional influence across systems that was often overlooked in other areas of psychology.[10] Ecological models specific to health behavior ensued, and continue to underscore that both a person's characteristics and their contextual elements influence behavior. With the shift in priority across many sectors to prioritize lifestyle choices and prevention practices, McLeroy and colleagues add a more specific iteration of ecological models with their Ecological Model of Health Behavior.[11] The nested levels are redefined to focus on behavior as the outcome and revised for application to health promotion research and programs.[11] McLeroy et al. arranged the nested levels specifically to study the determinants of behavior, and so defined the Behavioral Ecological Model using the following five broad, yet non-exclusive strata:

1. Personal factors – individual characteristics (e.g., processes of cognition, personal history, skills, and abilities)
2. Intrapersonal groups – close personal networks (e.g., family, friends, and neighbors)
3. Institutional factors – broader social associations and establishments (e.g., organizations with formal, or informal, rules and regulations)
4. Community factors – groups of institutions with shared characteristics, often social or geographical (e.g., local government, schools, and community agencies; may include institutions that compete for resources).
5. Public policy – local, state, federal governance (e.g., policy to restrict or promote behaviors, and policy to distribute resources).

Figure 1. Illustration of the Behavioral Ecological Model.



Similarities emerge across the various ecological perspectives. Both the Bronfenbrenner and McLeroy descriptions indicate nested levels of influence which are often represented visually with a series of concentric circles, or the 'onion' diagram, see Figure 1 as adapted from McLeroy, Bibeau, Steckler, and Glanz.[89] The center of these depictions is a person with their perceptions and individual characteristics. The model then expands to various spheres of influence; however, definitions of layers vary by specific model or theory. Moreover, ecological models stress interconnectedness, or interactions of the levels that add complexity as any level can affect or be affected by any other level, which creates a mesh or network of influence on behavior.[90] These interactions require multilevel investigations to describe and test the often-overlooked interplay of individuals within differing environments at any moment in time (e.g., for working people, both their home and worksite neighborhoods).

Applying ecological models, two stable and distinct settings are prime candidates for evaluation of their relationship to PA: the home neighborhood and workplace neighborhood. Most commonly utilized in the literature is the home neighborhood environment.[5,20,38-40,74,91,92] A much sparser area of investigation is worksite neighborhood environmental research with only two relevant locatable manuscripts that focus on objective measures of PA as on outcome and consider objectively measured worksite and home neighborhood environments[22,32,35]. This scarcity in evidence exists despite epidemiological evidence to show that greater time spent in active commuting to work was associated with lower cardiovascular disease and all-cause mortality;[93] incidence of Type 2 Diabetes in men;[94] and positive associations in fitness.[95] However, these epidemiological studies did not measure features of the BE, home or work.

Measures of the built environment

The public health entry into measuring the BE commonly relied on individual perceptions or audits to assess environmental features. In contrast, transportation and urban planning experts have traditionally made use of measuring the built environment using objective metrics such as traffic speed, automotive collisions, and land-use information. Additionally, direct observation/auditing, such as the Checklist of Health Promotion Environments at Worksites (CHEW) [96], and Microscale Audit of Pedestrian Streetscapes (MAPS) [97] also contribute to the methodological toolbox for describing urban form, but are outside the scope of this focused literature review. The underpinnings that of these measurements are similar: elements of density of people, land-use diversity, and structural design for both motorized and non-motorized transportation.[98] The capture and analysis of routinely archived spatial data (using geographical information systems, or GIS) is widely utilized in urban planning and transportation, and can add a geographic component to the understanding of how people move about their surroundings. Brownson and colleagues present a review of measures using perceived, observational, and archival (GIS) data to evaluate associations between PA and the BE [46], but a brief introduction to such techniques is presented next.

Subjective or perception based inquiries rely on recall measures of one's context and surroundings. Many questionnaires exist to evaluate perception of the physical BE, but also include social environments, and organizational policies that may influence PA.[27,46] Common themes include asking participants to report land-use patterns, access to recreational facilities, traffic conditions, personal safety, and aesthetics[46] and most commonly ask respondents about their home neighborhood environments. With extensive use in both US and international studies, the Neighborhood Environment Walkability Scale (NEWS),[6] is a comprehensive survey designed specifically for PA investigations and has shown validity with significant factor loadings in both individual and block-group level confirmatory factor analyses.[99]

Objective measures include GIS application to geoprocess existing data from public sources to characterize the built environment. Explicit and objective measurements of the built environment for PA research have been developing for a relatively short time.[15,37,100]

Differing methods exist for applying GIS techniques for PA research,[16] which complicates testing multilevel designs using person and neighborhood level data. The neighborhood "walkability" index developed for the Neighborhood Quality of Life (NQLS) study is a prime example of integrating individual level research within an environmental context,[20] and is a foundational element in the current project to link features of urban planning with health research to explain individual person-level PA engagement.

However, the argument has been made that perceptions may be more important than objective measures of the environment in some groups of people and for certain features that are transient.[101] Home neighborhood environments have also been shown to moderate PA relationships, in particular sex differences. Compared to women, men in lower walkable environments seem to respond better to intervention, however it appears that safety from traffic was more important for women to become more active.[102] Women walk more in safe/crime free neighborhoods,[103] and are less active if dogs are loose, where men are more active if they had exercise equipment in their home or see others being active in the neighborhood.[38] In a review by McCormack and Virk, there is compelling, although mostly cross-sectional and quasi-experimental evidence that objective attributes of the BE, such as neighborhoods designed with heavy reliance on car travel, are very important obstacles for those promoting transportation-related walking.[104] The region of study in the current project was designed with car travel as the primary mode of personal transportation, so it is from this backdrop that the study described herein has focused on using objective measures of the BE for home and worksite.

Home neighborhood environment and physical activity

Physical activity is influenced by myriad factors.[105] Sallis and colleagues reviewed the early evidence of the relationship between environment, policy and PA. This review identified many factors both within and outside the home (e.g., exercise equipment, home environment outside) and worksite (e.g., shower facilities, bike lockers) that correlate with physical activity; outcomes were more strongly associated with objective measures of both environments than with perceptions.[106] Since then, most of the inquiry within the field has examined the home neighborhood,[107,108] which has been operationalized in a variety of ways (e.g., Census block groups, 1-mile radius, 1-mile street network, 500-meter street network).[5,19,20,36,109,110]

Bauman and colleagues highlight numerous deficiencies and areas of improvement for the PA and BE field.[108] A small subset include the lack of standardized comparisons of the environment, a low range of BE features measured, and the need for advanced statistical techniques to move the field from associations to causation.[108]

The International Physical Activity and Built Environment Network (IPEN; www.ipenproject.org) aims to improve comparability and variety of BE features across a broader range of environments.[91,111] Through standardized GIS protocols, IPEN coordinates objectively measured BE. In doing so, the IPEN team revealed extensive cross-national differences in BE features, both with single environment features (e.g., net-residential density, land use mix) and multiple features combined (i.e., walkability index).[111] Internationally, the variability of home neighborhood environment across lower-to-higher walkability (i.e., 5th and 95th percentile) showed almost 90 minutes per week difference in moderate-to-vigorous PA (MVPA).[19] Furthermore, the IPEN study revealed neighborhood-level variance explained about 12.7 min/day (or 89 min/week) of MVPA, which accounted for 7-12% of variability across models.[19] These advancements are an improvement in the field, but are so far constrained to the home neighborhood environment.

Worksite neighborhood built environment and physical activity

For working individuals, over 1/3 of the total hours in a workday are spent in work related activities.[23] A greater amount of active commuting to work has been associated with positive health outcomes.[76] There is evidence that people who perform any active commuting to work had reductions in BMI, and waist circumference at follow-up compared to those who do not commute by active modes.[76,95,112] Similar to the general PA and BE literature, nearby transit stops, worksite policies and supports (e.g., incentives and facilities), use of the supports, and positive perceptions of the environment around one's worksite are related to greater odds of both active commuting to work[113] and meeting PA recommendations.[114 Marx 2017] However, most research in this area focuses on policies and facilities within the work place,[27] which relies on self-report surveys from the perspective of employees[115] and may over-emphasize the individual-level responsibility placed on PA behavior while ignoring wider contexts such as worksite neighborhoods. To focus on individual-level behavior and employer policies and supports inside the workplace (e.g. gym subsidies, on-site facilities, flexible work schedule) is akin to the pattern of PA research that previously focused narrowly on leisure-time physical activity. Additionally, worksite is routinely considered without home neighborhood environment. Work by Yang and colleagues combined work and home found that greater numbers of transit stops near home, low cost recreational facilities near work, and bike facilities near either location were associated with active commuting to work, though measures were self-report.[33,113]

Evaluations of the BE around the worksite and its association with health behavior and outcomes are sparse compared to home neighborhood. Adlahka and colleagues found perceptions of worksite neighborhood features related to greater odds of meeting PA guidelines in the domains of leisure and travel PA.[33] Two studies with accelerometer evaluated PA near the worksite showed mixed relationships; Troped et al. found associations to worksite BE features within 1-km of worksite,[32] but Schwartz et al. did not;[31] however the former utilized objective measures of BE and the latter subjective measures. Further, several studies reveal worksite BE features are negatively associated with BMI,[22,25] and positively associated with cardiorespiratory fitness[22] and PA.[32-34] In the only known prospective study to objectively evaluate worksite BE over 2-year follow-up, worksite neighborhood socioeconomic status (i.e., worksite property value) and higher residential density around the worksite showed a positive association with increased walking in employees during a wellness intervention.[34] Among the preceding studies, four evaluated home neighborhood BE as well,[22,25,32,33] but only two considered combinations of home and worksite neighborhood features.[22,25] No studies described the variance explained in PA by worksite BE and only two considered moderating effects of BE with person-level characteristics (i.e., differences by age, sex, race-ethnicity).[22,32]

Noticeably lacking in the worksite walkability literature is a) incorporation of home neighborhood environment to determine how much variance in PA is explained by the addition of worksite BE, b) use of objective measures of PA, c) use of objective measures of the BE around the workplace, and d) exploring moderation effects across ecological levels. Without evaluating home neighborhood context or using standardized methodology to evaluate both subjective and objective aspects of the environments, it is difficult to compare the work of Barrington et al. to similar projects.[91,102,111]

Moderation analysis in physical activity and built environment research

In a review of reviews on the topic of BE and PA, Ding and Gebel note that the most cited suggestion to enhance the science, found in over 41% of reviews (15 of 36), was to examine potential moderators.[116] As described by MacKinnon, a moderator is defined as a third variable that alters the direction or strength of the relationship of an independent variable (IV) to a dependent variable (DV).[117] Also described as "effect modifiers" and "statistical interactions" in various fields, the third variable is not in the causal pathway but it does affect relations between the IV and DV based on distinctive levels or across a range of values of the moderating variable (e.g., distinct levels for a particular subgroup of people, or across the continuous age range of participants). Moderators can help explain the response to differing conditions, often referred to as the "for whom does a given effect apply".[116] The nuanced understanding from moderation analyses applied in the current project illuminated the "for whom" does a relationship exist, or not, when considering relationships between worksite walkability and several measures of PA.

Statistical interactions have shown to be an important area of BE research, especially with regard to PA.[105,116,118] Transportation related PA has been observed to be modified by various BE features,[119] and although self-reported work-related PA was measured, work-neighborhood environment was not a focus. While moderation analyses have been employed to evaluate home environment, this has not yet been done to the same extent around worksites.[32,35] Moderation analyses found significant gender and race conditional effects on the relationship between BE and PA outcomes in Troped et al.; yet tests for moderation by sex and age were non-significant in relation to BMI and physical fitness outcomes in Hoehner and colleagues. Recently, Marquet et al. found a synergistic moderation effect considering a home and worksite walkability interaction to PA in an all-female sample of participants.[35] Furthermore, to the author's knowledge, there is no existing evidence of BE features modifying longitudinal relationships of daily PA over an intervention period to increase PA adoption. The limited, conflicting evidence base, along with the numerous calls to further investigate moderators of the relationships to PA, are key motivations of the current project.

Current Investigation

Though continuing efforts to enhance understanding of PA environments exist, the field has largely ignored worksite neighborhood environment. If the employed adults who travel outside the home to work are doing so on a regular and predictable basis (i.e., working multiple days per week and returning to the same (set of) worksite(s) for their job) the contextual factors around the worksite may be useful to better understand factors associated with daily PA. First, a clearer understanding is needed to determine to what extent worksite neighborhoods explain variation in minutes of PA. In a review of methods to measure worksite supports for health behaviors, Hipp and colleagues (2015) divided worksite strategies into five categories based on an ecological framework: 1) promotions and programs (e.g., informational media); 2) organizational policies and practices (e.g., incentives); 3) internal physical environment (e.g. access to PA options); 4) internal social environment (e.g., role models); and 5) external environment (e.g., worksite neighborhood options)[27,114] To further elucidate the relationship between worksite neighborhood environment and PA, the latter category, external environment, is the focus of the current project.

CHAPTER 3

METHODS

The current study aimed to fill a gap in the physical activity (PA) and worksite neighborhood built environment (BE) literature by exploring relationships in PA behavior captured using self-report and objective measure to walkability around the worksite. First, this project evaluated the amount of variance in PA behavior explained by worksite BE walkability after controlling for home neighborhood walkability and additional covariates. Next, this project aimed to better identify the subgroups of individuals who may respond differently across worksite neighborhood environments, such as men and women, younger and older, and those with or without children in the home. Finally, the project aimed to evaluate the influence of worksite neighborhood walkability during the first 56 days of a PA intervention. All aims include PA measures assessed through self-report either inside or outside the home neighborhood (Neighborhood Physical Activity Questionnaire (NPAQ)), and total PA measured through wrist-worn accelerometer (ActiGraph GT9X). Worksite-specific activity was not assessed.

Walking Interventions through Texting Arizona (WalkIT AZ) overview

The current study was a secondary analysis from the WalkIT Arizona project. WalkIT Arizona was a randomized controlled trial (RCT) to evaluate the effects of an mHealth behavior change intervention for encouraging free-living PA [ClinicalTrials.gov Identifier: NCT02717663]. WalkIT Arizona participants were relatively healthy, insufficiently active adults who resided in Maricopa County, Arizona, USA at study enrollment. One aim of WalkIT Arizona was to evaluate the behavioral interventions across a range of home neighborhood BE types. Stratified recruitment of participants occurred by *a prior* characterization of higher and lower walkability around the home to be eligible for enrollment. Additionally, *a priori* assessment of higher and lower home neighborhood socioeconomic status (SES) was assessed via Census block group median household income. Separation in BE types was created by removing middle-strata values of home walkability and SES, and then inviting participants from these areas to enroll. However, all worksite walkability evaluations were assessed after recruitment.

WalkIT Arizona's final recruitment total was 728 adults who provided written informed consent. The 24-month recruitment period (May 2016 – May 2018) was balanced across season by enrolling approximately 60 participants each calendar month. The entire WalkIT Arizona study protocol included 3 phases over a 2-year period, however only Phase 1 and 2 are relevant for this worksite study, see Figure 2. Phase 1 was a baseline period of approximately 2 weeks that began with an office visit at the study laboratory to obtain written consent, health screening, baseline surveys, anthropometric measurements, exercise testing, and accelerometer training. During Phase 1, participants wore a blinded accelerometer on the wrist and were instructed to continue their usual PA routines. Researchers monitored compliance and determined eligibility for randomization during Phase 1 (i.e., acceptable accelerometer wear and sync compliance) and activity level (i.e., not achieving ≥150 min per week of moderate-to-vigorous physical activity (MVPA) performed in bouts, see Objectively Measured Physical Activity section below for details). Phase 2 began with randomization to one of four behavioral interventions stratified by the home neighborhood type (i.e., Walkability x SES) as defined by home address.

Figure 2. Timeline Illustration of the Baseline and Intervention Phases within the WalkIT Arizona Study.

The current project was a secondary and subset analysis of the WalkIT Arizona study. A primary aim of WalkIT Arizona was to evaluate the adoption and maintenance of a behavioral intervention within the context of home neighborhood walkability. Not considered in the initial planning of WalkIT Arizona was the extent to which *worksite walkability*, as a separate yet complimentary contextual environment, can 1) explain additional variance in baseline PA behavior over and above that explained by neighborhood walkability, 2) interact with demographic and personal characteristics to explain baseline PA, and 3) interact with intervention components during the first 56 days of the mHealth intervention to increase activity. Published studies of and methodologies for evaluating PA behavior related to the worksite neighborhood environment are scarce.[31-34] These studies are characterized by limitations in their statistical methods,[31] reliance on perception-based assessments of the BE,[31,33] and failure to include adjustment for home neighborhood environment,[34] weaknesses addressed by this current study's methodology.

Inclusion and Exclusion for WalkIT Arizona

All WalkIT Arizona inclusion/exclusion criteria are applicable to the worksite analyses described below, with the addition of including only participants employed at an establishment outside their home. Home-based workers obviate exclusion due to the same home and worksite neighborhood environment. The general criteria for inclusion and exclusion within the WalkIT Arizona study were as follows: eligible men and women between 18 and 60 years old living in eligible census block groups within Maricopa County, Arizona. Participants were insufficiently active; not pregnant and not planning to become pregnant at the time of enrollment; not participating in physical activity, diet, or weight loss programs; had daily access to a mobile phone with text messaging; were willing to wear a wrist-worn accelerometer; were willing to send and receive several text messages per day. Additional participant inclusion-exclusion criteria specific to the worksite study:

a) Employed at a location outside their home residence.

b) Worksite address or cross streets geocodable within Maricopa County (i.e., exclude those with worksites located outside Maricopa County due to inability to perform spatial analyses).

c) Complete baseline phase, for aims 1 and 2 (i.e., exclude those disqualified in baseline for non-compliance).

d) Completed 56 days post-randomization, for aim 3 (i.e., exclude those disqualified in baseline for non-compliance or non-randomized for sufficient activity during baseline phase).

Recruitment and Setting

For the WalkIT Arizona study, participants are sampled from Census Block Groups (BGs) stratified as high and low walkability and high and low SES in Maricopa County, Arizona, USA. As described by Frank, et al., BGs are used as an administrative unit that approximates a neighborhood[20] and are often bounded by main streets, the larger "arterial" roads, and other geographic features. Publicly available geographical data at the BG further makes this spatial unit useful for characterizing local variations in BE features and SES across an entire county. For the WalkIT AZ study, the values of walkability and SES for each BG are rank ordered and then to then categorized into deciles. Block groups in the 1st – 4th deciles of walkability are classified as low, and those in the 7th – 10th deciles are classified as high. Block groups in the 5th or 6th deciles of walkability or the 6th decile of SES are excluded from the sampling frame to maximize the variability of built environments and to reduce the likelihood of misclassification of those participants on the boundary of high versus low on either characteristic in areas with mid-range walkability and SES values.

Recruitment materials were professionally designed to formulate a consistent and appealing flier and website aesthetic. Distribution of materials included paper and digital fliers in community spaces, email list distribution with study web link, paid advertisements on social media networks (i.e., Facebook), and free online advertisements on strategic social group sites devoted to specific demographics. Social media advertisements are geolocated to areas of study inclusion based on the walkability and SES within the sampling frame.

Participants were directed to the pre-screening online survey (hosted by Qualtrics, LLC) with a brief description of the study and check-box informed consent to answer a brief set of eligibility, health, and contact information questions. The pre-screening information was transmitted to a secure online customer relationship management (CRM) software system (Salesforce.com, Inc.). The CRM was designed to track and manage potential participants for contact by study staff. Trained researchers conducted a phone interviews to describe the study, further assess eligibility, and schedule of the initial study office visit (i.e., the baseline visit). Participants underwent a health screening by phone and again in person to determine needs for medical clearance as required before exercise testing. When participants disclosed a history of cardiac, pulmonary, or metabolic conditions, comorbidities, or extensive pharmacotherapeutic drug use, research staff consulted with the project’s exercise physiologist prior to or during the visit for the appropriate course of action for exercise testing and inclusion, see Health Screening section below for details.

Office Visit Overview

The WalkIT Arizona study protocol included three in-person visits for participant assessment over the course of the two years of participant involvement. For this project, only the initial (baseline) office visit was pertinent and is described here. Participants arrived to the study office for a 2 - 3-hour visit to complete written informed consent, health screening, survey measures administered using an online platform (Qualtrics, LCC), see Table 1 below for brief details and expanded section on Survey Measures below. Next, researchers perform laboratory measures (see Table 1 and an expanded Accelerometer Cutpoint Calibration section below for details). Visits concluded with demonstration of proper use of, and practice with, study equipment. Study staff gave verbal and written instructions of the training: wear and sync requirements, and data upload procedures for both phone app and desktop computer. Participants were instructed to wear the accelerometer at least 10 hours of wake time per day, not to change their usual physical activity patterns during the baseline, to upload (sync) the accelerometer data daily, and confirm they received the “sync successful” text from the study to verify each sync completed. Researchers perform a demonstration of the sync procedures and mobile phone text system. The written instructions, copy of written informed consent, study site parking validation, and accelerometer charging dock were provided in a document packet at the conclusion of the visit.

Health Screening

At the visit, prior to computerized survey measures, researchers conducted a general health screening. This included the 2015 PAR-Q+ and the American College of Sports Medicine (ACSM) logic model for cardiovascular disease (CVD) risk stratification.[54] Briefly, participants are categorized as low (less than 2 CVD risk factors, asymptomatic), moderate (equal or greater than 2 CVD risk factors, asymptomatic), or high risk (has any major sign or symptom, or known history of CVD, pulmonary or metabolic disease) of which only low or moderate risk individuals were accepted for exercise testing. Specific conditions are permissible with appropriate precautions, such as asthmatics with non-expired rescue inhaler, or those obtaining documentation of primary care physician's clearance to participate and review of history by the exercise physiologist co-investigator.

Measurement

Walkability index and GIS measures

Objective measures of both home and worksite walkability were calculated using geographical information systems (GIS) data. The Walkability Index is a composite measure of built environment features that have known relationships to walking for transport and biking behaviors,[6,120] and is regarded as a high-quality GIS-derived measure how the built environment fosters walking for transportation.[109] Definitions of the components are adapted from Frank et al. 2010,[20] with the addition of a transit density component more recently shown as an important BE feature.[19]

- Net residential density: the ratio of residential units to the land area devoted to residential use in square meters.

- Intersection density: the ratio of true intersections (3 or more legs) to the specified land area in square meters.
- Transit density: the ratio of transit stops (bus, light rail) to the specified land area in square meters.
- Land-use mix (i.e. entropy index): uses 7 types of land use designations (office, retail, civic, entertainment, recreation, food, and residential) to quantify the diversity of land use types present in a given area. Values were normalized such that a score of 0 indicates single land use and a score of 1 indicates even distribution of all 6 land uses across the area.

Note that the WalkIT Arizona version of the Walkability Index differs from Frank et al.[20] because retail floor area ratio, or retail FAR, was omitted due to the inadequate spatial data in the region to calculate this metric. Transit density was substituted for retail FAR. The final Walkability Index for the WalkIT Arizona project used z-scores from each component to normalize scores specific to Maricopa County, which is expressed with the following equation:

Walkability Index= [*(z-net residential density)* + *(z-intersection density)* + *(z-transit density)* + *(z-land use mix)*]

All data to derive the Walkability Index were publicly available (e.g., BG data, Tiger Line files, Property Use Codes, and land parcel information). Participant home addresses were geocoded to determine their BG-specific walkability at the time of enrollment. Worksite walkability was based on geocoded worksite address or nearest cross street to determine walkability in the immediate area of participants' worksite using 500-m and 1000-m street-network buffers, with a 25-m buffer from the centerline of the road to create individual neighborhood areas.

Table 1a. Baseline surveys and laboratory measures of the WalkIT Arizona study: Self-administered, computerized surveys.

Measure	Description	Full Survey or Section/Questions Included
NEWS	Neighborhood Environment Walkability Scale (NEWS) measures perceptions of design, density, destination features related to PA in the home neighborhood.[99,120]	Sections A, B, D(Q3,5), E(Q1,4,5), F(Q1,3,5,6), G(Q1,3,5,6), H(Q2,4,5,6)
IPAQ	International physical Activity Questionnaire (IPAQ) long form; Survey to measure domain-specific PA with acceptable reliability, validity, and interclass correlations.[50,121]	Parts 2 (Q10, 11, 12, 13),4 (Q 20, 21), 5 (Q 26, 27)
NPAQ	Neighborhood Physical Activity Questionnaire (NPAQ); self-reported PA performed within and outside the neighborhood to examine environmental features correlated to walking and cycling behavior; similar to the IPAQ.[122]	Questions 2, 3, 5, 6, 9, 10, 12, 13
Crime	Assess crime and personal response to crimes, including cognitive, emotional, behavioral responses that may affect PA occurring in one's home neighborhood. Psychometric testing currently ongoing.	Full Survey. Sections: A (Q 1, 6), B, C, D, E (Q 1-3), E (Q5-6), F, G, H, I, J, K (Q5), M, O, Q, R, S, T, U, V, W, X, Y, Z, AA, BB, CC, DD (Q9-11), (Q12, 13a, 13b), EE (Q5, Q6-9)
NQLS	Neighborhood Quality of Life (NQLS) survey 1 and 2 assessing benefits and barriers to PA; work related transportation and PA.[123]	Survey 1: Section M (Q 2, 3, 4, 5, 6, 8, 10), X, Y Survey 2: Section J (Q 1, 2, 3, 4, 5, 16, 17)
Self-Efficacy	Barrier self-efficacy to PA (0-9 Likert-type scale) in a range of contexts; adapted from previous work.[124]	Adapted by research team
Monetary Choice	Delayed discounting protocol using 27-item self-administered questionnaire.[125,12610,11]	Full Survey
Sleep Quality	Pittsburg Sleep Quality Inventory (PSQI) evaluated self-reported sleep quality, latency, duration, efficiency patterns, daytime sleepiness, and use of sleep medications.[127]	Full Survey

MVPA = moderate to vigorous physical activity

Table 1b. Baseline surveys and laboratory measures of the WalkIT Arizona study: Researcher performed in laboratory.

Measure	Description
Height and Weight	Measured using digital stadiometer and scale (Seca 284 measuring station, Seca GmbH & co. KG, Germany).
Blood Pressure	Brachial blood pressure (BP) assessed pre-post aerobic fitness testing after standardized rest period (IntelliSense Professional Digital monitor, Omron Healthcare, Inc.).
MVPA Cutpoint Assessment	A continuous treadmill protocol to assess oxygen consumption (VO_2) during walking at speeds of 2.0, 3.0, and 4.0 mph, 0% grade, for 6 min each speed. VO_2 data was then time-matched with accelerometer data to derive the vector magnitude (VM) threshold ≥ 3.1 METs of locomotion.
Aerobic Fitness	Maximal aerobic capacity (VO_{2peak}) measured using a continuous treadmill ramp protocol (modified Balke) with breath-by-breath indirect calorimetry (Oxycon mobile device, CareFusion Systems, Franklin Lakes, NJ) with silicone face mask (COSMED, Italy).

Survey Measures and Self-report Physical Activity

The WalkIT Arizona participants reported age, race/ethnicity, educational attainment, homeowner status, length at current residence, household income, and marital status in an online pre-screening questionnaire prior to the office visit. Survey measures performed at the initial office visit are outlined in brief in Table 1; however, this manuscript describes only the survey measures relevant to the aims of this secondary analysis. All PA measures are not worksite-specific, but assessed by asking about PA performed either inside or outside of the home neighborhood, as described next.

Neighborhood Physical Activity Questionnaire (*NPAQ).* Self-reported PA performed within and outside the neighborhood was assessed via the NPAQ to examine environmental features correlated with walking and cycling behavior.[122] The NPAQ is similar to the International Physical Activity Questionnaire (IPAQ) in format and assesses self-reported PA in a usual week with frequency and duration of specific PA behaviors, including walking and cycling, both within and outside the home neighborhood for domain-specific purposes (i.e., transport, recreation). Example questions from the NPAQ along with construct information (e.g., response options) can bee seen in Table 2, and an example computed variable for deriving the outcome variable "Combined walk and bike INSIDE neighborhood for Transport" can be seen in Table 3. The NPAQ has fair to excellent reliability (total PA interclass correlations [ICCs] of 0.82 to 0.91)[128] and moderate to strong validity (ρ = 0.26 to 0.90).[122] The WalkIT Arizona study used a reduced form of the NPAQ to eliminate redundancy with the CRIME survey (see Table 1 for NPAQ items used).

Crime-related perceptions of safety. The WalkIT Arizona study contributed as a testing site to validate the CRIME survey, a new self-report instrument designed to better understand and quantify associations between crime and PA. The instrument assesses personal experience with crime, along with cognitive, emotional, and behavioral responses to crime and safety scenarios. Developed from NQLS and Neighborhood Environment Walkability Scale (NEWS) surveys, the original instrument was retained in its entirety for psychometric testing by independent investigators. The NQLS and NEWS items that were redundant and/or highly overlapping with CRIME survey items were excluded from the questionnaire (see Table 1 for NQLS and NEWS questions retained).

The Neighborhood Quality of Life Study (NQLS) survey. The NQLS survey was designed to assess correlations between self-reported urban design and various health behaviors, including PA, that impact quality of life and well-being. The NQLS survey includes questions adapted from several other reliable and validated surveys as reported by Sallis, et al.[123] During the evaluation of the NQLS instrument, two surveys were deployed and elements from each are used in the present investigation.

Table 2. Construct item questions and response options from Neighborhood Physical Activity Questionnaire (NPAQ) survey measures.

Q#	Item Question	Response Options
Prompt: **Walking[a] INSIDE versus OUTSIDE of Your Neighborhood** Inside your neighborhood is within a 10-15 minute walk. Now we would like to know how much of your walking[a] takes place INSIDE your neighborhood as compared to OUTSIDE of your neighborhood. First we ask about walking[a] for transport. Then we ask about walking[a] for recreation, health, or fitness.		
Q83	In a **usual week**, how many days do you **walk as a means of transport,** such as going to and from work, walking to a shop, or walking to public transport **INSIDE** your neighborhood or local area?	0 – 7 Days
Q84	Please estimate the average time you usually spend walking **on ONE of those days** as a means of transport **INSIDE** your neighborhood or local area?	0 – 16 Hours, 0 – 59 Minutes
Q85	In a **usual week**, how many days do you **walk as a means of transport,** such as going to and from work, walking to a shop, or walking to public transport **OUTSIDE** your neighborhood or local area?	0 – 7 Days
Q86	Please estimate the average time you usually spend walking **on ONE of those days** as a means of transport **OUTSIDE** your neighborhood or local area?	0 – 16 Hours, 0 – 59 Minutes
Prompt: Walking for **recreation, health or fitness** **INSIDE** your neighborhood. Please do not include any transportation-related activity you already mentioned above.		
Q87	In a **usual week**, how many days do you **walk for recreation, health or fitness** (including walking your dog) **INSIDE** your neighborhood or local area?	0 – 7 Days
Q88	Please estimate the average time you usually spend walking **on ONE of those days** as for recreation, health or fitness **INSIDE** your neighborhood or local area?	0 – 16 Hours, 0 – 59 Minutes
Q89	Walking for **recreation, health or fitness** **OUTSIDE** your neighborhood. Please do not include any transportation-related activity you already mentioned above. In a **usual week**, how many days do you **walk for recreation, health or fitness** (including walking your dog) **OUTSIDE** your neighborhood or local area?	0 – 7 Days
Q90	Please estimate the average time you usually spend walking **on ONE of those days** as for recreation, health or fitness **OUTSIDE** your neighborhood or local area?	0 – 16 Hours, 0 – 59 Minutes

PA = physical activity
Q# = Question number
[a]Walking/walk replaced by biking/bike or cycling as appropriate for biking items

Table 3. Example computed variables for self-reported Neighborhood Physical Activity Questionnaire (NPAQ) survey measures.

	Example Question Excerpts	Formula	Computed Variable
Q84	"…average time you usually spend walking **on ONE of those days**…	(Hours * 60) + minutes = Total walking minutes on one day	
Q83	"In a **usual week**, how many days do you **walk [for] transport… INSIDE** your neighborhood…?	Days * Total walking minutes on one day = Weekly minutes of walking for transport INSIDE the neighborhood	NPAQ_WIT
Q9 4	"…average time you usually spend riding your bicycle **on ONE of those days**…	(Hours * 60) + minutes = Total biking minutes on one day	
Q9 3	"In a **usual week**, how many days do you **bike [for] transport… INSIDE** your neighborhood…?	Days * Total biking minutes on one day = Weekly minutes of biking for transport INSIDE the neighborhood	NPAQ_BIT
Computed total PA for transport INSIDE the home neighborhood.			
	NPAQ_WIT + NPAQ_BIT = Combined walk and bike INSIDE neighborhood for Transport		NPAQ_IT_tot

Q# = Question number

Objectively Measured Physical Activity

ActiGraph Accelerometer. To capture objectively measured PA participants were instructed to wear the wrist-worn ActiGraph GT9X Link (ActiGraph, LCC, Pensacola, FL, USA) at least 10 hours per day while awake. Accelerometer measures are not home- or worksite-specific as no GPS, travel diary, or the times of day at home or work were available to locate where PA took place. The ActiGraph device was a tri-axial, high-resolution sensor that uses a microelectromechanical system

(MEMS) to detect movement. It measures movement acceleration and deceleration (vectors) in three axes, the vertical (x), antero-posterio (y), and medio-lateral (z) planes. The axes are combined through summation of the squared values of each plane, and subsequently square rooted to derive the vector magnitude (VM) of the movement, expresses as VM counts. Epoch intervals were set a 1-min durations to achieve VM counts/min.

The GT9X was a small (3.5 cm^2 face by 1 cm thick, lightweight (14 g) device that was a slimmer design than previous ActiGraph models, has battery life of 10 - 14 days, and was water resistant up to 1 m in depth for 30 minutes. These design features are important for a device intended to be worn daily for extended periods as they are expected to increase participant compliance. The ActiGraph technology has broad calibration, reliability and validity data.[60,64,129,130] Participants are asked for daily wear and daily sync through a smartphone app using Bluetooth or a desktop computer using the USB dock.

Accelerometer Data Processing. The data output of the ActiGraph accelerometer was condensed to 1-minute epochs due to data transmission limitations for participants relying exclusively on the smartphone app to synchronize (sync, or upload). Non-wear was defined as greater than or equal to 90 consecutive zero counts per minute (cpm), with an allowance of no more than 2 minutes of non-zeros on the vertical axis to remove invalid valid hours in a day. Valid days include at least 10 valid hours wear per day. Researchers closely monitor participants for 10-hour wear compliance during the baseline phase. The first eligible day of accelerometer data was the day immediately after the initial office visit so the activity performed during exercise testing was not included in analyses. During the baseline period, participants were blinded to feedback about their activity minutes captured by the ActiGraph.

Accelerometer Cutpoint Calibration and Data Reduction. Moderate to vigorous physical activity (MVPA) for each 1-minute epoch was determined by a combination of two accelerometer-derived values. First, individualized calibration of the accelerometer counts (i.e., vector magnitude (VM)) to simultaneous laboratory measured indirect calorimetry was used to derive unique cutpoint values for each participant. This was accomplished using breath-by-breath assessed oxygen consumption (VO_2; Oxycon mobile, CareFusion Systems, Yorba Linda, CA) during a 5-min stand rest period followed by 3 stages of 6 min sustained walking at 2.0, 3.0, and 4.0 mph each, with 0% grade throughout. To allow for a steady-state of exercise to be reached, the final 3 min of each stage was used for VO_2 and VM comparison. These data are then time-matched to determine the VM threshold, or cutpoint equal to 3.1 METs. This VM was set as the cutpoint value and was the first criterion for a minute to be counted as MVPA. The second criterion incorporated steps per minute data. As the ActiGraph was worn on the wrist, its native step count algorithm was employed to reduce overestimation of MVPA by excluding non-ambulation-related arm movement. To be counted as MVPA both the personalized VM cutpoint must be met or surpassed and the step count must be greater than 30 steps for a given epoch.

Bouts of MVPA. Minutes of MVPA were further scored to produce persistent bouts of MVPA. The basis to calculate a 'bout' of MVPA was derived from the Toriano, et al. bout algorithm used to score Nation Health and Nutrition Examination Survey (NHANES) accelerometer data as described elsewhere,[2] but with important differences. A 5-minute moving window was used to examine each minute of data in relation to successive minutes. When a minute was determined to be MVPA (i.e., meeting or exceeding both the cutpoint threshold and steps criteria as explained above) the next 4 minutes were also evaluated for MVPA criteria with an allowance of

1- or 2-minute “breaks” under threshold. Thus, 3 out of 5 minutes were needed for the *onset* of a MVPA bout. This allowed a minimum bout of 3 minutes to be classified as MVPA. If 3 consecutive minutes were above threshold that would count as a bout; 2 or fewer consecutive MVPA minutes would not count as a bout. As the system scans 5 minutes at a time with allowances for 1- or 2-minute interruptions, the bout scoring system would classify 1 or 2 minutes below threshold as MVPA if flanked by 1-2 MVPA minutes within the same window. The *offset* of a bout occurred when 3 consecutive minutes fell below the MVPA threshold. This algorithm was designed to accommodate the widest range of participants during the intervention phase adaptive goal setting strategy, see Experimental Component section below for details.

Sedentary-Light PA. Sedentary-Light PA (SLPA) was defined by subtracting any minute defined as MVPA from total minutes the device was worn. Minutes of SLPA were therefore the not simply the inverse of MVPA bout minutes, as all minutes of MVPA, regardless of being classified as within a bout or not, were taken out of the total wear-time minutes. As mentioned above, MVPA classification required both the VM cutpoint to be reached and the step count must be greater than 30 steps/minute. If a minute met only one of those two criteria, it was *not* removed from SLPA and hence the decision to categorize it as “sedentary to light” PA as some movement occurred but it did not meet the definition for MVPA.

Intervention Components

Participants randomized to the intervention phase received text messages periodically from the study’s semi-automated mHealth interface. The system sent scheduled texts and had natural language recognition, which automated interpretation of and response to a limited number of expected texts. The text system was monitored by researchers; this allowed responses to questions, assistance with study equipment, and broadcast messages about system wide information. Incoming and outgoing messages were time-stamped and logged in MySQL databases.

Automated study emails were integrated into the mHealth system for routine notices. These were sent at study enrollment and as planned informational emails corresponding to the study phase. An email sent at randomization explained study group assignment and included brief PA brochures as attachments. Subsequent automated emails were sent for gift card incentives with explanation for the reason for the incentive and the gift card redemption information for selected retailer.

All participants received a brief "prompts-to-action" text message most days of the intervention period. The same set of messages was sent to all intervention groups to prompt physical activity and healthy behaviors; however, the order was randomized by participant. Messages were delivered one time per day on most days per week (5 out of 7 days) during Phase 2. Prompts were sent at a random time of day starting no earlier than 1.5 hours after the participant's reported wake time and no later than 10 hours after wake time to accommodate individual schedules.

Experimental Components

Goals setting strategies

Each participant received a text message daily goal for 'active minutes' to meet after the accelerometer data was uploaded (synced), see Objectively Measured Physical Activity section above for description of active minute classification. Two types of goal setting strategies were tested: adaptive goals and static goals. Adaptive goals were based on a percentile-rank algorithm with the most recent 9 observations (i.e., non-missing days) of an individual's physical activity (i.e., daily ‘active minutes’), with the goal set at the 60th percentile observation (i.e., 6th highest performance in last 9 days). Each new observation replaced the oldest observation in a 9-day moving-window, which allowed goals to be derived from the most recent 9 observations. Therefore, goals could adjust with the individual participant's performance over time during the intervention phase. This was in contrast to static goals that consisted of the standard public health messaging to achieve 30 minutes of activity (‘active minutes’) per day and do not adjust over course of the intervention phase.

Rewards scheduling

All four groups received feedback in the form of an automatic text with current daily minutes accrued, a message of praise when a goal was met or a brief acknowledgement of successful sync when a goal was not met (e.g. “Sync successful, 21 min today, goal for 7/25 is 34 min.”). Additionally, participants received a financial reward selected from a catalog of gift cards options, but the financial contingency differs across study groups: immediate incentives or delayed incentives. The two immediate incentive groups earned between 0 to 500 points each time they meet a goal (each point was worth $0.01, 100 points = $1.00). Upon accumulation of 500 points, points were deducted from their total and were immediately exchanged for a $5 in gift card sent via automated email. The two delayed incentive groups received progressively increasing financial incentives every other month for ongoing participation (i.e., wearing and syncing their device) in a pre-scheduled and increasing bi-monthly format starting at $15 in month 2 up to $95 in month 10. Participants were told of their goal and incentive type once randomized. The intervention and experimental components of WalkIT Arizona described above are a brief overview meant to focus the reader only on the pertinent information for aim 3 of this manuscript. The interventions components were controlled for statistically in the current project's analyses as indicated below.

Data Analysis

Aim 1 (A1) Title: the variation of PA explained by worksite walkability

To evaluate the relation of walkability around worksites on physical activity after accounting for home neighborhood walkability and socioeconomic status: a **cross-sectional** study used baseline data from the WalkIT AZ study.

A1: HYPOTHESIS 1A: Walkability around the worksite would *not* explain significant additional variance (i.e., deviance explained) in self-reported PA *inside* the home neighborhood (NPAQ minutes/week active transport-related walking and cycling *within* the home neighborhood local area) beyond that explained by home neighborhood walkability and covariates.

A1: HYPOTHESIS 1B: Walkability around the worksite *would* explain significant additional variance (i.e., deviance explained) in self-reported PA *outside* the home neighborhood (NPAQ minutes/week: active transport-related walking and cycling *outside* the home neighborhood local area) beyond that explained by home neighborhood walkability and covariates.

A1: HYPOTHESIS 2: Walkability around the worksite would explain significant additional variance (i.e., deviance explained) in accelerometer-measured MVPA bout min/week (averaged across all baseline accelerometer observations) beyond that explained by home neighborhood walkability and covariates.

A1: HYPOTHESIS 3: Walkability around the worksite would explain significant additional variance (i.e., deviance explained) in summed Vector Magnitude counts per week (VM/week) (daily sums of 1-minute counts averaged over the baseline days) beyond that explained by home neighborhood walkability and covariates.

A1: HYPOTHESIS 4: Walkability around the worksite would explain significant additional variance (i.e., deviance explained) in accelerometer-measured Sedentary-Light PA (SLPA) min/week (averaged across all baseline accelerometer observations) beyond that explained by home neighborhood walkability and covariates.

Outcome variables (DVs):

- Transport-related PA *inside* the home neighborhood environment
- Transport-related PA *outside* the home neighborhood environment
- MVPA bout min/week (averaged over baseline days)
- Sum of Vector Magnitude counts (VM) (average counts over baseline days)
- Sedentary-Light PA (SLPA) min/week (Total worn minutes minus MVPA minutes, then averaged over baseline days)

Exposure-Access variable of interest (focal independent variable):

GIS-derived walkability around the worksite neighborhood (continuous)

Main Control variables:

i. Home neighborhood walkability 500-m buffer (centered)
ii. Household annual income (7 levels, median centered)

Tested covariates:

iii. Neighborhood self-selection (continuous, centered)
iv. Age (continuous, centered)
v. Sex (dichotomous)
vi. Ethnicity (dichotomous, non-Hispanic white vs. other)
vii. Number of children (continuous, number 17 years and younger)
viii. Marital/cohabitation status (dichotomous)
ix. Current smoker (dichotomous)
x. Ratio of cars to people in household (continuous)
xi. Number of people in household (continuous, centered)

xii. Years at current residence (continuous, centered)

xiii. Distance to worksite (continuous, centered)

First, univariate and bivariate statistics were performed to evaluate outcome data in relation to all independent variables to identify relevant covariates. Of the tested covariates listed above, 6 were retained base on bivariate analysis *p*-values < .20 or because of conceptual relevance (sex, race, cohabitating status, age, distance to worksite, reason moved to home neighborhood) in addition to the 2 main control variables of annual household income and home neighborhood walkability. As the PA outcome variables had non-normal distributions due to abundance of zero and non-negative values, statistical analyses required a generalized linear model (GZLM) framework. Model selection criteria employed the use of AIC and -2 log likelihood (-2LL; lower values preferred) to determine appropriate GZLM techniques and was conducted using SPSS 25. Step-wise regression models were built to determine deviance explained in blocks (i.e., first demographics, then 'main' control variables, finally the exposure variable of interest "worksite walkability"). An empty null model, lacking any explanatory variables (Model 1), also known as the base model, was built to first determine each outcome's variance explained by background covariates (Model 2). Next, the two 'main' control variables (home neighborhood walkability and annual household income level) were added (Model 3). Finally, Model 4 included the focal variable, worksite walkability, and its explained variance was compared to the model with all previously-entered controlling variables and covariates.

Variance explained was estimated by using a deviance explained metric suitable for GZLMs. This compared the deviance of the null model to the deviance of the full model (i.e., model including the exposure of interest: worksite walkability). This deviance squared, or D^2, compares the model fit with the following equation:

Explained Deviance = {1 – [(Null Deviance – Residual Deviance)/Null Deviance]}

Explained deviance approaching 0 suggests the model does not explain the data well (i.e., underfitting), while explained deviance approaching 1 suggests the model explains the data too well (i.e., overfitting).[131] Additional model fit criteria were evaluated (i.e., AIC, Likelihood Ratio chi-squared tests) at each model building step and pseudo chi-square tests were employed in decisions about improvement in model fit. The alpha level = .05 to determine significant model improvement (D^2).

Aim 2 (A2) Title: the moderating effects of individual-level characteristics to the relationship between PA and worksite walkability

To examine the relationship between walkability around the worksite and physical activity when moderated by individual-level demographics and characteristics (age, sex, SES, presence of children, ratio of cars to people in household): a cross-sectional study used baseline data from the WalkIT AZ study.

A2: HYPOTHESIS 1A: The relationship between walkability around the worksite and self-reported PA *inside* the home neighborhood (NPAQ minutes/week of transport-related walking and cycling) would *not* be significantly moderated by demographic/personal characteristics as described below.

A2: HYPOTHESIS 1B: The relationship between walkability around the worksite and self-reported PA *outside* the home neighborhood (NPAQ minutes/week of transport-related walking and cycling) *would* be significantly moderated by demographic/personal characteristics as described below.

A2: HYPOTHESIS 2: The relationship between walkability around the worksite and MVPA bout min/week (measured by wrist-worn accelerometer, averaged across baseline days) would be significantly moderated by demographic/personal characteristics as described below.

A2: HYPOTHESIS 3: The relationship between walkability around the worksite and Sedentary-Light PA (SLPA) min/week (measured by wrist-worn accelerometer, averaged across baseline days) would be significantly moderated by demographic/personal characteristics as described below.

Hypotheses for previously described moderators:

i. Age group (continuous): The relationship between worksite walkability and PA *outside the home neighborhood* would be significantly higher (positive) for the older ages, than for the younger ages.[38]

ii. Sex (dichotomous): The relationship between worksite walkability and PA would be significantly higher (positive) for women than for men.[81,132]

iii. Race (white only vs. other): The relationship between worksite walkability would be significantly higher (positive) for whites than other race/ethnic groups.

iv. Income, household annual (dichotomous at median): The relationship between worksite walkability and PA would be significantly higher (positive) for the lower household income group, than for the higher income group.

Exploratory moderators not previously described:

v. Number of children under 18 years in the household (continuous, centered)

vi. Ratio of cars to drivers (continuous)

vii. Home walkability (continuous, centered)

Outcome variables (DVs):

- Transport-related PA *inside* the home neighborhood environment
- Transport-related PA *outside* the home neighborhood environment
- MVPA bout min/week (averaged over baseline days)

- Sedentary-Light PA (SLPA) min/week (Total worn minutes minus MVPA minutes, then averaged over baseline days)

Exposure-Access variable of interest (focal independent variable):

- GIS-derived walkability around the worksite neighborhood (continuous)

Covariates: adjust for home neighborhood walkability, distance to work, and the other potential covariates of importance as described above in Aim 1.

Prior to substantive analyses, univariate and bivariate statistics assessed the association between each potential moderator and each outcome variable. As in Aim 1, the PA outcome variables had non-normal distributions due to non-negative values (counts), statistical analyses required a generalized linear model (GZLM) framework. Separate models examined whether the moderators conditionally effected the relationship of worksite walkability (i.e., the exposure of interest) to each outcome. The same covariates controlled for in all moderation analyses as were noted in Aim 1 above. Model selection criteria included AIC and -2LogLikelihood (lower values preferred) to aid in determining model fit.

Aim 3 (A3) Title: differences in the rate of change over 56 days of a behavioral intervention by worksite walkability

Evaluate whether differences in worksite walkability at baseline explains the rate of change in PA through the first 56 days of a walking intervention. Does worksite walkability explain daily variation in participants' physical activity minutes (total MVPA bout minutes, sedentary-Light PA (SLPA) minutes) over the course of 56 days?

A3: HYPOTHESIS 1: The positive rate of change in PA would be significantly higher among individuals whose worksites are relatively higher in walkability than individuals with relatively lower walkability around their worksites. A cross-level interaction tested if worksite walkability moderated time since randomization and daily MVPA.

A3: HYPOTHESIS 2: The negative rate of change in SLPA would be significantly lower among individuals whose worksites are relatively higher in walkability than individuals with relatively lower walkability around their worksites. Again, a cross-level interaction tested if worksite walkability moderated time since randomization and daily SLPA.

Level 1 outcome variable:

i. Daily PA min (MVPA bout and SLPA; post-randomization)

Focal predictor at Level 1:

ii. Time since randomization (centered at end of 56 days)

Level covariate 1:

iii. Valid wear-time (minutes of valid wear time post-randomization; mean centered)

Level 2 focal variable (moderator):

iv. Worksite walkability value (continuous)

Additional Covariates tested (most are level-2):

v. Baseline MVPA bout minutes (continuous, mean centered)

vi. Day of week

vii. Month of year

viii. Reward intervention main effect (dichotomous)

ix. Goal intervention main effect (dichotomous)

x. Age (continuous)

xi. Sex (dichotomous)

xii. Race (dichotomous)

xiii. Annual Household Income (continuous, centered)

xiv. Home walkability (continuous)

xv. Any or no active comminuting to work

xvi. Children under 18 years (continuous)

Outcomes were count data and had other-than-normal distributions, therefore generalized linear mixed models (GLMMs) were applied. An unconditional random intercept model was run first to obtain variance components needed to compute the interclass correlation coefficient (ICC) for the outcome (i.e., Level 2 variance, or average squared difference in PA min between participants, divided by the sum of the Level 2 variance and Level1 variance, or average squared deviation of daily PA min from person-level mean daily PA min). A high magnitude of the ICC warranted multi-level modeling strategies to account for within-person non-independence of repeated within-person observations. Model building steps are provided in the Results section below.

CHAPTER 4

RESULTS

Sample description and preliminary analyses

This secondary analysis included a subset of the 728 participants who provided informed consent in the WalkIT Arizona study. For all analyses, participants were excluded for indicating something other than full-time or part-time employment (n = 103), and for further evaluation criteria (n = 113), see details in Figure 3 CONSORT Diagram for worksite analyses analytical samples.

Self-report outcomes analyses included 512 participants. For accelerometer outcomes we excluded those not having accelerometer data (n= 80) which afforded a smaller analytical sample (n = 472) for baseline analyses (Aim 1 and Aim 2). For longitudinal analyses (Aim 3), only randomized participants with valid worksite information and greater than 14 days of accelerometer data were retained (n = 364), see CONSORT diagram in Figure 3 for details.

Participant characteristics of the baseline worksite sample indicated an average of 44 years old, were 59% female, had an average BMI of 33 kg/m^2, and included mostly White, non-Hispanic individuals (70%), see Table 4. Descriptive information for independent can be found in Figures 4-5 and dependent variables descriptives can be found in Table 5.

Model Fit of Baseline Outcome Variables: Aims 1 and 2

As anticipated, PA outcome variables were found to have non-normal distributions, as is common with count data. Distributions were characterized by an abundance of zero and low positive values and long tails comprising higher values, resulting in strong positive skewness. Accordingly, a generalized linear model (GZLM) framework was chosen to model these outcomes. As seen in Table 6, comparisons of relative model fit (using AIC and -2 log likelihood [likelihood ratio or LR] values) showed that models specifying a negative binomial distribution, a log link, and a maximum likelihood-estimated dispersion parameter (α) yielded better model fit than models specifying either (a) a Poisson distribution (with log link) or (b) a negative binomial distribution (with log link) and α fixed at 1. Likelihood ratio tests for comparison of model fit to fit of NB MLE model were all significant (*p*'s < .001), see Table 6.

Figure 3. Consort Diagram for Worksite Analyses of the WalkIT Arizona Study.

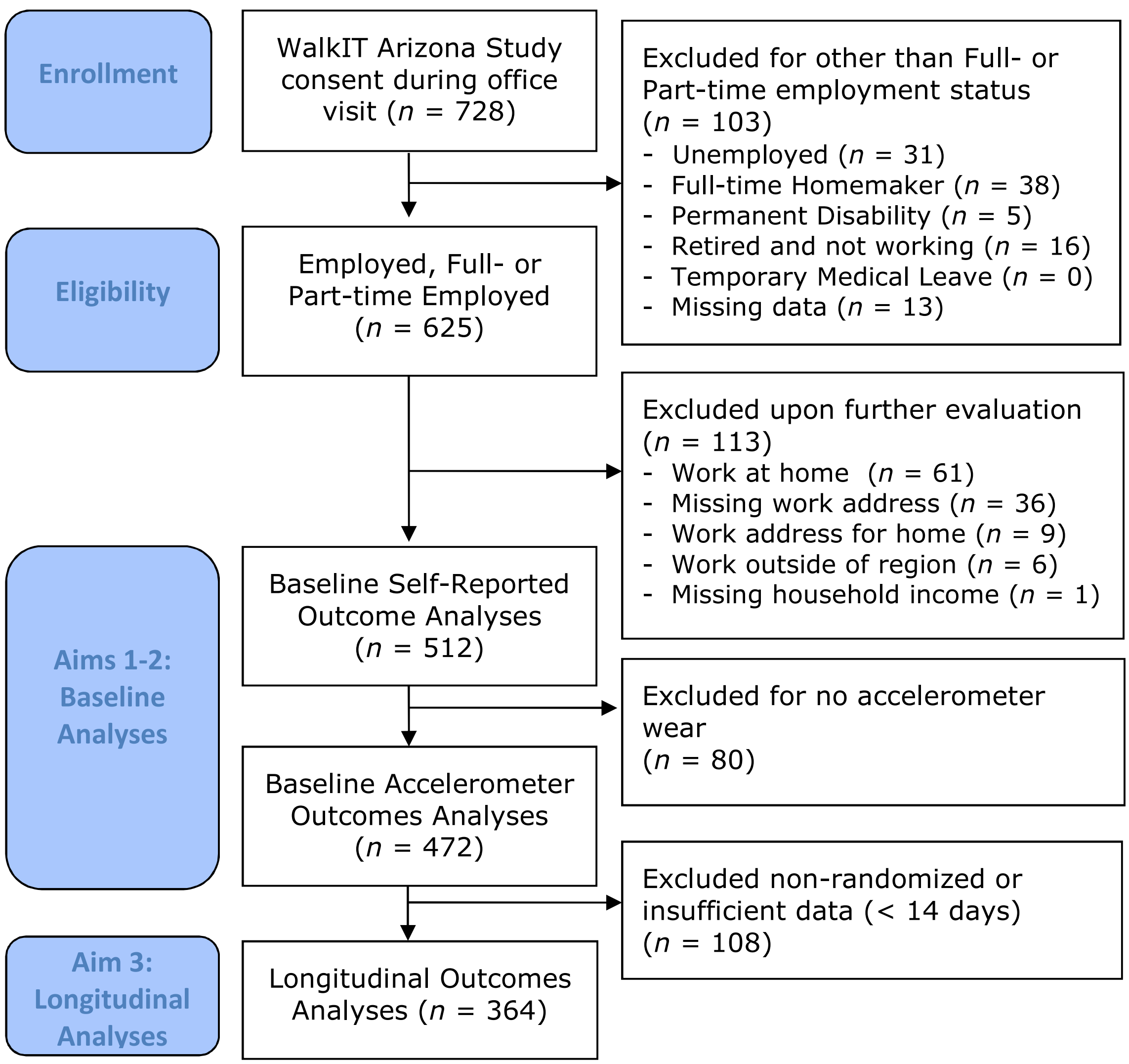
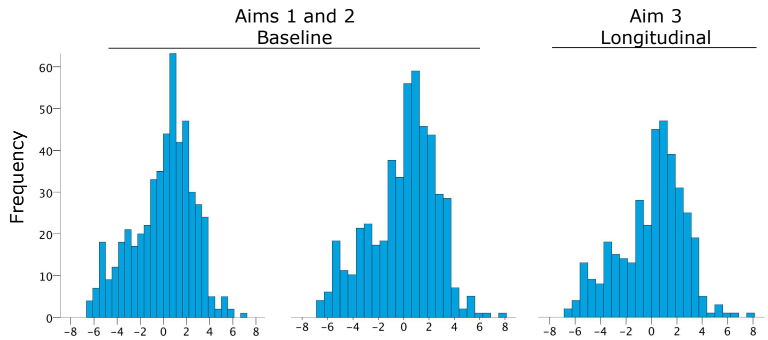


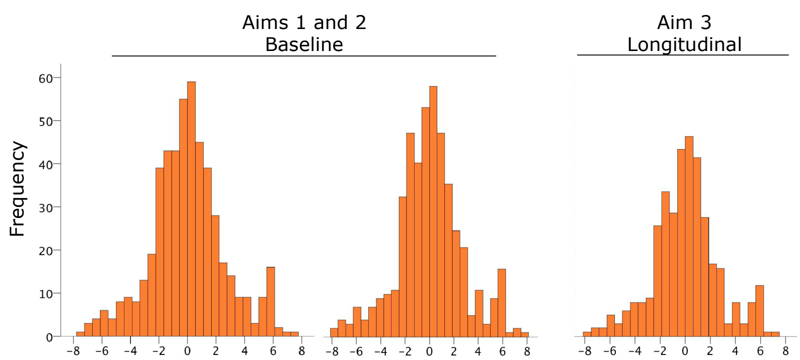
Figure 4. Comparison of Worksite Walkability[a] Values by Analytical Sample: 500-m Buffer Distance.



	Self-report	Accelerometer	Accelerometer
n	512	472	364
Mean (SD)	0 (2.6)	0 (2.6)	0 (2.6)
Minimum	-6.5	-6.5	-6.5
Maximum	7.8	7.8	7.8
Median	0	0	1
IQR	3.5	3.5	3.2

SD = Standard Deviation
IQR = Interquartile Range
[a]Walkability values are z-scored.

Figure 5. Comparison of Worksite Walkability[a] Values by Analytical Sample: 1000-m Buffer Distance.



	Self-report	Accelerometer	Accelerometer
n	512	472	364
Mean (SD)	0 (2.7)	0 (2.7)	0 (2.6)
Minimum	-8.1	-8.1	-8.1
Maximum	8.2	8.2	8.2
Median	0	0	1
IQR	3.0	3.0	2.9

SD = Standard Deviation
IQR = Interquartile Range
[a]Walkability values are z-scored.

Table 4. Demographic and Descriptive Characteristics by Analytical Sample.

Analytical Sample Type:	Aims 1 and 2		Aim 3
	Self-Report (*n* = 512)	Accelerometer (*n* = 472)	Accelerometer (*n* = 364)
Age, Mean (SD)	44.3 (9.3)	44.1 (9.4)	44.9 (9.1)
Female, %	59.4	58.5	62.3
BMI self-reported, Mean (SD)	33.1 (7.0)	33.0 (6.9)	33.4 (7.1)
Race and Ethnicity[a]			
White (non-Hispanic), %	70.1	69.9	70.8
Hispanic, %	18.9	19.1	18.7
Black, %	6.6	6.6	6.3
Asian, %	2.3	2.3	2.8
American Indian or Native American, %	2.9	3.0	1.9
Hawaiian, %	1.2	1.3	1.7
Prefer not to answer, %	4.7	4.9	5.9
Married or living with partner, %	66.2	67.4	67.6
Employment Status			
Full-time, %	88.7	88.8	88.2
Part-time, %	11.3	11.2	11.8
Current Tobacco or E-cig Smoker, %	5.9	5.9	6.0
Children in household under 18 years old			
Median	0	0	0
Mean	1.0 (1.2)	1.0 (1.2)	.9 (1.2)
Zero children under 18, %	52.0	51.3	51.9
One child under 18, %	16.6	16.9	17.9
Two children under 18, %	20.5	20.1	19.2
Three or more under 18, %	10.9	11.6	10.9
Household Income			
Median, for all samples		$60,000 – 79,999	
Less than $20,000	2.9	3.0	2.2
$20,000 - $39,999	10.9	10.4	10.7
$40,000 - $59,999	20.7	19.9	20.3
$60,000 - $79,999	18.9	19.3	19.8
$80,000 - $99,999	13.9	13.6	14.6
$100,000 - $119,999	12.9	13.6	12.4
Greater than $120,000	19.7	20.3	20.1
Education			
Median, for all samples		College graduate	
8th grade or less, %	.2	.2	.3
Some high school, %	.2	.2	.3
High school graduate or GED, %	5.5	5.7	4.9
Trade or technical school, %	3.5	3.6	3.3
Some college, %	25.4	24.2	24.2
College graduate, %	31.4	32.0	31.9
Post-graduate training, %	7.0	7.4	8.2
Graduate degree (MS, PhD, MD, etc.), %	26.8	26.7	26.9

Table 4. (Continued) Demographic and Descriptive Characteristics by Analytical Sample.

Analytical Sample Type:	Aims 1 and 2		Aim 3
Ratio of vehicles to drivers, Mean (SD)	1.1 (.5)	1.1 (.5)	1.1 (.5)
Any active commuting to work, %	8.0	8.3	6.9
Reason moved to neighborhood, Mean(SD)	2.9 (1.0)	2.9 (1.0)	2.9 (1.0)
Years at current resident, Mean (SD)	6.8 (7.1)	6.8 (7.1)	7.0 (7.2)
Accelerometer Wear Time hours/day, Mean (SD)	--	15.7 (3.3)	16.4 (4.0)
Sufficiently Active[b] at baseline, % (Measure)	28.1 (NPAQ)	43.6 (MVPA bout)	31.9 (MVPA bout)

[a]Race/Ethnicity cumulative >100% as response allowed ‘select all that apply’.
[b]Sufficiently active based on NPAQ total time *or* MVPA bout min/week >=150 min/week
SD = Standard Deviation
NPAQ = Neighborhood Physical Activity Questionnaire
MVPA = Moderate-to-vigorous Physical Activity (assessed by accelerometer ‘bout’ minutes)

Table 5. Dependent Variable Descriptive Statistics by Analysis Type.

Analytical Sample Type:	Aims 1 and 2 Baseline						Aim 3 Longitudinal	
	Self-Report PA (*n* = 512)			**Accelerometer PA** (*n* = 472)			**Accelerometer PA** (*n* = 364)	
	Total PA[a] min/week	TranPAin min/week	TranPAout min/week	MVPA bout min/week	VM counts/week	SLPA hours/week	MVPA bout min/day	SLPA hours/day
Minimum	0	0	0	0	2,934,282	65	0	7.6
Maximum	1680	1800	1920	913	28,845,031	167	300	24.0
Mean	137	18.6	22.9	155	13,990,080	108	29.7	16.0
(SD)	(233.6)	(93.9)	(106.6)	(129.3)	(4,024,106)	(23)	(29.3)	(4.0)
Median	60	0	0	129	13,823,090	100	22.0	15.0
IQR	150	0	0	155.8	5175155.0	1455.8	336	5.0

SD = Standard deviation
PA = Physical activity
TranPAin = Transportation PA inside the home neighborhood
TranPAout = Transportation PA outside the home neighborhood
min/week = minutes per week
IQR = Interquartile Range
[a]Total PA is a summation of walking and bicycling for recreation *and* transport both inside *and* outside the home neighborhood.

Table 6a. Model Fit Indices From Intercept-only Poisson and Negative Binomial Regression Models for *Self-report* Outcome Variables.

Dependent Variable		Poisson (DF = 511)		Negative Binomial $\alpha = 1$[a] (DF = 511)		Negative Binomial MLE α[b] (DF = 510)	
Self-report Outcomes	N	LR	AIC	LR	AIC	LR	AIC
Total PA min/week	512	122076.1	122078.0	6067.2	6069.2	5597.8	5601.8
LR test[c]		$\chi2$ = 116478.3 *p* < .001		$\chi2$ = 469.4 *p* < .001		-ref-	
TranPAin min/week	512	46826.8	46828.7	4045.7	4047.7	1694.1	1553.9
LR test[c]		$\chi2$ = 45132.7 *p* < .001		$\chi2$ = 2351.6 *p* < .001		-ref-	
TranPAout min/week	512	57049.7	57051.7	4252.8	4254.8	1653.8	1657.8
LR test[c]		$\chi2$ = 55395.9 *p* < .001		$\chi2$ = 2599.0 *p* < .001		-ref-	

DF = degrees of freedom
LR = Likelihood Ratio (-2*log likelihood)
AIC = Akaike Information Criterion
[a]Disperson parameter (α) fixed at 1
[b]Maximum likelihood-estimated dispersion parameter (α) used
[c]Likelihood ratio test for comparison of model fit to fit of NB MLE model
TranPAin = Transportation PA inside the home neighborhood
TranPAout = Transportation PA outside the home neighborhood
min/week = minutes per week

Table 6b. Model Fit Indices From Intercept-only Poisson and Negative Binomial Regression Models for *Accelerometer* Outcome Variables.

Dependent Variable *Accelerometer Outcomes*	N	Poisson (DF = 471) LR	Poisson (DF = 471) AIC	Neg. Binomial $\alpha = 1$[a] (DF = 471) LR	Neg. Binomial $\alpha = 1$[a] (DF = 471) AIC	Neg. Binomial MLE α[b] (DF = 470) LR	Neg. Binomial MLE α[b] (DF = 470) AIC
MVPA bout min/week	472	48987.4	48989.4	5711.2	5713.2	5683.9	5687.9
LR test[c]		$\chi2 = 43303.5$ $p < .001$		$\chi2 = 27.3$ $p < .001$		-ref-	
Vector Magnitude counts/week	472	550643508.1	550643510.1	16476.4	16478.4	15694.3	15698.3
LR test[c]		$\chi2=550627813.7$ $p < .001$		$\chi2 = 782.1$ $p < .001$		-ref-	
SLPA min/week	472	137029.9	137031.8	9225.4	9227.4	8106.5	8110.5
LR test[c]		$\chi2 = 1289$ $p < .001$		$\chi2 = 1118.9$ $p < .001$		-ref-	

DF = degrees of freedom
LR = Likelihood Ratio (-2*log likelihood)
AIC = Akaike Information Criterion
[a]Disperson parameter (α) fixed at 1
[b]Maximum likelihood-estimated dispersion parameter (α) used
[c]Likelihood ratio test for comparison of model fit to fit of NB MLE model
min/week = minutes per week

Aim 1 Results: The Variation in PA explained by worksite walkability

To evaluate the relation of walkability around worksites on physical activity (PA) after accounting for home neighborhood walkability and socioeconomic status: a study using baseline data from the WalkIT AZ study. Note that Hypotheses 1 - 4 of Aim 1 are presented after an unplanned analysis of Total PA.

Self-Reported Outcomes

For Total PA minutes (truncated at 1680 minutes/week) the negative binomial regression model with background covariates showed better model fit compared to the null (intercept-only) model (Table 7, Model 2) via reduction in AIC value and significant LR Test (p <.001). However, deviance explained approaching a value of 1.0 suggests overfitting of the model. Total self-reported PA had a significant negative relationship to the background covariates of sex (female status B = -0.42; 95% CI = -.72, -.11; p = .008) and cohabitation status (lives with partner/spouse B = -0.38; 95% CI = -.70, -.07; p = .018). A significant positive relationship was found for reason moving to home neighborhood (B = 0.27; 95% CI = .11, .43; p = .001). Race, age, and distance to worksite were not found to be significant covariates in regression models.

Model 3, which including background covariates with the 'main' control variables of annual household income and home neighborhood walkability (Table 7, Model 3) showed improved fit with a significant LR Test (p = .028), however, improvement in AIC was less than 2 points and deviance explained compared to the null model again suggested overfitting. Parameter estimates were attenuated such that the relationship of cohabitation status with total PA was non-significant (p = .302); but those for sex and reason moving to home neighborhood remained relatively unchanged. In Model 4, adding the worksite walkability variable (Table 8, Model 4) showed model fit improvement by LR Test (p = .032), but again, reduction in the AIC value was modest (<2) and deviance explained suggested overfitting. A negative relationship between Total PA and the worksite walkability parameter did not reach statistical significance (B = -0.05; 95% CI = -0.11, 0.01; IRR = .95; p = .064). A plot of final-model predicted Total PA minutes/week plotted by worksite walkability at the 500-m distance (Figure 6) illustrates the lack of main effect relationship, adjusted for covariates (age, sex, race, cohabitation, distance to worksite, reason moved to home neighborhood, household income, and home walkability).

Aim 1: HYPOTHESIS 1A: Walkability around the worksite would not explain additional variance (i.e., deviance explained) in self-reported PA inside the home neighborhood (NPAQ minutes/week active transport-related walking within the home neighborhood local area.)

For transportation walking and biking inside the home neighborhood PA (minutes/week) the negative binomial regression model with the background covariates was determined to fit well compared to the null model with a reduction in AIC and a significant LR Test (p = .003) (Table 8, Model 2). Parameter estimates showed a significant negative relationship to the background covariates sex (female status B = -1.02; 95% CI = -1.96, -.08; p = .033) and distance to worksite (B = <-.001; 95% CI = <-.001, <-.001; p = .003). In Model 3, included background covariates and the 'main' control variables of annual household income and home walkability significantly improved model fit (p = .046 for LR Test); however, reduction in AIC was negligible (<1) , and deviance explained suggested overfitting. The parameter estimates for both 'main' control variables were non-significant. Model 4, which included all previous covariates plus worksite walkability did not show improvement in model fit with respect to Model 3 (Table 9, Model 4). This supports hypothesis 1A that worksite walkability would not explain additional variance in self-reported PA *inside* the home neighborhood.

Aim 1: HYPOTHESIS 1B: Walkability around the worksite would explain additional variance (i.e., deviance explained) in self-reported PA outside the home neighborhood (NPAQ minutes/week: active transport-related walking outside the home neighborhood local area).

For transportation walking and biking *outside* the home neighborhood PA (minutes/week) the negative binomial regression model with only the background covariates did not improve model fit criteria compared to the null model, with an *increase* in AIC of 3, and a non-significant LR Test (p = .092) (Table 9, Model 2). Deviance explained approached 1 suggesting overfitting. No significant relationships were detected with any background covariates (sex, race, cohabitating status, age, distance to worksite and reason moved to home neighborhood). Model 3 and 4, the 'main' covariates and worksite walkability models, respectively, each showed no significant improvement in model fit over the previous model (Table 9: Model 3 LR Test p = .088; Model 4 LR Test p = .288). These results do not support hypothesis 1B.

Accelerometer Outcomes

Aim 1: HYPOTHESIS 2: Walkability around the worksite would explain additional variance (i.e., deviance explained) in accelerometer-measured MVPA bout min/week (averaged across all baseline accelerometer observations).

For accelerometer MVPA bout minutes (minutes/week) the negative binomial regression model fit with background covariates showed significantly improved model fit compared to the null model, with a reduction in AIC of 20 points and significant LR

Test (p < .001). Deviance explained approached a value of 1 which suggests overfitting (Table 10, Model 2). MVPA had a significant negative relationship to the background covariates of sex (female status B = -.36; 95% CI = -.52, -.21; p = .033) and age (B = -.01; 95% CI = -.022, -.005; p = .001). Model 3 and 4, the 'main' covariates and worksite walkability models, respectively, each indicated no significant improvement in model fit over the previous model (i.e., increased AIC values and non-significant LR Tests). This does not support hypothesis 2.

Aim 1: HYPOTHESIS 3: Walkability around the worksite would explain additional variance (i.e., deviance explained) in summed <u>Vector Magnitude (VM) counts per week</u> (counts/week) (daily sums of 1-minute counts averaged over the baseline days) beyond that explained by home neighborhood walkability and covariates.

For VM counts (counts/week) the negative binomial regression model fit with background covariates was significantly improved compared to the null model with reduction in AIC by 88 points and significant LR Test (p < .001), however, Deviance Explained approached 1 which suggests overfitting, see Table 11, Model 2. VM had significant positive relationships to several background covariates: sex (female status B = .11; 95% CI = .06, .16; p < .001); cohabitating (B = .06; 95% CI = .01, .11; p = .032); and reason moved to neighborhood (B = .03; 95% CI = .01, .06; p = .015). Distance to worksite and wear time reached significance indicating positive relationships (distance B <.001, p = .011; wear time B < .001, p <.001). In Models 3 ad 4, the 'main' covariates and worksite walkability showed no significant improvement in model fit of any evaluation method (Table 11). These findings do not support hypothesis 3.

Aim 1: HYPOTHESIS 4: Walkability around the worksite would explain additional variance (i.e., deviance explained) in accelerometer-measured <u>Sedentary-</u>

Light PA (SLPA) minutes/week (averaged across all baseline accelerometer observations) beyond that explained by home neighborhood walkability and covariates.

For SLPA (minutes/week) the negative binomial regression model fit with background covariates was significantly improved compared to the null model with reduction in AIC value by 1845 points, significant LR Test (p < .001), and Deviance Explained indicating the model fits the data well (Table 12, Model 2). SLPA had a significant positive relationship to the covariates of sex (female status B = .01; 95% CI = .004, .015; p < .001). Both age and wear time reached significance with positive relationships (age B <.001, p = .001; wear time B < .001, p <.001). Model 3 and 4, with the 'main' covariates and then the worksite walkability models, respectively, failed to show significant improvement in model fit compared to the previous model as supported by increased AIC values and non-significant LR Tests (Table 12). These results do not support hypothesis 4.

Figure 6. Association of Total Physical Activity by Worksite Walkability.

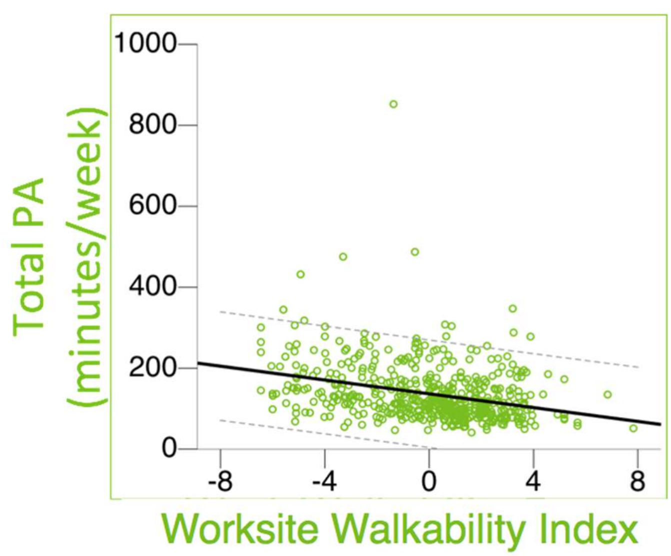


Table 7. Negative Binomial Regression Models Total Physical Activity Self-Reported.

	Model 2[d]				Model 3				Model 4				
Parameter	B	95% CI		*p*	B	95% CI		*p*	B	95% CI		*p*	IRR
Sex (female)	-.42	-.72	-.11	.008	-.40	-.72	-.10	.010	-.34	-.66	-.03	.04	.71
Race[a] (White)	-.15	-.49	.18	.38	-.17	-.50	.17	.34	-.15	-.48	.19	.39	.86
Cohabitates with partner	-.38	-.70	-.07	.018	-.19	-.56	.17	.30	-.16	-.52	.21	.40	.86
Age	-.01	-.03	.01	.29	-.01	-.02	.01	.73	<-.01	-.02	.01	.72	1.0
Distance to worksite	<-.01	<-.01	<.01	.25	<-.01	<-.01	<-.01	.70	<-.01	<-.01	<.01	.45	1.0
Reason moved to neighborhood	.27	.11	.43	.001	.24	.07	.40	.005	.24	.08	.41	.004	1.3
Annual household income					-.06	-.16	.04	.21	-.06	-.16	.04	.23	.94
Home walkability 500-m					.06	<-.01	.13	.056	.06	<.01	.13	.049	1.1
Worksite walkability 500-m									-.05	-.11	<.01	.06	.95

Model Fit Information	Model 2[c]	Model 3	Model 4
Deviance Explained	.9952	.9942	.9935
AIC (null = 5601.8)	5586.9	5585.2	5583.7
LR Test[b,c]	$\chi 2$ = 26.89 *p* <.001	$\chi 2$ = 5.77 *p* = .028	$\chi 2$ = 3.46 *p* = .032
Degrees of Freedom	6	8	9

AIC = Akaike Information Criterion.
LR = Likelihood Ratio (-2*log likelihood).
[a]Caucasian or White was the only Race and Ethnicity reported. [b]Likelihood ratio test using -2Log Likelihood for comparison of model fit to fit of the previous model; for model 2, the previous model ("model 1") was a model without any predictors (a "null" model). [c]One-tailed tests for chi square p-values in LR Tests. [d]Model 1 is not shown as it was the null model.

Table 8. Negative Binomial Regression For Physical Activity **Inside** The Neighborhood for **Transportation** Self-Reported.

	Model 2[d]				Model 3				Model 4				
Parameter	B	95% CI		*p*	B	95% CI		*p*	B	95% CI		*p*	IRR
Sex (female)	-1.02	-1.96	-.08	.03	-1.02	-1.96	-.09	.03	-.92	-1.86	.02	.06	.40
Race[a] (White)	.36	-.65	1.37	.48	.11	-.92	1.13	.84	.07	-.95	1.08	.90	1.1
Cohabitates with partner	-.94	-1.91	.03	.06	-.50	-1.59	.59	.37	-.45	-1.51	.61	.41	.64
Age	-.02	-.07	.02	.34	<-.01	-.05	.04	.83	<-.01	-.05	.05	.93	1.0
Distance to worksite	<-.01	<.-01	<-.01	.003	<-.01	<-.01	<.01	.06	<-.01	<-.01	< .01	.04	1.0
Reason moved to neighborhood	.49	-.02	1.0	.06	.52	.03	1.0	.04	.52	.06	.99	.03	1.7
Annual household income					-.15	-.46	.16	.33	-.15	-.44	.15	.34	.87
Home walkability 500-m					.18	-.04	.39	.10	.19	-.03	.40	.09	1.2
Worksite walkability 500-m									-.09	-.26	.09	.32	.92

Model Fit Information	Model 2[d]	Model 3	Model 4
Deviance Explained	.9892	.9864	.9858
AIC (null = 1698.1)	1691.8	1691.0	1692.0
LR Test[b,c]	$\chi 2$ = 18.26 *p* = .003	$\chi 2$ = 4.77 *p* = .046	$\chi 2$ = 1.00 *p* = .159
Degrees of Freedom	6	8	9

AIC = Akaike Information Criterion.
LR = Likelihood Ratio (-2*log likelihood).
[a]Caucasian or White was the only Race and Ethnicity reported. [b]Likelihood ratio test for comparison of model fit to fit of the previous model; for model 2, the previous model ("model 1") was a model without any predictors. [c]One-tailed tests for chi square p-values in LR Tests. [d]Model 1 is not shown as it was the null model.

Table 9. Negative Binomial Regression for Physical Activity **Outside** Neighborhood for **Transportation** Self-Reported.

	Model 2[d]				Model 3				Model 4				
Parameter	B	95% CI		*p*	B	95% CI		*p*	B	95% CI		*p*	IRR
Sex (female)	-.47	-1.5	.53	.36	-.48	-1.6	.58	.37	-.42	-1.5	.67	.45	.66
Race[a] (White)	.09	-1.0	1.2	.88	.03	-1.0	1.1	.96	-.04	-1.1	1.05	.94	.96
Cohabitates with partner	-.95	-2.0	.05	.06	-.60	-1.7	.53	.30	-.65	-1.8	.50	.27	.52
Age	-.04	-.08	.01	.14	-.01	-.06	.04	.71	-.01	-.06	.04	.63	.99
Distance to worksite	<.01	<.01	<.01	.39	<.01	<.01	<.01	.90	<.01	<.01	<.01	.96	1.0
Reason moved to neighborhood	.43	-.11	.97	.12	.26	-.30	.85	.35	.30	-.29	.90	.32	1.4
Annual household income					-.08	-.41	.25	.63	-.07	-.40	.26	.68	.93
Home walkability 500-m					.18	-.03	.39	.10	.17	-.04	.39	.12	1.2
Worksite walkability 500-m									-.05	-.24	.13	.58	.95

Model Fit Information	Model 2[d]	Model 3	Model 4
Deviance Explained	.9947	.9926	.9924
AIC (null = 1657.8)	1660.9	1661.5	1663.2
LR Test[b,c]	$\chi2$ = 8.80 *p* = .092	$\chi2$ = 3.48 *p* = .088	$\chi2$ = 0.31 *p* = .288
Degrees of Freedom	6	8	9

AIC = Akaike Information Criterion.
LR = Likelihood Ratio (-2*log likelihood).
[a]Caucasian or White was the only Race and Ethnicity reported. [b]Likelihood ratio test for comparison of model fit to fit of the previous model; for model 2, the previous model ("model 1") was a model without any predictors. [c]One-tailed tests for chi square p-values in LR Tests. [d]Model 1 is not shown as it was the null model.

Table 10. Negative Binomial Regression Models **Moderate-to-Vigorous Physical Activity** Bout Minutes.

	Model 2[d]				Model 3				Model 4				
	B	95% CI		*p*	B	95% CI		*p*	B	95% CI		*p*	IRR
Sex (female)	-.36	-.52	-.21	<.01	-.37	-.52	-.21	<.01	-.39	-.55	-.23	<.001	.68
Race[a] (White)	.04	-.13	.21	.65	.05	-.13	.22	.59	.05	-.13	.22	.59	1.0
Cohabitates with partner	-.07	-.24	.09	.38	-.05	-.24	.14	.59	-.05	-.24	.14	.59	.95
Age, mean centered	-.01	-.02	-.01	<.01	-.01	-.02	-.01	.02	-.01	-.02	-.01	.002	.89
Distance to worksite	<.01	<.01	<.01	.66	<.01	<.01	<.01	.69	<.01	<.01	<.01	.86	1.0
Reason moved to neighborhood, mean centered	.07	-.01	.15	.07	.07	-.05	.15	.07	.08	-.02	.15	.06	1.1
Wear sum per week, mean centered	<.01	<.01	<.01	.25	<.01	<.01	<.01	.25	<.01	<.01	<.01	.26	1.0
Annual household income					-.01	-.06	.04	.60	-.02	-.07	.04	.54	.98
Home walkability 500-m					<-.01	-.03	.03	.92	<-.01	-.03	.03	.85	1.0
Worksite walkability 500-m									.02	-.01	.05	.19	1.0

Model Fit Information	Model 2[d]	Model 3	Model 4
Deviance Explained	.9940	.9939	.9936
AIC (null = 5687.9)	5667.8	5671.5	5671.8
LR Test[b,c]	$\chi 2$ = 34.161 p < .001	$\chi 2$ = 0.284 p = .434	$\chi 2$ = 1.705 p = .096
Degrees of Freedom	7	9	10

AIC = Akaike Information Criterion.
LR = Likelihood Ratio (-2*log likelihood).
[a]Caucasian or White was the only Race and Ethnicity reported. [b]Likelihood ratio test for comparison of model fit to fit of the previous model; for model 2, the previous model (“model 1”) was a model without any predictors (a “null” model). [c]One-tailed tests for chi square p-values in LR Tests. [d]Model 1, the null model, is not shown.

Table 11. Negative Binomial Regression Models **Vector Magnitude** Sum Minutes.

	Model 2[d]				Model 3				Model 4				
	B	95% CI		*p*	B	95% CI		*p*	B	95% CI		*p*	IRR
Sex (female)	.11	.06	.16	<.001	.11	.06	.16	<.001	.11	.06	.16	<.001	1.1
Race[a] (White)	-.02	-.07	.04	.50	-.01	-.07	.04	.60	-.02	-.07	.04	.60	.99
Cohabitates with partner	.06	.01	.11	.032	.07	.01	.13	.033	.07	.01	.13	.03	1.1
Age	<-.01	-.01	<-.01	.010	-.01	-.01	-.01	.014	-.01	-.01	<-.01	.01	1.0
Distance to worksite	<.01	<.01	<.01	.011	<.01	<.01	<.01	.011	<.01	<.01	<.01	.01	1.0
Reason moved to neighborhood	.03	.01	.06	.015	.03	.01	.06	.014	.03	.01	.06	.01	1.0
Wear sum per week	<.01	<.01	<.01	<.001	<.01	<.01	<.01	<.001	<.01	<.01	<.01	<.01	1.0
Annual household income, median centered					-.01	-.03	.01	.32	-.01	-.03	.01	.32	.99
Home walkability 500-m					-.01	-.02	.01	.36	-.01	-.02	.01	.36	1.0
Worksite walkability 500-m									<.01	-.01	.01	.94	1.0

Model Fit Information	Model 2[d]	Model 3	Model 4
Deviance Explained	.9935	.9934	.9934
AIC (null = 15698.3)	15610.5	15612.9	15614.9
LR Test[b,c]	$\chi2$ = 101.73 *p* < .001	$\chi2$ = 1.68 *p* = .216	$\chi2$ = 0.01 *p* = .471
Degrees of Freedom	7	9	10

AIC = Akaike Information Criterion.
LR = Likelihood Ratio (-2*log likelihood).
[a]Caucasian or White was the only Race and Ethnicity reported. [b]Likelihood ratio test for comparison of model fit to fit of the previous model; for model 2, the previous model ("model 1") was a model without any predictors (a "null" model). [c]One-tailed tests for chi square p-values in LR Tests. [d]Model 1 is not shown as it was the null model.

Table 12. Negative Binomial Regression Models for **Sedentary-Light-Physical-Activity** Minutes.

	Model 2[d]				Model 3				Model 4				
	B	95% CI		*p*	B	95% CI		*p*	B	95% CI		*p*	IRR
Sex (female)	<.01	<.01	.02	<.001	<.01	.<01	.02	<.001	.01	.01	.02	<.001	1.0
Race[a] (White)	<-.01	-.01	<.01	.50	<-.01	-.01	<.01	.42	<-.01	-.01	<.01	.46	1.0
Cohabits with spouse/partner	<.01	<-.01	.01	.44	<.01	-.01	.01	.84	<.01	-.01	.01	.86	1.0
Age	<.01	<.01	<.01	.001	<.01	<.01	<.01	.004	<.01	<.01	<.01	.004	1.0
Distance to worksite	<.01	<.01	<.01	.34	<.01	<.01	<.01	.44	<.01	<.01	<.01	.60	1.0
Reason moved to neighborhood	<-.01	<-.01	<.01	.62	<-.01	<-.01	<.01	.67	<-.01	<-.01	<.01	.62	1.0
Wear sum per week	<.01	<.01	<.01	<.001	<.01	<.01	<.01	<.001	<.01	<.01	<.01	<.001	1.0
Annual household income, median centered					<.01	<-.01	<.01	.43	.<01	<-.01	<.01	.39	1.0
Home walkability 500-m					<.01	<-.01	<.01	.58	<.01	<-.01	<.01	.65	1.0
Worksite walkability 500-m									<-.01	<-.01	<.01	.10	1.0

Model Fit Information	Model 2[d]	Model 3	Model 4
Deviance Explained	.7707	.7706	.7703
AIC (null = 8110.5)	6265.8	6268.8	6268.1
LR Test[b,c]	$\chi 2$ = 1858.70 *p* < .001	$\chi 2$ = 1.01 *p* = .302	$\chi 2$ = 2.70 *p* = .050
Degrees of Freedom	7	9	10

AIC = Akaike Information Criterion.
LR = Likelihood Ratio (-2*log likelihood).
[a]Caucasian or White was the only Race and Ethnicity reported.
[b]Likelihood ratio test for comparison of model fit to fit of the previous model; for model 2, the previous model ("model 1") was a model without any predictors.
[c]One-tailed tests for chi square p-values in LR Tests.
[d]Model 1 is not shown as it was the null model.

Aim 2 Results: Moderating effects of person-level characteristics on the relationship between PA and worksite walkability

As Aim 2 focuses on potential moderators of the relationship between worksite walkability and each of four measures of PA, results are reported below first grouped by each moderator variable (e.g., age, sex, race), then presented in order the four PA outcomes: 1) inside the home neighborhood, 2) outside the home neighborhood, 3) MVPA bout minutes/week, 4) SLPA minutes/week. Analyses with significant tests for moderation were then probed, visualized, and presented in a separate section below, "Probing Significant Interactions." The focal independent variable was worksite walkability in all analyses. Only tables and figures are presented for 500-m worksite walkability analyses with significant moderation results.

Age

Overall, no moderation effects were found with any outcome measure and age. For self-reported walking and biking inside the home neighborhood min/week, the interaction between age and worksite walkability did not reach the level of statistical significance (B = .01, p = .58). This supports the hypothesis that no moderation would be found for PA inside the home neighborhood area between worksite walkability and age. For self-reported walking and biking outside the home neighborhood min/week, the interaction between age and worksite walkability did not reach the level of statistical significance (B = -.01, p = .31). This does not support hypothesis that older adults would have a stronger relationship to PA outside the home neighborhood area, compared to younger adults.

For MVPA bout min/week, the interaction between age and worksite walkability did not reach the level of statistical significance (B = .001, p = .63). This does not support hypothesis that older adults would have a stronger relationship to MVPA bout min/week, compared to younger adults. For SLPA min/week, the interaction between age and worksite walkability did not reach the level of statistical significance (B $<-.001$, $p = .59$). This does not support hypothesis that older adults would have a stronger relationship to SLPA bout min/week, compared to younger adults.

Sex

While no moderation effects were found for self-report outcomes, significant interaction terms were revealed with respect to the accelerometer measured PA outcomes. For self-reported walking and biking inside the home neighborhood min/week, the interaction between sex and worksite walkability did not reach the level of statistical significance (B = .57, $p = .75$). This supports the hypothesis that no moderation would be found for PA inside the home neighborhood area between worksite walkability and sex. For self-reported walking and biking outside the home neighborhood min/week, the interaction between sex and worksite walkability did not reach the level of statistical significance (B = .11, $p = .56$). This does not support hypothesis that females would have a stronger relationship to PA outside the home neighborhood area, compared to males.

For MVPA bout min/week, the interaction between sex and worksite walkability did reach statistical significance (Table 13, B = .06, $p = .04$). This supports the hypothesis that females have a stronger relationship to MVPA bout min/week, compared to males. For SLPA min/week, the interaction between age and worksite walkability did not reach the level of statistical significance (Table 14, B =-.002, $p = .09$). This supports hypothesis that females have a stronger relationship to SLPA bout min/week, compared to males.

Race (white only) vs. other race

Moderation was found only for the self-report outcome of transportation PA outside the home neighborhood, yet not in the expected direction for 'white only' participants. No a priori hypotheses were determined for these relationships. For self-reported walking and biking for transportation inside the home neighborhood min/week, the interaction between race and worksite walkability did not reach the level of statistical significance (B = -.09, p = .65). For self-reported walking and biking for transportation *outside* the home neighborhood min/week, the interaction between race and worksite walkability was found to reach statistical significance (Table 17, B = -.42, p = .07).

No moderation by race was detected for accelerometer outcomes. For MVPA bout min/week, the interaction between race and worksite walkability did not reach the level of statistical significance (B = -.01, p = .71). For SLPA min/week, the interaction between race and worksite walkability did not reach the level of statistical significance (B =.01, p = .14).

Income

For income, no moderation effects were found with any outcome measured. For self-reported walking and biking inside the home neighborhood min/week, the interaction between income and worksite walkability did not reach the level of statistical significance (B = .01, p = .87). For self-reported walking and biking outside the home neighborhood min/week, the interaction between income and worksite walkability did not reach the level of statistical significance (B = -.04, p = .60).

For MVPA bout min/week, the interaction between income and worksite walkability did not reach the level of statistical significance (B = .01, *p* = .55). For SLPA min/week, the interaction between income and worksite walkability did not reach the level of statistical significance (B <.001, *p* = .20).

Number of children under 18 years old in the household

While no moderation effects were found for self-report outcomes, significant interaction terms were revealed with respect to the accelerometer-measured PA outcomes only. For self-reported walking and biking inside the home neighborhood min/week, the interaction between number of children <18 years and worksite walkability did not reach the level of statistical significance (B = -.03, *p* = .62). For self-reported walking and biking outside the home neighborhood min/week, the interaction between number of children <18 years and worksite walkability did not reach the level of statistical significance (B = -.06, *p* = .34).

For MVPA bout min/week, the interaction between number of children <18 years and worksite walkability was found to be statistically significance (Table 15,B = -.03, *p* = .02). For SLPA min/week, the interaction between number of children <18 years and worksite walkability was found to reach statistical significance (Table 16,B = .001, *p* = .02).

Ratio of cars to drivers

No moderation effects were found with any outcome measure and ratio of cars to drivers. For self-reported walking and biking inside the home neighborhood min/week, the interaction between the ratio of cars to people and worksite walkability did not reach the level of statistical significance (B = .02, *p* = .90). For self-reported walking and biking outside the home neighborhood min/week, the interaction between the ratio of cars to people and worksite walkability did not reach the level of statistical significance (B = .20, p = .15).

For MVPA bout min/week, the interaction between the ratio of cars to people and worksite walkability did not reach the level of statistical significance (B = .01, p = .88). For SLPA min/week, the interaction between the ratio of cars to people and worksite walkability did not reach the level of statistical significance (B <.001, p = .65).

Home Walkability

No moderation effects were found with any outcome measure and home walkability at the 500-m buffer size. For self-reported walking and biking inside the home neighborhood min/week, the interaction home walkability and worksite walkability did not reach the level of statistical significance (B = -.0005, p = .99). For self-reported walking and biking outside the home neighborhood min/week, the interaction between the home walkability and worksite walkability did not reach the level of statistical significance (B = .04, p = .33).

For MVPA bout min/week, the interaction between home walkability and worksite walkability did not reach the level of statistical significance (B = .005, p = .28). For SLPA min/week, the interaction between home walkability and worksite walkability did not reach the level of statistical significance (B = .0001, p = .42).

Probing Significant Interactions

Overall, sex and number of children under 18 years moderated the relationships of worksite neighborhood walkability with accelerometer-measured MVPA and SLPA. Race moderated the relationship of worksite neighborhood walkability with self-reported Total PA Outside the Home Neighborhood. Descriptions of the visualizations to explore significant interactions are presented next.

Sex by Worksite Walkability interaction. Moderation found for the outcomes of MVPA and SLPA each in expected directions. For women, the conditional effect of worksite neighborhood walkability on MVPA was positive (p = .04) while the conditional effect of worksite neighborhood walkability on SLPA was negative (p = .04); effects were not different from zero for men, see Tables 13-14 and Figures 7-8.

Number of children <18 years by Worksite Walkability interaction. For adults with no children <18, the conditional effect of worksite neighborhood walkability on MVPA was positive (p = .01) while the conditional effect of worksite neighborhood walkability on SLPA was negative (p = .01); however, the effect was not different from zero for those with at least 1 child, see Tables 15-16 and Figures 9-10.

Race by Worksite Walkability interaction. For White participants, the conditional effect of worksite neighborhood walkability on Total PA Outside the home neighborhood was negative (p = .07); not different from zero for non-Whites, see Table 17 and Figure 11.

Sensitivity Analyses

Sensitivity analyses were conducted testing the aforementioned moderators in models with 1000 m worksite walkability. Two of the three significant findings reported above were corroborated. Testing moderation in 1000-m worksite walkability models, race moderated the relationship on self-reported total PA (p = .055); and children <18 in household moderated MVPA (p = .095), and SLPA (p = .084), independently. However, sex was not a significant moderator to any outcome in the 1000-m worksite walkability models (data not shown). All remaining potential moderators (age, income, children under 18 in the household, ratio of cars to drivers, and home walkability) were, not found to alter the relations between 1000-m worksite walkability and PA.

Figure 7. Conditional Effect of Worksite Walkability on MVPA by Males and Females.

Figure 8. Conditional Effect of Worksite Walkability on SLPA by Males and Females.

Figure 9. Conditional Effect of Worksite Walkability on MVPA Among Those Relatively Low, Average, and High in Number of Children Under 18 Years in Household.

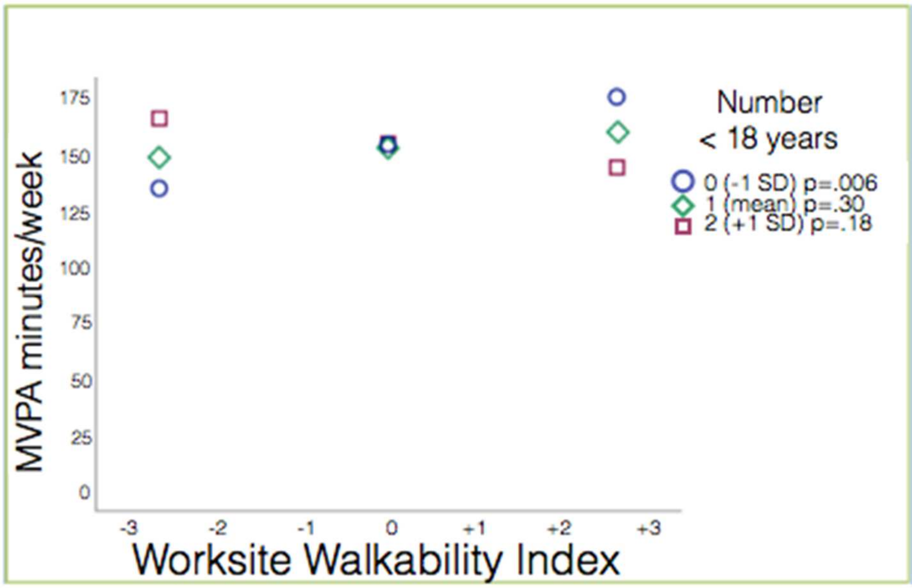


Figure 10. Conditional Effect of Worksite Walkability on SLPA Among Those Relatively Low, Average, and High in Number of Children Under 18 Years in Household.

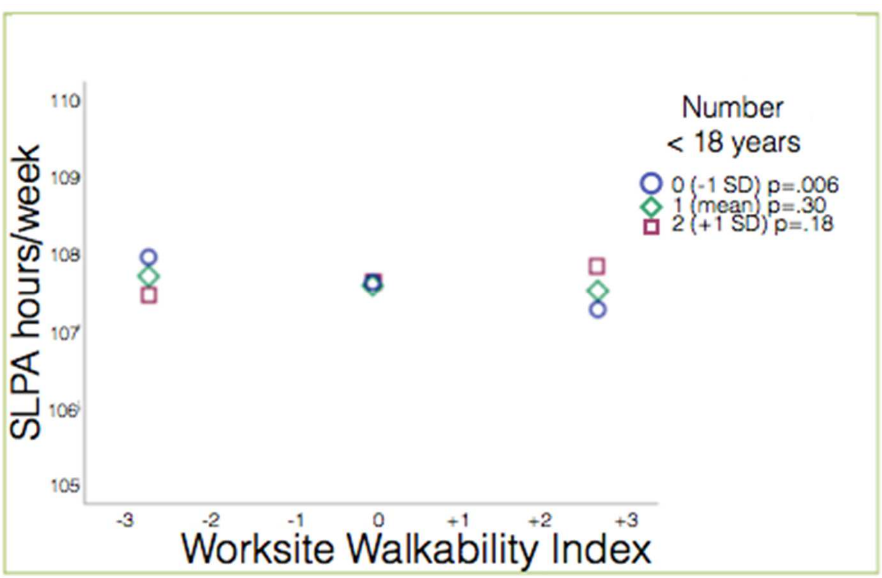


Figure 11. Conditional Effect of Worksite Walkability on Transportation Physical Activity Outside the Home Neighborhood Among Those Reporting Race as White only or Other Race.

Table 13. Negative Binomial Regression for **Sex** Moderation Model on **MVPA** Bout Minutes/week.

Parameter	B	*p*	IRR	90% CI for IRR Lower	Upper
Age, mean centered	-.016	.001	.99	.98	.99
Sex (female)	-.392	<.001	.68	.59	.77
Race[a] (White)	.027	.762	1.03	.89	1.19
Cohabitating	-.094	.385	.91	.76	1.09
Number Under 18, centered	.041	.484	1.04	.95	1.15
Annual household income, centered	-.008	.763	.99	.95	1.04
Reason moved to neighborhood, centered	.059	.139	1.06	.99	1.13
Wear-time week average, centered	<.001	.189	1.00	1.00	1.00
Cars:People in household, centered	-.084	.255	.92	.82	1.04
Distance to works, centered	<.001	.891	1.00	1.00	1.00
Household number, centered	-.015	.771	.99	.91	1.07
Tenure at Residence, centered	.012	.041	1.01	1.00	1.02
Home walkability 500-m, centered	<.001	.987	1.00	.97	1.03
Worksite walkability	-.010	.660	.99	.96	1.03
Interaction Worksite Walkability x Sex	.061	.042	1.06	1.01	1.12

[a]Caucasian or White was the only Race and Ethnicity reported.

Table 14. Negative Binomial Regression Models for **Sex** Moderation Model with **SLPA** Minutes/Week.

Parameter	B	*p*	IRR	90% CI for IRR Lower	Upper
Age, mean centered	.001	.002	1.00	1.00	1.00
Sex (female)	.011	<.001	1.01	1.01	1.02
Race[a] (White)	-.001	.615	1.00	.99	1.00
Cohabitating	<.001	.936	1.00	.99	1.01
Number Under 18, centered	.002	.396	1.00	1.00	1.01
Annual household income, centered	.001	.538	1.00	1.00	1.00
Reason moved to neighborhood, centered	<.001	.747	1.00	1.00	1.00
Wear-time week average, centered	<.001	<.001	1.000143	1.000142	1.000145
Cars:People in household, centered	.001	.742	1.00	1.00	1.01
Distance to works, centered	<.001	.520	1.00	1.00	1.00
Household number, centered	<.001	.888	1.00	1.00	1.00
Tenure at Residence, centered	<.001	.401	1.00	1.00	1.00
Home walkability 500-m, centered	<.001	.837	1.00	1.00	1.00
Worksite walkability	<.001	.899	1.00	1.00	1.00
Interaction Worksite Walkability x Sex	-.002	.088	.99823	.99653	.99994

[a]Caucasian or White was the only Race and Ethnicity reported.

Table 15. Negative Binomial Regression Models for Number of Household Members **Under 18 years** and **MVPA** Bout Minutes/Week.

Parameter	B	*p*	IRR	90% CI for IRR Lower	Upper
Age, mean centered	-.01	.003	.986	.978	.994
Sex (female)	-.38	<.001	.68	.60	.78
Race[a] (White)	.04	.67	1.04	.90	1.20
Cohabitating	-.08	.44	.92	.77	1.10
Number Under 18, centered	.03	.66	1.03	.93	1.13
Annual household income, centered	-.01	.79	.99	.95	1.04
Reason moved to neighborhood, centered	.07	.08	1.07	1.01	1.15
Wear-time week average, centered	<.001	.24	1.00	1.00	1.00
Cars:People in household, centered	-.07	.36	.94	.83	1.06
Distance to works, centered	<.001	.96	1.00	1.00	1.00
Household number, centered	-.01	.84	.99	.91	1.08
Tenure at Residence, centered	.01	.12	1.00	1.00	1.02
Home walkability 500-m, centered	<.01	.87	1.01	.98	1.03
Worksite walkability	.02	.14	1.02	1.00	1.05
Interaction Worksite Walkability x Number < 18 years in Household	-.027	.017	.97	.96	.99

[a]Caucasian or White was the only Race and Ethnicity reported.

Table 16. Negative Binomial Regression Models for Number of Household Members **Under 18 years** and **SLPA** Minutes/Week.

Parameter	B	*p*	IRR	90% CI for IRR Lower	Upper
Age, mean centered	<.001	.004	1.00	1.00	1.00
Sex (female)	.010	<.001	1.01	1.01	1.02
Race[a] (White)	-.002	.581	1.00	.99	1.00
Cohabitating	<.001	.959	1.00	.99	1.01
Number Under 18, centered	.002	.264	1.00	1.00	1.01
Annual household income, centered	.001	.514	1.00	1.00	1.00
Reason moved to neighborhood, centered	-.001	.647	1.00	1.00	1.00
Wear-time week average, centered[b]	<.001[b]	<.001	1.00[b]	1.00[b]	1.00[b]
Cars:People in household, centered	<.001	.853	1.00	1.00	1.01
Distance to works, centered	<.001	.590	1.00	1.00	1.00
Household number, centered	-.001	.769	1.00	1.00	1.00
Tenure at Residence, centered	<.001	.632	1.00	1.00	1.00
Home walkability 500-m, centered	<.001	.746	1.00	1.00	1.00
Worksite walkability	-.001	.126	1.00	1.00	1.00
Interaction Worksite Walkability x Number Under 18 years in Household	.001	.023	1.00	1.00	1.002

[a]Caucasian or White was the only Race and Ethnicity reported.
[b]Wear-time B = .000143; IRR = 1.000143; 90%CI = 1.000142, 1.000145.

Table 17. Negative Binomial Regression Models for **Race** Moderation on **Total Physical Activity Outside The Home Neighborhood** Self-Reported Minutes/Week.

Parameter	B	*p*	IRR	90% CI for IRR Lower	Upper
Age, mean centered	-.010	.773	.99	.93	1.06
Sex (female)	-.302	.602	.74	.24	2.30
Racea (White)	.084	.875	1.09	.38	3.09
Cohabitating	-.197	.783	.82	.20	3.35
Number Under 18, centered	-.244	.534	.78	.36	1.69
Annual household income, centered	-.100	.583	.91	.63	1.29
Reason moved to neighborhood, centered	.254	.427	1.29	.69	2.41
Cars:People in household, centered	-.282	.610	.76	.26	2.23
Distance to works, centered	<.001	.832	1.00	1.00	1.00
Household number, centered	.030	.933	1.03	.51	2.10
Tenure at Residence, centered	.005	.909	1.01	.92	1.10
Home walkability 500-m, centered	.245	.054	1.28	1.00	1.64
Worksite walkability	.298	.181	1.35	.87	2.08
Interaction Worksite Walkability x **Race**	-.424	.071	.66	.41	1.04

aCaucasian or White was the only Race and Ethnicity reported.

Aim 3 Results: Differences in the rate of change in PA over 56 days of a behavioral intervention by worksite walkability

Data Descriptive Information and Interclass Correlation.

To test both hypotheses of Aim 3, data were structured as repeated measures nested within persons (i.e., daily PA totals [level-1] within participants [level-2]). Data were stacked (i.e., 'long' format) with one row for each repeated measurement, with a maximum of 56 rows representing the first 56 days of the intervention period. A variable that captures the passage of time was included and because the substantive research question concerns examining differences after participants have received 56 days of the intervention, time was centered at day 56.

Days with fewer than 10 hours of valid wear time were excluded from all analyses. Wear-time was then centered at the sample mean [16.4 hours/day for n=16099 observations for valid days). Day of week was included using 6 dummy variables with Saturday as the reference day, and month of year was added using 11 dummy variables with December as the reference month. Person level covariates [level-2] were centered at the mean of the analytical sample (i.e., age, sex, race, annual household income, home neighborhood walkability, distance to work, number of children under 18 in the household) to aid interpretation of coefficient values for an average participant.

Descriptive statistics of the longitudinal outcome variables are shown in Table 5 (in Results Section 0). In brief, the analytical sample included 364 participants (level-2 units) and 16,099 daily observations (level-1 units); sample averages included 29.3 MVPA minutes/day and 16.0 SLPA hours/day, see Table 5. The distribution of MVPA minutes showed heavy positive skew with and abundance of low and zero values, while SLPA had a relatively normal distribution except wide tail of higher values and an abundance of maximum values (1440 minutes [24 hours] of

SLPA). Due to the nature of the outcome data being counts and displaying other-than-normal distributions, preliminary model fitting step included testing for relative fit of intercept-only models specifying Poisson, negative binomial, and gamma distributions for greatest model fit. For MVPA and SLPA, a Negative Binomial distribution with Log link provided the best model fit based on lowest AIC and -2 Log Likelihood information criteria, see Table 18.

With respect to the daily repeated measures within participants, residual error covariance was not assumed to be independent. Relative model fit was compared for three error covariance structures: Identity, Diagonal, and First-order Autoregressive. For MVPA and SLPA models, First-order Autoregressive improved model fit by reduced AIC and LR tests (data not shown). An unconditional random intercept and slope model, an 'empty' model provided variance components for the interclass correlation (ICC) for each outcome. As expected, the magnitude of the ICC warranted multi-level modeling strategies to account for within-person non-independence of repeated observations for MVPA and SLPA (ICC = .552 and .032 respectively). Polynomial expressions of time were tested to determine if modeling non-linear trajectories improved model fit. Inclusion of quadratic and cubic expressions worsened model fit; only the linear expression of time was retained as an appropriate trajectory.

Moderate-to-Vigorous Physical activity

After fitting the empty model, time was included as a fixed effect, although it only slightly altered model fit (see Table 20, Panel A, Model Number 2). Overall, worksite walkability did not show a significant relationship to MVPA rate of change as either a main effect (Table 19, Panel B, Model Numbers 6, 8-12; p = .38 to .69) or a moderator effect (Worksite Walkability x Time interaction) before or after controlling for participant-level covariates (Table 19, Panel B, Model Numbers 7 and 13; p = .43 and .44, respectively). As for improving model fit, covariates included baseline average MVPA minutes/week (Panel A, Model 8); day of week (Model 9; Saturday as reference day), several person-level (time-invariant) covariates (Model 11; i.e., reward status, goal status, age, sex, race, income, home walkability, and any active commuting), and children under 18 years in the household (Model 12).

A plot of final-model predicted MVPA bout minutes/day plotted by days since randomization using data from a random subset of participants stratified into higher, average, and lower worksite walkability at the 500-m distance (Figure 12) illustrates the lack of main effect and interactive relationship. In summary, worksite walkability did not moderate the rate of change in MVPA during the intervention phase (Phase 2) after controlling for MVPA in baseline (Phase 1) and relevant covariates described above.

Sedentary-and-Light Physical activity

For SLPA, time was included as a fixed and random effect; see Table 16, Panel A, Models 2-3. Worksite walkability did not relate to SLPA as either a main effect (Table 20, Panel B, Model Numbers 6, 8-12; p = .66 to .93) or moderation effect (Worksite Walkability by Time interaction) before or after controlling for participant-level covariates (Model Numbers 7 and 13; p = .99 and .99 respectively). Covariates that improved SLPA model fit included baseline average MVPA minutes/week (Table 20, Panel A, Model 8), month (Model 10; December as reference), and children less than 18 years in the household (Model 12). To summarize, worksite walkability did not moderate the rate of change in SLPA during the intervention phase (Phase 2) after controlling for MVPA in baseline (Phase 1) and relevant covariates mentioned previously.

Figure 12. Final-model Predicted Daily MVPA Bout Minutes/Day Stratified into Higher, Average, and Lower Worksite Walkability for a Subset of 15 Randomly Selected Participants.

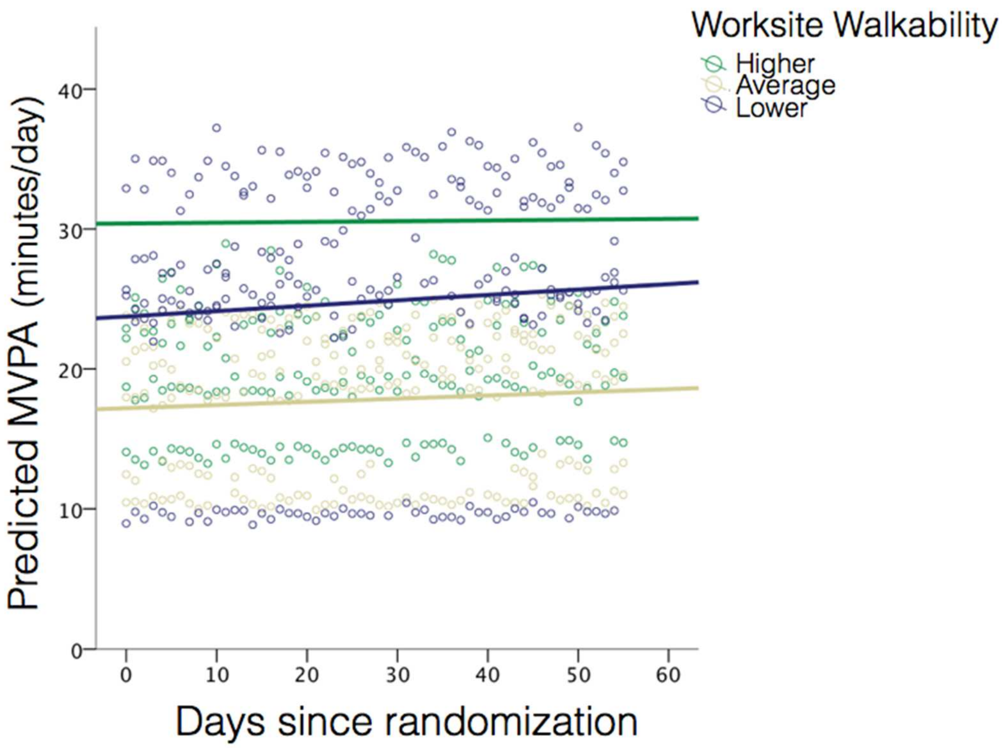


Table 18. Model Fit Indices From Unconditional Random Intercept Models for Longitudinal Outcomes.

Dependent Variable	Obs.	Poisson (DF =16098) LR	Poisson (DF =16098) AIC	Negative Binomial, α = MLE[a] (DF =16097) LR	Negative Binomial, α = MLE[a] (DF =16097) AIC	Gamma[b] (DF =14002) LR	Gamma[b] (DF =14002) AIC
MVPA	16099	0	243,162.8	44,917.2	44,919.2	65,406.3	65,402.4
LR test[c]		χ2 = 198,243.6 *p* < .001		-ref-		χ2 = 20,489.1 *p* < .001	
		Poisson (DF =16098) LR	**Poisson (DF =16098) AIC**	**Negative Binomial, α = MLE[a] (DF =16097) LR**	**Negative Binomial, α = MLE[a] (DF =16097) AIC**	**Gamma (DF =14002) LR**	**Gamma (DF =14002) AIC**
SLPA	16099	286,426.9	286,428.9	7,905.5	7,903.5	225,459.7	233,361.2
LR test[c]		χ2 = 278,521.4 *p* < .001		-ref-		χ2 = 2351.6 *p* < .001	

DF = degrees of freedom.
LR = Likelihood Ratio (-2*log likelihood).
AIC = Akaike Information Criterion.
[a]Maximum likelihood-estimated dispersion parameter (α).
[b]Gamma distribution requires positive non-zero integers which reduced the sample by 2096 observations (n = 14003)
[c]Likelihood ratio test for comparison of model fit to fit of NB MLE model.
Modeling used SPSS procedure GENLINMIXED.

Table 19. Multilevel Negative Binomial Regression Model Building for Moderate-to-Vigorous Physical Activity.

Panel A: Model Progression and Fit Information							Panel B: **Worksite Walkability** Explanatory Variables of Interest by Model						
Model	Parameter(s)	Effect Type	AIC[a]	(-2LL) LR[b]	*dF difference*	*p*	Model	Worksite Walkability Parameter Effect Type	B	*p*	90% CI of B Lower	Upper	IRR
1	Empty Model (Intercept)	Fixed, Random	44919	(44917)	-ref-	*na*[c]	1	--	--	--	--	--	--
2	Time	Fixed	44925	-6	1	*na*	2	--	--	--	--	--	--
3	*Time*	*Random*	*45328*	*-403*	*2*	*na*	*3*	--	--	--	--	--	
4	Wear-time	Fixed	44941	-16	1	*na*	4	--	--	--	--	--	--
5	*Wear-time*	*Random*	*52410*	*-7469*	*2*	*na*	*5*	--	--	--	--	--	--
6	Work walkability	Fixed	44944	-3	1	*na*	6	Main	-.006	.69	-.032	.019	.99
7	*Work Walkability X Time*	Fixed	*44962*	*-19*	*1*	*na*	*7*	*Interaction*	*<-.001*	*.49*	*-.001*	*<.001*	*1.0*
8	Baseline MVPA bout minutes, average	Fixed	44336	607	1	<.001	8	Main	-.010	.43	-.032	.011	.99
9	Day of week	Fixed	44326	10	6	.058	9	Main	-.010	.43	-.032	.011	.99
10	*Month*	Fixed	*44349*	*-22*	*11*	*na*	*10*	*Main*	*-.010*	*.46*	*-.031*	*.012*	*.99*
11	Level-2 Covariates[d]	Fixed	44293	33	8	<.001	11	Main	-.012	.38	-.033	.010	.99
12	Children < 18 in the home	Fixed	44290	3	1	.033	12	Main	-.012	.37	-.033	.010	.99
13	*Work Walkability X Time*	Fixed	*44309*	*-19*	*1*	*na*	*13*	*Interaction*	*<.001*	*.44*	*-.001*	*<.001*	*1.0*

[a]Akaike Information Criteria.
[b]Likelihood ratio test using -2Log Likelihood (-2LL) for comparison of model fit to the previous model; negative values indicates worse fit.
[c]na = not applicable due to negative LR test.
[d]Level-2 Covariates included: Reward status, Goal status, Age, Sex, Race, Income, Home walkability, Any active commute.
Note: Italicized parameters were omitted from subsequent models.

Table 20. Multilevel Negative Binomial Regression Model Building for Sedentary-and-Light Physical Activity.

Panel A: Model Progression and Fit Information							Panel B: **Worksite Walkability** Explanatory Variables of Interest by Model						
Model	Parameter(s)	Effect Type	AIC[a]	(-2LL) LR[b]	*dF difference*	*p*	Model	Worksite Walkability Parameter Effect Type	B	*p*	90% CI of B Lower	Upper	IRR
1	Empty Model (Intercept)	Fixed, Random	-7904	(-7906)	-ref-	*na*	1	--	--	--	--	--	--
2	Time	Fixed	-7893	10	1	.001	2	--	--	--	--	--	--
3	Time	Random	-5305	2588	2	<.001	3	--	--	--	--	--	
4	*Wear-time*	*Fixed*	*-59358*	*-54053*	*1*	*na*	4	--	--	--	--	--	--
5	*Wear-time*	*Random*	*-62001*	*-2645*	*2*	*na*	*5*	--	--	--	--	--	--
6	Work walkability	Fixed	-5303	2	1	.061	6	Main	.001	.67	-.003	.005	1.0
7	*Work Walkability X Time*	Fixed	*-5293*	*9*	*1*	*.001*	*7*	*Interaction*	*<.001*	*.99*	*-.003*	*.003*	*1.0*
8	Baseline MVPA bout minutes, average	Fixed	-5291	2	1	.068	8	Main	.001	.67	-.003	.005	1.0
9	*Day of week*	*Fixed*	*-5424*	*-133*	*6*	*na*	*9*	*Main*	*.001*	*.66*	*-.003*	*.006*	*1.0*
10	Month	Fixed	-5264	28	11	.002	10	Main	.001	.74	-.003	.005	1.0
11	Level-2 Covariates[d]	Fixed	-5330	-66	8	*na*	11	Main	<.001	.93	-.004	.005	1.0
12	Children < 18 in the home	Fixed	-5327	3	1	.055	12	Main	<.001	.88	-.004	.005	1.0
13	*Work Walkability X Time*	Fixed	*-5321*	*9*	*1*	*.002*	*13*	*Interaction*	*<-.001*	*.99*	*-.003*	*.003*	*1.0*

[a]Akaike Information Criteria.
[b]Likelihood ratio test using -2Log Likelihood (-2LL) for comparison of model fit to the previous model; negative values indicates worse fit.
[c]Model 1 is not shown as it was the null model.
[d]Level-2 Covariates included: Reward status, Goal status, Age, Sex, Race, Income, Home walkability, Any active commute.
Note: Italicized parameters were omitted from subsequent models.

CHAPTER 5

DISCUSSION

This project examined the relationships between worksite walkability and several physical activity (PA) outcomes in three aims: direct relationships, moderated effects, and longitudinal analyses. Following an ecological framework, this project tested individual behavior in the context of relevant built environments (BE), specifically worksite neighborhoods for employed adults.

Using GIS-measured environmental features combined by a walkability index, a limited number of patterns of PA were revealed, of which a greater number occurred with accelerometer-captured PA data. First, the direct relationship between worksite walkability to explain additional variance in PA was explored after controlling for home walkability and important covariates. The relationships between worksite walkability and several PA outcomes indicated limited support for the hypothesis that worksite walkability was specifically related to self-reported total PA. However, other indicators of PA were not directly related to worksite walkability. Next, moderation analyses were performed to investigate if specific socio-demographic characteristics moderated the relationship between PA and worksite walkability. Significant interactions were revealed most robustly in models considering, independently, sex and people without young children in the household to the relationship between worksite walkability and accelerometer PA outcomes. Finally, a longitudinal analysis explored the first two months of a behavioral intervention in relation to worksite walkability. Worksite walkability was treated as a moderator to the trajectory of the initial 56 days of a walking-focused PA intervention; however, the interaction between time and worksite walkability was non-significant.

In the current project, the inclusion of the worksite walkability term in the models resulted in slight improvements in model fit only for self-reported Total PA. Additionally, the direct associations of worksite walkability with most outcomes were non-significant, though its relationship to self-reported Total PA did approach significance (p = .064). This direct relationship was negative, however, indicating that a higher worksite walkability score was associated, on average, with lower Total PA across the full sample. Findings in the current report do not conform to the majority of prior literature in which worksite walkability was found to have the expected positive relationships with PA[1,2], cardiorespiratory fitness[3] and BMI.[3,4] However, one prior study found a lack of association between PA and worksite BE features when average weekdays steps tracked during work hours was the outcome of interest.[5]

Aim 1: Direct relationship between worksite walkability and physical activity

This project found no direct relationship between worksite walkability and self-reported PA outside the home neighborhood for transportation (p = .578). This finding at least partially, matches those from Adlakha et al. (2015) where the authors similarly found that features of the worksite BE were not related to PA specifically around the workplace, despite being related to self-reported total PA.[6] The use of self-reported PA in these contexts may be one reason for this absence of evidence due to the inherent biases and misreporting with such measures.

Focusing on evidence using objective PA data, most literature supports the hypothesis that worksite BE relates to PA and other health indicators.[1-4] Using similar methodology, Troped et al. (2010) and Marquet et al. (2018) tethered accelerometer PA to GPS-tracked location to quantify moderate-to-vigorous PA (MVPA) occurring specifically within the worksite neighborhood environment. Using a sample of about 75 participants intercepted while using a recreational trail, Troped and colleagues showed the work-neighborhood MVPA was positively related to population density and housing unit density, respectively.[2] In the Marquet et al. sample of 147 women, both worksite walkability index and work Walkscore© related positively to MVPA in the worksite neighborhood after adjusting for a number of participant covariates.[1]

The current report did not find associations between worksite walkability index and three accelerometer outcomes tested in the first aim: MVPA minutes, SLPA minutes, and VM (vector magnitude) counts. To the author's knowledge, this study was the first to examine how accelerometer-measured SLPA and VM (in addition to MVPA, which is commonly reported) are related to worksite walkability. The study did not find associations between worksite walkability index and the 3 accelerometer outcomes, as such, the findings for MVPA do not support the hypothesized associations or conform with the prior literature. When comparing the current report to the existing literature, beyond the inclusion of GPS-tracked PA data, the previously published work relied on smaller samples sizes (*n*s = 80 to 147) from differing geographic locales (although all based in the USA) and participants with somewhat differing socio-demographic backgrounds who were generally more active. For example, the Marquet et al. study included an all-female sample who on average were more than 10 years older, and more highly educated (age 55 years vs. 44 years in the current study; college or post-grad educated 91% vs. 65% in the current study). However, the relationships reported this the current study were the result of averages over the analytical samples; specific groups of participants showed relationships that differed from the average total sample.

Ancillary testing of individual components of the worksite walkability index may be of interest given the chiefly null relationship reported here. In post-hoc testing of individual components of the walkability index (i.e., separate models with singular index components assessed as the focal independent variable, data not shown), land-use mix appeared to be the driver of the slight negative yet non-significant relationship between Total PA and worksite walkability index.

Aim 2: Moderators of the relationship between worksite walkability and physical activity

To better understand for whom the relationships between worksite walkability and PA may differ, analyses under Aim 2 tested potential moderation of these associations by background factors. The seven potential moderators were tested in relation to four PA outcomes (i.e., moderators: age, sex, race, income, children <18 in the household, ratio of cars to drivers, and home walkability; outcomes in minutes/week: transportation PA inside home neighborhood, transportation PA outside home neighborhood, MVPA bouts, and SLPA).

Moderation by number of children under 18 years old.

The most consistent significant moderation effect tested was the number of children < 18 years in the household, and therefore is discussed first. The number of household members under the age of 18 years moderated relationships of the worksite walkability with MVPA and SLPA (both *p*-values = .02) relationships. Upon probing these interactions, the findings presented above revealed that significant conditional effects were only present for participants reporting no children under 18 years living in the household, and that the relationship was positive for MVPA and negative for SLPA (both *p*'s = .01). So, with higher worksite walkability, those with no young children showed higher baseline MVPA and lower SLPA. However, those reporting any young children did not show a conditional effect on worksite walkability associations to these outcomes (i.e., effects tested were not statistically different than zero). Furthermore, these findings were confirmed in the current report's sensitivity analyses testing 1000-m worksite walkability buffers, indicating this relationship remained when testing a different size of worksite neighborhood area.

To the author's knowledge, there was no existing literature detailing a modifying effect of the absence of young children in the household to the relationship between worksite walkability and PA in a sample of adult men and women. However, a general review of correlates of PA by Bauman et al. briefly noted that the evidence available at the time showed "childlessness" had a weakly positive, or mixed, relationship.[7] In the worksite specific literature, a few studies described the proportion of their sample having young children in the household versus not,[1,3,8] and 2 of the 3 statistically controlled for it as a dichotomous covariate.[1,3] However, this report may be the first to describe that PA behavior in adults without young children was potentially more sensitive to the BE around the worksite. This report supports the need to evaluate parental status in future studies of associations between BE features and PA, especially for those living with young children. The behavioral interventionist could consider whether children live in the household when providing tailored PA programming such as worksite-based just-in-time-adaptive-interventions (JITAI).

Moderation by gender

The moderation of the relationship between worksite walkability and PA by sex reflects findings from prior studies showing that women are generally more influenced by environmental variables.[1,2,9,10] This report identified a conditional effect whereby only female participants had an association of worksite walkability to accelerometer measured MVPA and SLPA (*p-values* = .04) with each relationship being in the expected direction (i.e., higher worksite walkability values were associated with higher MVPA and lower SLPA values). For men, the conditional effect tested was not statistically different from zero for any PA outcome.

The finding that women exhibit a different relationship than men when parsing out the association between worksite walkability and PA supports the author's hypothesis that sex was an important moderator. On average, women are generally less physically active than men,[11] which lends weight to investigating factors affecting the PA levels of women in particular.[1] Several previous reports have noted similar effect modifying relationships for sex across a spread of worksite BE features and health outcomes in epidemiological studies,[12,13] and is further supported in reports of accelerometer-captured MVPA.[1,2] However, the current findings were not supported in sensitivity analyses, which tested 1000-m worksite walkability buffers a larger walkability area around the worksite neighborhood. This may indicate that relatively proximal neighborhood features are more important for women around the worksite.

In the general literature, a 2017 systematic review by Pollard and Wagnild found women reported somewhat more leisure and total walking than men in the age groups enrolled in the current study (<60 years old), although effects were small and duration of walking may have obscured results.[14] Future work may benefit the understanding of for whom environmental contexts are related to PA behaviors by considering multiple-moderator models.

However among just women in the current report, those women with higher worksite walkability achieved greater MVPA than women with lower worksite walkability scores. In a women-only study, Van Dyck and colleagues surveyed over 4100 women and found that transportation-walking related positively to objective home BE, and then furthered revealed that perceptions of personal safety strengthened this relationship.[15] Likewise, Marquet et al. recruited only women participants and as discussed above, found strong relationships between worksite BE and PA, although no perception information was available.[1] Perceptions of BE around the worksite neighborhood may reveal nuanced relationships between objective BE and PA.

Curiously, in the review by Pollard and Wagnild, only one article reviewed was noted to control for aesthetics in their analysis. Van Dyck, et al. considered perceptions of aesthetics in their mediation models, however only found it to partially explain the relationship to walking for leisure.[15] Taken together, reasons why gender moderates the association between worksite walkability and PA are likely complex (e.g., perceptions of safety, aesthetics, additional moderation by age). Further speculation may even consider interactions between perceived safety and aesthetics, where by multiple, possibly moderated-mediation pathways could explicate complex pathways linking external environment to internal thoughts or historical experience which combine to produce behavioral output. Revealing the underlying causes of gender differences and testing the identifying gender-differentiated factors through intervention design may be helpful in PA promotion efforts. The current findings and previous literature support further investigation into gender differences within PA and BE research.

Moderation by race/ethnicity

For participants identifying as non-Hispanic white, there was a conditional effect revealing a negative relationship between worksite neighborhood walkability on self-reported transportation PA *outside* the home neighborhood (p = .07). However, for non-Whites, this was not different from zero. This result is contrary to previous literature that describes general patterns of PA being higher in whites compared to those reporting non-white race/ethnic classifications.[11] Others have also found that PA located in the worksite neighborhood was higher for whites compared to non-whites when specifically looking at interactions with worksite neighborhood residential density and race.[2] The previous studies, however, did not address transportation PA which is a unique distinction. Specific types of PA, such as the current report's use of PA within the transportation domain that occurs outside the home neighborhood environment, are not represented in the worksite BE literature, and although some research could precisely locate the PA captured to within versus outside the worksite neighborhood, they do not report information regarding the PA domain (i.e., transportation or leisure).

As noted in chapter 2, Samitz and colleagues, in a meta-analytic review, showed PA domain-specific differences to reducing mortality. The combined category of activities of daily living, (including transport with household PA) indicated a 36% reduction in mortality when comparing the lowest to highest levels of activity, the largest reduction of the domains reviewed.[16] The results of the current project provide initial support that domain-specific PA and BE features may have unique relationships to subgroups of people, and if substantiated in future inquiry could impact long-term health outcomes by race or ethnic status.

Non-significant interactions

The remaining moderators tested were not found to significantly alter the relationship between worksite walkability and PA (i.e., age, annual household income, ratio of cars to drivers, home walkability). Both age and income were among non-significant interactions. Although there is support for the direct association between these variables and PA,[7] a more recent review on the subject notes inconsistencies across the evidence base.[11] The worksite BE and PA literature has not previously described testing age or income as a moderators, with analyses only controlling for them statistically.[1,4,6,17] The potential moderators of ratio of cars to drivers, and home walkability were also not found to conditionally effect worksite walkability and PA. While this study is the first known report of testing the ratio of cars to drivers as a moderator and therefore exploratory, recently Marquet et al. describe what they call a 'synergistic' effect, that is a stronger association to PA behaviors with an interaction term combining home and worksite walkability.[1] As mentioned above, a key difference between the current project's design and that of the Marquet et al. study, is the use of geolocated PA within the worksite neighborhood in the latter, which may yield a more precise measure of PA occurring in the context under investigation.

Limitations and Strengths for Aim 1 and 2

In regards to the largely null results for aim 1, possible confounders included neighborhood SES of the worksite, area demographics, household income, property value of the workplace,[17] and unknown time of day at work which were unmeasured in this report. The deviance metric calculated for Generalized Linear Mixed Models also suggested model overfitting early in model building at the inclusion of background covariates of all outcomes except SLPA. Overfitting is a concern because it suggests an overly complex model; possibly too many parameters. However, prior to substantive analyses as mentioned in Chapter 3 above, parameter reduction techniques included using only covariates of high conceptual relevance or which had *p*-values < .20 in bivariate testing, which lead to 8 covariates included out of 15 tested. Another potential reason for model overfitting may be the abundant true zeros in the dataset inherent of PA data. Future work may consider alternative statistical techniques with greater sensitivity to handling these properties.

For both Aims 1 and 2, the composite focal variable of worksite walkability may be masking relationships of the individual BE features contained within. Recent work by Sallis and colleagues analyzed single-environment variables (SEV) models compared to multiple environment-variable (MEV) models. They found that more home BE features related to PA in SEV models, but in MEV models, which adjusted for the other environment variables, only residential density and public transport density around the home remained correlated.[18] Separating the variables could help clarify which worksite BE features are more relevant to PA behavior.

Also, as noted in Chapter 2, the retail FAR (floor area ratio) component of the Frank et al. walkability index could not be computed in the region under investigation, so it is not known how the addition of this aspect of the BE would have altered results of this project. Considering that retail FAR is a metric to capture building set-back from the road (smaller set-backs are considered to be more accessible by pedestrians) the walkability index used herein was missing a possibly relevant BE feature for workers who may travel to worksite neighborhood destinations on foot during, or just outside of work hours (e.g., for shopping or errands).

Additionally, other factors may be relevant for the worksite context, including density of specific land use types. Food or banking institutions, for which employed adults may visit regularly, are plausible factors that are accounted for the walkability index component of Land Use Mix. Their specific relationships may be masked by the composite index. For example, with regard to food, proximity of the nearest food-related land use, or clusters of food-related land use near to the worksite may be relevant BE features that could be evaluated in future investigations. As mentioned above, analyzing SEV models prior to MEV models may help clarify how BE around the worksite relates to PA.

Further considerations of this body of work include plausible unmeasured or untested confounding variables. Job type was not measured for individuals, which could relate to PA based on physical demands required by the job (e.g., lifting, moving objects) or a restrained ability to move from a work location (e.g., seated repetitive tasks or desk work). Other job-related factors such as inside-the workplace supports for PA were not accounted for. An indoor gym at work or policies allowing or encouraging workers to move during the workday, or incentives to take public transport may support PA regardless of the outdoor neighborhood environment. Discretionary time may be less available to those with children less than 18 years in the household, or whether one is the primary child caretaker may be similarly important, however determining discretionary time in PA studies may be problematic. While the analyses presented here controlled for annual household income and participants were recruited from neighborhoods with a wide range of socioeconomic statuses (i.e., median household income) using inclusion criteria, examining education as an additional controlling variable, or potential moderator, could provide further insights as to whom is more sensitive to BE features. A review of PA correlates and determinants specified education and income as variables of interest. While both appear correlated, neither appear to be determinants of adults' PA behavior.[11] This highlights the difficultly in establishing metrics for SES. For example, highly paid skilled laborers with relatively lower levels of education (e.g., electrician, pipe-fitter), compared to graduate degree holders in sectors typically receiving modest pay (e.g., education, non-profit organization) may obscure the influence of individual-level SES when applying only household income as a covariate, but for the same reasons, educational attainment alone may also be problematic. Future works could investigate including multiple metrics of SES, such as household income and education, as potential confounders or moderators.

A major strength of the current project includes accelerometer analyses using unique cutpoint values derived from laboratory-assessed walking matched to VO_2 consumption. All other accelerometer studies cited here quantify MVPA using generic single axis cutpoints. The current study's more personalized approach may not be comparable to previous literature assessing accelerometer MVPA with general cutpoint values, which limits generalizability, but the current study may have stronger internal validity of accelerometer results. An option for future investigation could compare the unique cutpoints and generic cutpoints on the same minute-level single-axis accelerometer to quantify how the two methodologies differ.

Further strengths of this work include the relatively large sample size of employed adults with objective measures of worksite (and home) neighborhood environment. Also, using several measures of PA outcomes, including domain- and context-specific self-report and accelerometer variables, is useful when considering the results in context with PA guidelines that were developed prior to widespread accelerometer use and relied on various questionnaire methodologies to relate PA to health benefits.[19]

Aim 3: Differences in the rate of change in PA over 56 days of a behavioral intervention by worksite walkability

This project did not find the rate of change in MVPA or SLPA to be moderated by worksite walkability during the initial 56 days of a PA intervention (Phase 2). Multilevel modeling (days nested within participants and including a time indicator) found no evidence of a direct association or moderation effect (worksite walkability x time interaction) before or after controlling for participant-level covariates (*p's* = .38 to .93 in Tables 19 and 20). Thus, this project did not support the hypothesis that worksite walkability would significantly moderate the rate of change in MVPA or SLPA over the first 56 days of a PA intervention.

Several covariates tested did show relationships to MVPA and SLPA analyses in notable ways. The expected improvements in model fit were discovered when adding baseline level of MVPA to the MVPA longitudinal model, (p <.001, Table 19). Interestingly, baseline MVPA was also shown to be important to modeling the rate of change of SLPA (p = .07, Table 20). Further, stemming from the Aim 2 results, having at least one child under 18 years in the household greatly improved model fit to rates of change for both MVPA and SLPA (p =.03 and p = .06, respectively). Curiously, in MVPA change models, day of the week was important for model fit (p = .06) yet month was not. However, the opposite was found in SLPA models, where month was (p = .002), yet day of week was not significantly improving model fit. These covariates may provide initial guidance for future studies investigating the BE in relation to longitudinal PA outcomes. While the findings presented here do not support the author's hypothesis that worksite walkability relates to PA during the initial 56 days of an intervention (i.e., the first two months of Phase 2), the project uncovers several points of interest.

Limitations for Aim 3

Several considerations of the longitudinal analyses of Aim 3 are noteworthy. While many of the strengths and limitations mentioned for Aims 1 and 2 apply, in Aim 3 an important strength is that participants were enrolled in a behavioral intervention purposely designed and previously found to increase PA.[20] The worksite BE is a theoretically important context in which PA can occur due to the frequency of exposure and the routine need to travel to the worksite. However, no part of intervention was targeted towards increasing PA specifically within the worksite neighborhood, and the intervention was ongoing for much longer than this analysis considered (participants consented to the intervention of period of 1 year). Participants would have had to serendipitously decide the worksite area was a context in which to be more active; they could have chosen areas around the home, or other places for PA. This may happen at different relative times for participants, some of which may have been later than the initial 56 days.

Another potential confounder is that the overall average relationship modeled in the longitudinal analyses may not be sensitive enough to specific subgroups of participants. As seen in Aim 2, which found particular person-level covariates that interacted with the direct relationship of worksite walkability to baseline levels of PA, the possibility of additional moderators to the worksite walkability by time interaction could reveal more nuanced relationships for important subgroups of participants.

While this analysis only included only days with at least 10 hours of accelerometer wear, then adjusted for accelerometer wear-time to further control for length of valid data capture on any given day, and modeled day-of-week to capture important the time-varying covariates, there may be additional time-varying covariates of importance that were not accounted for. Daily weather events, such as fog and thunder, have been shown to be important weather covariates in PA intervention studies in the same geographical region as the current project (Southwest USA).[20] Perhaps curiously, the same study found that the extreme temperatures common to the region were not related to PA[20] (i.e., summer high temperatures of 40-46 degrees Celsius). However, weather was not controlled for in the current project.

Of note, the analyses performed herein to test for moderated differences in rate of change during the intervention (Phase 2) after controlling for baseline PA (in Phase 1) does not test for average differences in level of PA from baseline to intervention. In future work, PA over the baseline (Phase 1) could be disaggregated in order to understand if differences were seen over time in both Phase 1 and Phase 2, instead of focusing on the trajectory of Phase 2. While change in PA due to the intervention was not of primary focus in this report, future studies of how behavioral interventions alter PA within varying BEs may provide additional context in which to better understand, and effect change on, health behavior.

The only two known studies that combined GPS located accelerometer data showed associations between worksite walkability measures and MVPA behavior.[1,2] Due to the current project's lack of concurrent GPS data, hypotheses including location-specific MVPA could not be tested. However, this secondary analysis project was designed to test associations in a larger sample of participants and part of a year-long behavioral intervention. Limited resources for equipment acquisition, GPS processing capacity and concerns over participant compliance were impactful considerations for excluding GPS data capture. The availability of self-reported PA data in specific contexts was explored in Aims 1 and 2, where inside versus outside the home neighborhood was included as a proxy for contextual behavior; however, most analyses showed no relationships.

This project was largely informed by cross-sectional relationships found in relatively modest samples of participants, and notably were not recruited chiefly because they were determined to be inactive before starting. Notably, the studies with geo-located accelerometer data included participants regardless of *a priori* PA status (i.e., intercepted trail users of Troped et al.; convenience sample of full-time women employees of Marquet et al.), which likely contributes to an important difference between participant samples in the current project's stringent screening for low-active individuals to be included in the longitudinal analyses. Notably, an early investigation in this topic area also found a lack of significant relationships, where Schwartz et al. looked at steps measured by accelerometer during the times of the day corresponding to work hours.[5] However, since that study, evidence has emerged that supports an association between worksite environment and health outcomes,[3,4,12,13,21] including PA.[2,6,17] New paths may need to be revealed to further explore longitudinal analysis of PA behavior in regards to contextual exposures, and access to a variety of neighborhoods with differing walkability characteristics. These considerations and more that have yet to be identified temper the strength of conclusions developed from the reported analyses, and results should be interpreted with caution.

This project had noteworthy strengths. The large sample sized afforded in this secondary analyses ranged from 364 to 512 participants, much greater than previous literature describing accelerometer-derived PA and objective worksite walkability.[2] Study participants were a convenience sample recruited for a PA intervention, but were heavily screened for insufficient PA prior to enrollment. This unique difference helps broaden the literature base to potentially generalize to those who are not currently meeting PA guidelines, which is a priority population to understand correlates and determinants of health behavior – they have the most to gain from becoming more active. And finally, the longitudinal design of Aim 3 over part of intervention to increase PA was the first known analyses looking at a cross-level interaction of worksite walkability to daily change in PA.

CHAPTER 6

CONCLUSION

In summary, worksite walkability was only related to physical activity (PA) for specific subgroups of relatively inactive adults employed outside the home. Independent analyses found that for women, adults without young children, and those identifying as non-Hispanic white (but not men, those with young children, and non-whites), PA is influenced by the walkability of the worksite neighborhood environment in the expected directions. The body of work presented within this dissertation was grounded in ecological models, and identified gaps in the literature to examine the relationships between worksite walkability and several PA outcomes in relatively large samples of insufficiently active participants. Following the ecological framework, this project examined individual behavior, both cross-sectionally and over the early period of a behavioral intervention, to understand how the built environment (BE) of worksite neighborhoods may be associated with context- and domain-specific PA along with total PA captured in various ways (i.e., self-report and objective accelerometer). Further investigation is compelled to understand which environmental contexts are more appropriate for promoting PA behavior, how to measure the environments, and in particular for whom environmental access or exposure may be most relevant.

Future Implications

We must further our efforts to understand the interplay between behavior and the BE, especially across multiple, or even continuous contexts. Near ubiquitous technology to capture behavior in situ, and existing data streams that can be crafted into informative data is within the grasp of health and other researchers. Ecological models and behavioral theories guide the understanding of both mechanisms and context of human movement. In particular, knowing who are more or less impacted by the BE and then working to create and redevelop places for equitable access and promotion of PA across sex, family status, and race-ethnicity, may be one avenue for improving the health of populations.

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