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Ecological correlates of physical activity among urban adult and adolescent populations: Findings from global and US contexts

A dissertation submitted in partial satisfaction of the
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in

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by

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The Dissertation of Lilian G. Perez is approved, and it is acceptable in quality and form for publication on microfilm and electronically:

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DEDICATION

This dissertation is dedicated to my loving parents who have been an incredible source of motivation, strength, and support throughout my academic and personal journey. They taught me to dream big and to never give up, no matter how difficult the path. This work is also dedicated to all the mentors in my life who placed their faith in me and shaped me to become the scientist that I am today. I owe many of my successes to these influential individuals.

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4. **Perez, L.G.**; Conway, T.L.; Arredondo, E.M.; Elder, J.P.; Kerr, J.; McKenzie, T.L.; & Sallis, J.F. (Under review). Where and when adolescents are physically active: Neighborhood environment and psychosocial correlates and their interactions.

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ABSTRACT OF THE DISSERTATION

Ecological correlates of physical activity among urban adult and adolescent populations: Findings from global and US contexts

by

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Doctor of Philosophy in Public Health (Global Health)

University of California, San Diego, 2017

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Background: Ecological models posit that interactions among factors at multiple levels (e.g., individual, psychosocial, and environmental) influence physical activity (PA). However, interactions involving environmental factors are the least understood. Intervention studies also suggest PA behavior change may depend on

the environments in which participants are encouraged to be active but such evidence from interventions targeting Latinos is limited.

Methods: Chapter 2 tested interactions between neighborhood environmental and socio-demographic factors on total moderate-to vigorous physical activity (MVPA) among an international adult sample (N=10,258). Chapter 3 examined interactions between neighborhood environmental and psychosocial factors on context-specific PA among an adolescent sample from the Baltimore/Seattle regions (N=910). Chapter 4 assessed the moderating effects of neighborhood environmental factors on the impacts of a physical activity intervention targeting Latinas in San Diego, CA at 12-months post-intervention (N=319).

Results: Chapter 2 found moderating effects by education and gender on the association between safety from crime and meeting high PA levels, with inverse associations found only among the high-education group and men. Education and gender moderated associations of safety from crime and the presence of transit stops with meeting minimum PA guidelines, with positive associations found for safety from crime only among women and the presence of transit stops only among men and the high-education group. Chapter 3 found moderating effects by decisional balance on the association between recreation facility density and neighborhood leisure-time PA among female adolescents, with a negative association found only among those with high decisional balance. Decisional balance also moderated the associations of neighborhood walkability with non-school MVPA among females and non-neighborhood leisure-time PA among males, with positive associations only among adolescents with high decisional balance. Chapter 4 showed higher total MVPA and leisure-time MVPA at 12-months post-intervention among participants with favorable perceived neighborhood aesthetics than those with less favorable evaluations.

Conclusions: This dissertation supports the ecological models' hypothesized interactions between environmental and individual/psychosocial factors on PA and the moderating role of the neighborhood environment on the impacts of a multilevel PA intervention targeting Latinas. Findings support global efforts targeting multiple levels of influence to promote population PA, health, and environmental sustainability.

CHAPTER 1: INTRODUCTION

OVERVIEW

Physical inactivity is a global pandemic that has serious negative health and economic impacts. The prevalence of physical inactivity is disproportionately higher in some countries, particularly high-income countries, and certain population groups within countries like females, older adults, and racial/ethnic minorities (in the US). The drivers of these disparities are not well understood but according to ecological models of health behavior, the correlates or determinants of physical activity exist at multiple levels such as individual (e.g., socio-demographic), psychosocial (e.g., self-efficacy), and environmental (e.g., neighborhood walkability). A key principle of ecological models is that factors across levels interact with one another to influence behavior. Such interactions suggest that the influence of a factor at one level (e.g., environment) on a behavior varies across subgroups of a second factor at a different level (e.g., individual). These second factors are known as effect modifiers or moderators. Of the possible interactions across levels of the model, those involving environmental factors are the least understood. Evidence of such interactions can help inform health behavior interventions identify and target the most important correlates of physical activity. Some studies have also shown that the environments in which participants are encouraged to be active may moderate the impacts of an intervention on physical activity behavior change. However, the overall evidence on the moderating effects of environmental factors on the impacts of physical activity interventions remains elusive. Thus, to further our understanding of the complex role of environmental factors on physical activity, this dissertation will examine the following Specific Aims in the context of diverse geographic settings and populations:

1. To test interactions between environmental and socio-demographic factors in relation to total physical activity among an international sample of urban adults;
2. To examine interactions between environmental and psychosocial factors in relation to context-specific physical activity among US adolescents; and
3. To assess whether perceived neighborhood environmental factors moderate the impacts of a multilevel intervention targeting Latinas' total and domain-specific physical activity at 12-months post-intervention.

To address these aims, analyses use cross-sectional data collected among an international sample of adults from nine countries in the "International Prevalence Study on Physical Activity" (IPS) (Aim 1 – Chapter 2) and a sample of urban adolescents, and one of their parents/guardians, from the Baltimore/Seattle regions in the "Teen Environment and Neighborhood" (TEAN) study (Aim 2 – Chapter 3). This dissertation also uses prospective data (baseline and 12-month follow-up) collected among a sample of Latina women from the "Faith in Action/*Fe en Acción*" multilevel physical activity intervention in San Diego, CA (Aim 3 – Chapter 4).

Findings from this dissertation contribute to a better understanding of whether and how environment-physical activity associations vary by population socio-demographic/psychosocial characteristics (e.g., low/high income or low/high levels of social support) and whether the impacts of a multilevel intervention on physical activity behavior change depend on how participants perceive characteristics (activity-supportiveness) of their neighborhood environments. In addition, evidence of interactions across levels of the ecological model can provide evidence to support, reject, or improve on current ecological models of physical activity. Overall, findings from this dissertation may help inform the development of future multilevel physical

activity interventions to promote physical activity among adult or adolescent populations.

BACKGROUND

Physical Activity

The World Health Organization defines physical activity as any bodily movement that works the skeletal muscles and requires energy expenditure.[1] From a public health perspective, physical activity refers to movement that enhances health.[2] Physical activity is a complex behavior that can be undertaken in different domains such as leisure (e.g., exercise or sports), transportation (e.g., walking or bicycling to get to/from destinations), and work. The total amount of physical activity is based on the intensity, duration, and frequency of activity from each domain. Physical activity can also be defined by the specific context in which activity takes place such as the location (e.g. neighborhood) or time (e.g., outside of school hours).

Physical activities of moderate- to vigorous-intensity are the focus of current physical activity recommendations due to their associated health benefits.[1,2] Physical activity intensities are expressed in metabolic equivalents (METs), which is the ratio of a person's working metabolic rate to their resting metabolic rate.[3] Activities of 3-6 METs such as brisk walking are defined as moderate-intensity and those of 6 or more METs such as running are considered vigorous. Light-intensity activities of less than 3 METs like stretching/yoga are also important for overall activity levels but are not usually emphasized because of the limited evidence of their health benefits.[4]

Physical activity can be measured by self-report (surveys) or objectively such as with accelerometers. Both types of measures have their strengths and limitations and their selection for research will depend on the research question and resources available.[5] For observational study designs (e.g., surveillance) and experimental

studies (e.g., interventions), self-report measures may be sufficient, though the use of accelerometer measures in such studies is now feasible and preferable when the interest is intensity-specific activity. Activity counts captured by accelerometers characterize the duration and intensity of movement of the device and can be translated into estimates of weekly or daily activity patterns (e.g., total moderate-to vigorous activity per week).[5] Accelerometer files can be truncated to estimate activity during specific times of the day such as beyond school or work hours. Accelerometers can also be combined with global position system (GPS) devices to capture contextual information such as activity in specific locations.[6] One limitation of accelerometry is that it cannot differentiate between domains of activity (e.g., leisure vs. transportation) unless combined with GPS or other measures. Thus, self-report measures remain valuable for assessing domain-specific behaviors.

Epidemiology and Global Health Impacts

Physical inactivity is now considered a global pandemic, with 23% of adults and 80% of adolescents (11-17 years of age) worldwide engaging in less than the minimum levels of physical activity recommended for health.[7] Adults aged 18 years and older are recommended at least 150 minutes per week of moderate-intensity aerobic activity, or 75 minutes per week of vigorous-intensity aerobic activity, or an equivalent combination of moderate- and vigorous-intensity physical activity (MVPA).[1,2] Children and adolescents aged 5-17 years are recommended at least 60 minutes of physical activity daily, with most of that activity being either of moderate- or vigorous-intensity.

The prevalence of physical inactivity is disproportionately higher in high-income countries compared to those of low- or middle-income.[8] The highest rates of physical inactivity among adults are in the Americas and eastern Mediterranean,

while the lowest is in southeast Asia.[8] Disparities also exist among populations within countries. National health survey data show women and racial/ethnic minorities have the lowest rates of physical activity.[9] In particular, Latinos are the largest racial/ethnic minority group in the US,[10] but only 45% meet the physical activity recommendations, based on self-report, compared to 54% of non-Latino Whites.[11] Among Latinos, women are significantly less active than men.[12,13] Gender differences in the prevalence of physical activity are also observed among adolescents in the US and globally.[7,14] Approximately 27% of adolescents in the US meet the physical activity recommendations, with the rate among males being double (36%) that of females (17%).[14] This difference may be due to female adolescents' lower rates of sports participation[14] and lower activity levels in specific contexts, including their neighborhood and near their school, compared to males.[15]

Physical inactivity has major global health and economic consequences. In 2013, physical inactivity was responsible for 13 million DALY's (disability-adjusted life years) and cost health-care systems international $54 billion worldwide.[16] It is estimated that if all adults met the physical activity recommendations, 6-10% of the global burden of major non-communicable chronic diseases (coronary heart disease, type 2 diabetes, and breast and colon cancers), 4% of the burden of dementia, and 9% of all-cause mortality could be averted annually.[7,17] Youth can also attain health benefits from engaging in physical activity, including improved bone health, mental health, cardio-metabolic risk factors, and reduced risk of breast cancer in adulthood.[18-20] Youth who engage in physical activity are also more likely to be physically active as adults, thus promoting active lifestyles in early ages can have both short- and long-term health benefits.[20]

CONCEPTUAL FRAMEWORK

The conceptual framework for this dissertation is adapted from ecological models of health behavior.[21] This framework posits that physical activity behaviors are influenced by interactions between correlates at multiple levels of influence, such as individual (biological/socio-demographic), psychosocial, and environmental (see Figure 1.1).

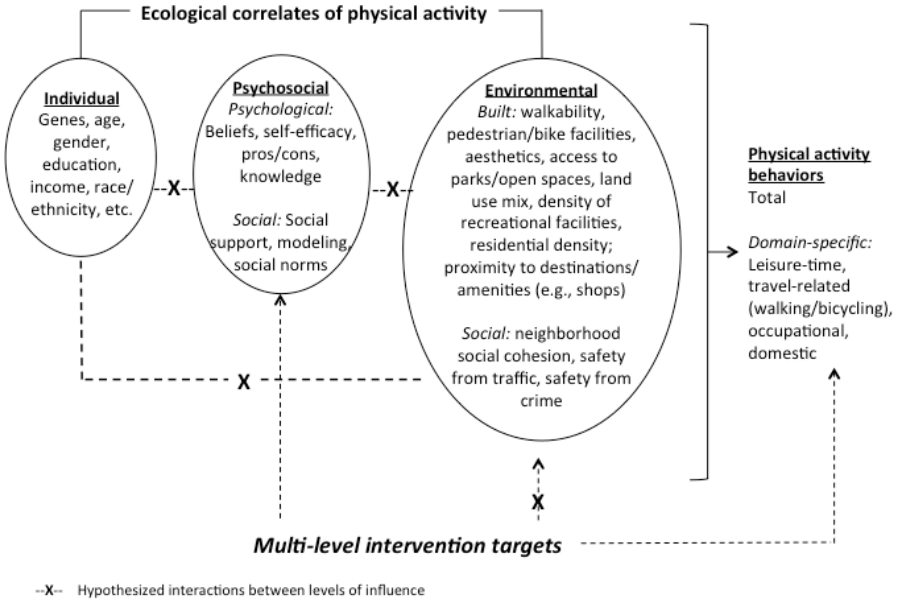

Figure 1.1: Ecological correlates and hypothesized interactions in relation to physical activity.

At the individual-level, socio-demographic correlates related to higher physical activity include younger age, being male, and high education, among others.[7,22] Positive psychosocial correlates include high social support, high self-efficacy to do physical activity, high perceived benefits of physical activity, etc.[7,23] Positive environmental correlates include high access to destinations (land use mix) and parks/recreational facilities, enjoyable scenery and aesthetics, etc.[7,24] Multilevel

physical activity interventions based on the ecological model target correlates at multiple levels, namely psychosocial and environmental.

Several studies have reported interactions across levels of the model in relation to physical activity among adults[25-27] but there is less evidence available for adolescents[28,29]. One study involving an international sample of adults found interactions of gender and age with some perceived neighborhood environmental factors in relation to accelerometer-based MVPA.[25] For example, higher perceived neighborhood safety from crime was significantly related to higher accelerometer-based MVPA among women and respondents above average age (of the sample) while the associations were non-significant among men and younger respondents. A different study involving Belgian adolescents found interactions between self-efficacy (a psychosocial factor) and several perceived neighborhood environmental factors in relation to self-report active transportation and leisure-time physical activity.[29] For example, closer proximity to destinations from home was significantly related to less active transportation among adolescents with high levels of self-efficacy while the association was positive among those with lower levels. A major limitation of previous research investigating interactions across the ecological levels in relation to physical activity is the focus on populations from single countries. Findings from such studies can have limited external validity to other population groups or geographic contexts. Few studies have the opportunity to test such interactions using data from multiple countries representing broad geographic and sociopolitical diversity.

Furthermore, although interventions targeting multiple levels of influence to promote physical activity are becoming available, few studies have examined the moderating effects of participants' environments on the impacts of such interventions. There is limited evidence showing that certain characteristics of the environments in

which participants are encouraged to be active facilitate or impede an intervention's effects on physical activity behavior change. One study examined longitudinal data from three different physical activity interventions and found moderating effects by perceived traffic safety.[30] That is, participants in the physical activity condition who reported less safety from traffic had fewer self-reported physical activity minutes/week at follow-up compared to those who reported traffic to be less of an issue.[30] There was no reduction in physical activity among the comparison group by perceived safety from traffic.[30] Few studies have tested such moderating effects in the context of physical activity interventions targeting Latina women. Because Latinos tend to report less favorable perceptions of their neighborhoods (e.g., lower perceived safety from crime)[31,32] compared to non-Latino Whites, studies are needed examining the moderating effects of Latinos' perceptions of their neighborhood environments on the effects of physical activity interventions. Evidence of perceived environmental moderators could help identify the environmental conditions needed to maximize intervention effects on increasing Latinos' physical activity levels.

This dissertation aims to address the aforementioned gaps in the literature by testing interactions between environmental and socio-demographic factors in relation to total physical activity among an international sample of adults (Aim 1) and interactions between environmental and psychosocial factors in relation to adolescents' context-specific physical activity (Aim 2). We also test the moderating effects of perceived neighborhood environmental factors on the impacts of a multilevel intervention on Latinas' physical activity levels at 12-months post-intervention (Aim 3).

AIMS AND HYPOTHESES

Based on the conceptual framework described above and a review of the

literature on the ecological correlates of physical activity among adults and adolescents, this dissertation has the following aims and corresponding hypotheses:

Aim 1 (Chapter 2): To test interactions between environmental and socio-demographic factors in relation to total MVPA among an international sample of urban adults. Hypothesis 1.1: Only among younger age groups, men, and adults with higher education, there will be positive associations of perceived residential density; the presence of shops, transit stops, sidewalks, bicycle facilities, or recreation facilities in the neighborhood; and overall neighborhood walkability with total MVPA. Hypothesis 1.2: Only among older adults, women, and those with higher education, there will be positive associations between perceived safety from crime and total MVPA.

Aim 2 (Chapter 3): To examine interactions between environmental and psychosocial factors in relation to context-specific physical activity (neighborhood, non-neighborhood, and non-school activity) among US adolescents. Hypothesis 2.1: Only among adolescents with higher levels of social support, decisional balance, or self-efficacy for physical activity, there will be positive associations of the objective neighborhood environment and parental perceived neighborhood safety factors and aesthetics with context-specific physical activity. Hypothesis 2.2: Only among adolescents with fewer parental rules for physical activity, there will be positive associations of the objective neighborhood environment and parental perceived neighborhood safety factors and aesthetics with context-specific physical activity.

Aim 3 (Chapter 4): To assess whether perceived neighborhood environmental factors moderate the impacts of a multilevel intervention targeting Latinas' total MVPA and domain-specific physical activity (leisure and transportation) at 12-months post-inter. Hypothesis 3.1: Total MVPA and domain-specific physical activity at 12-months

follow-up will be significantly higher among intervention participants compared to attention-control participants only if they reported higher (favorable) baseline perceptions of their neighborhood environment, i.e., sidewalk maintenance, safety from traffic, safety from crime, neighborhood aesthetics, neighborhood social cohesion, and access to destinations or recreational facilities near the home.

GLOBAL HEALTH IMPLICATIONS

Findings from this dissertation can contribute to a better understanding of the ecological models' hypothesized interactions between physical activity correlates at the individual, psychosocial, and environmental-levels. This dissertation examines such interactions among populations from diverse geographic settings, age groups, and cultures. Findings from our analyses of interactions between environmental and socio-demographic factors among an international sample of adults (Aim 1) can provide support for international recommendations for interventions and policies targeting built environment changes to promote physical activity equitably across a population. Findings from our analyses of interactions between environmental and psychosocial factors among a sample of US adolescents (Aim 2) can help identify the most important psychosocial and environmental targets for interventions aimed to promote adolescents' physical activity in specific contexts, which may lead to more overall physical activity. Furthermore, this dissertation examines whether certain characteristics of participants' neighborhood environments maximize or impede the effectiveness of a multilevel intervention promoting physical activity (Aim 3). Findings from Aim 3 can help inform future physical activity multilevel interventions targeting Latinas by identifying the environmental conditions that might facilitate and/or sustain physical activity behavior change. Overall, findings from this dissertation research have the potential to support, reject, or improve upon current ecological models of

physical activity and inform the development of future public health multilevel interventions to promote population levels of physical activity.

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CHAPTER 2: SOCIO-DEMOGRAPHIC MODERATORS OF ENVIRONMENT-PHYSICAL ACTIVITY ASSOCIATIONS: RESULTS FROM THE INTERNATIONAL PREVALENCE STUDY

ABSTRACT

Purpose: Single-country studies suggest associations between the built environment and physical activity (PA) vary by socio-demographic factors. However, such evidence from international studies involving more diverse samples and geographical contexts is limited. This study tested the moderating effects of socio-demographic factors on associations between perceived environment and self-report total PA among adults from the International Prevalence Study (IPS).

Methods: Between 2002-2003, adults from nine countries (N=10,258) completed surveys assessing total PA (IPAQ-short), perceived neighborhood environment, and socio-demographics. Total PA was dichotomized as meeting/not meeting a) high PA levels (per IPAQ-short categories) and b) minimum PA guidelines (PAG). Logistic models tested interactions between eight environment and three socio-demographic factors (age, gender, and education).

Results: The association between safety from crime and meeting high PA levels was moderated by education and gender (interaction $p<0.05$), with significant (inverse) associations found only among the high-education group and men. Education and gender also moderated associations of safety from crime and the presence of transit stops with meeting minimum PAG (interaction $p<0.05$), with significant (positive) associations found for safety from crime only among women and the presence of transit stops only among men and the high-education group.

Conclusions: We found few moderating effects by gender and education, but not age, on associations between perceived environment and self-report total PA. The limited evidence for socio-demographic moderators provides support for population-wide environment-PA associations. International efforts to improve built environments are needed to promote health-enhancing PA, and maintain environmental sustainability.

Keywords: Built environment, urban planning, effect modification, global health, physical activity, socio-demographics

INTRODUCTION

A quarter of adults worldwide does not meet the minimum physical activity guidelines (PAG), with older adults, women, and individuals with lower education being the least active and therefore at highest risk of adverse health outcomes.[1-4] The WHO recommends adults engage in a minimum of 150 minutes/week of aerobic moderate-to vigorous-intensity physical activity (MVPA).[2] Exceeding the minimum PAG can provide additional health benefits such as preventing unhealthy weight gain.[2] Because physical inactivity is contributing to the high rates of obesity worldwide,[5,6] a clear understanding of the factors influencing PA is warranted. According to ecological models, factors at the individual- (e.g., biological and psychological), social- (e.g., social support), and physical (built) environmental-level interact with one another to influence PA.[7-9] Of the possible interactions across levels, those involving environmental factors remain the least understood. Examining interactions between environmental and individual-level characteristics of residents (socio-demographics) can help inform interventions targeting environments to promote PA equitably across a population.

The neighborhood environment has been of particular focus in PA research given it's potential to promote or impede PA, including leisure-time and transport-related PA (walking or bicycling to/from places).[10] For example, neighborhood environmental factors related to total PA include proximity of recreational facilities and neighborhood aesthetics.[9] However, there are inconsistent associations reported for some environmental factors like safety from crime.[11] Such inconsistencies merit further examination such as testing whether certain characteristics of the population are explaining these variations (i.e., socio-demographic moderators). Some studies suggest that associations between neighborhood environmental factors and PA vary

by age, gender, and socio-economic status, but findings have been inconsistent.[12-19] Much of the evidence on interactions between environmental and socio-demographic factors has come from single country studies, whose findings are limited by the samples and context under study. Differences in methodology across studies can also contribute to inconsistencies. Multi-country studies that employ comparable measures and protocols across sites can enhance our understanding of the moderating effects of socio-demographic factors on associations between the environment and PA among nationally-representative samples from a geographically diverse set of countries.

In 2015, the International Physical Activity and Environment Network (IPEN) examined socio-demographic moderators of associations between perceived environmental factors and accelerometer-based PA among an international sample of adults and found a few moderating effects by gender and age, but not education.[15] The study reported positive associations between perceived environmental factors (e.g., safety from crime) and accelerometer-based PA only among older adults and women. Because associations between the environment and PA can depend on the measure of PA (objective or self-report),[20] the socio-demographic moderators of associations of the environment with PA based on accelerometry may differ from those with associations involving self-report PA. As such, to better understand whether and how associations of the neighborhood environment with PA differ systematically by socio-demographic factors, evidence from self-report and objective PA studies is needed. Consistent findings from both types of studies would support stronger recommendations for interventions and policies.

The present multi-country analyses attempted to replicate findings and extend understanding from the aforementioned IPEN study[15] by examining socio-

demographic moderators of associations of perceived environmental factors with self-report total PA. Replicating or reproducing population health associations is critical for assessing the robustness of research findings among different populations, increasing confidence in findings from previous research, and for informing program/policy decisions.[21] The present study used data from the earlier International Prevalence Study (IPS),[22] which involved a different set of countries, samples, and PA measures (self-report) than the IPEN study. We focused on total PA because the frequency of PA in each domain varies greatly between countries (e.g., leisure-time PA rates are higher in high-income countries).[23] Thus, total PA allows us to account for those differences.

The aim of the present study was to test whether age, gender, and education moderated associations of perceived environmental factors with self-report total PA. In line with the findings reported in the IPEN study,[15] we hypothesized positive associations between perceived safety from crime and self-report total PA only among older adults and women. Although the IPEN study did not find moderating effects by education, such effects were found in two other studies from the US[14] and Australia[18]. Those studies reported positive associations between environmental factors (e.g., safety and walkability) and self-report PA only among adults with higher education, leading to our corresponding hypothesis.

METHODS

Study Design

This cross-sectional study used data collected between 2002 and 2003 from the International Prevalence Study (IPS). IPS was a collaborative international project whose goal was to obtain nationally or regionally representative prevalence estimates of PA among adults aged 18-65 years from a geographically diverse set of countries.

Eleven of the 20 countries approved for IPS also included a perceived environment survey. For the present research, only the nine countries with comparable measures for PA, perceived environment, and socio-demographics (age, gender, and education) were included in the analyses: Canada, Colombia, Hong Kong (special administrative unit of China), Japan, Lithuania, New Zealand, Norway, Sweden, and the USA. At the time of the study (2002-03), Colombia was a lower-middle income country, Lithuania an upper-middle income, and the rest high-income countries.[24] The final analytical sample included 10,258 adults. Participants provided informed consent verbally or in writing. All participating centers provided a statement of ethics approval.

Recruitment

Details of IPS's sampling, recruitment, and data collection are described elsewhere.[22] Countries meeting the following criteria were invited to participate: willing to obtain a population sample at least 1,500 adults representative of the overall population in a country or significant region within a country (i.e., at least 1,000,000), use comparable data collection methods, and use approved cultural translations of the short version of the International Physical Activity Questionnaire (IPAQ-short).[22] The majority of countries used either multistage stratified random sampling or simple random sampling. Only Japan sampled from universities and worksites from different regions of the country. Adults (aged 18-65; or 18-40 in Japan) from each site were selected by random household sampling.

Data Collection

Data were collected in the spring or fall of 2002/2003 to reduce possible seasonal variation in total PA. Participants completed the questionnaires on their own, or via phone or face-to-face interviews with trained interviewers. Prior to data collection, surveys developed in a language other than English were translated and

back-translated to English and approved by the investigators. Present analyses were limited to participants living in towns or cities with population sizes of 30,000 or more because the environmental surveys were not suitable for rural environments, consistent with a previous IPS publication.[25]

Measures

Total physical activity. The 9-item IPAQ-short assessed self-report total PA in the last 7 days across all domains (i.e., leisure, domestic, transportation, and occupational)[26] and at 4 intensity levels: vigorous (e.g., aerobics), moderate (e.g., leisure cycling), walking, and sitting. In a 12-country study with adults, the IPAQ-short showed acceptable test-retest reliability (ρ = 0.76) and fair-to-moderate criterion validity against accelerometers (ρ = 0.30).[26] For the present study, we dichotomized self-report total PA 2 ways: (a) meeting/not meeting high PA levels and (b) meeting/not meeting minimum PAG. The former outcome was based on categories proposed in the IPAQ scoring protocol,[27] while the latter outcome was based on the WHO's recommendations for aerobic PA.[2]

The WHO recommends at least 75 min/week of vigorous-intensity PA, or 150 min/week of moderate-intensity PA, or an equivalent combination of moderate-and vigorous-intensity PA. Analysis of this outcome allowed for comparison of present results to those of previous studies, including IPS publications.[25] However, because the WHO recommendations [2] are largely based on leisure-time PA and the IPAQ-short measured total PA across all domains, we expected the prevalence of meeting minimum PAG would be overestimated.[25,28] Thus, we used the PA categories proposed in the IPAQ-short scoring protocol[27] to categorize respondents as meeting/not meeting high PA levels, defined as reporting (a) vigorous-intensity PA on at least three days, achieving a minimum of at least 1500 MET-min/wk or (b) seven or

more days of any combination of walking, moderate-, or vigorous-intensity PA, achieving at least 3000 MET-min/wk. This high PA category equates to approximately 1.5-2 hours of moderate-intensity total PA per day.

Perceived environment. The Physical Activity Neighborhood Environment Survey (PANES)[29] assessed perceived environmental factors for walking/bicycling in the neighborhood, defined as the area within a 10- to 15-minute walk from home. The 17-item scale used single items instead of multi-item scales to measure each environmental attribute. Each item has been validated against the abbreviated Neighborhood Environment Walkability Scale (NEWS-A) with spearman correlations ranging from 0.27 to 0.81.[29] Test-retest reliability of the scale has been evaluated in multiple countries, such as Sweden (ICCs: 0.36-0.98)[30] and Nigeria (ICCs: 0.43-0.91)[31].

The seven core environmental items assessed across the 9 countries included: a) main type of residential housing (residential density), b) having shops and other retail destinations in the neighborhood (mixed land use), c) presence of transit stops near home, d) presence of sidewalks, e) presence of bicycle facilities, f) access to free/low cost recreational facilities (e.g., parks), and g) safety from crime at night. Response options for all items except residential housing ranged from 1= 'strongly agree' to 4= 'strongly disagree' and were recoded as 1= 'strongly agree/agree' or 0= 'strongly disagree/disagree.'[28] Residential housing type was dichotomized to contrast detached single-family homes (lower residential density) from all other housing types (higher residential density).[28]

We computed a neighborhood environment index based on the six built environment items, i.e., excluding safety from crime.[28] In separate analyses, it was evident that the safety from crime variable reduced the Cronbach's alpha and should

be assessed separately from the index.[28] The final built environment index had scores ranging from 0-6 and a Cronbach's alpha=0.55.[28] We examined the environment index as a continuous variable, with higher scores indicating greater neighborhood walkability and activity-supportiveness.

Socio-demographics. Surveys assessed respondents' age, gender, and highest level of education attained. We dichotomized education as <13 years versus ≥13 years of education.[28] Using the median split of age, we grouped respondents into one of two categories, 18-37 versus 38-65 years of age.

Analyses

We computed descriptive statistics for the pooled and weighted sample. Data were weighted to each country's population to account for differential probabilities of sampling within each site. Two separate multivariate logistic regression models, adjusted for country site, examined the associations of the socio-demographic and perceived environmental factors with each PA outcome. Because the environmental index included scores from 6 of the environmental factors, we fitted additional models with just the environmental index, safety from crime, and socio-demographic variables included. This was done to avoid multicollinearity issues.

To examine whether the environment-PA associations depended on socio-demographic factors, we first tested 2-way interactions of all 3 socio-demographic factors with each environmental factor. With 8 environmental factors, this lead to 8 initial models testing 3 two-way interactions for each outcome. This step allowed us to assess for the presence of multiple socio-demographic moderators of the relationship between a single environmental factor and PA outcome. From these initial interaction models, we identified interaction terms with $p<.10$. This p-value was used to minimize type 2 error. Finally, we tested those interactions with $p<.10$ simultaneously in a full

model for each outcome. Using a backwards elimination approach, we removed the least significant interaction terms from the full models one at a time until only those terms with $p<.05$ remained. All interaction models were adjusted for country site and the other environmental factors not in the interaction terms. The models involving interactions with the environmental index were adjusted for country site and the safety from crime variables only. For each significant interaction from the full models, we estimated the association between the perceived environmental factor and PA outcome at each level of the socio-demographic moderator. Because the analyses involved multiple hypothesis testing, we also used a Bonferroni adjustment to identify interaction terms with $p<.002$ (i.e., 0.05/24 statistical tests). The Bonferroni adjustment reduces the probability of making a type 1 error; however, it also increases the chance of committing a type 2 error.[32] Some researchers view this method as too conservative.[32] For the present analyses, we present results for the models not adjusted for Bonferroni and indicate those that remained significant with the adjustment.

RESULTS

Sample characteristics

Among the sample (mean age ±SD =38 ±13 years), approximately half were women and respondents with high education (Table 2.1). The proportion of respondents who met high PA levels was 48% and about 83% met minimum PAG. The majority of respondents reported the environmental factors in question were present in their neighborhoods, except for bicycle facilities (Table 2.1). Half of respondents reported their neighborhoods were safe from crime.

Associations of socio-demographic and perceived environmental factors with PA

There were significant inverse associations of age and being female with both

PA outcomes (Table 2.2). There was also a significant inverse relation between education and meeting high PA levels. Significant positive associations for both PA outcomes were found with the presence of shops or bicycle facilities, and a higher built environmental index. Additional significant associations were found for each PA outcome, with an inverse association between high residential density and meeting high PA levels and a positive association between the presence of sidewalks in the neighborhood and meeting minimum PAG.

Socio-demographic moderators of associations of perceived environment with PA

For meeting high PA levels, 2 out of 24 interactions were significant at $p<.05$, i.e., between perceived safety from crime and both education and gender (Table 2.2). With the Bonferroni adjustment, only the interaction between perceived safety from crime and gender was significant ($p<.002$). Probing the interactions showed that perceived safety from crime was significantly related to lower odds of meeting high PA levels only among the high-education group (OR=0.83, 95% CI: 0.73, 0.94) and men (OR =0.80, 95% CI: 0.70, 0.90) (Table 2.3).

For meeting minimum PAG, 3 out of 24 interactions were significant at $p<.05$, i.e., between perceived safety from crime and gender as well as perceived presence of transit stops and both gender and education (Table 2.2). There was a significant positive association between perceived safety from crime and meeting minimum PAG only among women (OR= 1.23, 95% CI: 1.06, 1.44) (Table 2.3). Significant positive associations were found between perceived presence of transit stops and meeting minimum PAG only among men (OR=1.27, 95% CI: 1.01, 1.59) and the high-education group (OR=1.26, 95% CI: 1.03, 1.54) (Table 2.3). But those with lower education had a significant inverse relationship between perceived presence of transit stops and meeting minimum PAG (OR=0.70, 95% CI: 0.53, 0.94) (Table 2.3).

DISCUSSION

This multi-country study found only a small number of socio-demographic moderating effects, consistent with the overall results of the IPEN study that investigated socio-demographic moderators of associations between perceived environment and objective PA.[15] The only moderating effects found in the present study were for gender and education. The presence of such moderating effects and the direction of the associations appeared to depend on the PA outcome examined. Only gender had a consistent direction of moderating effects on the association between perceived safety from crime and both PA outcomes, with associations in the positive direction only among women. Surprisingly, among men and respondents with higher education, higher perceived safety from crime was related to lower likelihood of meeting high PA levels. In addition, among these same sub-groups, there were positive associations between the presence of transit stops and meeting minimum PAG.

A previous IPS publication found no significant relationship between perceived safety from crime and meeting minimum PAG.[28] Thus, present analyses extended prior results by showing the associations of perceived safety from crime with meeting high PA levels or the minimum PAG varied by gender and education. Perceived safety from crime was significantly related to higher odds of meeting minimum PAG among women but lower odds of meeting high PA levels among men. When accounting for the Bonferroni adjustment, only the moderating effects of gender on the relationship between perceived safety from crime and meeting high PA levels was significant. Evidence of gender differences in the relationship between perceived safety (from crime, traffic, etc.) and PA was reported in a review of 41 studies from the US, Australia, and Europe.[11] The review found 5 studies reporting a positive

association only among women; none of the studies reviewed reported inverse associations. The IPEN study also found moderating effects by gender on the association between perceived safety from crime and accelerometer-based PA, with a positive association found only among women.[15] Perceptions of feeling less safe from crime tend to be more prevalent among women than men.[33] Our findings suggest women may be more sensitive to perceptions of neighborhood safety than men, which may lend to less engagement in PA in the neighborhood, potentially leading to lower overall activity levels.

Our finding that perceived safety from crime was inversely related to meeting high PA levels among men and those with higher education was unexpected, but we provide a few possible explanations. The gender moderating effect was in line with one US study, which found inverse associations between perceived safety from crime and PA (accelerometer-based MVPA and self-report walking for leisure) only among men.[14] That same study also reported a *positive* association between perceived safety from crime and self-report walking for leisure among the high-education group.[14] However, our findings show an *inverse* relationship between perceived safety from crime and meeting high PA levels among the high-education group. Because the aforementioned studies used a different operationalization of PA from the present study (i.e., domain-specific/accelerometer-based vs. self-report total PA), findings are not directly comparable. Nevertheless, a possible explanation for the inverse associations of perceived safety from crime and high PA among men and the high-education group is that they are spending more time outside their neighborhood (e.g., at work) and may be less aware of crime activity in their neighborhoods, thereby perceiving it to be safe. People who spend less time in their neighborhoods may be less aware of their neighborhood surroundings.[34] Among those perceiving low levels

of neighborhood safety, there may be higher motivation to access gyms/recreational facilities outside their neighborhood. Another possible explanation is that for those with high education, living in a safer but less dense/walkable neighborhood may pose a barrier to PA. In our study, a higher proportion of respondents with high education reported living in neighborhoods with predominantly single-family homes (less dense neighborhoods) compared to those with lower education. Overall, compared to the other perceived environmental factors, associations between perceived safety from crime and PA appeared to be more complex and may depend on contextual factors (e.g., location and purpose of PA). Examination of the influence of additional contextual factors was beyond the scope of the present study.

Gender and education also moderated the association between perceived presence of transit stops and meeting minimum PAG. A previous IPS publication found a positive relationship between the presence of transit stops and meeting minimum PAG among the overall sample.[28] In our study, such positive associations were found only among men and the high-education group. Among the low education group, the presence of transit stops was inversely related to meeting minimum PAG. A related finding was reported in the IPEN study, which found moderating effects by gender, but not education, on the relationship between land use mix-access and accelerometer-based PA.[15] The land use mix-access measure assessed the presence of stores/destinations and transit stops in the neighborhood. The authors found a positive association between land use mix-access and accelerometer-based PA only among men.[15] Our findings showed that only the presence of transit stops, but not shops, were related to meeting minimum PAG among men. The IPEN study authors explained that land use mix-access was mostly related to men's PA because they had a higher prevalence of meeting minimum PAG while the prevalence was

much lower in women, thereby reducing power. We found a similar gender difference in PA levels. Another potential explanation for the positive associations observed among men and respondents with high education may be that these individuals used public transit more often (e.g., to get to and from work) and were therefore more aware of the presence of transit stops. Individuals who use public transit can achieve 30 or more min/day of PA solely by walking to and from transit stops.[35] Although in the US those with lower education and women tend to show higher mean daily minutes of walking to and from transit stops compared to those of higher education and men,[35] respectively, public transit use patterns in other countries may show different patterns. Public transit use is more common in European countries than in the US and Australia because European cities tend to be more compact and dense and have greater land use mix, greater restrictions on car use, and high costs associated with owning/operating a vehicle (e.g., high gasoline prices).[35] Additional research is needed to better understand public transit use patterns in an international context.

Strengths and limitations

Strengths of the present study include the use of comparable data from a large sample of adults from multiple countries and use of validated questionnaires to assess PA and the perceived environment. Multi-country studies provide greater variability in neighborhood and population characteristics that are often relatively homogeneous in single-country studies. However, our analyses only involved middle- to high-income countries. It is possible that low-income countries would yield different results. Another limitation was use of self-report measures. The IPAQ has been shown to overestimate PA.[36,37] To address the overestimation issue, we also examined associations with meeting high PA levels, which had greater variability than

meeting minimum PAG. Self-report PA measures can introduce recall bias, but they are valuable in assessing activities that standard accelerometer techniques may not capture (e.g., biking and swimming). Self-report measures of the environment are moderately correlated with some objective environment measures, but there are differences for certain factors such as proximity to transit stops.[38] Self-report environment measures can also assess perceptions of the social environment such as safety from crime, which can be challenging to measure using objective tools. Our measure of PA was not specific to the neighborhood, potentially weakening associations with the neighborhood environmental factors.

Overall, the present multi-country study found limited evidence for socio-demographic moderators of associations between the perceived neighborhood environment and self-report total PA, a conclusion consistent with the IPEN study.[15] Consistent conclusions from two different multi-country studies (IPS and IPEN) involving a different set of countries, sample selection methods, and measures (objective/self-report PA), provide strong evidence for population-wide associations between the neighborhood environment and PA. The present research demonstrates the importance of replicating and extending published research for assessing the robustness of research findings and informing future interventions.[21] Interventions targeting the neighborhood environment to make it more activity-supportive and that inform the population of the resources and opportunities to be active, may help improve residents' perceptions of their neighborhoods and in turn, encourage PA in the neighborhood. Prospective studies are needed to examine the mechanisms by which improvements to the environment influences PA behavior change. In conclusion, present findings provide additional support for international

recommendations to improve built environments for population-wide benefits for physical activity, health, and environmental sustainability.[39-41]

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Table 2.1: Weighted characteristics of the pooled sample of 10,258 adults from nine countries. IPS, 2002-2003.

Characteristic	
Socio-demographic	
Age in years, mean (SD)	37.8 (12.6)
Female, %	50.8
High education (≥ 13 years), %	48.9
Physical activity (PA)	
Meets high PA levels, %[a]	48.0
Meets minimum PA guidelines, %[b]	83.2
Perceived environment [c]	
High residential density, %	64.4
Presence of shops near home, %	78.3
Presence of transit stops near home, %	87.6
Presence of sidewalks, %	82.2
Presence of bicycle facilities, %	47.7
Presence of recreational facilities, %	64.4
Safety from crime, %	52.3
Environmental index (range: 1-6), mean (SD) [d]	4.2 (1.5)

Notes: IPS= International Prevalence Study; SD= standard deviation

[a] Reported vigorous PA on ≥3 days, achieving ≥1500 MET-min/wk OR ≥7 days of any combination of walking or moderate- or vigorous- PA, achieving ≥3000 MET-min/wk.

[b] Reported ≥75 min/wk of vigorous PA, or ≥150 min/wk of moderate PA, or any equivalent combination of moderate-and vigorous-PA.

[c] Percentages represent proportion of respondents who somewhat/strongly agreed the environmental factor was present or high.

[d] Average of scores from the perceived environmental factors listed except safety from crime.

Table 2.2: Socio-demographic moderators of associations between perceived environmental factors and physical activity. IPS, 2002-2003.

	Meets high PA levels [a]		Meets minimum PAG [b]	
	B (SE)	*p*	B (SE)	*p*
Models without interactions [c]				
Age [d]	-0.21 (0.02)	<.0001	-0.22 (0.03)	<.0001
Female	-0.22 (0.02)	<.0001	-0.09 (0.03)	0.0006
High education	-0.15 (0.02)	<.0001	-0.03 (0.03)	0.38
High residential density	-0.07 (0.03)	0.005	-0.05 (0.03)	0.09
Presence of shops near home	0.06 (0.03)	0.03	0.11 (0.03)	0.002
Presence of transit stops near home	-0.04 (0.04)	0.29	0.01 (0.04)	0.74
Presence of sidewalks	0.03 (0.03)	0.28	0.18 (0.04)	<.0001
Presence of bicycle facilities	0.13 (0.02)	<.0001	0.07 (0.03)	0.03
Presence of recreational facilities	0.04 (0.02)	0.11	0.009 (0.03)	0.78
Safety from crime	-0.03 (0.02)	0.21	0.03 (0.03)	0.31
Models for environmental index without interactions [c, e]				
Age [d]	-0.20 (0.02)	<.0001	-0.22 (0.03)	<.0001
Female	-0.43 (0.04)	<.0001	-0.18 (0.06)	0.001
High education	-0.29 (0.05)	<.0001	-0.05 (0.06)	0.40
Safety from crime	-0.03 (0.05)	0.55	0.07 (0.06)	0.22
Environmental index [d]	0.11 (0.02)	<.0001	0.17 (0.03)	<.0001
Models with significant interactions [c]				
Age [d]	-0.21 (0.02)	<.0001	-0.22 (0.03)	<.0001
Female	-0.59 (0.06)	<.0001	-0.06 (0.16)	0.70
High education	-0.18 (0.06)	0.006	-0.53 (0.16)	0.0009
High residential density	-0.14 (0.05)	0.006	-0.12 (0.06)	0.07
Shops near home	0.11 (0.06)	0.04	0.22 (0.07)	0.002
Transit stops near home	-0.07 (0.07)	0.35	-0.16 (0.17)	0.34
Sidewalks present	0.06 (0.06)	0.31	0.36 (0.07)	<.0001
Bicycle facilities present	0.27 (0.05)	<.0001	0.13 (0.06)	0.03
Recreational facilities present	0.08 (0.05)	0.10	0.03 (0.06)	0.64
Safety from crime	-0.11 (0.07)	0.13	-0.09 (0.08)	0.26
Safety from crime X education	-0.24 (0.08)	0.004	-	-
Safety from crime X gender	0.31 (0.08)	0.0002 [f]	0.28 (0.11)	0.02
Presence of transit stops X gender	-	-	-0.32 (0.16)	0.04
Presence of transit stops X education	-	-	0.55 (0.17)	0.001 [f]

Notes: IPS= International Prevalence Study; PA = physical activity; PAG = Physical Activity Guidelines; SE= standard error.

[a] Reported vigorous PA on ≥3 days, achieving ≥1500 MET-min/wk OR ≥7 days of any combination of walking or moderate- or vigorous- PA, achieving ≥3000 MET-min/wk.

[b] Reported ≥75 min/wk of vigorous PA, or ≥150 min/wk of moderate PA, or any equivalent combination of moderate-and vigorous-PA.

[c] Models are weighted and adjusted for country site.

[d] Variables were standardized to have a mean=0 and SD=1.

[e] Because of multicollinearity with the environment variables, the index was tested in a separate model with the socio-demographic and "safety from crime" variables only.

[f] Interactions significant at Bonferroni adjusted *p*-value of 0.002.

Table 2.3: Associations of perceived environmental factors with physical activity at varying levels of the socio-demographic moderators. IPS, 2002-2003.

Environmental factor and level of moderator	Meets high PA levels [a] OR (95% CI) [c]	Meets minimum PAG [b] OR (95% CI) [c]
Safety from crime		
Association in low education	1.06 (0.94, 1.19)	
Association in high education	0.83 (0.73, 0.94)	
Safety from crime		
Association in men	0.80 (0.70, 0.90)	0.90 (0.76, 1.06)
Association in women	1.09 (0.97, 1.23)	1.23 (1.06, 1.44)
Transit stops present		
Association in men		1.27 (1.01, 1.59)
Association in women		0.84 (0.67, 1.06)
Transit stops present		
Association in low education		0.70 (0.53, 0.94)
Association in high education		1.26 (1.03, 1.54)

Notes: CI=Confidence interval; IPS= International Prevalence Study; OR=Odds Ratio; PA = physical activity; PAG = Physical Activity Guidelines

[a] Reported vigorous PA on at least 3 days, achieving a minimum total PA of at least 1500 MET-min/wk OR 7 or more days of any combination of walking or moderate- or vigorous- PA, achieving a minimum total PA of at least 3000 MET-min/wk.

[b] Reported ≥75 min/wk of vigorous PA, or ≥150 min/wk of moderate PA, or any equivalent combination of moderate-and vigorous-PA.

[c] Models are weighted and adjusted for age, country site, and all other environmental factors in the model.

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CHAPTER 3: WHERE AND WHEN ADOLESCENTS ARE PHYSICALLY ACTIVE: NEIGHBORHOOD ENVIRONMENT AND PSYCHOSOCIAL CORRELATES AND THEIR INTERACTIONS

ABSTRACT

Background: Female adolescents are less active than male peers in certain contexts including the neighborhood. Adolescents' physical activity can be explained by interactions between environmental and psychosocial factors, but few studies have tested such interactions in relation to context-specific behaviors. This study tested interactions between neighborhood environmental and psychosocial factors in relation to adolescents' context-specific physical activity.

Methods: Data were collected in 2009-11 from 910 adolescents and a parent/guardian from the Baltimore/Seattle regions. Measures included adolescent-reported neighborhood leisure-time physical activity (LTPA) and non-neighborhood LTPA, accelerometer-based non-school moderate-to vigorous-physical activity (MVPA), psychosocial factors, and objective and parent-perceived neighborhood environmental factors. Gender-stratified mixed effects linear models tested associations of 6 environmental and 4 psychosocial factors and their interactions in relation to each physical activity outcome.

Results: The psychosocial factors had consistent associations with the physical activity outcomes but the environmental correlates were context-specific. Decisional balance (weighing of pros and cons of physical activity) moderated the association between recreation facility density and neighborhood LTPA among females, with a negative association only among those with high decisional balance (pros outweighed cons). Decisional balance also moderated associations of neighborhood walkability

with non-school MVPA among females and non-neighborhood LTPA among males, with positive associations among only those with high decisional balance.

Conclusions: Results support context-specific ecological models of physical activity. Targeting environmental factors that may promote opportunities for physical activity in specific contexts as well as adolescent decision-making may help promote their physical activity in those contexts, potentially leading to increased overall physical activity.

Keywords: Adolescent, behavioral context, effect modification, psychosocial, recreation facility, walkability

INTRODUCTION

Childhood/adolescent obesity rates over the past four decades have risen as their rates of physical activity have declined, especially in areas like active transportation (walking/bicycling), school-based physical education, and outdoor play.[1] Youth who engage in physical activity gain numerous health benefits[2-4] and are more likely to be physically active as adults[4]. National guidelines recommend youth engage in at least 60 minutes of physical activity daily, with most of that activity being of moderate-to vigorous-intensity.[5] Based on national surveys, only 27% of adolescents meet these recommendations, with the prevalence among males (36%) being double that of females (17%).[6] This difference may be explained partially by the higher sports participation rate among male adolescents.[6] Female adolescents are also significantly less active than males in specific contexts like their neighborhood and near their school.[7] Studies based on ecological models suggest that the individual (e.g., socio-demographic), psychosocial, and environmental correlates of adolescents' physical activity may be gender-specific.[8-11] For example, males with higher peer social support and females with fewer barriers are more physically active than their peers with less social support or more barriers, respectively.[9,10] In another study, accelerometer-assessed moderate-to vigorous- physical activity (MVPA) among female adolescents was related to several objectively-measured environmental factors like neighborhood walkability and distance to recreational centers (inverse), but significant environmental correlates for males' MVPA were not found.[9] Although ecological models posit that factors at multiple levels (e.g., environment and psychosocial) interact with one another to influence behavior,[8] few studies have examined such interactions in relation to adolescents' physical activity within specific time and location contexts. Specifying the context in which physical

activity takes place may help improve the predictive capacity of relevant correlates, and interactions among them.[12]

Although some consistent psychosocial (e.g., self-efficacy) and environmental (e.g., good access to recreation facilities) correlates of adolescents' physical activity have been identified,[13] other potential correlates have had mixed results. For example, at the psychosocial-level, fewer perceived barriers (cons) and greater perceived benefits (pros) have been linked to higher physical activity in adolescents in some studies but others report null associations.[13-15] The mixed findings for some of these correlates may be partly due to differences in measurement assessment of the outcome or exposure (e.g., objective vs. perceived) across studies.[16] In addition, because most environment measures are specific to a certain setting such as the neighborhood while physical activity measures are typically broader (e.g., overall walking), this lack of context-specificity of the behavior may weaken the environment-physical activity associations.[12] The inconsistent associations between environmental factors and physical activity may also be due to differences in population characteristics. For example, one study found moderating effects by self-efficacy (a psychosocial factor) on the association between land use mix and adolescents' self-reported active transportation, with a positive association found among those with lower self-efficacy and negative association in those with higher self-efficacy.[17]

There is limited evidence of interactions between environmental and psychosocial factors on adolescents' physical activity,[17,18] especially in relation to context-specific behaviors. Evidence of such interactions may extend our understanding of factors driving adolescents to be more or less active during specific times (e.g., during/beyond school hours) and locations (e.g., within/outside the neighborhood). For example, if adolescents living in neighborhoods with easy access

to parks are active in their neighborhoods only if they have high levels of social support, then interventions could be developed to target family/friends to support adolescents to use the neighborhood parks.

The aims of the present study were to test associations of environmental and psychosocial factors, and their interactions, with adolescents' context-specific physical activity, specifically (a) self-report neighborhood leisure-time physical activity (LTPA), (b) self-report non-neighborhood LTPA, and (c) accelerometer-based non-school MVPA (i.e., beyond school hours). Further, given the evident gender differences in adolescents' physical activity, we examined these aims among males and females separately.

METHODS

This cross-sectional study analyzed data from the Teen Environment and Neighborhood (TEAN) study. TEAN was an observational study of the neighborhood environment and physical activity among adolescents (aged 12-16 years) residing in the Baltimore, MD/Washington, DC and Seattle-King County, Washington metropolitan regions.

Participant recruitment

As described previously,[19] the 2000 Census was used to identify 447 block groups in the Baltimore, MD/Washington, DC and Seattle/King County, WA regions that met study design criteria for household income and walkability. Median household incomes for block groups were deciled and dichotomized by median split to create low- and high-income categories. A walkability score for each block group was estimated using Geographic Information Systems (GIS) measures of residential density, intersection density, retail floor area ratio, and land use mix.[19] The block group walkability index scores were deciled and dichotomized by the median split to

create low- and high-walkability categories. Using these income/walkability categories, the census block groups were grouped into one of the four quadrants: a) low income/low walkability, b) low income/high walkability, c) high income/low walkability, and d) high income/high walkability. A list obtained from a marketing company was used to identify households within each quadrant with adolescents 12-16 years of age. The study team contacted households selected at random via phone and mailed the occupants information about the study. Recruitment and measurement occurred across all quadrants simultaneously, but during the school year only. Adolescents were excluded if they had a condition that could affect their physical activity (e.g., physical disability), dietary habits (e.g., eating disorder), or participation (e.g., developmental disability). Out of 2619 eligible households contacted by phone, 36% agreed to enroll in the study. Participation rates were similar across the four neighborhood quadrants. The final sample included 928 adolescents and one of their parents/guardians. Parent informed consent and adolescent assent was obtained in writing and the Institutional Review Boards of the participating institutions approved the study.

Data collection

Data were collected between 2009 and 2011. Participating adolescents wore an accelerometer and completed a survey assessing physical activity, psychosocial factors, perceived neighborhood environment, and socio-demographics. One parent/guardian of each participant completed a separate survey assessing similar variables.

Measures

Table 3.1 describes the survey and objective measures. In brief, adolescents reported their frequency of neighborhood leisure-time physical activity (LTPA)[20]

(Cronbach's alpha=0.81) and non-neighborhood LTPA[21] (Cronbach's alpha=0.80). Participants were also mailed an Actigraph accelerometer with detailed instructions on wearing the device for at least 7 days with at least one weekend day. Non-school moderate-to vigorous-physical activity (MVPA) was defined as MVPA (≥2296 counts/min)[22] accrued between 3-11 pm on weekdays and all day on weekend days. Neighborhood walkability and recreation facility density were measured within a 1-km buffer around the participant's home address.

Adolescents and their parent/guardian evaluated the same neighborhood environment measures in separate surveys. Preliminary analyses showed stronger correlations between the physical activity outcomes and the parent/guardian-perceived environment scores than the adolescent scores. Thus, we used only the parent/guardian scores, including safety from traffic, pedestrian safety, safety from crime, and neighborhood aesthetics.[23] A previous study reported ICC's of 0.66 (traffic and pedestrian safety combined), 0.78 (safety from crime), and 0.61 (aesthetics).[23]

Adolescent psychosocial factors included six physical activity-specific measures adapted from previous surveys[18,24] including social support (ICC range: 0.68-0.74),[24] decisional balance or the weighing of the benefits (pros) and barriers (cons) to being physically active[25] (pros ICC=0.74 and cons ICC=0.86),[24] self-efficacy (ICC=0.71),[24] and parental rules (ICC=0.68)[18].

Adolescents reported their age, gender, ethnicity, and employment/volunteer status, among other factors. Parents reported their highest level of education, marital status, household income, number of vehicles in the household, number of children/adults in the household, and work status. Variables significantly (p<.05) related to the outcomes were included as covariates in the models.

Analyses

Data from the two regions were pooled for analysis. One male participants' accelerometer data was deemed an extreme outlier and was excluded from the non-school MVPA model. Two female participants' GIS data for recreation facility density were also extreme outliers and were excluded from all analyses.

The final analytical sample included 454 females and 456 males and their parent/guardian, i.e., those with complete data for self-report physical activity, perceived and objective neighborhood environment, and the psychosocial variables. The analytical sample for the accelerometer outcome was reduced because 23 females and 21 males did not provide accelerometer data. Student t-tests or chi-square tests revealed that those excluded from analysis due to missing data did not differ significantly on socio-demographics compared to the analytical sample.

Mixed-effects linear models assessed the multivariate associations of the neighborhood environment and psychosocial factors with each outcome – neighborhood LTPA, non-neighborhood LTPA, and non-school MVPA. All continuous variables were centered on the gender-specific grand means. All models controlled for walkability/income quadrant, site (King County or Maryland regions), and census block group (random effect). The accelerometer-based non-school MVPA analyses also controlled for the device model and wear time. For all models, we tested for multicollinearity among the independent variables.

To assess the moderating effects of the psychosocial factors, we tested 24 interaction terms (between the six neighborhood environment and four psychosocial variables) separately for each outcome. Interaction terms from the single-interaction models with $p<.10$ were identified and tested in a full model to assess their multiplicative effects. From the full models, we used a backwards elimination

approach, removing the least significant interaction terms one at a time until only those with $p<.05$ remained. We did not adjust for multiple hypothesis testing given the reduced power to detect interactions and the exploratory nature of the study. We plotted significant interactions to show the association of the neighborhood environment factor with the physical activity outcome at low (-1 SD) or high (+1 SD) levels of the psychosocial moderator.

RESULTS

Participant characteristics

Participants (mean age ± SD= 14.1 ± 1.4 years) were predominantly non-Hispanic Caucasian (66%) and high socio-economic status as shown by their parent/guardian's high education and household income (Table 3.2).

Males were significantly more active than females for all three physical activity outcomes but their neighborhood environment scores were similar (Table 3.2). Although similar levels of social support and decisional balance were found among males and females, males had significantly higher self-efficacy and females had significantly more parental rules (Table 3.2).

Multivariate associations of neighborhood environment and psychosocial factors with context-specific physical activity

Table 3.3 shows neighborhood environmental and psychosocial correlates of physical activity among female participants. The only significant main effect for neighborhood environmental correlates was parent/guardian-perceived safety from crime, specifically in relation to non-neighborhood LTPA (B (SE) = 0.08 (0.03), $p=0.02$) and non-school MVPA (B (SE) = 1.15 (0.57), $p=0.04$). Regarding psychosocial factors, social support was positively related to both neighborhood LTPA (B (SE)= 0.48 (0.06), $p<.0001$) and non-neighborhood LTPA (B (SE) = 0.33

(0.04), $p<.0001$). Self-efficacy was also positively related to both non-neighborhood LTPA (B (SE) = 0.09 (0.04), $p=0.01$) and non-school MVPA (B (SE) = 1.48 (0.59), $p=0.01$). Parental rules were negatively related to both neighborhood LTPA (B (SE) = -0.05 (0.02), $p=0.005$) and non-neighborhood LTPA (B (SE) = -0.02 (0.01), $p=0.04$).

Table 3.3 also shows the only significant neighborhood environmental correlate of physical activity among males was recreation facility density, which related to more non-neighborhood LTPA (B (SE) = 0.02 (0.01), $p=0.03$). For the psychosocial factors, social support and self-efficacy were positively associated with all three physical activity outcomes. Parental rules were negatively related to neighborhood LTPA (B (SE) = -0.05 (0.02), $p=0.005$).

Psychosocial moderators of associations between neighborhood environmental factors and context-specific physical activity

Among female participants, only decisional balance had significant moderating effects, specifically on associations of some of the neighborhood environmental factors with neighborhood LTPA and non-school MVPA (Table 3.4). For neighborhood LTPA, there was a significant interaction between recreation facility density and decisional balance (B (SE) = -0.03 (0.01), interaction $p=0.03$). Among females with high decisional balance (pros outweighed cons to being physically active), there was a negative association between recreation facility density and neighborhood LTPA (Figure 3.1 A). For non-school MVPA, the only significant interaction was between neighborhood walkability and decisional balance (B (SE) = 0.51 (0.25), interaction $p=0.04$) (Table 3.4). Walkability was positively related to non-school MVPA only among females with high decisional balance (Figure 3.1 B). Among females living in a high walkable neighborhood, those with higher levels of

decisional balance accrued about 3 more minutes of non-school MVPA daily than those with lower levels, which translated to about 21 additional minutes/week.

Among male participants, decisional balance moderated the association between walkability and non-neighborhood LTPA (B (SE) = 0.04 (0.02), interaction *p*=0.01) (Table 3.5). The association between walkability and non-neighborhood LTPA was positive among males with higher levels of decisional balance and negative among those with lower levels (Figure 3.2).

DISCUSSION

We found associations of neighborhood environmental and psychosocial factors, and their interactions, with adolescents' physical activity in specific locations and times, thereby supporting context-specific ecological models of physical activity. The psychosocial factors self-efficacy, social support, and parental rules had consistent associations in the main effects models for all three outcomes. The neighborhood environmental factors showed gender- and context-specificity, with positive associations of parent/guardian-perceived safety from crime with non-neighborhood LTPA and non-school MVPA among females only and between recreation facility density and non-neighborhood LTPA among males only. The interaction models showed that only decisional balance had moderating effects on some of the neighborhood environment-physical activity associations but the moderating effects were not always in the expected direction. There was an *inverse* association between recreation facility density and neighborhood LTPA only among female participants with high decisional balance (reported more pros than cons to being physically active). However, among adolescents with high decisional balance, there was a *positive* association between neighborhood walkability and non-school MVPA in females and non-neighborhood LTPA in males.

From the main effects models, parent/guardian-perceived neighborhood safety from crime was related to higher non-neighborhood LTPA and non-school MVPA among females only. In another study, parents reporting greater perceived risk of harm to their child in the neighborhood (lower safety) were more likely to report constraining behaviors (e.g., forbidding their child to play with friends outdoors in the neighborhood), which related to less self-reported active transportation and accelerometer-based MVPA in the evening among female adolescents.[26] Parents may perceive girls to be at greater risk of harm such as by molestation or assault and, perhaps unintentionally, permit or promote greater risk-taking among boys.[27] Parents with higher perceived neighborhood safety may have had fewer rules in place for where/when their child can do physical activity, potentially lending to females' higher physical activity outside the neighborhood and beyond school hours.

Among males, greater recreation facility density was related to higher non-neighborhood LTPA. In a different study of adolescent's context-specific physical activity, greater recreation facility density was related to higher self-reported outdoor non-school physical activity (away from school) among males only.[28] Our finding was unexpected given the contextual mismatch between the exposure (recreational facilities in the *neighborhood*) and outcome (*non-neighborhood* LTPA). To our surprise, none of the neighborhood environmental factors were significantly related to neighborhood LTPA. One hypothesis for why we found an association between neighborhood recreation facility density and non-neighborhood LTPA among males may be due to differences in how the "neighborhood" was defined by participants, the parent/guardian, and the objective measures. Children/adolescents may perceive smaller spatial neighborhood boundaries than their parents or GIS-based buffers.[29,30] Using consistent neighborhood boundaries may help reduce Type 2 error and

improve statistical power to detect significant associations between neighborhood environmental factors and neighborhood-based physical activity.[12,31]

Context-specific physical activity was positively related to social support and self-efficacy but inversely related to parental rules in both males and females. These findings are consistent with other studies on non-context-specific physical activity among adolescents.[9,14,26] In another TEAN publication, none of the four psychosocial factors examined here were significantly related to adolescents' active travel to/from school.[18] It is possible that psychosocial factors are more influential on leisure-time or personal choice physical activity than that accrued from necessity (e.g., walking to school).

The moderating effects by decisional balance reflect an interaction between adolescent decision-making and opportunities for physical activity (e.g., neighborhood environment). Among the few studies examining psychosocial moderators of associations between neighborhood environmental factors and adolescent physical activity,[17,18] none that we are aware of has reported moderating effects by decisional balance. We found that decisional balance moderated the association between recreation facility density and females' neighborhood LTPA, with an unexpected *inverse* association found only among those with high decisional balance (reported more pros than cons to being physically active). A similar unexpected finding was reported in a study that found an inverse association between land use mix (closer proximity to destinations) and active transportation among adolescents with high self-efficacy.[17] Other features of the recreation facilities not measured in this study may be explaining this finding. For example, the quality of those facilities may be just as important as their access/proximity to adolescents' LTPA. If adolescents live in neighborhoods with good access to recreation facilities but those facilities are run-

down or vandalized, then adolescents may be discouraged to use them. Examining access/proximity and quality of recreation facilities in the neighborhood may provide a more comprehensive picture of the role of recreation facilities on neighborhood LTPA. For females with low decisional balance, access to more recreation facilities and therefore more opportunities for physical activity in the neighborhood may help them overcome some barriers to being active.

We also found moderating effects of decisional balance on associations of neighborhood walkability with females' non-school MVPA and males' non-neighborhood LTPA, with positive associations only among those with high decisional balance as expected. More walkable neighborhood environments support active lifestyles, including both choice - (leisure) or necessity- (transportation) driven physical activity behaviors. When neighborhoods are more walkable, female adolescents with high decisional balance may perceive greater opportunities to reap the benefits of physical activity after school hours. Females with low decisional balance may not perceive such opportunities because their perceived benefits to physical activity are outweighed by barriers like feeling embarrassed if seen doing physical activity. Females with lower decisional balance may also have lower self-efficacy to do physical activity.

Living in a more walkable neighborhood may also reduce some of the perceived barriers to physical activity among males with low decisional balance and encourage them to be physically active in their neighborhood instead of further away. In contrast, living in a less walkable neighborhood may contribute to their perceived barriers and motivate them to seek physical activity opportunities outside their neighborhood. Males with high decisional balance living in high walkable neighborhoods may also be from high SES households and have parents that model

or encourage physical activity and sports outside the neighborhood. Sports participation among adolescents is more common in higher-income families than those of lower income.[32] We did not control for household income or parent education/employment because they were not significantly correlated with any of the physical activity outcomes. Thus, neighborhood walkability may be related to non-neighborhood LTPA among males through socio-economic and parental influences not measured in our study.

Strengths and limitations

Strengths of this study include using perceived and objective measures of the environment and physical activity. Future studies could strengthen the measures of context-specific physical activity by using simultaneous global positioning system-accelerometer monitoring.[33] The study had a large enough sample to conduct gender-stratified analyses. In addition, the environmental data were collected from participants from two different US regions and from neighborhoods selected to be diverse in SES and built environments.

Limitations of the study include potential variations in perceived and objective neighborhood boundary definitions, which may introduce Type 2 error and weaken associations between neighborhood environmental factors and neighborhood-based physical activity. The cross-sectional nature of the study did not allow for causal inferences. Also, because no other study that we are aware of has tested interactions across levels of the ecological model in relation to context-specific physical activity among adolescents, our analyses were exploratory. As such, we did not adjust for multiple hypothesis testing and until additional studies are conducted, the results should be interpreted with caution.

Conclusions

This research supports the application of ecological models for examining the plurality of potential influences on adolescents' physical activity across multiple time/location contexts. The main effects results indicate that both psychosocial and environmental factors have relevance for context-specific physical activity among adolescents. Findings for the interactions suggest that the combination of neighborhood environmental opportunities and decision-making by adolescents are related to their physical activity behaviors. Multilevel interventions targeting both psychosocial and environmental factors are needed to help promote adolescents' physical activity in specific contexts, which may potentially lead to increased overall physical activity.

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Table 3.1: Teen Environment and Neighborhood (TEAN) study measures.

Measure	Description/sample items	Response options	Scoring
Physical activity			
Neighborhood leisure-time physical activity (LTPA)	Frequency of LTPA in 5 specific locations outside the home in the neighborhood, (e.g., nearby park/open space).	0= 'never,' 1= 'once a month or less,' 2= 'once every other week,' 3= 'once a week,' 4= '2 or 3 times/week,' 5= '4 or more times/week'	Mean score.
Non-neighborhood LTPA	Frequency of LTPA in 15 specific locations outside the neighborhood such as indoor recreation/exercise facility, trails, and indoor swimming pool. Items adapted from original scale to ask about use instead of distance/proximity to location.	0= 'never,' 1= 'once a month or less,' 2= 'once every other week,' 3= 'once a week,' 4= '2 or 3 times/week,' 5= '4 or more times/week'	Mean score.
Non-school moderate-to vigorous-physical activity (MVPA)	Models: Actigraph 7164 (90% of sample), GT1M (7%), or GT3X (3%). Epoch: 30 seconds. Non-wear time: 30 minutes of consecutive zero-count values. Valid wear time: ≥10 hours/day on ≥5 valid days, including at least 1 weekend day. Non-school time: between 3-11 pm on weekdays and all day on weekend days. Cut points: Evenson MVPA (≥ 2296 counts per minute). Data processing software: MeterPlus.	N/A	Mean daily non-school MVPA minutes.
Objective neighborhood environment			
Walkability	For each study region, standardized scores were computed for 4 GIS-based urban form measures within a 1-km network buffer around participant's home: residential density, land use mix, intersection density, and retail floor area ratio (retail building square footage divided by retail land square footage).	N/A	Weighted sum of z-scores for the four normalized environmental measures.
Recreation facility density	Count of parks and private recreation facilities within the 1-km network buffer around participant's home.	N/A	Total number of parks/recreation facilities.
Parent/guardian -perceived neighborhood environment			
Safety from traffic	3 items, e.g., "the speed of traffic on most streets is usually low (30 mph or less)."	1= 'strongly disagree' to 4= 'strongly agree'	Mean score after reverse-coding 2 negative statements.
Pedestrian safety	3 items, e.g., "streets have good lighting at night."	1= 'strongly disagree' to 4= 'strongly agree'	Mean score.
Safety from crime	1 item, "there is a high crime rate."	1= 'strongly disagree' to 4= 'strongly agree'	Reverse-coded score.
Neighborhood aesthetics	4 items, e.g., "there are many interesting things for my child to look at while walking."	1= 'strongly disagree' to 4= 'strongly agree'	Mean score.
Adolescent psychosocial factors			
Social support	Frequency of instrumental and encouragement social support for physical activity from adults in the household (3 items) and siblings/friends (2 items).	0= 'never' to 4= 'very often'	Mean score.
Decisional balance	5 items asked about the benefits of physical activity (pros) such as "physical activity would help me stay fit" and 5 items were about the negative aspects (cons) such as "physical activity takes time away from being with my friends."	1= 'strongly disagree' to 4= 'strongly agree'	Mean score of the pros items minus mean score of the cons items.
Self-efficacy	6 items asked how sure respondents were that they could do physical activity in given situations (e.g., "when you feel sad or stressed"), in the past year.	1= 'I'm sure I can't' to 5= 'I'm sure I can'	Mean score.
Parental rules	14 yes/no parental rules such as "stay close to or within sight of your home/parent" and "come in before dark."	Yes/No	Sum of the number of 'yes' responses.

Table 3.2: Characteristics of TEAN study sample, stratified by gender (N=910).

Characteristic	Females n=454	Males n=456
Adolescent socio-demographics		
Age in years, mean (SD)	14.2 (1.4)	14.0 (1.4)
Non-Hispanic Caucasian, n (%)	301 (67.2)	300 (65.8)
Works/volunteers outside home, n (%)	151 (33.3)	130 (28.5)
Parent/guardian socio-demographics		
Completed college education or higher, n (%)	344 (76.4)	339 (74.3)
Married/living as married, n (%)	373 (82.9)	389 (85.3)
Employed, n (%)	331 (73.7)	352 (77.2)
Annual household income, n (%) [a]		
< $60,000	85 (19.6)	96 (22.0)
$60,000-$90,000	111 (25.6)	99 (22.7)
≥ $90,000	238 (54.8)	242 (55.4)
Children in household, mean (SD)	2.1 (1.2)	2.0 (1.0)
Vehicle access, mean (SD) [b]	1.1 (0.4)	1.1 (0.4)
Adolescent physical activity		
Self-report neighborhood LTPA score, mean (SD) **	1.4 (1.2)	2.0 (1.3)
Self-report non-neighborhood LTPA score, mean (SD) **	1.2 (0.7)	1.4 (0.8)
Accelerometer-based non-school MVPA (min/day), mean (SD) **	16.1 (10.2)	23.5 (13.6)
Valid number of hours/day, mean (SD) *	6.4 (1.2)	6.6 (1.1)
Objective neighborhood environment		
Walkability index, mean (SD)	0.02 (2.6)	-0.2 (2.7)
Recreation facility density, mean (SD)	4.5 (5.1)	4.2 (4.9)
Parent/guardian-perceived neighborhood environment		
Traffic safety, mean (SD)	2.6 (0.6)	2.6 (0.6)
Safety from crime, mean (SD)	3.1 (0.9)	3.1 (0.9)
Pedestrian safety, mean (SD)	2.8 (0.6)	2.8 (0.7)
Neighborhood aesthetics, mean (SD)	3.1 (0.6)	3.1 (0.6)
Adolescent psychosocial factors		
Social support, mean (SD)	2.1 (0.9)	2.1 (0.9)
Decisional balance, mean (SD)	2.1 (0.7)	2.0 (0.7)
Self-efficacy, mean (SD) *	3.5 (1.0)	3.6 (1.0)
Parental rules, mean (SD) **	9.2 (3.0)	8.2 (3.1)

Notes: LTPA= leisure-time physical activity, MVPA= moderate-to vigorous-physical activity, SD= standard deviation, TEAN= Teen Environment and Neighborhood

* Sex differences significant at $p<.05$.

** Sex differences significant at $p<.0001$.

[a] Missing n=20 in female sample and n=19 in male sample.

[b] Number of vehicles per licensed driver in household.

Table 3.3: Gender-specific multivariate associations of neighborhood environment and psychosocial factors with context-specific physical activity outcomes. [a]

	Self-report neighborhood LTPA	Self-report non-neighborhood LTPA	Accelerometer-based non-school MVPA (min/d)
Independent variables	B (SE)	B (SE)	B (SE)
Females	n=454	n=454	n=431
Objective neighborhood environment			
Walkability index	0.004 (0.03)	0.01 (0.02)	0.42 (0.27)
Recreation facility density	-0.02 (0.01)	-0.01 (0.01)	-0.06 (0.13)
Parent/guardian-perceived neighborhood environment			
Traffic safety	-0.03 (0.09)	-0.03 (0.05)	-0.23 (0.86)
Safety from crime	0.08 (0.06)	0.08 (0.03)*	1.15 (0.57)*
Pedestrian safety	0.05 (0.08)	-0.07 (0.05)	-0.74 (0.80)
Neighborhood aesthetics	-0.08 (0.09)	0.05 (0.05)	1.00 (0.82)
Adolescent psychosocial factors			
Social support	0.48 (0.06)**	0.33 (0.04)**	1.12 (0.61)†
Decisional balance	-0.003 (0.08)	-0.005 (0.05)	0.96 (0.76)
Self-efficacy	0.10 (0.06)†	0.09 (0.04)*	1.48 (0.59)*
Parental rules	-0.05 (0.02)*	-0.02 (0.01)*	-0.29 (0.17) †
Males	n=456	n=456	n=435
Objective neighborhood environment			
Walkability index	0.003 (0.04)	-0.001 (0.02)	-0.02 (0.39)
Recreation facility density	0.01 (0.02)	0.02 (0.01)*	0.12 (0.18)
Parent/guardian-perceived neighborhood environment			
Traffic safety	0.17 (0.11)	0.05 (0.06)	0.95 (1.21)
Safety from crime	-0.11 (0.07)	-0.02 (0.04)	-0.80 (0.77)
Pedestrian safety	-0.00005 (0.09)	0.05 (0.05)	0.67 (0.98)
Neighborhood aesthetics	0.02 (0.09)	0.06 (0.05)	0.43 (1.05)
Adolescent psychosocial factors			
Social support	0.42 (0.07)**	0.31 (0.04)**	2.39 (0.85)*
Decisional balance	0.03 (0.09)	0.002 (0.05)	-0.65 (0.94)
Self-efficacy	0.23 (0.07)*	0.20 (0.04)**	2.95 (0.74)**
Parental rules	-0.05 (0.02)*	-0.02 (0.01)	-0.40 (0.22)†

Notes: LTPA= leisure-time physical activity, MVPA = moderate-to vigorous-physical activity, SE = standard error

†$p<.10$

*$p<.05$

**$p<.0001$

[a] All models adjusted for adolescents' age and work/volunteer status, walkability/income quadrant, site (King County or Maryland regions), and census block (random effect). Accelerometer-based models also adjusted for valid wear time and device used. All independent variables were centered on the gender-specific grand means.

Table 3.4: Significant psychosocial moderators of associations between neighborhood environmental factors and context-specific physical activity among *female* participants. [a]

	Self-report neighborhood LTPA (n=454)		Accelerometer-based non-school MVPA (n=431)	
	B (SE)	*p*	B (SE)	*p*
Objective neighborhood environment				
Walkability index	0.01 (0.03)	.74	0.44 (0.27)	.10
Recreation facility density	-0.02 (0.01)	.19	-0.09 (0.13)	.47
Parent/guardian-perceived neighborhood environment				
Traffic safety	-0.02 (0.09)	.80	-0.24 (0.86)	.78
Safety from crime	0.09 (0.06)	.16	1.15 (0.56)	.04
Pedestrian safety	0.06 (0.08)	.45	-0.80 (0.80)	.31
Neighborhood aesthetics	-0.08 (0.09)	.35	1.09 (0.82)	.18
Adolescent psychosocial factors				
Social support	0.48 (0.06)	<.0001	1.14 (0.61)	.06
Decisional balance	-0.02 (0.08)	.85	1.05 (0.76)	.17
Self-efficacy	0.11 (0.06)	.09	1.50 (0.59)	.01
Parental rules	-0.05 (0.02)	.004	-0.26 (0.17)	.13
Significant interactions				
Recreation facility density X decisional balance	-0.03 (0.01)	.03	-	-
Walkability index X decisional balance	-	-	0.51 (0.25)	.04

Notes: LTPA= leisure-time physical activity, MVPA = moderate-to vigorous-physical activity, SE = standard error

[a] All models adjusted for adolescents' age and work/volunteer status, walkability/income quadrant, site (King County or Maryland regions), and census block (random effect). Accelerometer-based model also adjusted for valid wear time and device used. Independent variables are centered on the grand means for the female sample.

Table 3.5: Significant psychosocial moderators of associations between neighborhood environmental factors and context-specific physical activity among *male* participants (n=456). [a]

	Self-report non-neighborhood LTPA	
	B (SE)	*p*
Objective neighborhood environment		
Walkability index	-0.002 (0.02)	.93
Recreation facility density	0.02 (0.01)	.02
Parent/guardian-perceived neighborhood environment		
Traffic safety	0.03 (0.06)	.58
Safety from crime	-0.02 (0.04)	.69
Pedestrian safety	0.05 (0.05)	.33
Neighborhood aesthetics	0.06 (0.05)	.26
Adolescent psychosocial factors		
Social support	0.32 (0.04)	<.0001
Decisional balance	0.003 (0.05)	.96
Self-efficacy	0.19 (0.04)	<.0001
Parental rules	-0.01 (0.01)	.23
Significant interaction		
Walkability index X decisional balance	0.04 (0.02)	.01

Notes: LTPA= leisure-time physical activity, SE = standard error

[a] Adjusted for adolescents' age and work/volunteer status, walkability/income quadrant, site (King County or Maryland regions), and census block (random effect). Independent variables are centered on the grand means for the male sample.

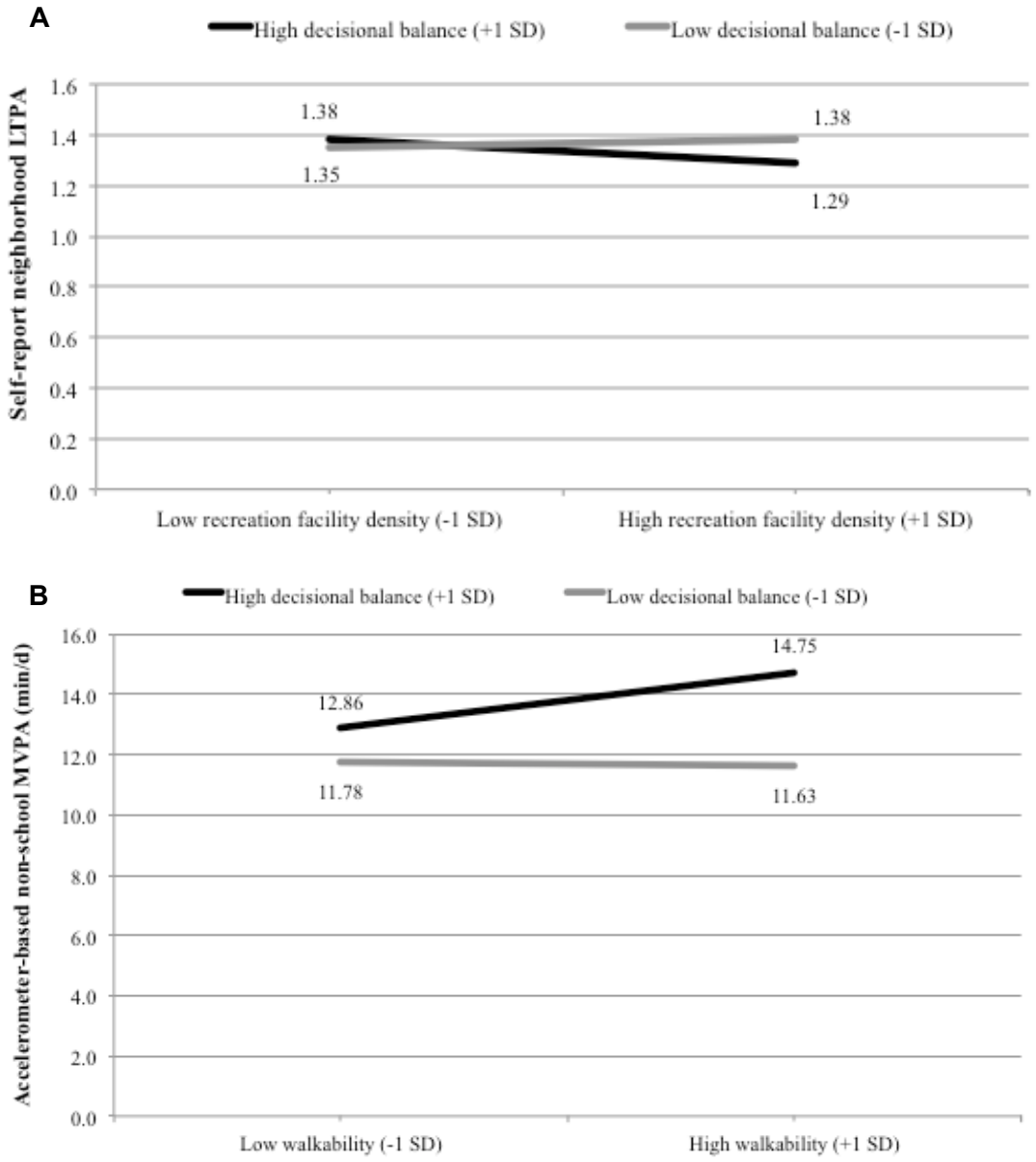

Figure 3.1: Significant interactions between psychosocial and neighborhood environmental factors in relation to **(A)** self-report neighborhood leisure-time physical activity (LTPA) and **(B)** accelerometer-based non-school moderate-to vigorous-physical activity (MVPA) among *female* participants.

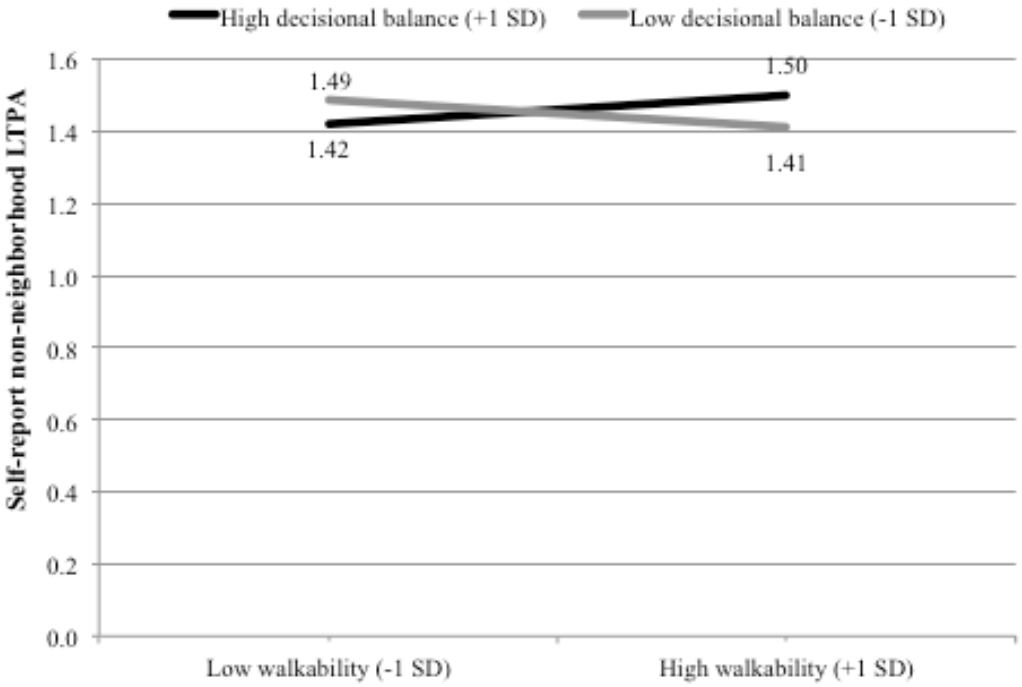

Figure 3.2: Significant interaction between psychosocial and neighborhood environmental factors in relation to self-report non-neighborhood leisure-time physical activity (LTPA) among *male* participants.

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CHAPTER 4: NEIGHBORHOOD ENVIRONMENTAL FACTORS THAT MAXIMIZE THE EFFECTIVENESS OF A MULTILEVEL INTERVENTION PROMOTING PHYSICAL ACTIVITY AMONG LATINAS

ABSTRACT

Purpose: This study tested whether a multilevel physical activity (PA) intervention had differential effects on PA according to participants' perceptions of their neighborhood environment.

Design: Two-group cluster randomized controlled trial.

Setting: San Diego, California.

Subjects: Analytical sample included 319 Latinas (18-65 years) from churches randomized to condition: PA (N=8 churches, n=157 participants) or attention-control (N=8 churches, n=162 participants).

Intervention: Over 12 months, PA participants were offered free PA classes (6/week) while attention-control participants were offered cancer prevention workshops.

Measures: Baseline and 12-month follow-up measures included self-report and accelerometer-based moderate-to vigorous-physical activity (MVPA), socio-demographics, and perceived neighborhood environment variables.

Analysis: Mixed effects models examined each PA outcome at 12-month follow-up, adjusted for church clustering, baseline PA, and socio-demographics. We tested interactions between 7 baseline perceived environment variables and study condition.

Results: Neighborhood aesthetics was the only significant moderator of intervention effects on accelerometer-based MVPA and self-report leisure-time MVPA. Participants in the PA intervention had significantly higher PA at follow-up than attention-control participants, only when participants evaluated their neighborhood

aesthetics favorably.

Conclusion: Perceived neighborhood aesthetics appeared to maximize the effectiveness of a multilevel PA intervention among Latinas. For sustainable PA behavior change, the environments in which Latinas are encouraged to be active may need to be evaluated prior to implementing an intervention to ensure they support active lifestyles.

Keywords: Health promotion, built environment, physical activity, church-based intervention, Latinas

PURPOSE

Physical inactivity is a modifiable risk factor for numerous health conditions,[1] yet 1 in 10 US adults die each year due to insufficient activity.[2] Given Latinos are the largest, and one of the fastest-growing, racial/ethnic minority groups in the US[3] and only 42% meet national recommendations for physical activity (PA),[4] effective interventions to increase their PA are needed. Most PA interventions with Latinos have targeted women due to their disproportionately lower rates of PA compared to men.[5] Such interventions have focused on motivating individuals, such as by increasing social support and self-management strategies like goal setting and problem solving.[6] Although individual-level approaches (i.e., that target inter/intra-personal factors) have shown promise in increasing Latinos' PA,[6] little is known on whether the environments in which individuals are encouraged to be active moderate the effects of health promotion efforts. In particular, residential neighborhoods may be important for sustainable PA behavior change because they can provide convenient opportunities for PA (e.g., parks/recreational facilities within walking distance of the home) and have the potential to shape social norms regarding walking/PA.[7] When neighborhood environments are not conducive to PA, due to limited access to recreational facilities or low safety for example,[8,9] individuals may be less likely to be active even if they are highly motivated.

Ecological models of health behavior underscore the influence of the environment on PA behaviors, along with individual (e.g., biological), psychosocial (e.g., social support), and policy-level factors.[10] Such models posit that factors across levels interact with one another to influence behavior and that interventions targeting multiple levels may be more effective at changing behavior than those targeting only one level.[10] Interactions between individual (socio-demographic) and neighborhood

environmental factors, for example,[11] suggest that environment-PA associations vary across subgroups of a population and that PA interventions targeting the neighborhood environment to make it more activity-supportive may have differential impacts on these groups.

A few PA intervention studies involving Latino and non-Latino samples have also tested interactions between neighborhood environmental factors and intervention allocation (e.g., intervention vs. control) to assess whether PA behavior change among intervention participants depends on the physical (built) and/or social environmental features of their neighborhoods.[12-17] Some studies report greater intervention benefits (i.e., increases in PA) among participants living in neighborhoods with characteristics favorable to PA – such as greater safety from traffic and better neighborhood aesthetics – compared to those living in neighborhoods with less favorable characteristics.[12-15] However, one study found that among overweight men in a lifestyle intervention, those living in less walkable neighborhoods had greater increases in walking compared to those in more walkable areas.[13] The latter study suggests that the intervention may have helped men overcome environmental barriers to PA. Other studies have reported no differential intervention impacts on PA by neighborhood environmental characteristics.[16,17] Overall, the mixed evidence on the moderating effects of neighborhood environments on intervention effects on PA suggest additional research is needed on this topic. In particular, evidence from PA intervention studies involving immigrant groups is warranted given predominantly immigrant neighborhoods often have less favorable environmental characteristics for PA (e.g., low perceptions of safety among residents).[18,19]

Among PA intervention studies targeting Latinos, group-based interventions and others that targeted social support and other interpersonal processes have shown promise in increasing PA.[20] Interventions that have relied on *promotores* (community health workers) to educate and lead community members in changing PA behaviors have also been successful at promoting PA and social cohesion among Latino participants.[20-22] To our knowledge, no study has examined whether participants' perceptions of their neighborhood environments have moderating effects on *promotora*-led interventions to promote Latinas' PA. Evidence of differential intervention impacts by perceived neighborhood environmental factors may help us understand the environmental factors that maximize or impede intervention effectiveness.

The purpose of the current study was to test whether the effects of a *promotora*-led intervention on changing PA, assessed objectively and with self-report, varied according to participants' perceptions of their home neighborhood environments.

METHODS

Design and sample

This study used data collected among 319 churchgoing Latinas (18-65 years old) participating in a two-group randomized controlled trial to promote PA (primary aim) or cancer screening (attention-control) among Latinas in San Diego, CA – *Fe en Acción*/Faith in Action. The intervention lasted two years but for the present analyses, we only used baseline and 12-month data collected between 2011-2014. Sampling, recruitment, data collection, and intervention activities are described in detail elsewhere.[23]

The study recruited 16 eligible churches and 436 eligible participants from

these churches (approximately 27 women/church). Sample size calculations were based on a comparison between conditions across the two follow-up periods as a vector of repeated measures on MVPA min/day. A staggered recruitment strategy was used to recruit churches in waves from January 2011 through March 2013. Church eligibility criteria were to have a minimum of 200 Latino families, be willing to be randomized to study condition, and be able to commit space for program activities. To minimize the possibility of contamination, churches had to be at least 1 mile apart, and participants could attend only one of the participating churches. Following recruitment, churches were stratified by size and then randomized to study condition, with 8 churches allocated to each condition.

Women were recruited using fliers, word of mouth, and printed and oral announcements at the participating churches. Participants were blinded to condition during recruitment. Participant eligibility criteria included self-identifying as Latina/Hispanic, being between 18-65 years of age, attending the church at least 4 times/month, residing within 15 minutes driving distance to the church, planning on attending the church for the next 24 months, reporting no health condition that would interfere with their ability to be physically active, and reporting no or mostly light-intensity PA on 2 screeners[24,25]. Women that met the aforementioned criteria were then asked to wear an accelerometer for 7 days, with those accruing <250 min/week of moderate-to-vigorous PA (MVPA) being eligible to participate. The accelerometer threshold allowed for inclusion of women with lower activity levels who could benefit most from a PA intervention. For the purposes of the present study, only participants with complete baseline and 12-month follow-up data were included in the analyses (N=319). The San Diego State University Institutional Review Board approved this study and participants provided written informed consent.

Intervention

The ecological model informed the design of *Fe en Acción,* with intervention activities designed to target individual, interpersonal, organizational and environmental influences of PA (primary intervention) or cancer screening (attention-control condition). Program evaluation staff including data collectors, were blinded to condition throughout the intervention period.

Participants in the PA intervention were offered free PA classes led by 2-3 *promotoras* (community health agents) recruited from each church. The 8 PA intervention churches provided space for the classes and allowed their schedules to be advertised in the church bulletins and at church fairs. Throughout the intervention year, approximately 6 classes were offered each week – including 2 walking groups, 2 cardio dance classes, and 2 strength-training classes – at or near the church at different days/times. Each class started with a 10-minute warm up period, followed by 30-40 minutes of moderate-to vigorous-intensity activities, and concluded with a 10-minute cool-down period and brief review of a relevant health handout. Each month, study staff mailed intervention participants educational handouts related to PA such as the benefits of PA, overcoming barriers to PA, and incorporating non-leisure activities like active transportation in the day. In the handouts, participants could list small goals for increasing PA such as going on walks in their neighborhood, exercising with family members, and walking to destinations (e.g., church, park, or grocery store) instead of driving. In addition, the *promotoras* conducted up to 3 Motivational Interviewing (MI) calls over the year with participants to discuss barriers to PA, identify ways to incorporate PA outside of classes, and provide social support for PA. The *promotoras* were also trained by the environmental advocacy group Circulate San Diego[26] on conducting environmental audits of their church grounds

and surrounding neighborhoods. The audits helped identify targets for improvement that the *promotoras* and community members could address via local projects such as trash pick-up. Because the environmental projects were implemented at various times throughout the intervention, we did not evaluate changes in the environment in the present study. Preliminary analyses also did not find significant changes in the perceived environment variables during the first 12-months of the intervention so we focused on baseline perceptions as a moderator.

Participants from the 8 attention-control churches were invited to a series of *promotora*-led workshops on breast, cervical, colorectal, and skin cancer prevention. Throughout the intervention year, the *promotoras* conducted a minimum of 6 series of 6-week classes. Participants could attend the same class more than once throughout the intervention. The attention-control churches provided space for the classes and allowed *promotoras* to advertise the classes in the church bulletins and church fairs. In addition, *promotoras* conducted up to 3 MI calls over the year addressing barriers to cancer screening and solutions to those barriers, and goals for completing recommended screenings. Throughout the intervention, MI calls and incentives were used to maintain cohort retention.

Measures

This study used PA data collected at baseline and 12-months follow-up as well as baseline data for the perceived environment and covariate variables. At each time point, participants completed a survey in their preferred language (English or Spanish), had their anthropometric measures taken by a trained research assistant (RA), and were asked to wear an accelerometer for 7 days. Survey measures used in the present study were available in Spanish.

Physical activity outcomes. Objective MVPA was assessed using ActiGraph GT3-X or GT3-X+ activity monitors (Actigraph, Pensacola, FL). Participants were asked to wear the device over the right hip for 7 days and to remove it during water activities (e.g., shower) and sleeping. The monitors collected data in 1-second epochs. Minimum wear time was defined as ≥5 valid days (with ≥1 weekend day) and ≥10 valid hours/day of data.[23] Non-wear time was defined as ≥60 consecutive minutes of zero count values. Up to two re-wears were allowed for those not meeting the wear time criteria. Accelerometer files were converted to 60-second epoch files and processed using ActiLife software version 6 (ActiGraph, Pensacola, FL). Using the Troiano 2008 cutoff points,[27] time spent in MVPA was determined by summing each minute where the count met the criterion for moderate activity (2020 cpm) or vigorous activity (5999 cpm). We estimated average MVPA min/wk at each time point. The data were normally distributed. Thus, accelerometer-based MVPA was treated as a continuous variable.

Self-reported PA was assessed using the Global Physical Activity Questionnaire (GPAQ).[28] This study used data from the leisure-time MVPA (6 items) and transportation PA (3 items) domains as they are deemed the most relevant to the neighborhood environment[29]. Among Latinas in San Diego, the GPAQ has shown moderate validity for vigorous activity when compared to the accelerometer.[30] The transportation PA data were highly skewed with about 60% of the sample reporting 0 minutes/week at 12-month follow-up. After attempts to fit a negative binomial distribution failed, we decided to dichotomize the transportation PA data from each time point as 0= ‘none’ or 1= ‘any’ (≥ 10 min), similar to other studies.[9,11] The leisure-time MVPA data were also highly skewed, with about 45% reporting 0 minutes/week at 12-months follow-up. A negative binomial distribution fit the data and was thus

used for subsequent analyses, similar to another publication using data from this intervention.[22]

Perceived home neighborhood environment. The most relevant environmental factors identified in a previous focus group study with churchgoing Latinas in San Diego were used in the *Fe en Acción* survey.[8] Items assessing perceived safety from crime, safety from traffic, and neighborhood aesthetics were taken from the abbreviated Neighborhood Environment Walkability Scale (NEWS-A).[31] Response options for these items ranged from 1='strongly disagree' to 5='strongly agree.' Following standard protocol, we reverse coded negative statements and averaged scores on the 2 items for safety from crime and the 4 items for neighborhood aesthetics (e.g., there are many interesting things to look at while walking in my neighborhood").[32]

Items assessing perceived access to destinations near the home (e.g., businesses) (yes/no), access to recreational facilities near the home (yes/no), and sidewalk maintenance were taken from the US Determinants of Exercise in Women Phone Survey.[33] Respondents reporting having sidewalks in their immediate home neighborhood were asked to evaluate sidewalk maintenance with 1 item that had response options ranging from 1='not at all maintained' to 4='very well maintained.'

Both environment scales have demonstrated moderate-to-high test-retest reliability among Latinas.[34] All continuous perceived neighborhood environment scores were standardized and mean-centered (mean=0 and SD=1) for ease of interpretation.

Neighborhood social cohesion was assessed using the Neighborhood Social Cohesion Scale.[35] Participants were asked to rate 6 statements on psychological sense of community, attraction to the neighborhood, and social interactions with

neighbors on a scale from 1= ‘not al all true’ to 3= ‘very true’. An example statement included “I feel like I belong to this neighborhood.” Negative statements were reverse coded. The average of the 6 statements was used, and higher scores indicated higher levels of neighborhood social cohesion. The scale had moderate internal consistency in our sample (α = 0.67).

Socio-demographics. Age, years living in the US, country of birth, marital status, education, and monthly household income were assessed using questions from the 2005 Behavioral Risk Factor Surveillance System (BRFSS) questionnaire.[36] We dichotomized household income based on a median split of $2000/month. Income was based on ranges so we could not properly calculate poverty level.

Analysis

We used mixed or generalized linear mixed effects models (with binary or negative binomial distributions), adjusted for church clustering, to examine differences in key variables across the study conditions. To identify the environmental correlates of each of the 3 PA outcomes, we examined the bivariate relations between each perceived environment and PA variable at baseline. For the main analyses, we used ANCOVA models for each PA outcome, entering the intervention or attention-control designation as the ‘condition’ variable and baseline PA, age, marital status, vehicle access, and employment status entered as covariates. Within these models, we tested for environmental moderators separately. That is, we included each of the 7 perceived environment variables and their interaction with study condition in separate models (7 models per outcome). These models tested whether PA levels at 12-month follow-up differed between intervention and attention-control participants with favorable vs. less favorable perceptions on each environment variable. Favorable perceptions included ‘yes’ responses on the binary variables or

scores 1 SD above the mean for continuous variables. Less favorable perceptions included ‘no’ response for binary variables or scores 1 SD below the mean for continuous variables. Interactions significant at the .10 level from the separate models were then tested simultaneously in a full model. The least significant terms were removed one by one so that only those significant at the .05 level remained in the final model. Significant moderators were plotted to show the intervention effects at each level of the environment variable.

RESULTS

Baseline and 12-month follow-up PA data and baseline environment scores were available for 73% of the sample. Chi-square or t-tests found no significant differences in baseline socio-demographic characteristics for those with and without available data. Table 1 shows characteristics of the sample with complete data, stratified by study condition. The majority of participants were immigrants from Mexico (90%) and of low socio-economic status as noted by the low income and education levels. There were no significant baseline differences in the means and percentages for socio-demographic, PA, and perceived environment variables by study condition.

Among the overall sample, we found domain-specific associations between the perceived environment and self-reported PA variables at baseline (Table 2). Perceived safety from crime was positively associated with self-reported leisure-time MVPA (β=0.29, SE=0.15, *p*=0.05). Having access to destinations near the home was also positively related to reporting any transportation PA (OR=2.74, 95% CI: 1.22-6.17).

The only significant perceived environment moderator of intervention effects on accelerometer-based MVPA was neighborhood aesthetics (interaction *p*=0.05) (Table 3). Among participants reporting favorable perceived neighborhood aesthetics,

those in the PA intervention had about 48 more min/week of accelerometer-based MVPA at 12-months follow-up than attention-control participants (Figure 1). Among those reporting less favorable perceived neighborhood aesthetics, accelerometer-based MVPA at 12-month follow-up was similar across study conditions.

Perceived neighborhood aesthetics was also a significant moderator of intervention effects on self-report leisure-time MVPA (interaction p=0.003) (Table 3). Among those who reported favorable perceived neighborhood aesthetics, PA participants had significantly more log leisure-time MVPA min/wk (4.6) than attention-control participants (4.1). Among those with less favorable perceived neighborhood aesthetics, self-reported leisure-time MVPA was similar across study condition. No other interactions were significant at p<0.05.

DISCUSSION

Among this sample of low-active Latinas participating in a *promotora*-led PA intervention in San Diego County, those reporting more favorable neighborhood aesthetics seemed to benefit from the intervention more than those reporting less satisfying neighborhood aesthetics. Specifically, reporting more favorable neighborhood aesthetics appeared to enhance the intervention's effects of increasing both participants' accelerometer-based MVPA and self-report leisure-time MVPA, independent of socio-demographic characteristics. Because no other built or social environmental moderators of intervention effects were found, our overall findings suggest a *promotora*-led PA intervention may promote PA equitably among Latinas with or without environmental barriers to PA.

Moderating effects of perceived neighborhood aesthetics on a PA intervention were found in two other studies.[12,37] Gebel et al. found favorable perceived neighborhood aesthetics combined with having facilities (e.g., benches) nearby

facilitated the effects of a mass media campaign on self-reported walking among adults, particularly the least active at baseline.[12] That is, study participants who reported favorable neighborhood aesthetics/having facilities had about 45 minutes/week more of walking at 3-months follow-up than those reporting less favorable aesthetics/lack of facilities.[12] This finding is consistent with our results. Merom et al. also found perceived neighborhood aesthetics moderated the effects of a self-help walking program on self-reported walking among low-active adults.[37] However, the authors found that the intervention seemed to benefit more participants with *less* favorable neighborhood aesthetics. The authors of that study suggested the intervention could help those with perceived environmental barriers to become more physically active.

One possible explanation for our findings is that participants reporting less favorable neighborhood aesthetics (based on the presence of trees, attractive buildings/homes in the neighborhood, etc.) lived in areas with greater neighborhood poverty and disorder (crime, vandalism, graffiti, etc.), which may hinder participants' motivation to perform PA in the neighborhood.[8,18] Although we did not measure neighborhood income or indicators of neighborhood disorder, studies suggest predominantly Latino neighborhoods are likely to have more physical disorder, disrepair (e.g., worse sidewalk conditions), and vacant lots/houses than predominantly White neighborhoods.[18] Perceived neighborhood disorder has been linked to feelings of mistrust and fear of victimization.[38] Perceived neighborhood social cohesion and safety from crime did not moderate intervention effects in our sample. Thus, other social environmental barriers not measured in our study may have impeded participants with less satisfying neighborhood aesthetics from

increasing their PA to the same extent as their peers reporting more favorable neighborhood aesthetics.

We also observed that among attention-control participants, those with favorable perceived neighborhood aesthetics scores had lower accelerometer-based and self-report leisure-time physical activity levels at 12-months than those with less favorable evaluations of their neighborhood aesthetics. A possible explanation for this finding is that compared to those reporting high scores on their neighborhood aesthetics, participants reporting low scores may have walked more in their neighborhoods for exercise or out of necessity (e.g., to get to/from destinations) and greater exposure to their neighborhood surroundings may have led to more biased (e.g., critical) evaluations of their neighborhood aesthetics.

Possible explanations for the lack of moderating effects by other perceived environmental factors include weak associations between the home environment perceptions and PA that occurred outside of the home environment. Although the intervention distributed handouts that encouraged participants to perform PA (leisure and transportation-related) outside of classes such as walking in their neighborhoods, the focus of the intervention was on PA classes that occurred in or around the church. Thus, it is not surprising that most home neighborhood environment perceptions did not have significant moderating effects on the intervention. To more accurately examine PA in or outside the home neighborhood, global positioning system-based assessments are recommended.[39,40] It is possible that participants who had less favorable evaluations of their neighborhood environments found alternative locations for PA. Other reasons for the lack of moderating effects include lack of statistical power to test interactions and lack of environmental variability. At baseline, perceived neighborhood aesthetics showed the most difference between study conditions, with

the PA condition reporting a much lower mean score on neighborhood aesthetics compared to the attention-control condition. Further, favorable perceptions of neighborhood aesthetics (the most subjective environmental factor in this battery) may reflect other participant-related constructs such as positive attitude or optimism.

Despite the limited number of moderating effects found by perceived neighborhood environmental factors, our finding for neighborhood aesthetics can help inform future *promotora*-led PA interventions. A *promotora*-led intervention that encourages Latinas to be active in their neighborhoods may target aesthetics-related factors such as the attractiveness of the neighborhood as part of environmental advocacy efforts with remedial actions taken to address those factors that could potentially discourage PA. Further, our overall findings suggest a *promotora*-led PA intervention may equitably enhance PA among Latinas with varying perceptions of their home neighborhood environment. Understanding the mechanisms by which this type of intervention promoted PA among participants regardless of their perceived environment is beyond the scope of this paper and could be a topic for future studies. We hypothesize PA programs that build interpersonal relationships and enhance social support for PA may be particularly effective at promoting Latinas' PA even when neighborhood environments are not conducive to activity. However, for sustainable PA behavior change, efforts may be needed to ensure the environments in which participants are to be active continue to support active lifestyles when the intervention is removed.

Strengths and limitations

Strengths of this study included use of both accelerometer and self-report measures of PA. In contrast to most studies of PA, which use only cross-sectional data, we included longitudinal data. Because we did not recruit participants to

purposively maximize variability in neighborhood environmental characteristics, the environmental effects on PA behavior change may be underestimated. Our findings may not be generalizable to other populations or geographical contexts. We only used perceived environment measures; thus, findings using objective environment measures could supplement our findings. Although multiple hypothesis testing (7 interactions tested per outcome) can increase the type I error rate, we made no adjustments to our analyses because it was exploratory in nature. Given the limited and inconsistent evidence from studies testing environmental moderators of physical activity intervention effects, we did not have any a priori hypotheses for how participant perceptions might impact the effects of the intervention. *Fe en Acción* was not powered to detect sub-group differences in intervention effects by participant perceived environmental factors, Therefore, our findings should be interpreted with caution and need to be replicated in other studies. Future studies would need to sample from geographically diverse neighborhoods to achieve greater variation in environmental characteristics, enhancing statistical power.

SO WHAT?

What is already known on this topic?

Although *promotora*-led interventions have shown promise in promoting Latinos' physical activity, few studies have examined whether participants' perceptions of their neighborhood environments moderate the effects of such interventions on PA behavior change. Evidence from studies examining environmental moderators of physical activity intervention effects has varied with respect to which environmental characteristics are more likely to maximize intervention effects.

What does this article add?

This prospective study involving a low-active sample of Latina women showed that favorable perceptions of neighborhood aesthetics maximized the effects of a *promotora*-led intervention on increasing accelerometer-based moderate-to vigorous-physical activity (MVPA) and self-report leisure-time MVPA levels, independent of socio-demographic factors. Specifically, intervention participants had higher activity levels at 12-month follow-up compared to attention-control participants only when neighborhood aesthetics were evaluated favorably (i.e., more conducive to activity). No differences in activity levels by study condition were observed among those with less favorable perceived neighborhood aesthetics. These findings suggest neighborhood aesthetics may be an important facilitator for physical activity behavior change among Latinas in interventions that promote leisure-time PA.

What are the implications for health promotion practice or research?

Our findings suggest better neighborhood aesthetics may maximize the effectiveness of a *promotora*-led intervention promoting active lifestyles among Latinas. Overall, lack of evidence for other environmental moderators suggests a *promotora*-led physical activity intervention may promote Latinas' PA regardless of how participants perceive their neighborhood environments. Nevertheless, because predominantly-Latino neighborhoods are characterized by poor perceptions of safety, physical disorder, and unfavorable aesthetics,[18] it is important that physical activity interventions and policies identify ways of reducing environmental disparities that may be placing Latinos at risk for inactive lifestyles and consequently, obesity and chronic health conditions. In addition, for sustainable PA behavior change, efforts are needed to ensure the environments in which Latinos are encouraged to be active support active lifestyles following participation in an intervention.

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Table 4.1: Baseline characteristics of Latinas (18-65 years) by study condition. *Fe en Acción*/Faith in Action, 2011-2014. San Diego, CA.

	Study condition [a]			
Characteristic	Physical activity (n=157)		Attention-control (n=162)	
Socio-demographic	Mean	SE	Mean	SE
Age in years	45.26	1.00	44.27	0.99
Years living in the US	22.43	1.07	19.77	1.06
Number of vehicles in household	2.04	0.08	1.85	0.08
Number of adults in household	3.00	0.12	2.89	0.12
	n	%	n	%
Born in Mexico	140	89.17	148	91.93
Married/living as married	125	80.13	122	76.25
Monthly household income < $2,000	84	54.90	93	62.42
Completed less than high school	80	51.28	88	54.66
Employed	112	72.73	104	64.20
Physical activity				
Accelerometer-assessed MVPA, min/wk	103.44	7.40	106.21	7.37
Log self-reported leisure-time MVPA, min/wk [b]	4.30	0.25	4.18	0.25
	n	%	n	%
Self-reported any transportation PA	48	30.57	59	36.42
Perceived neighborhood environment [c]	Mean	SE	Mean	SE
Sidewalk maintenance (range: 1-4)	3.40	0.07	3.39	0.07
Safety from traffic (range: 1-5)	3.69	0.10	3.67	0.10
Safety from crime (range: 1-5)	3.78	0.11	3.77	0.10
Neighborhood aesthetics (range: 1-5)	3.06	0.08	3.26	0.08
Neighborhood social cohesion (range: 1-3)	2.49	0.03	2.48	0.03
	n	%	n	%
Has access to destinations	127	80.89	143	88.27
Has access to recreational facilities	133	84.71	146	90.12

Notes: MVPA= moderate to vigorous physical activity; PA= physical activity; SE= standard error

[a] No significant differences (.05 < *p*) were found between study condition on any of the baseline characteristics.

[b] Based on negative binomial distribution. Results are in logged units.

[c] Higher scores indicative of more favorable perceptions.

Table 4.2: Bivariate associations of perceived neighborhood environment variables with participants' physical activity at baseline. [a] *Fe en Acción*/Faith in Action, 2011-2014. San Diego, CA.

Perceived neighborhood environment variable	Accelerometer-based MVPA			Log self-reported leisure-time MVPA [b]			Self-reported any transportation PA		
	ß	SE	*p*	ß	SE	*p*	OR	95% CI	*p*
Sidewalk maintenance	-3.20	3.55	0.37	0.08	0.11	0.29	0.94	0.74-1.20	0.62
Safety from traffic	1.06	3.52	0.76	0.18	0.10	0.07	1.00	0.79-1.27	0.99
Safety from crime	1.13	3.54	0.75	0.29	0.15	0.05	0.98	0.77-1.25	0.88
Neighborhood aesthetics	5.18	3.53	0.14	0.10	0.07	0.18	1.10	0.87-1.40	0.43
Neighborhood social cohesion	-1.44	3.53	0.68	0.02	0.09	0.81	1.05	0.82-1.33	0.71
Has access to destinations	18.45	9.79	0.06	-0.03	0.21	0.88	2.74	1.22-6.17	0.02
Has access to recreational facilities	-0.04	10.64	0.99	-0.02	0.35	0.96	0.72	0.36-1.46	0.36

Notes: MVPA= moderate to vigorous physical activity; PA= physical activity; SE= standard error. Bold values are significant at .05 level.

[a] Mixed effects or generalized linear mixed models used to control for clustering effects of the churches.

[b] Model used a negative binomial distribution.

Table 4.3: Significant perceived environment moderators of intervention effects on participants' physical activity at 12-months follow-up. Fe en Acción/Faith in Action, 2011-2014. San Diego, CA.

Physical activity model	ß [a]	SE	*p*-value
Accelerometer-based MVPA			
Baseline accelerometer-based MVPA	0.73	0.09	<.0001
Neighborhood aesthetics	-5.67	7.77	0.47
Condition (ref: Attention-control)	25.11	11.49	0.03
Neighborhood aesthetics x condition	22.56	11.62	0.05
Log self-reported leisure-time MVPA [b]			
Baseline self-reported leisure-time MVPA	0.003	0.001	<.0001
Neighborhood aesthetics	-0.19	0.03	<.0001
Condition (ref: Attention-control)	0.25	0.14	0.08
Neighborhood aesthetics x condition	0.29	0.10	0.003

Notes: MVPA = moderate to vigorous physical activity; PA= physical activity; SE= standard error

[a] Mixed effects or generalized linear mixed models used to adjust for clustering effects of the churches. Models controlled for baseline PA, age, marital status, vehicle access, and employment.

[b] Model used a negative binomial distribution.

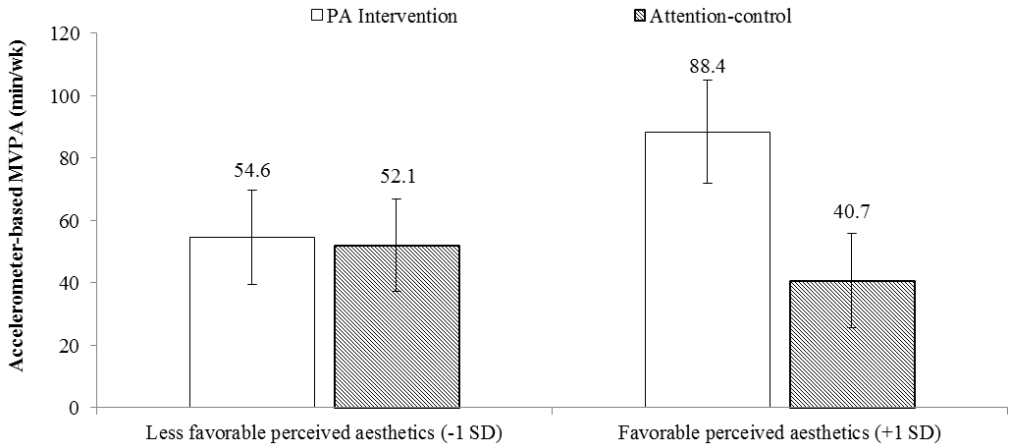

Figure 4.1: Perceived neighborhood aesthetics moderated intervention effects on participants' accelerometer-based MVPA at 12-months follow-up. *Fe en Acción*/Faith in Action, 2011-2014. San Diego, CA.

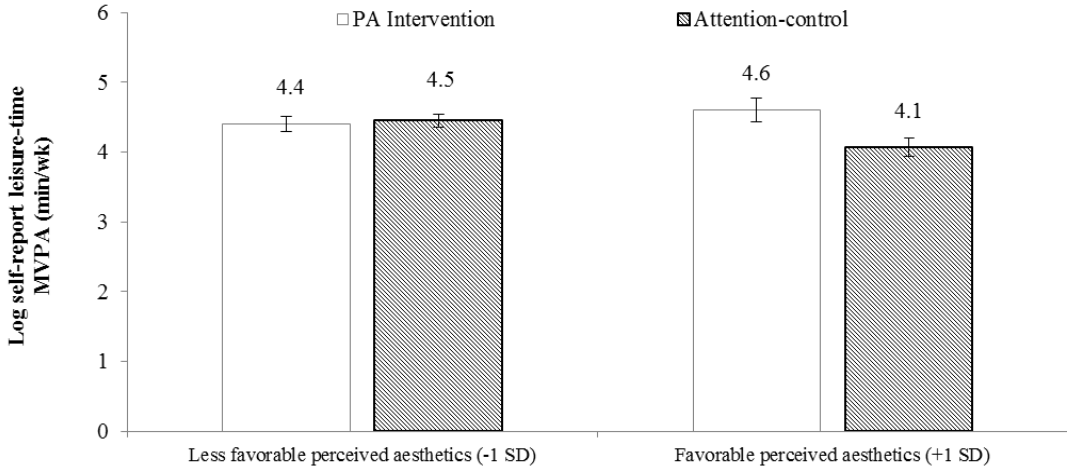

Figure 4.2: Perceived neighborhood aesthetics moderated intervention effects on participants' self-reported leisure-time MVPA at 12-months follow-up. *Fe en Acción*/Faith in Action, 2011-2014. San Diego, CA

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CHAPTER 5: DISCUSSION

OVERVIEW

Ecological models of health behavior guided this dissertation given their focus on the plurality of potential influences on physical activity behaviors. A key tenet of these models is that factors at multiple levels such as individual (e.g., socio-demographic), psychosocial (e.g., social support), and environmental (e.g., neighborhood features) interact with one another to influence behavior. Among the possible interactions across levels of the model, those involving environmental factors are the least understood. Thus, this dissertation focused on interactions between environmental and socio-demographic (Chapter 2) or psychosocial factors (Chapter 3). Such interactions tested whether the environmental correlates of physical activity among adolescents and adults varied by population socio-demographic or psychosocial characteristics. In addition, ecological models can be useful in guiding the development of physical activity interventions targeting multiple levels of influence but their effects may depend on the environments in which participants are encouraged to be physically active. The evidence on environmental moderators of physical activity intervention effects has produced mixed results. In addition, few studies have examined this research question in the context of racial/ethnic minorities such as Latinos. Physical activity interventions targeting Latinos have focused on women (Latinas) because of their disproportionately low rates of leisure-time physical activity compared to non-Latino White women and Latino men.[1,2] Thus, Chapter 4 examined whether the effects of a physical activity intervention based on the ecological model varied according to how participants (Latina women) evaluated

specific features of their neighborhood environment hypothesized to be related to physical activity.

Results from Chapter 2, which used cross-sectional data from an international sample of adults (IPS), provide some evidence to support the ecological models' hypothesized interactions between environmental and individual (socio-demographic) factors in relation to self-reported total moderate-to vigorous- physical activity (MVPA), dichotomized as meeting/not meeting high physical activity levels and meeting/not meeting minimum physical activity guidelines. The interaction models found significant moderating effects by gender and education, but not age. Specifically, gender moderated the associations between perceived safety from crime and both physical activity outcomes. Gender also moderated the association between perceived presence of transit stops and meeting minimum physical activity guidelines. Education moderated the association between perceived safety from crime and meeting high physical activity levels and the association between perceived presence of transit stops and meeting minimum physical activity guidelines.

As expected, there was a significant positive association between perceived neighborhood safety from crime and meeting minimum physical activity guidelines only among women. The relationship between perceived neighborhood safety from crime and meeting high physical activity levels among women was also in the positive direction but it was not significant. A different international study (IPEN) also reported a positive association between perceived neighborhood safety from crime and accelerometer-based MVPA only among women.[3] Our finding suggests that women may be more sensitive to perceptions of neighborhood safety than men, such that low perceptions of safety may discourage women from engaging in physical activity in the neighborhood, possibly leading to lower overall activity levels.

Unexpectedly, there were significant inverse associations of perceived neighborhood safety from crime with meeting high physical activity levels among the high-education group and men. This finding suggests that compared to the other perceived neighborhood environmental factors, the relationship between safety from crime and physical activity is more complex. Other contextual factors not measured in the present study such as location or purpose of physical activity may be explaining this unexpected finding. For example, among high-education respondents and men, lower perceived safety in the neighborhood might not be a barrier to leisure-time physical activity because they can engage in this behavior outside their neighborhood such as in gyms/recreation facilities. It is also possible that high-education respondents who reported high levels of neighborhood safety lived in less residentially dense/walkable neighborhoods (e.g., predominantly single-family homes). Lower neighborhood walkability may impede choice- (leisure activity) or necessity- (active transport) driven behaviors in the neighborhood, potentially leading to lower overall physical activity levels.

There were also positive associations of the presence of transit stops with meeting minimum physical activity guidelines only among men and the high-education group, consistent with our hypotheses. The aforementioned IPEN study also reported a positive association between land use mix-access (i.e., the presence of stores/destinations and transit stops in the neighborhood) and accelerometer-based MVPA only among men, but no significant moderating effects by education.[3] Public transit use may be more common among men and individuals with high education (e.g., to get to and from work). Because walking to and from transit stops can help individuals achieve 30 or more minutes of physical activity a day,[4] active

transportation linked to public transit use may have contributed to the overall higher physical activity levels among men and individuals with high education.

Overall, only a small number of moderating effects by socio-demographic factors on the neighborhood environment-physical activity associations were found in Chapter 2. This conclusion is consistent with the aforementioned IPEN study.[3] Thus, consistent conclusions from two international studies testing the same research question with different samples/set of countries and measures (e.g., self-report vs. accelerometer-based physical activity) provide support for international recommendations to improve the activity-supportiveness of neighborhood environments for population-wide benefits for physical activity, health, and environmental sustainability.[5-7]

Chapter 3, which used cross-sectional data from a sample of adolescents from two urban regions in the US (TEAN), found some evidence to support context-specific ecological models and their hypothesized interactions between psychosocial and environmental factors in relation to self-reported neighborhood leisure-time physical activity (LTPA) and non-neighborhood LTPA, and accelerometer-based non-school MVPA (i.e., beyond school hours). Only one out of four psychosocial factors tested as potential moderators was significant – decisional balance, which can be defined as one's weighing of the pros (perceived benefits) and cons (perceived barriers) of engaging in physical activity.[8] A high decisional balance score was indicative of reporting more pros than cons while a low score meant the respondent reported more cons than pros. Among female adolescents, decisional balance moderated the association between neighborhood recreation facility density and neighborhood LTPA and the association between neighborhood walkability and non-

school MVPA. Among males, decisional balance moderated the relationship between neighborhood walkability and non-neighborhood LTPA.

Although a few studies have examined psychosocial moderators of associations between the neighborhood environment and adolescents' physical activity,[9,10] no study that we are aware of has tested these moderating effects in relation to context-specific behaviors. As such, we were unable to directly compare our findings to those of other studies but we provide some potential explanations and implications for our results.

There was an unexpected negative association between neighborhood recreation facility density and neighborhood LTPA only among females with high decisional balance (pros outweighed the cons). Other features of the recreation facilities not measured in this study may be explaining this finding. For example, the quality of those facilities may be just as important for adolescents' physical activity as their proximity/access. It is possible that despite living in a neighborhood with good access to recreation facilities, if the facilities are vandalized or run-down, then adolescents may be discouraged to use them. For females with low decisional balance (cons outweighed the pros), having good access to recreation facilities and therefore more opportunities for physical activity in the neighborhood may help them overcome some barriers to being active.

In addition, among adolescents with high decisional balance, there were positive associations of neighborhood walkability with non-school MVPA among females and non-neighborhood LTPA among males, as hypothesized. A more walkable neighborhood environment can provide greater opportunities for active lifestyles, including both choice - (leisure activity) or necessity- (active transport) driven behaviors.

The positive association between neighborhood walkability and non-school MVPA only among females with high decisional balance suggests that these adolescents may be more motivated to take advantage of the opportunities for physical activity provided by living in a high-walkable neighborhood, including leisure/active transportation after school and on the weekends, compared to their female peers with low decisional balance. According to the trans-theoretical model, individuals who have a decisional balance score favoring the pros are more likely to already engage in physical activity (maintenance stage) or change their behavior to be more physically active (action) compared to those with lower scores who are not considering changing their behaviors (pre-contemplation).[8] Females with higher levels of decisional balance living in a high walkable neighborhood reported about 21 more minutes per week of non-school MVPA than their female peers with lower levels.

There was also a positive association between neighborhood walkability and non-neighborhood LTPA only among males with high decisional balance. It is possible that males with high decisional balance were from high SES households and their parents modeled or encouraged physical activity and sports outside the neighborhood. Thus, neighborhood walkability may be related to male adolescents' non-neighborhood LTPA via socio-economic and parental influences not measured in this study.

Overall, the interactions between decisional balance and neighborhood environmental factors found in Chapter 3 suggest that the combination of neighborhood environmental opportunities and adolescents' decision making are related to their physical activity behaviors in specific time/location contexts. Multilevel interventions targeting both environmental and psychosocial factors (e.g., enhancing perceived benefits and reducing perceived barriers to engaging in physical activity)

may help promote adolescents' physical activity in specific contexts, potentially leading to greater/increased overall physical activity.

Finally, Chapter 4, which used longitudinal data from a multilevel physical activity intervention targeting Latinas (Faith in Action), found that out of seven perceived neighborhood environmental factors tested, only neighborhood aesthetics had significant moderating effects on the intervention's impacts. Specifically, among participants with favorable perceptions of their neighborhood aesthetics, those in the physical activity intervention had significantly higher accelerometer-based MVPA and self-reported LTPA at 12-months post-intervention compared to attention-control participants. Among those with less favorable evaluations of their neighborhood aesthetics, the intervention effects were similar across the study conditions.

The neighborhood aesthetics subscale was based on the presence of trees, attractive buildings/homes in the neighborhood, etc. It is possible that participants who reported less favorable neighborhood aesthetics lived in areas with greater neighborhood poverty and disorder (crime, vandalism, graffiti, etc.), which may pose a barrier to do physical activity in the neighborhood.[11,12] In addition, because the neighborhood aesthetics subscale was highly subjective, favorable perceptions may have reflected other participant-related constructs not measured in this study such as positive attitude or optimism that could be explaining these findings.

For sustainable physical activity behavior change, the environments in which participants are encouraged to be active may need to be evaluated prior to implementing an intervention to ensure they support active lifestyles. Remedial actions to improve the activity-supportiveness of environments may lead to improved environmental perceptions and potentially positive behavior change. However, environmental improvements may not be enough for changing behavior and other

important correlates such as social support and self-efficacy (psychosocial factors) may need to be addressed concurrently. As such, multilevel interventions that target the plurality of influences on physical activity have potential to promote positive physical activity behavior change among Latinas.

LIMITATIONS

Generalizability

Chapter 2 used data collected from nationally- or regionally-representative samples of adults from nine countries, thereby obtaining greater variability in neighborhood and population characteristics that are often relatively homogeneous in single-country studies. Efforts to obtain representative samples were achieved using multistage stratified random sampling, simple random sampling, or random household sampling (Japan only). However, because the analyses only involved urban residents from middle-to high-income countries, the results may not be generalizable to rural populations or low-income countries.

Chapter 3 used data collected from a large sample of adolescents from two different regions in the US selected to represent various combinations of income and walkability groups. Thus, the recruitment approach allowed for greater geographic and population diversity. Households were selected at random using a list of households with adolescent residents. However, the sample was still comprised of predominantly non-Hispanic Caucasian adolescents and those living in higher SES households (about 55% lived in households earning $90,000 or more annually). Thus, findings may not be generalizable to other regions of the US, adolescents living in lower SES households, and other racial/ethnic groups.

Chapter 4 used data collected among low-active churchgoing Latinas living in San Diego, CA. Participating churches from which women were recruited were

selected using a staggered recruitment strategy. The study did not recruit participants to purposively maximize variability in neighborhood environmental characteristics. The inclusion criteria only allowed women to participate if they had low physical activity levels as determined by self-report and the accelerometer, reported few health conditions, were frequent church-goes, and lived near the participating churches. Thus, findings may not be generalizable to Latinas that do not fit the study inclusion criteria, Latino men, or Latinos in other geographical contexts.

Measurement

Analyses for Chapters 2-4 involved self-report physical activity measures, which are valuable in assessing activities that standard objective techniques may not capture (e.g., biking and swimming). However, self-report measures have been shown to overestimate physical activity due to recall bias or social desirability (e.g., reporting more physical activity so that they can be viewed favorably by the investigator).[13,14] To address potential overestimation of the proportion of adults meeting minimum physical activity guidelines in Chapter 2, we also examined meeting high physical activity levels as an outcome because it showed greater variability. In Chapters 3 and 4, we included accelerometer-based measures to obtain more accurate estimates of physical activity.

Another limitation for the physical activity measures used in Chapters 2-4 is that most were not specific to the neighborhood, potentially weakening associations with the neighborhood environmental factors. Although for Chapter 3 we examined neighborhood-based physical activity, it was not significantly related to any of the neighborhood environmental factors in the main effects models. This may be due to potential variations in how the “neighborhood” was defined by participants, their parent/guardian, and the objectively-measured neighborhood buffer. This mismatch in

neighborhood definitions can introduce Type 2 error and lead to non-significant associations between the neighborhood factors and neighborhood-based physical activity. In future studies, use of simultaneous global positioning system-accelerometer monitoring may help strengthen the measures of physical activity by limiting activity to the specific environmental setting being studied.[15]

We also used self-report measures of the neighborhood environment in Chapters 2-4. Such measures are moderately correlated with some objective neighborhood environment measures, but there are differences for certain factors such as proximity to transit stops.[16] In addition, there is some evidence suggesting that individuals who spend more time in their neighborhood may be more aware of their neighborhood surroundings, potentially leading to biased evaluations of their environments (e.g., more critical).[17] Nevertheless, self-report environment measures can be valuable in assessing social environmental factors such as safety from crime, which can be challenging to evaluate using objective tools. In addition, most of our neighborhood environment measures focused on the presence or proximity/access to certain environmental features (e.g., recreation facilities). Only a few measures assessed the quality of environmental features (e.g., sidewalk maintenance). To provide a more comprehensive understanding of the environmental correlates of physical activity, studies are needed measuring the quality of environmental features in addition to their proximity/access.

Inferential Causation

Use of cross-sectional data in Chapters 2 and 3 limited our ability to make causal inferences regarding the relationships between the neighborhood environmental factors and physical activity. For example, results in Chapter 3 showed that higher neighborhood walkability was related to higher non-school MVPA only

among females with high decisional balance. Compared to adolescents with low decisional balance, those with higher decisional balance (pros outweighed the cons) were likely more motivated to engage in physical activity and this motivation may have led to more active lifestyles beyond school hours especially if they lived in a high walkable neighborhood that provided opportunities to be active. It is also possible that living in a high neighborhood walkability led to more active lifestyles beyond school hours, and engaging in more physical activity led to higher decisional balance, i.e., increased recognition of the benefits of being physically active and reduced barriers. The directionality of these relationships could not be determined due to the cross-sectional design of the study.

One prospective study tested the longitudinal effects of physical activity behavior change on decisional balance and found that exercise predicted changes (decreases) in the pros and cons of doing physical activity at 3-years follow-up among adolescents.[18] The authors of that study hypothesized that the pros unexpectedly decreased because the pros of continuing regular exercise may be different from those for adopting exercise.[18] That study did not examine the influence of neighborhood environmental factors. Thus, additional controlled longitudinal trials are needed to determine the directionality of the relationships between environmental and psychosocial factors and physical activity.

One strength of Chapter 4 was the use of longitudinal data (baseline to 12-months follow-up) from a multilevel physical activity intervention. A key component of the intervention was to train the community health workers (*promotoras*) to promote environmental changes at the churches (intervention sites) and surrounding neighborhoods. The *promotoras* conducted environmental audits to identify targets for improvement such as removal of pedestrian barriers, aesthetic improvements, etc.

Because women had to report living within .25 mile (or 10-15 minutes walking distance) of the participating church to participate in the study, they were more likely to be exposed to the *promotora*-led environmental changes than community members living far from the churches. As such, it was expected that positive changes to participants' physical neighborhood environments would lead to positive changes to their perceptions of their neighborhoods, and this in turn would facilitate the intervention effects on physical activity behavior change. Preliminary analyses of the 12-month follow-up data, however, showed no significant changes in scores for any of the perceived neighborhood environmental factors. It is possible that the observation period may have been too short to detect such changes in participant perceptions. In addition, many of the *promotora*-led environmental projects were not completed until the end of the 5-year trial and it is possible that participants were not aware of the environmental changes since there was no educational component to inform them of these changes or how those changes could provide additional opportunities to be physically active. A major challenge of multilevel interventions is implementing changes to the built environment due to limited resources and time constraints of a typical grant period. A longer observation period may have allowed for observation of changes to the perceived neighborhood environmental factors and their potential mediating effects on the intervention impacts on physical activity behavior change.

Multiple Hypothesis Testing

For Chapters 2-4, testing several interactions simultaneously involved multiple hypothesis testing, which increases the probability of making a Type 1 error (concluding that a significant effect/relationship exists when in fact it does not). Although adjustments for multiple hypothesis testing like Bonferroni reduce the

probability of making a Type 1 error, they can also increase the chance of committing a Type 2 error (failing to detect a significant effect/relationship when one exists).[19] For Chapter 2, we presented results without a Bonferroni adjustment (setting the *p*-value at .05) but indicated which interactions remained significant with the adjustment ($p<.002$). We did not make adjustments in Chapters 3 or 4 given the exploratory nature of the research questions, thus results should be interpreted with caution until additional studies are conducted to replicate our findings.

FUTURE RESEARCH IN GLOBAL HEALTH

Given physical inactivity is a major contributor to the burden of chronic disease, premature mortality, and high medical care costs worldwide,[20-22] understanding the plurality of influences on physical activity is a global health research priority. Ecological models can help guide the development of programs to promote population physical activity because such models recognize the individual, psychosocial, and environmental correlates/determinants of physical activity within the unique contexts in which the behavior occurs. Although this dissertation addresses a major gap in our understanding of interactions across the multiple levels of the ecological model in relation to physical activity, our results highlight the complexity of such interactions and the need for additional research on this topic. A better understanding of how environmental correlates of physical activity vary within a population such as by their socio-demographic or psychosocial characteristics, can help guide future multilevel interventions identify and prioritize targets that can have the greatest impacts on increasing population physical activity levels.

One specific recommendation that can help advance the study of the environmental correlates of physical activity is to improve contextual matching of environmental factors with physical activity behaviors.[23] Researchers examining

associations of the environment with physical activity often assume that a substantial amount of activity occurs in the neighborhood. However, most validated measures of physical activity lack contextual information (i.e., location of the behavior). Mismatched associations such as between the neighborhood environment and overall walking can lead to Type 2 errors. Reviews of the environment and physical activity that combine 'contextually mismatched' with 'contextually matched' results may lead to an underestimation of the consistency of associations.

One way to improve contextual matching of environmental exposures and physical activity outcomes is to use simultaneous accelerometer-global positioning system (GPS) monitoring.[15,24] This method allows researchers to estimate activity within specific locations. One study used this approach and found that objective environmental factors within 1-km buffers representing participants' home neighborhoods were related to physical activity only when activity was within that buffer (i.e., not activity from all locations).[25] In addition to correlational studies, this method can be valuable for future intervention studies. That is, GPS devices may be used to track if participants change where they are physically active as a result of improved access to physical activity resources (e.g., parks/recreation facilities).

Assessing contextual information can also be desirable for physical activity surveillance as public health objectives often focus on specific types of activity (e.g., leisure-time activity or number of walking trips made). However, simultaneous accelerometer-GPS monitoring can present additional burdens on participants and study staff. The large volumes of data obtained from such methods can also be challenging for large population-based studies with limited data storage and processing capacities.[23] Thus, self-report measures can be valuable when additional contextual information is incorporated to items such as location/purpose of activity. In

summary, future research can help improve current understanding of the links between the environment and physical activity by improving on physical activity measurement to include more contextual information and moving research towards focusing on contextually-matched associations.

Another area that has received little attention to date, but which may advance physical activity research, is examination of the causal relationship between environments and physical activity. Cross-sectional studies on the environment and physical activity often conclude with recommendations to improve environments to make them more activity-supportive to help increase population physical activity levels. However, prospective studies testing the mechanisms by which changes to environmental factors lead to physical activity behavior change are lacking. A key challenge of conducting such studies is that environmental changes often require longer periods of time to be completed than the typical research timeframe allows.[26] Current funding opportunities recognize the need to better understand the causal relationships between the environment and physical activity as such evidence can help guide policy. Studies demonstrating a causal link between environmental improvements and increases in physical activity can strengthen the case for strategic urban planning to make environmental modifications that can lead to positive behavior change.

One type of experiment that can address potential causal pathways is natural experiments that monitor environmental changes led by community members/developers (e.g., development of a new transit line), not by researchers, and physical activity levels before and after those changes were implemented. However, a limitation of such studies is the potential for selection bias as there may be something different about those individuals taking advantage of the environmental

changes compared to the general population. Randomized-controlled designs can address these limitations but this type of research is a challenge in time/resource-limited settings.

Finally, while understanding how environmental changes can lead to physical activity behavior change and improved health is critical for informing policy, such evidence may be more convincing if the proposed environmental changes are also shown to be cost effective. Few cost-benefit analyses have been conducted to date linking environmental changes to health care savings.[23,27] Such evidence can help accelerate progress towards addressing the global physical inactivity pandemic.

CONCLUSIONS

Evidence of interactions across levels of the ecological model has been limited to cross-sectional designs and studies focused on single-countries, adults, and predominantly Caucasian samples. Thus, this dissertation addresses these important limitations by analyzing data from a multi-country study, a US adolescent study, and a prospective physical activity intervention study with Latinas. Findings from this dissertation provide evidence to support the application of ecological models to examine the plurality of potential influences on physical activity across multiple contexts: geographic, behavioral (domain-specific, time/place-specific), and populations. The findings may help inform the development of future interventions targeting individual, psychosocial, and environmental factors to promote population levels of physical activity. In addition, multisectorial approaches involving the health, transportation, communication, and urban planning sectors are needed to promote population physical activity, health, and environmental sustainability.[5,28]

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