UNIVERSITY OF CALIFORNIA, SAN DIEGO

SAN DIEGO STATE UNIVERSITY

"Ecological Moderators of the Relation Between Neighborhood Safety and Physical Activity"

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

in

Public Health (Health Behavior)

by

Jessa Kelsey Engelberg

Committee in charge:

University of California, San Diego
James Sallis, Chair
Terry Conway
Linda Hill

San Diego State University
John Elder
Hala Madanat
Sherry Ryan

2017

The Dissertation of Jessa Kelsey Engelberg is approved, and it is acceptable in quality and form for publication on microfilm and electronically:

Chair

University of California, San Diego

San Diego State University

2017

DEDICATION

To my Mom & Dad

EPIGRAPH

When walking, you see things that you miss in a motor car or on the train.
You give your mind space to ponder.

Tom Hodgkinson

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LIST OF ABBREVIATIONS

BMI, body mass index

CA, California

CDC, Center for Disease Control and Prevention

CI, confidence interval

DOT, United States Department of Transportation

GLM, generalized linear model

MAPS, Microscale Audit of Pedestrian Streetscapes

MD, Maryland

NHTSA, National Highway Traffic Safety Administration

PA, physical activity

US, United States

WA, Washington

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ACKNOWLEDGEMENTS

I would like to thank Dr. Jim Sallis for his support and guidance as my primary mentor and chair. You are honestly an inspiration to me and I feel incredibly privileged to have had the opportunity to grow under your mentorship for nearly 5 years. Your emphasis on my individual development and your encouragement and feedback were instrumental in getting me to this point (including responding to frantic dissertation emails!). I would also like acknowledge, Dr. Linda Hill, for her ongoing support and enthusiasm. You were an integral form of support from when I first entered the program, and I so value your mentorship (and our Bread & Cie meetings!). Dr. Hala Madanat, your guidance and input were invaluable, particularly your knowledge of the program and expectations, but also your informative feedback. I would also like to thank Dr. John Elder, who provided valuable input from his years of experience. You also showed me what an amazing professor looks like and cultivated my interest in teaching, to the point where I had the confidence to independently teach courses. Dr. Terry Conway, your statistical expertise and ongoing guidance throughout the years made this dissertation possible and I cannot thank you enough. Finally, Dr. Sherry Ryan, thank you for contributing your unique perspective, time, and guidance, especially related to urban planning and community safety.

I want to express my immense gratitude for my cohort (aka “Oprah”) for getting me through this process and *always* pushing me to continue. Jen Sanchez, Kate Machado, Sandra Soto and Michelle Takemoto—you were all there for me, from struggling over our stats homework together to going for walks to commiserating over wine and chocolate to just having fun together! These experiences helped forge lasting friendships and I am incredibly grateful to each of you. Thank you!!

After moving back to San Diego for this PhD program, I fully appreciate what an integral role my parents and my family played. Some of my earliest memories are related to public health and health behaviors, from doing early morning exercises with my mom as a toddler to my Dad’s ongoing lectures on the evils of cigarettes. Dad, I literally would not be here if you had not pushed me to apply to this PhD program and encouraged me to reach out to my (now) mentors! Mom without your constant encouragement (and many meals!), I do not think I could have gotten through the program. Thank you both for your unconditional love and support. You taught me how to always strive to grow and become a better version of myself. To my siblings, Alyssa, Hana and Ben, thank you for your patience with me and ongoing support. Alyssa, I especially appreciate your willingness to field my panicked calls and texts over the years! My extended family and my friends have supported me in more ways than one and always believed in me, and I thank you all for that. And finally, Austin, I want to thank you for the love, support and patience you have shown me, and for always pushing me to grow and improve.

Chapter 1, in full, has been submitted for the publication of the material. Co-authors include Dr. Job G. Godino, Dr. James F. Sallis, Dr. Terry L. Conway, Dr. Linda Hill, Dr. Hala Madanat, and Dr. Kevin Patrick. The dissertation author was the primary investigator and author of this material.

Chapter 2 is currently being prepared for submission for the publication of the material. Co-authors include Dr. Terry L. Conway, Dr. Jordan A. Carlson, Kelli L. Cain, Carrie Geremia, Dr. Brian E. Saelens, Dr. Karen Glanz, Dr. Lawrence D. Frank, Dr. Hala Madanat, Dr. Linda Hill and Dr. James F. Sallis. The dissertation author was the primary investigator and author of this material.

Chapter 3 is currently being prepared for submission for the publication of the material. Co-authors include Dr. Terry L. Conway, Kelli L. Cain, Carrie Geremia, Dr. Brian E. Saelens, Dr. Karen Glanz, Dr. Lawrence D. Frank, Dr. Abby C. King, Dr. Hala Madanat, Dr. Linda Hill, Dr. Sherry Ryan, Dr. John P. Elder and Dr. James F. Sallis. The dissertation author was the primary investigator and author of this material.

VITA

EDUCATION

Doctor of Philosophy, Public Health (Health Behavior) — March 2017
San Diego State University/University of California, San Diego, Joint Doctoral Program, San Diego, California

Bachelor of Arts in Psychology and in English Literature Analysis — December 2009
University of Colorado, Boulder Colorado

RESEARCH INTERESTS

Physical Activity • Sedentary Behavior • Built Environment • Injury Prevention • Obesity Prevention •Social Determents of Health• Health Behavior • Health Disparities • Policy • Ecological Model • Health Promotion • Health Behavior Interventions • Behavioral Health Science

RESEARCH EXPERIENCE

Graduate Student Research Assistant to Dr. James Sallis — October 2012-present
University of California, San Diego
Manage and assist with research related activities for a variety of research grants at UCSD, including ample experience with data entry, data cleaning, syntax development and data analysis in SPSS for numerous studies.
NIH Grant R01 HL117884 (NHLBI): CRIME-PA: CRIme Measures Evaluations for Physical Activity
PI: James F. Sallis

- Helped lead and conduct qualitative research to develop a survey on neighborhood safety from crime and physical activity.
- Activities included leading focus groups and using qualitative methods to identify themes from the data collected
- Other work with the study includes assistance in recruitment and management of survey entry

The California Endowment: Evidence-Based School Policies to Promote Physical Activity
PI: James F. Sallis

- Assisted with data collection and analyses on a study assessing the implementation of classroom physical activity breaks in 6 CA school districts
- Led the structured interviews after the intervention with key administrative officials
- Played a pivotal role in data analysis, including mixed-effects linear regression
- Assisted in the preparation of the report with the findings

Expertise with Specific Measures and Instruments

- Trained in Microscale Audit of Pedestrian Streescapes (MAPS) as the "gold standard rater" and evaluated hundreds of routes in San Diego, CA, Seattle, WA, Boston, MA, Louisville, Kentucky, and Austin, TX. Involved in the entire process, from selecting routes, creating maps, data collection, data entry, data cleaning and running analyses with the data.
    - Helped collect and analyze data from 8 separate studies with MAPS data, including helping to develop abbreviated and mini versions and modifying for other locations
    - Led multiple trainings, both at conferences and to employees or interns

- Led inter-reliability analyses using SPSS to compare an in-person vs. online audit tool to rate streetscapes and helping lead the writing of the manuscript with the findings
- Trained in System for Observing Play and Recreation in Communities (SOPARC) and evaluated physical activity at parks from winter 2012-spring 2013 for a park validation study

Collaboration outside of UCSD

- Initiated collaboration with Dr. Deborah Cohen at RAND to use the National Study of Neighborhood Parks (NSNP) data to add in park quality
    - Rated parks online using the EAPRS-mini tool, trained an intern to assess reliability, and led validity analyses with park-based physical activity outcomes
- Helped lead the evaluation and analyses of San Diego's first open streets event (CicloSDias), including applying the findings to the next event

Independent Contractor for ResearchWorks Ongoing 2014-present

ResearchWorks, Inc., San Diego, CA

Consultant as needed on variety of projects, ranging from KPBS to Phillips Medical Devices

- Assisted on projects, including organizing and observing focus groups, identifying themes and writing up the findings to report to stakeholders
- Led the quantitative analysis for projects, including conducting factor analysis, recoding and cleaning data, and running regressions. Also interpreted the data and reported key findings

Graduate Student Research Associate to Dr. Linda Hill for TREDS August 2012-2014

University of California, San Diego

Worked for TREDS (Training, Research and Education for Driving Safety) on a study funded through AllState Insurance

- Responsibilities included helping to create, pilot and analyze a survey on attitudes and behaviors towards distracted driving among middle aged adults
- Ran exploratory factor analysis to create a distracted driving scale (DDS) to be used in future studies
- Presented at conferences on the findings and led the distracted driving publication

Research Assistant at the Gary and Mary West Health Institute November 2012-2013

Gary & Mary West Health Institute, San Diego

Helped develop and implement a pilot randomized control trial ("Passport to Health") with high-risk older adults at the Mary and Gary West Senior Center downtown

- Developed and tested the assessment tool by researching measures with established psychometrics
- Aided in participant recruitment into the Passport for Health program

Project Coordinator/Assistant at ResearchWorks, San Diego, CA August 2009-2012

ResearchWorks, Inc., San Diego, CA

Helped organize projects with companies including CDC, Draeger and Phillips, as well as aided with research and editing of reports.

- Provided secondary research on the association between motor vehicle injury prevention and helmet laws by states across the US for a CDC report
- Assisted in the research and development of a motor vehicle injury prevention (MVIP) campaign among American Indians living on tribal land in the US

Research Assistant to Dr. Louise Silvern, Boulder, CO January 2008- 2011
University of Colorado, Boulder
Researched Childhood Traumatic Grief (CTG) in children attending Judi's House, a non-profit, in Denver.

- Responsibilities included collecting data from in-depth interviews, validated and then coding and entering data using SPSS
- Participated in running support groups for bereaved children and collecting process evaluation data

TEACHING ACTIVITIES

Instructor, San Diego State University Fall Semester 2016
PH402: Public Health Communication

- Mean 4.20 (out of 5) on quantitative assessment by students, meaning "good" to "excellent," though over 60% rated excellent for "the instructor was professional and understanding in relationships with students"
- Comments from the qualitative assessments by students included:
    - *Not only was she very knowledgeable about the subject matter but of all public health issues brought up in class. Funny, engaging, relatable and approachable.*
- Developed all course materials, including the syllabus, lectures, assignments, for the 142 students. Supervised a GA who contributed 5 hours/week to help with grading. The course emphasis was on how to successfully develop and implement a health communication campaign, including formative research, communication theory, audience segmentation, message development, source and channel selection, and evaluation.

Instructor, San Diego State University Spring Semester 2016
PH662: Motivating Health Behavior in the Graduate School of Public Health

- Mean 4.19 (out of 5) on quantitative assessment by students, meaning "agree" to "strongly agree" with the positive statements. For example, 88% of the students strongly agreed with the statement "Provided adequate feedback regarding student performance in the course."
- Comments from qualitative questions included:
    - *Was very responsive to emails and questions. Always asked for our opinions on assignment and how the class was going, like what information we wanted to learn about. Very glad she taught this class I wish more instructors were like her*
- Developed all course materials, including the syllabus, lectures, assignments, and grading homework, quizzes and essays. The emphasis of the course was on an ecological model approach, designing interventions targeting different levels and evaluation (formative, process, outcome and impact).

Co-Instructor, San Diego State University Fall Semester 2014 & 2015
PH663: Health Communication (Master's Level Course) in the Graduate School of Public Health

- Responsible for writing and grading student homework and exams throughout the semester. Independently taught five class lectures each semester

Guest Lectures San Diego State University

- PH663: Health Communication, "Entertainment Education" Fall 2016

- PH861: Health Behavior Measurement, “Defining and Measuring Physical Activity” Fall 2015
- PH603: Behavioral and Social Science in Public Health, “Evaluating and Conducting Needs Assessments” Fall 2015
- PH700: Seminar in Women’s Health, “Gendercide: Systematic Killing of Females” Spring 2013

PEER-REVIEWED PUBLICATIONS

Engelberg, J.K., Conway, T.L., Geremia, C., Cain, K.L., Saelens, B.E., Glanz, K., Frank, L.D., and Sallis, J.F. (2016). Socioeconomic and race/ethnic disparities in observed park quality. *BMC Public Health*, 16:395. DOI 10.1186/s12889-016-3055-4. Open access: https://bmcpublichealth.biomedcentral.com/articles/10.1186/s12889-016-3055-4

Engelberg, J.K., Carlson, J.A., Conway, T.L., Cain, K.L., Saelens, B.E., Glanz, K., Frank, L.D., Sallis, J.F. (2016). Dog walking among adolescents: correlates and contribution to physical activity. *Preventive Medicine, 82*, 65-72.

Carlson, J.A., **Engelberg, J.K**., Cain, K.L., Conway, T.L., Mignano A.M., Bonilla, E.A., Geremia, C., & Sallis, J.F. (2015). Implementing classroom physical activity breaks: associations with student physical activity and classroom behavior. *Preventive Medicine, 81*, 67-72.

Engelberg, J.K., Hill, L.L., Rybar, J., & Styer, T. (2015). Distracted Driving Behaviors Related to Cell Phone Use among Middle-Aged Adults. Journal of Transport & Health *2*(3), 434-440.

Sallis, J. F., Spoon, C., Cavill, N., **Engelberg, J. K.,** Gebel, K., Parker, M., Thornton, C.M, Lou, D., Wilson, A.L., Cutter, C.L., & Ding, D. (2015). Co-benefits of designing communities for active living: an exploration of literature. International Journal of Behavioral Nutrition and Physical Activity, 12(1), 30. http://www.ijbnpa.org/content/pdf/s12966-015-0188-2.pdf. DOI 10.1186/s12966-015-0188-2.

Engelberg, M., Sanchez, T., & **Engelberg, J.K.** (2015). Social Marketing and If You Can’t Fix It, Feature It!. Social Marketing Quarterly, 21(1), 51-54.

Engelberg, J. K., Carlson, J. A., Black, M. L., Ryan, S., & Sallis, J. F. (2014). Ciclovía participation and impacts in San Diego, CA: The first CicloSDias. *Preventive medicine*, 69, S66-S73.

Manuscripts in Under Review or in Preparation

Engelberg J.K., Godino, J.G., Sallis, J.F., Conway, T.L., Hill, L., Patrick, K. (2016). Perceived Neighborhood Safety and Physical Activity among Overweight/Obese Adults: Multilevel Moderators (under review).

Engelberg, J.K., Conway, T.L., Geremia, C., Cain, K.L., Saelens, B.E., Glanz, K., Frank, L.D., and Sallis, J.F (in preparation) Objectively Measured Neighborhood Safety and Physical Activity among Adolescents: Multilevel Moderators.

Philips, C., **Engelberg, J.K.**, Adams, M.A., Conway, T.L., Geremia, C., Cain, K.L., Sallis, J.F. (In preparation). Online versus in-person Microscale Audit Pedestrian Streetscapes (MAPS) assessments: Reliability of alternate methods.

Carlson, J.K., **Engelberg, J.K**., Kerner, J., Cain, K., Conway, T., Geremia, C., Bonilla, E., Mignano, A., & Sallis, J. (in preparation). Contextual factors explaining implementation of classroom physical activity breaks.

OTHER PUBLICATIONS

Briefs & Reports

Engelberg, J.K. & Thornton, C. (2016). Disparities in Park Quality and Pedestrian Streetscape Environments. Research Brief. San Diego, CA: University of California, San Diego, Active Living Research. Available online at http://activelivingresearch.org/disparities-park-quality-and-pedestrian-streetscape-environments

Carlson, J.A., Ryan, S., Sallis, J.F., **Engelberg, J.K**., Black, M.L., Sanchez, J., Brown, M., Blackmar, C., Delaney, T., Clancy, E., Lambert, M. Evaluation of San Diego's First CicloSDias Open Streets Event. *Brief Report.* (February 2014).

Engelberg, M., Remba, D., & **Engelberg, J**. National Center for Injury Prevention Program, CDC Tribal Motor Vehicle Injury Prevention Program. (2011). Essential components in Tribal MVIP. Select publication and distribution only.

Chapters

Sallis, J. F., Spoon, C., Cavill, N., **Engelberg, J. K.,** Gebel, K., Parker, M., Thornton, C.M, Lou, D., Wilson, A.L., Cutter, C.L., & Ding, D. (2017). Co-benefits of designing communities for active living: an exploration of literature. Reprinted as Chapter 2, pp. 51-71. In Etingoff, K., Ed. *Urban land use: Community-based planning*. Waretown, NJ: Apple Academic Press.

PEER-REVIEWED SCIENTIFIC ORAL PRESENTATIONS & TRAININGS

Engelberg, J.K. (2016). *Considering the ConTxt: Ecological moderators of intervention effects on physical activity among overweight and obese adults.* Oral presentation at the 6th International Congress on Physical Activity and Public Health (ISPAH 2016): Bangkok, Thailand, November 16-19.

Engelberg, J.K. (2016). *Socioeconomic and Race/Ethnic Disparities in Observed Park Quality.* Oral presentation at the Active Living Research 2016 Annual Meeting: San Diego, CA, March 9-12.

Sallis, J., Thornton, C., & **Engelberg, J.K.** (2015) Disparities in microscale characteristics of streetscapes and park quality. Disparities in Health Promoting Environments: Physical Activity and Nutrition. Haifa, Israel, June 9. (Invited)

Engelberg, J.K., Black, M.L., (2014). *Ciclovía Participation and Impacts in San Diego, CA: The First CicloSDias.* Oral presentation at the Active Living Research 2014 Annual Meeting: San Diego, CA, March 9-12.

Trainings & Workshops

Spoon, C., & **Engelberg, J.K.** (2015). A*uditing the Pedestrian Environment: A Brief Tool for Practitioners & Community Members*. Training at the National Walking Summit: Washington, D.C., October 28-30.

Spoon, C., & **Engelberg, J.K.** (2015). A*uditing the Pedestrian Environment: A Brief Tool for Practitioners & Community Members*. Training at the Active Living Research 2015 Annual Meeting: San Diego, CA, Sunday February 22nd.

PEER-REVIEWED SCIENTIFIC POSTER PRESENTATIONS

Engelberg, J.K., Godino, J.G., Sallis, J.F., Conway, T.L,, Hill, L., Patrick, K. (2016). Moderators of the relation between Perceived Neighborhood Safety and Physical Activity. Poster presentation at the Society of Behavioral Medicine Annual Meeting. March 30-April 2, Washington, D.C.

Engelberg, J.K., Carlson, J.A., Conway, T.L., Cain, K., Saelens, B.E., Glanz, K., Frank, L.D., & Sallis, J.F. (2015). Dog walking as physical activity and ecological correlates of dog walking among adolescents. Poster presentation at the American College of Sports Medicine Annual Meeting. May 26-30, San Diego, CA.

Engelberg, J.K., Hill, L., Rybar, J., & Schmied, E. (2015). Distracted Driving in Middle-Aged San Diego Adults. Poster presentation at the American College of Preventive Medicine Annual Meeting, February 25-28, Atlanta, GA.

Engelberg, J.K., Conway, T.L., Cain, K., Saelens, B.E., Glanz, K., Frank, L.D., & Sallis, J.F. (2014). Socioeconomic and race/ethnic inequalities in observed park quality. Poster presentation at the International Society of Behavioral Nutrition and Physical Activity Annual Meeting, May 21-24, San Diego, CA.

HONORS AND AWARDS

SDSU Graduate Student Travel Fund- Student Success Fee March 2016

- Awarded $1000 to present research at the SBM conference in Washington D.C.

National Walking Summit Conference scholarship
October 2015

- To attend and present a training at the National Walking Summit in Washington, D.C

ORGANIZATION MEMBERSHIP

Professional Affiliations

Student member: Society of Behavioral Medicine (SBM); International Society for Physical Activity and Health (ISPAH)

COMMUNITY SERVICE

Professional services

Invited representative of Active Living Research (ALR) at San Diego American Indian Health Center (SDAIHC) HEAL Coalition Meeting (January, 2015)

Helped SDAIHC with their REACH grant, including assisting with advocacy and trainings using MAPS to identify built environment features to modify to promote safety and PA among AI youth (January 2013-July 2013)

Reviews:
Journal Referee/Reviewer: BMC Public Health; Journal of Transport & Health
Conference Referee/Reviewer: Active Living Research Conference (2016 & 2017)

APPEARANCES & COVERAGES

Media

Goodchild van Hilten, L. (2015, August 20). Elsevier Connect: Distracted driving is prevalent among middle-aged drivers too, study finds. Retrieved from http://www.elsevier.com/connect/distracted-driving-is-prevalent-among-middle-aged-drivers-too-study-finds

Mozes, A. (2015, August 26). Teens not the only ones using cellphones while driving. Retrieved from http://www.wkow.com/story/29882327/teens-not-the-only-ones-using-cellphones-while-driving

Presentations to Lay or Professional Audiences

Invited panel speaker in the Seminar in Health Behavior & Global Health class for 1st year PhD students in Public Health, San Diego State University (February 2016)

ABSTRACT OF THE DISSERTATION

Ecological Moderators of the Relation Between
Neighborhood Safety and Physical Activity

by

Jessa Kelsey Engelberg

Doctor of Philosophy in Public Health

University of California, San Diego, 2017
San Diego State University, 2017

James F. Sallis, Chair

Objective: Targeting neighborhood characteristics (e.g., pedestrian infrastructure) is a promising mechanism to increase physical activity (PA). However, the association with neighborhood safety and PA is unclear. An ecological approach, which considers multiple levels of influence, may help clarify the association. The current dissertation bridged the PA and injury prevention fields by assessing multilevel moderators of the association between neighborhood safety and PA. **Methods:** The three samples were overweight/obese adults from San Diego, CA (Study 1, n=298), adolescents from Seattle, WA and Baltimore, MD (Study 2, n=878) and older adults from Seattle, WA (Study 3, n=367). The PA outcomes were self-reported active transport and leisure-time PA, and objective moderate-to-vigorous PA (MVPA). Study 1 assessed perceived neighborhood safety (e.g., safety from crime, pedestrian safety). Studies 2 and 3 assessed objectively-measured pedestrian streetscape safety. Moderators were from individual/demographic, psychosocial, home and neighborhood environment levels.

Results: Fifteen of the 17 significant ($p<.10$) moderators found across studies were from individual/demographic or psychosocial levels. Though some moderators were shared across outcomes within the same study (e.g., sex and BMI in Study 1 or barriers in Study 2), race/ethnicity was the only significant moderator across studies (Studies 1 & 2). White non-Hispanic participants benefitted most in safe vs. unsafe neighborhoods, but there were few benefits among minorities. In Studies 2 & 3, the utility of the new objective streetscape safety measure was demonstrated. It was significantly positively associated with neighborhood-based PA among older adults, but negatively associated among adolescents.

Conclusion: The association of neighborhood safety with PA was complex and varied by subgroup. The findings demonstrate the utility of an ecological approach to better understand PA, particularly exploring cross-level interactions. Both perceived and objectively-assessed neighborhood safety had subgroup-specific effects, suggesting each age-group should be targeted separately (e.g., targeting pedestrian safety for older adults). More research is needed that incorporates objectively-assessed pedestrian safety, and interventions should tailor based on individual/demographic and psychosocial characteristics. Interventions can modify safety-related streetscape characteristics to reduce or eliminate traffic-related fatalities and injuries among pedestrians, and may have a dual benefit of facilitating greater physical activity in neighborhoods.

GENERAL INTRODUCTION

BACKGROUND AND THE CURRENT STATE OF THE LITERATURE

Ecological models and correlates of physical activity

The Centers for Disease Control and Prevention (CDC) recommend applying an ecological model as a best practice to help conceptualize and understand influences on health behavior, as there is ample evidence that supports the need to consider the multiple factors that influence desired health outcomes (CDC: The Social-Ecological Model, 2015; Sallis, Bauman, & Pratt, 1998). Specifically, ecological models posit that health interventions are most effective when they are designed to account for the multiple levels that influence a person's behavior, including individual, social, community, built environment and policy factors (Sallis & Owen, 2015; Sallis, Floyd, Rodríguez, & Saelens, 2012).

Because there are numerous documented health benefits related to achieving adequate amounts of physical activity, including lower risks of developing many chronic diseases (e.g. diabetes, heart disease) and improved mental health (Kim et al., 2012; Kohl et al., 2012; Penedo & Dahn, 2005; Warburton et al., 2006), physical activity is a health behavior of interest. Despite the well-documented benefits of physical activity, the rates of people in the US meeting the 2008 Physical Activity Guidelines recommended 150 minutes a week for adults and 60 minutes a day for children of moderate to vigorous physical activity (MVPA) (HHS PAG, 2008) is low, particularly when assessed objectively (Brownson et al., 2004; Troiano et al., 2008).

In spite of several decades of research focused on physical activity, including interventions (largely individual-based), the small proportion of individuals meeting guidelines remains high across the world, especially in the US (Hallal et al., 2012; Kohl et al., 2012). A review of the reviews on physical activity correlates around the world concluded that most studies focused on individual factors, and age, sex, health status, self-efficacy, and motivation were consistently associated with physical activity (Bauman, Reis, Sallis, Wells, F Loos, et al., 2012; Trost, Owen, Bauman, Sallis, & Brown, 1996). Despite these interventions, the rates of individuals meeting physical activity guidelines is still low, which demonstrates solely targeting the individual to increase physical activity is an ineffective approach. Focusing on only the individual ignores the complex influences on a behavior, such as relationships with other people, their home, work/school and neighborhood environment, the built environment and other community factors, including local policies (Brownson et al., 2009; Golden & Earp, 2012; Sallis et al., 1998). The environment surrounding the individual—including access to recreational facilities/parks, pedestrian and biking infrastructure, perceived safety from traffic and crime, and limited barriers—may be particularly influential factors in understanding if people will engage in regular physical activity (Boarnet et al., 2011; Harris et al., 2013; Sallis et al., 1998; Sallis et al., 2012).

The Built Environment, Safety and Physical Activity

Though the built environment has been defined in several ways by researchers, it generally refers to the physical environment created by humans that is modifiable (Handy et al., 2002; Papas et al., 2007; Saelens & Handy, 2008). The built environment includes urban design, the transportation system, land use patterns, the presence and quality of roads and sidewalks, types of housing, aesthetics (e.g. presence of art, views), and traffic volume, flow and safety (e.g. crosswalks, speed humps, traffic lights) (Handy et al., 2002). Reviews of the built environment and physical activity found positive associations between both perceived and objectively measured built environment features with physical activity, including accessibility to facilities and safety (Humpel, 2002a; McCormack et al., 2004; Saelens et al., 2012a; Wendel-Vos, et al., 2007). However, all the reviews called for more research using objective physical activity outcomes and both objectively measured and perceived neighborhood built environment features (Humpel, 2002; McCormack et al., 2004; Saelens et al., 2012; Wendel-Vos et al., 2007). In a review of the reviews on physical activity correlates, environmental correlates were frequently associated with physical activity outcomes, but the correlation with safety (i.e., traffic and safety from crime) was inconclusive (Bauman et al., 2012).

Given the evidence supporting an association between the neighborhood built environment and physical activity (Humpel, 2002; McCormack et al., 2004; Saelens et al., 2012; Wendel-Vos et al., 2007), it is necessary to assess interactions across levels of the ecological model (e.g. individual characteristics, psychosocial characteristics, home environment) to help further explain the relation. To help clarify inconsistent findings and advance the field, moderator analyses should be used to assess *interactions of influences across ecological model levels*, where known *correlates of physical activity from multiple ecological levels* are explored as moderators. The idea that variables from different ecological levels influence and interact with variables from other levels is a tenet of ecological models (Sallis & Owen, 2015). *Multilevel moderators* are critical to assess for whom and under what conditions the relation between neighborhoods and physical activity exists and in what direction (e.g., if they differ by gender, income, race/ethnicity, self-efficacy, social support, physical activity equipment around the home). *Interactions of influences across ecological model levels* are important to explore because the interactions can provide valuable clues about the patterns of interventions most likely to be successful for specific subgroups (e.g., target females with low-self efficacy in neighborhoods with high perceived traffic safety).

These cross-level interactions can be assessed as mediators or moderators. Moderators are variables that influence the strength of a relation between two variables (i.e., for whom the variables are most and least important), and can use cross-sectional or longitudinal data. Mediators are variables that can explain the relation between two variables; that is, they identify mechanisms of change. Prospective or intervention trial data are needed for classic mediation analyses. Moderators are important to assess, especially when only cross-sectional data are available, because they can help clarify unclear or inconsistent findings by illuminating subgroup-specific effects, However, some variables can be a mediator or a moderator, because both test interactions between an independent variable and outcome variable, and as such, it depends on the framing of the research question and type of analysis (e.g., cross-sectional). The limited research available on moderators of the relation between built environment features and physical activity is promising, though unclear. Some studies found significant interactions of physical activity and the neighborhood environment by demographics, psychosocial and environmental variables, though often in inconsistent directions (Bauman et al., 2002; Bracy et al., 2014; Carlson et al., 2014; Kerr et al., 2010; King et al. 2006; Marshall et al., 2004). The use of objective measures of both the neighborhood environment and physical activity are necessary to further the field (Bauman, Reis, Sallis, Wells, Loos, et al., 2012).

Though there is ample literature on physical activity and the built environment, there is a lack of data that explicitly assesses neighborhood safety environmental features and physical activity. A review of the limited studies concluded the relation between the built environment, perceptions of safety and physical activity was inconsistent and unclear, and utilized weak measures (Foster & Giles-Corti, 2008; Yen et al., 2009). Considering safety moderators (both objective and perceived) may help clarify these inconsistent findings.

There are limited studies that assess moderators of neighborhood safety and physical activity, particularly for specific age groups. A cross-sectional study explored sociodemographic moderators of the association between perceived neighborhood safety and objectively measured physical activity among adults and older adults found significant positive interactions with perceived neighborhood safety by high affluence (i.e., both high income and high education). One-third of the interactions involved gender (in inconsistent directions) and race/ethnicity was only significant among older adults (Carlson et al., 2014). One of the few studies that assessed moderators of physical activity interventions (i.e., utilized a prospective study design) and neighborhood environments found some perceived safety of the neighborhood environment variables were significant moderators, particularly traffic safety (King et al., 2006).

Objective measures of Microlevel Neighborhood Built Environment Features

Built environment features primarily fall into two geographic scales: macro or micro. *Macroscale* refers to large structural features, like land use mix, intersection density and housing units per residential area, while *microscale* refers to small environmental features, such as aesthetics, the presence of street lights, and sidewalk presence and quality (Brownson et al., 2009; Saelens & Handy, 2008; Sallis et al., 2011). In general, environmental attributes from the microscale level are easier to modify than macroscale attributes, as the latter often involve a high monetary cost and changing zoning laws. Environmental microscale modifications of neighborhoods are promising, and may significantly improve pedestrian safety in the short term.

For example, adding speed humps forces drivers to slow down because the environment dictates the behavior (Tester et al., 2004). Microscale features are typically self-reported as an individual's perceptions, but in contrast macrolevel features are often assessed objectively, such as with GIS-derived measures of walkability. The results from the few studies that used objective measures of microscale features of the built environment with physical activity are promising and found at least some significant associations. Well-maintained sidewalks, sidewalk infrastructure, traffic calming features (e.g., traffic humps), and public transit were positively associated with physical activity, particularly for transport, in one or more studies (Boarnet et al., 2011; Brownson et al., 2009; Cain et al., 2014; Pikora et al., 2002; Pikora et al., 2006). Despite these encouraging findings, more data are needed. The measures used were inconsistent, and there were a lack of valid measures and consistent scoring. Additionally, more studies are needed with diverse population subgroups to demonstrate generalizability, (e.g., different age groups and varied geographical locations). A validated instrument of microscale environmental features is the Microscale Audit of Pedestrian Streetscapes (MAPS) (Cain et al., 2014; Millstein et al., 2013).

A study used MAPS to assess the relation between physical activity (transport, leisure-time physical activity and accelerometer-measured total MVPA) and microscale environmental attributes, specifically by each MAPS item, subscale, section level and total streetscape score. The study used 4 age groups (i.e., children, adolescents, adults and older adults) and found significant associations with the physical activity outcomes that varied by age group (Cain et al., 2014). The grand score (i.e., total streetscape score) was significantly related to walking and biking for transport in all age groups, leisure-time physical activity in the neighborhood among only children and adolescents, and average total minutes/day of MVPA among only children and older adults (Cain et al., 2014), though not always in the expected directions. Though the analyses were adjusted for age, gender, education, GIS-defined walkability and clustering of block groups, no main effects of these variables were reported and no moderating effects were assessed. Safety attributes were collected and some items were included in different subscales, yet no safety specific scale was created using the validated safety-specific MAPS items.

Traffic and Pedestrian Safety

Traffic and pedestrian safety as correlates of physical activity have unclear and inconsistent findings (Carlson et al., 2014; Carver, Timperio, & Crawford, 2008; King et al., 2006; McCormack et al., 2004; Sallis et al., 2012; Sugiyama et al., 2012). Traffic and pedestrian safety is recognized as an important issue in the US, particularly due to the high rates of traffic fatalities. Rates of pedestrian fatalities are at a 20-year high, and increased by nearly 10% from 2014 to 2015 (NHTSA, 2016b). There is a currently a call for action to better understand the factors relating to this increase (Patil & Rosekind, 2016). Because of the high rates of pedestrian fatality and injury, pedestrian traffic safety is a recognized and important issue in the US (CDC: Injury Research Agenda, 2009-2018; NHTSA, 2016a; Sleet et al., 2010). Vision Zero is an initiative that originated in Sweden with the goal of having zero traffic-related fatalities, because these deaths are considered preventable, particularly when city design, infrastructure and enforcement is taken into account (Belin, Tillgren, & Vedung, 2012; Tingvall & Haworth, 1999). Many cities around the world, including at least 15 within the US, have adopted Vision Zero initiatives and policies (White, 2016).

According to the most recent complete Safety Report from the National Highway Traffic Safety Administration (NHTSA, 2016a) in 2014 there were 4,884 pedestrians killed in traffic crashes and about 65,000 injured in the US. In other words, a pedestrian was killed every 2 hours and injured every 8 minutes from traffic crashes in 2014. A pedestrian is defined as, “any person on foot, walking, running, jogging, hiking, sitting, or lying down who is involved in a motor vehicle traffic crash. A traffic crash is defined as an incident that involved one or more motor vehicles where at least one vehicle was in transport and the crash originated on a public traffic way, such as a road or highway” (NHTSA, 2016a, p. 1). Pedestrian deaths were up 2% in 2014 from 2013 and accounted for 15% of all traffic fatalities. However, more recent data showed a 9.5% increase in pedestrian fatalities in 2015 from 2014 (NHTSA, 2016b), but the complete report is currently unavailable.

There were important environmental, gender and age differences in the 2014 NHTSA data. For example, nearly 80% of the pedestrian traffic crashes occurred in urban vs. rural areas and about 70% at non-intersections compared to intersections (20%) or other areas (10%) (e.g. parking lanes/zones, bicycle lanes, shoulders/roadsides, sidewalks). There were disparities in rates of fatalities by sex and age. The majority of the pedestrians killed were male (70%) and the total male pedestrian fatality rate was more than double the rate for females (2.17 and 0.91 per 100,000 population, respectively). Older adults had the highest fatality rate than any other age group (2.12 per 100,000 population) and older adolescents (15-19 years old) had the highest rate of injury (37 per 100,000 population) (NHTSA, 2016a).

Despite the current emphasis on pedestrian safety, including at the policy level, there are few studies that assess the relation of neighborhood pedestrian safety with physical activity. It is particularly important to consider in relation to physical activity, because walking has numerous health benefits and is a common form of physical activity for both transport and leisure/recreational physical activity (Haskell et al., 2007; Sugiyama et al., 2012; Weuve et al., 2004). The streets near people's homes, worksites or schools are a common place for people to walk, yet pedestrians are exposed to traffic from vehicles while on the streets. A review of correlates of walking concluded that walking for transport and recreational walking should be conceptualized differently from one another. Pedestrian infrastructure was found to be significant only for walking for recreation, though personal safety (e.g., safety from crime) appeared to be important for both types of physical activity (Saelens & Handy, 2008). There are limited data on the association between objective and perceived measures of pedestrian safety (i.e., built environment features related to protecting pedestrians from traffic) in neighborhoods related to physical activity, especially domain-specific physical activity.

Previous studies that considered safety often used an undifferentiated view of "safety" that combined numerous aspects of safety into a single composite measure. Use of generic measures of safety or composite measures makes the findings from the limited studies particularly difficult to interpret (Foster & Giles-Corti, 2008). Studying perceptions of safety in different categories can offer specificity and help differentiate unclear findings from other studies, particularly if they utilize a validated measure. Specific perceived neighborhood safety variables of interest are safety from crime, traffic (i.e., speed and volume) and pedestrian safety (e.g., sidewalk presence and quality). Because of the high rates of pedestrian fatalities among all populations and age groups, pedestrian safety and safety from traffic are especially relevant to assess. Researchers and city planners can then use these data to help prevent fatalities and better design neighborhoods to be more conducive to safe physical activity. Objective measures of pedestrian and traffic safety are also important to use to advance the fields of injury prevention and physical activity.

Summary

Though the literature on the built environment and physical activity is conceptually related to the literature on injury prevention and safety, the two are still very separate. When safety is considered in the physical activity literature, it is only assessed as a correlate and not considered in interventions. There have been recommendations to bring the fields and agendas together (Sleet et al., 2010), but few examples of this happening in practice. The current dissertation advances this combined agenda with data from three studies (i.e., adolescents, older adults and overweight adults) and the application of an ecological approach. The overall specific aim was to examine moderators of the association between physical activity and the safety of the neighborhood environment.

ADDITION TO THE LITERATURE:

The primary aim was to use data from three studies and different age groups to assess multilevel moderators of the relation between physical activity and neighborhood safety. The existing literature highlights the importance of considering multiple factors, including the neighborhood built environment and safety-specific features, to explain and ultimately increase physical activity among different populations. However, findings were inconsistent or varied by population segments in unclear ways. A principle of ecological models is that behaviors are influenced by interactions among correlates from multiple levels (Sallis & Owen, 2015). Moderator analyses can help to clarify the associations because a moderator is a variable that affects the direction or strength of a relationship between an independent variable and outcome. For example, the effect of neighborhood traffic safety on leisure time physical activity may vary by gender (i.e., for men vs. women) or by age (e.g., younger vs. older adolescents). Bauman et al. (2002) explained that "a moderator produces different estimates of the association at different levels of the variable" (p. 8). The aim of the current analyses was to assess moderators of the association between physical activity and the safety of the neighborhood built environment among three different samples and age groups. Moderators, rather than mediators, were selected because of the cross-sectional data and the aim of the research, which was to assess for subgroup-specific effects to help clarify unclear findings.

All studies applied principles of the ecological model, such as exploring hypothesized moderators from different ecological levels (i.e., multilevel) to better understand the neighborhood safety factors associated with physical activity (Fig. A, B, C). The physical activity outcomes across the 3 studies were objective physical activity (i.e., total minutes/day of MVPA data from accelerometers), as well as self-reported active transport and leisure-time physical activity. All three studies also used similar versions of a measure to report perceived neighborhood safety and features. Strengths of the current dissertation were the consistent themes across all three studies, such as shared moderators from different levels of the ecological model, multiple physical activity measures (including objective) and explicitly combining concepts from the fields of injury prevention/pedestrian safety and physical activity. Examining samples at different points in the life course, such as the focus on adolescents vs. older adults, was also important contribution to help compare across the lifespan. Using a similar analytical approach allowed for rough comparability of results across age groups. However, given these were unique populations and age groups, it was hypothesized that significant moderators would vary by dataset.

Two of the studies (Study 2: adolescents and Study 3: older adults) included objective microscale measures of streetscape safety of the neighborhood. There are some data that show objective measures versus perceived measures of environmental characteristics are not interchangeable (Bailey et al., 2014) and reviews of environmental correlates (including safety) have called for the assessment of both (Saelens & Handy, 2008). The studies both assessed ecological moderators of the association of neighborhood streetscape safety (e.g., pedestrian safety from traffic) and physical activity by using a safety specific index created using validated

MAPS items and was tested in two of the current studies. The items used were explicitly related to known features of pedestrian safety from traffic (DOT, 2002; Zegeer et al., 2009), and included items such as sidewalk presence, presence of streetlights and traffic calming features (see Appendix 1 for items and scoring). The MAPS streetscape safety index can further the field by adding to the dearth of literature on objectively measured safety features of neighborhoods and the relation to physical activity. This can serve to help combine the injury prevention and physical activity fields, and contribute to the research that is influencing policies like Vision Zero.

Brief descriptions of the three studies included are listed below, but each study is presented in its entirety in Chapters 1-3. The final chapter is a General Discussion that identifies common themes and highlights key lessons and implications for intervention.

STUDY 1: OVERWEIGHT ADULTS

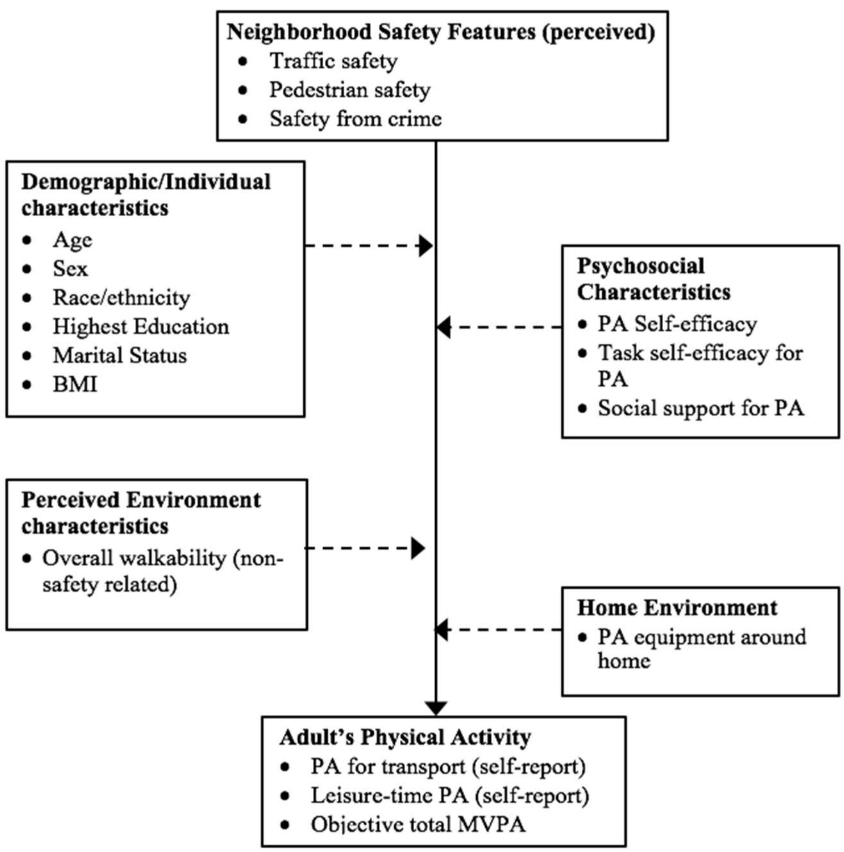

Figure A: Hypothesized association of perceived neighborhood safety with physical activity, and ecological moderators of the association among overweight/obese adults

The ConTxt study was a randomized controlled trial (RCT) funded by the National Cancer Institute (NCI) assessing a theory-based text-message intervention for weight loss and increased physical activity. Participants were overweight and obese (BMI 25–39.9) men and women ages 21–60. Only baseline data were used and reported in the current study.

An ecological approach was applied to assess if there were multilevel moderators of the relation with perceived neighborhood safety (i.e., safety from crime, pedestrian safety and traffic safety) and physical activity (i.e., leisure-time physical activity, active transport and objective total MVPA). Hypothesized moderators were from different ecological levels and included individual/demographic (e.g., age, gender, BMI), psychosocial (e.g., self-efficacy, social support), home environment (e.g., home physical activity equipment) and neighborhood environment (i.e., overall non-safety related walkability) characteristics (Figure A). A final cross-level model with the significant interactive and main effects for each outcome was ultimately reached.

STUDY 2: ADOLESCENTS

The adolescent analyses used cross-sectional data from the Teen Environment and Neighborhood (TEAN) Study to assess moderators between MAPS streetscape safety data and the same three physical activity outcomes. The objective minutes/day of MVPA outcome was specific to the neighborhood immediately around the home (i.e., by using a GPS device). The independent variable was the MAPS streetscape safety index that was created for these analyses. The relation between physical activity and objective neighborhood streetscape safety is the basic analysis within which moderators were examined.

An ecological model approach was used to assess hypothesized moderators of different levels, including individual/demographic (e.g., age, race, sex, age), psychosocial (e.g., social support, self-efficacy, perceived barriers to physical activity in the neighborhood), home environment (e.g., exercise equipment access, parent restrictions, personal electronic devices ownership) and perceived neighborhood environment (e.g., pedestrian safety, safety from crime) characteristics (Figure B). The association of MAPS safety streetscape index with physical activity and multi-level moderators of the association were explored, until a final cross-level model was reached for each outcome.

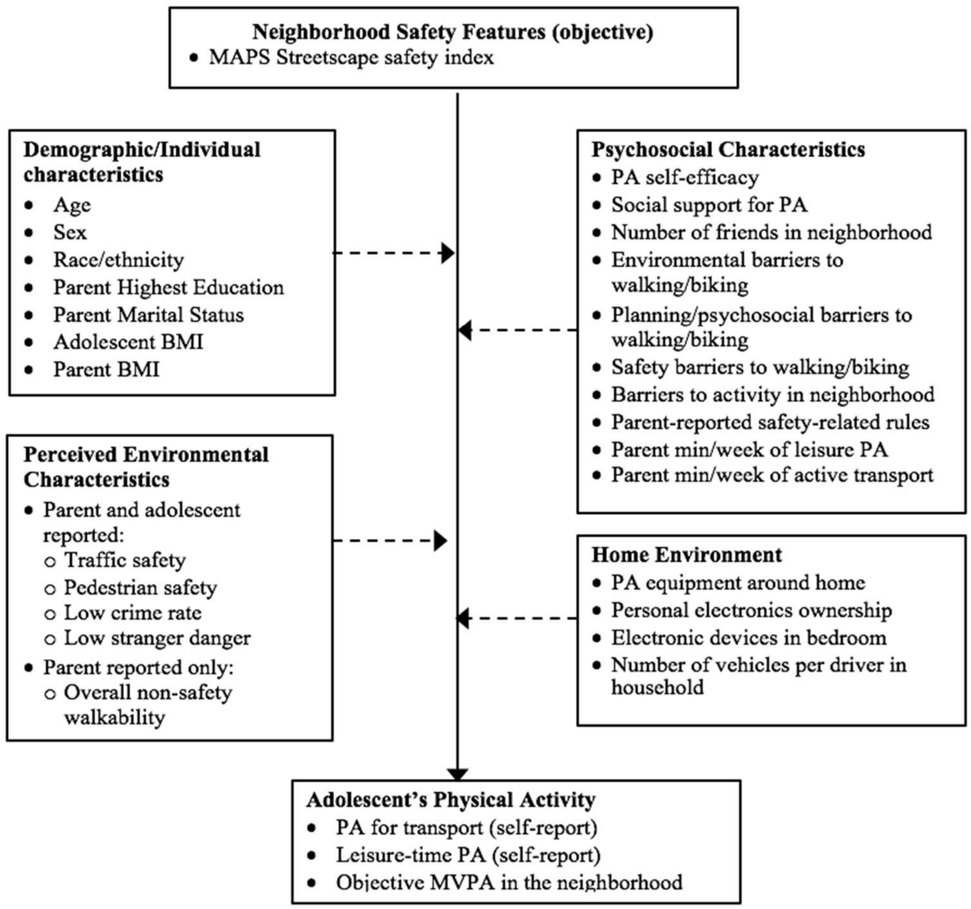

Figure B: Hypothesized association of objective streetscape safety in the neighborhood with physical activity, and ecological moderators of the association among adolescents

STUDY 3: OLDER ADULTS

The older adult analyses used cross-sectional data from the Seniors Neighborhood Quality of Life Study (SNQLS) and followed a similar approach to Study 2 (i.e., TEAN adolescent data). Moderators of the association between the MAPS streetscape safety index with the three physical activity outcomes (i.e., walking for leisure, active transport and objective total MVPA) was explored.

An ecological model approach was used to assess hypothesized moderators by ecological level, including individual (e.g., age, race, gender, education), psychosocial (e.g., social support, self-efficacy), home environment (e.g., physical activity equipment) and perceived neighborhood environment (e.g., pedestrian safety, traffic safety) characteristics (Figure C). The association of MAPS safety streetscape index with physical activity and multi-level moderators of the association were explored, until a final cross-level model was reached for each outcome. Because older adults often have health conditions associated with age, after a final cross-level model was reached, health variables were added in to assess for confounders.

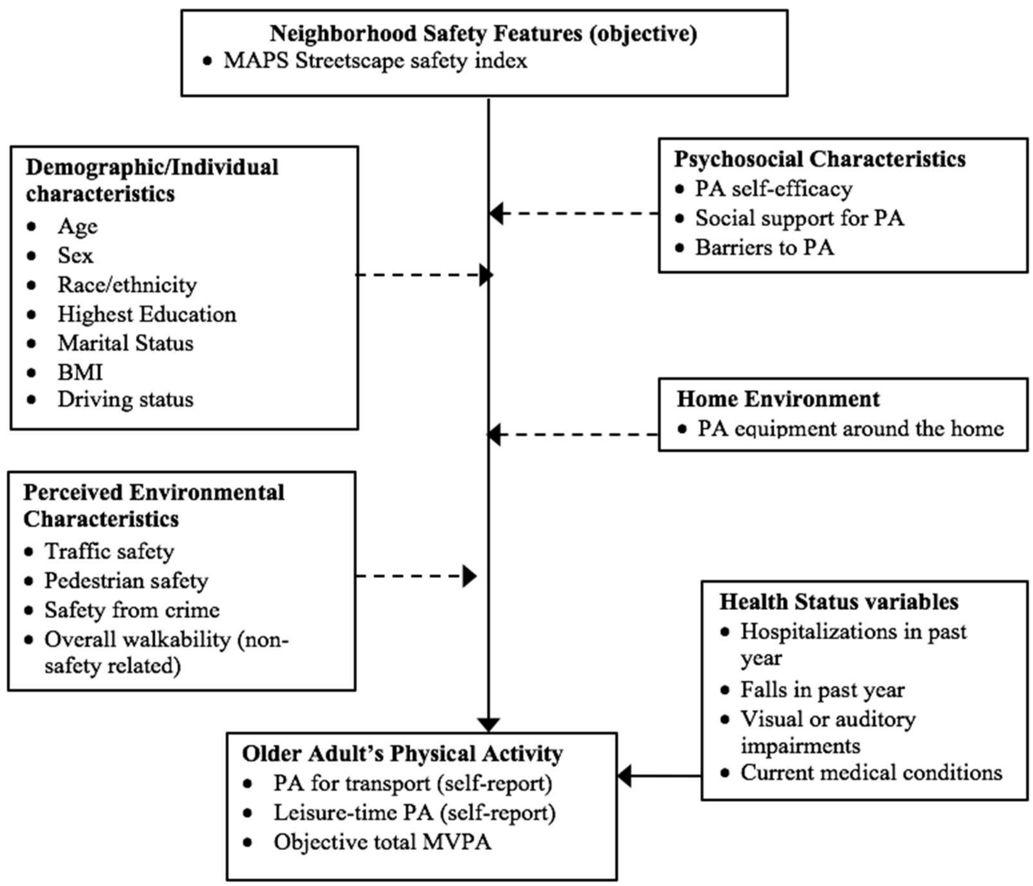

Figure C: Hypothesized association of objective streetscape safety in the neighborhood with physical activity, and ecological moderators of the association among older adults

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CHAPTER 1

Perceived Neighborhood Safety and Physical Activity among Overweight and Obese Adults: Multilevel Moderators

ABSTRACT

Background: The relation between neighborhood safety and physical activity (PA) is unclear.

Purpose: To explore moderators of the relation between PA and perceived neighborhood safety among overweight/obese adults.

Methods: Participants were male and female adults (N=298) aged 21-60 years with BMIs of 25-39.8. PA outcomes included accelerometer-derived minutes/day and self-reported days/week of active transport and leisure-time MVPA. Demographic, psychosocial and environmental moderators of perceived neighborhood safety (i.e., traffic, pedestrian, crime) and PA were explored using multilevel GLM models.

Results: Demographics moderated the relation between perceived safety and total MVPA and active transport. Perceptions of pedestrian infrastructure were positively associated with more total PA and active transport among males, White non-Hispanics, and/or overweight adults. Social support, self-efficacy, and home PA equipment were positively associated with leisure-time MVPA among participants in low-safety neighborhoods.

Conclusions: Significant findings from multiple levels support the use of ecological models. Demographics moderated the relation of safety environments to active transport and total MVPA, and psychosocial characteristics were moderators for leisure-time MVPA.

INTRODUCTION

Because most US adults do not meet physical activity guidelines (PAGA, 2008), nearly 40% according to self-report and 90% according to accelerometer outcomes (Tucker et al., 2011), the World Health Organization (WHO, 2013) and the US Surgeon General (HHS, 2015), among others, recommend interventions that target physical activity-related factors at multiple levels of influence. The design of interventions to promote physical activity should be guided by both theory and evidence of correlates. Applying ecological models can be useful because such models lead to the examination of multiple levels of influence, including individual, social, community, built environment, and policy levels, and correlates at all levels of the ecological model have been found (Bauman et al., 2012). The evidence supporting the relation between the neighborhood built environment and physical activity is strong (McCormack et al., 2004; Saelens et al., 2012; Wendel-Vos et al., 2007). In a review of correlates of physical activity, findings were still inconclusive for traffic safety and safety from crime (Bauman et al., 2012). Further study of these factors is needed to clarify the relation.

Safety is defined by the World Health Organization (WHO, 1998) as: "…a state in which hazards and conditions leading to physical, psychological or material harm are controlled in order to preserve the health and well-being of individuals and the community" (p. 5). The relation between neighborhood safety (perceived and objective) and physical activity remains unclear (CDC, 1996; Carlson et al., 2014; Bracy et al., 2014; Foster & Giles-Corti, 2008; Christian et al., 2011). A meta-analysis found the best-supported safety-related environmental correlates of physical activity were perceived presence of heavy traffic and sidewalks, which explained 4% and 6% of the variance in physical activity respectively (Duncan et al., 2005). Reports of associations of crime-related safety with physical activity are inconsistent. One review found some group-specific associations (Foster & Giles-Corti, 2008), but a more recent review found no association (da Silva et al., 2016).

These inconsistent findings between perceived safety and physical activity may be related to methodological problems. Three reviews critiqued the lack of objective physical activity data, weak and inconsistent measures of the perceived environment (e.g., the use of composite scores), and a lack of clarity of definitions and measures in studies that assessed pedestrian infrastructure and safety from crime and traffic (Foster & Giles-Corti, 2008; Duncan et al., 2005; da Silva et al., 2016).

This lack of consensus suggests the need for a deeper understanding of the complex association between safety and physical activity. A principle of ecological models is that behaviors are influenced by interactions across the different levels (Sallis & Owen, 2015). Thus, it can be useful to examine safety-related variables as potential moderators of other correlates. The few studies that analyzed interactions between perceived safety and variables from multiple levels to explain physical activity had mixed results (Carlson et al., 2014; Bracy et al., 2014; Beenackeres et al., 2011). These findings emphasize the need to continue studying moderators to better understand under which conditions and for whom perceived safety variables are associated with physical activity. The data used in the current study were ideal to explore moderating effects because it was theory-based and applied an ecological approach, including measures from multiple levels.

The purpose of this study was to leverage cross-sectional multilevel data collected in a large randomized controlled trial (RCT) of an obesity intervention among adults to address four gaps in the literature related to perceived neighborhood safety and physical activity. First was the problem of inaccurate measurement of physical activity. In this study, physical activity was explored with three physical activity outcomes, one objectively measured and two self-reported but domain-specific. Second was the poor quality of measures of perceived safety. Three elements of this construct, including crime, traffic, and pedestrian safety infrastructure, were assessed with a validated measure in the present study. Third, given the inconsistent findings on the relation between physical activity and perceived neighborhood safety, the current study explored if other known correlates of physical activity moderated the relation. Fourth, the use of an overweight/obese sample was unique and allowed for assessment of the generalizability of previous findings in a group that is at-risk for multiple chronic diseases. It was hypothesized that factors from different ecological levels may moderate the relation of perceived neighborhood safety and physical activity. For example, Foster and Giles-Corti (2008) found some evidence of sex-specific effects, and it was hypothesized that sex may be a significant moderator in the present study. However, because the exploratory nature of the study, there was no basis for hypothesizing more specific moderation findings.

METHODS

Design

The larger "ConTxt" study was a RCT evaluating a 12-month weight loss intervention funded by the National Cancer Institute (NCI). The intervention focused primarily on theory-based interactive text-messaging (SMS) and assigned participants (N=298) to one of three conditions: SMS Only (n=101), SMS + Health Coach (n=96), and Control (i.e., standard materials; n=101). However, in the current cross-sectional analyses presented, only baseline data were used. Future manuscripts are planned to leverage the longitudinal data to explore moderators of the intervention effect on physical activity. The study was conducted in both English and Spanish, and Hispanic participants were oversampled. Participants were incentivized with $50 at baseline for completing all assessment activities. The study was approved by the Institutional Review Board at the University of California, San Diego, and all participants provided informed consent.

Participants and Recruitment for ConTxt:

Participants were recruited from October 2011 through March 2013 from the community using newspaper ads, flyers, email listserves, announcements on Craigslist, community events (e.g., farmer's markets) and through word of mouth. Bilingual staff screened potential participants for the following inclusion criteria: 21– 60 years old, overweight or obese (BMI ≥27-39.8), owned a cell phone capable of SMS messaging, not taking medications known to cause weight gain, no history of eating disorder or weight loss surgery, and willingness and ability to comply with study protocols. Interested individuals were also screened using the Physical Activity Readiness Questionnaire (PAR-Q) (Shepard, 1988; Thomas et al., 1992). Any individual who answered "yes" to at least one of the PAR-Q questions needed to have his/her doctor's approval to be eligible. A total of 298 participants enrolled and completed a baseline study visit, including a survey with measures assessing correlates from multiple ecological levels.

MEASURES

Table 1.1 depicts all measures of outcomes and correlates used in the current study, though brief descriptions are included below.

Physical activity outcomes

Self-reported days per week of leisure-time MVPA and active transport

The Global Physical Activity Questionnaire (GPAQ) is a validated measure used to collect physical activity information in different domains (Armstrong & Bull, 2006; Cleland et al., 2014). The current study used travel to and from places (i.e., active transport), and leisure-time moderate and vigorous activities (i.e., leisure-time MVPA). The outcome variables were expressed as days per week.

Objective total MVPA minutes per day (accelerometer)

Accelerometer measured total MVPA is strongly related to health (Atienza et al., 2011). Accelerometer technology has been shown to be valid for quantifying activity levels in laboratory and field settings among adults (Welk, 2002). To be included in present analyses, a minimum of 3 valid days were necessary, yielding 279 participants. Total MVPA minutes per day were calculated using a cut point of ≥2020 counts per minute (Troiano et al., 2008; Choi et al., 2012).

The measure used in analyses was the average of total MVPA minutes across all valid wearing days.

Independent variables: Perceived neighborhood safety

The Abbreviated Neighborhood Environment Walkability Scale (NEWS-A) is a 53-item survey developed to assess participants' perceptions of their neighborhood related to being physically active (Cerin et al., 2006; Cerin et al., 2009). According to a recent review, NEWS was the most frequently used measure to assess perceived neighborhood safety and physical activity (da Silva et al., 2016). The original NEWS was a 68-item survey, and the validity is well-documented, including in multiple countries (De Bourdeaudhuij et al., 2013; Leslie et al., 2005; Saelens et al., 2003). Through confirmatory factor analysis, a shortened version of the measure was developed and evaluated (i.e., NEWS-A) (Cerin et al., 2009). Though there are 7 subscales in NEWS-A, the current study only used the 3 safety-related subscales because the study aimed to clarify the relation of safety and physical activity by assessing multilevel moderators. The three safety related subscales used were: traffic safety (mean 3 items), pedestrian safety infrastructure (mean 3 items), and safety from crime (mean 6 items).

Multilevel moderator variables

Moderators were known correlates of physical activity and included variables from multiple levels of influence (e.g., demographics, BMI, self-efficacy for physical activity, task self-efficacy, social support, physical activity equipment around the home and perceived overall neighborhood walkability).

Statistical Analyses

All models used generalized linear regression models in SPSS V.22.0, using the GLM procedure. All outcome variables were normally distributed and did not need to be transformed. The same initial models were run for all three dependent variables. Models were adjusted for demographic covariates (age, sex, race/ethnicity [i.e., Hispanic, White non-Hispanic, Other minority], marital status, education, BMI). The continuous independent variables, correlates and covariates were grand mean centered to create orthogonal interaction terms such that the intercept would approximate the sample mean for outcomes.

Independent variables were first analyzed in three separate models per outcome based on NEWS-A safety subscales: (1) walking infrastructure safety, (2) traffic safety, and (3) safety from crime. Each model included variables from four other levels of the ecological model: (1) individual/demographic (six variables), (2) psychosocial (three variables), (3) home environment (one variable), and (4) neighborhood non-safety related walkability environment (one variable). All possible cross-level interactions for each NEWS-A safety subscale were tested, for a total of 11 interactions per model (and 33 tested interactions per outcome).

Main effects and interactions with $p \leq 0.10$ were entered into a final model with the three NEWS-A subscales. Additionally, all models were adjusted for the demographic variables (regardless of significance). To reach the final model for each physical activity outcome, all interaction terms that did not retain their significance were manually removed, one at a time, starting with the highest p-value, until a model containing only significant ($p<.05$) interaction terms was achieved. All removed interactions were re-entered into the final model one at a time to ensure they were still not significant after other variables had been removed, similar to the approach described in Saelens et al. (2012).

Interactions were graphed by creating equal tertiles for continuous variables to represent high, mid, and low perceived neighborhood safety (i.e., crime, traffic and pedestrian) and then plotting the average model-predicted physical activity score for each of the safety tertiles. Unstandardized regression coefficients (B) were reported and can be interpreted as the change in the dependent variable for a 1-unit change in the independent variable.

RESULTS

Sample Characteristics

The study sample was composed of adults (n=298) with a mean age of 44.6 years. Over three-quarters were women (76.5%). The racial/ethnic composition of the sample was diverse, with 42% White non-Hispanic, 39% Hispanic, and 19% a different minority. Over 50% were married or living with a partner, and almost 45% had a college-degree or higher. The average BMI was approximately 33, which is classified as Obese Class I (N.O.E.I.E., 1998) (Table 1.2).

Accelerometer-derived total minutes of MVPA/day Outcome

In the final models, no demographic variables were associated as main effects with total MVPA minutes per day; however, they were included in the final cross-level model as covariates. Across the other ecological levels, there was a main effect of greater pedestrian safety infrastructure associated with almost 8 minutes more total MVPA per unit of perceived pedestrian safety ($p<.05$). Three of the 11 interactions tested in the final cross-level model were significant ($p<.05$) (Table 1.3). The relation of pedestrian safety infrastructure with total MVPA was moderated by three demographic factors: sex, race/ethnicity and BMI.

In the sex interaction, there was a difference of nearly 21 minutes a day of total MVPA among men, ranging from 17.5 minutes (in low safety neighborhoods) to 38.5 minutes (in high safety neighborhoods) (Fig. 1.1A). There was no difference in total MVPA by perceptions among women. Race/ethnicity moderated the relation between pedestrian safety and total MVPA, where White non-Hispanic participants in neighborhoods with high safety obtained nearly 20 minutes more total MVPA than those with low safety. There was a small difference among other minorities by neighborhood (about 6 minutes), but no difference among Hispanics (Fig. 1.1B). In the BMI interaction, overweight participants obtained 19 minutes more total MVPA and Obese Class I participants obtained 8 minutes more total MVPA in neighborhoods with high vs. low pedestrian safety. There was no difference among the most obese participants (Fig. 1.1C).

Days/week of Active Transport Outcome

There were no significant demographic main effects with active transport in the final model, but the variables were retained as controls (Table 1.4). In the psychosocial category, each 1-unit increase in physical activity self-efficacy was associated with 0.34 more days/week of active transport (p=0.026). Each SD difference in perceived overall neighborhood walkability (non-safety related) was associated with 1.7 more days of active transport (p<.001). There were 2 significant interactions (p<.05), where sex and BMI moderated the relation of perceived safety from crime in the neighborhood and days/week of active transport.

In the sex interaction, men who perceived the neighborhood as safer from crime reported over 1 full day more of active transport than those in neighborhoods with low safety from crime, but this was not the case among women (Fig. 1.2A). The BMI interaction showed overweight participants in neighborhoods with high safety from crime reported nearly 1 full day more of active transport than those with low safety from crime. The finding was reversed among the most obese participants, where participants reported almost 1 day more of active transport in neighborhoods with low vs. high safety from crime (Fig. 1.2B).

Days/week of leisure-time MVPA Outcome

No demographic factors were significantly associated as main effects with leisure-time MVPA (Table 1.5). There were 3 significant (p<.05) main effects with variables also involved in the 3 significant interactions. Self-efficacy and home physical activity equipment ownership were positively associated with leisure-time MVPA, with each unit increase associated with about 1/3 and 1/5 more days/week of leisure-time MVPA respectively. Safety from crime had a negative association, where each unit increase in perceived safety from crime was associated with about 1/3 day less a day of leisure-time MVPA. Social support of physical activity moderated the relation between pedestrian infrastructure and leisure-time MVPA. The relation of safety from crime in the neighborhood and leisure-time MVPA was moderated by physical activity self-efficacy and home physical activity equipment.

Participants with high social support reported almost 2 days a week of leisure-time MVPA, while those with low social support reported <1 day in neighborhoods with low pedestrian safety. However, in neighborhoods with high pedestrian safety, all participants reported about 1.5 days a week of leisure-time PA regardless of social support (Fig. 1.3A). The self-efficacy and safety from crime interaction showed a similar pattern to the social support interaction. In neighborhoods with low safety from crime, high self-efficacy was associated with a full day more leisure-time MVPA than those with low self-efficacy. In neighborhoods with high safety from crime, reported days of leisure-time MVPA was lower for those with high self-efficacy and did not significantly differ for those with low or mid self-efficacy (Fig. 1.3B). Examining interactions between home physical activity equipment and safety from crime, participants who owned >7 equipment items obtained >2 days of leisure-time MVPA in neighborhoods with low safety from crime, yet only 1.5 days in neighborhoods with high safety from crime. Those with the fewest items reported the fewest days/week of leisure-time MVPA, regardless of neighborhood safety (Fig. 1.3C).

DISCUSSION

The hypothesis that correlates of physical activity would moderate the relation of perceived neighborhood safety was supported. Sixteen of the total 99 tested interactions across the 3 outcomes were significant at $p<.10$, which is greater than the expected 10%. Of those 16 interactions that were tested in the final cross-level models, 50% of the interactions (i.e., 8 out 16) were significant ($p<.05$) and maintained in the final cross-level model.

The findings were consistent with the ecological principle of cross-level interactions (Sallis & Owen, 2015), considering that moderators were found from three of four tested ecological levels. Demographic characteristics, especially sex and BMI, were moderators of the relation between perceived neighborhood safety and two physical activity outcomes (total MVPA and active transport). Psychosocial and home environment characteristics significantly moderated the relation between perceived neighborhood safety and leisure-time MVPA. Thus, present results indicated that the association between neighborhood safety and physical activity was modified by a wide range of variables that differed across outcomes. It is possible that the complex moderator effects documented may help explain inconsistent findings in prior studies focused on main effects. The results are interpreted for each physical activity outcome in turn.

Findings with Accelerometer-derived total MVPA/day Outcome

Given that few studies used an objective physical activity measure to explore the relation with perceived safety (Foster & Giles-Corti, 2008; Christian et al., 2011; Duncan et al., 2005), the present findings help advance the field. The main effect that greater perceived pedestrian safety infrastructure (e.g., sidewalk presence, marked crossings) was associated with more total MVPA among all participants was consistent with a study of perceived safety moderators and physical activity (Bracy et al., 2014). The authors concluded this could be partially explained because pedestrian safety infrastructure items (e.g., presence of crosswalks or sidewalks) were not as subjective as the other perceived safety scales (Bracy et al., 2014). However, the present study also found 3 demographic moderators of pedestrian infrastructure, which demonstrates that certain subgroups may benefit from the infrastructure more than others.

Surprisingly, higher pedestrian safety was only related to total MVPA among men, though it was hypothesized that women would be more sensitive to perceived neighborhood safety. Despite the unexpected direction of the association, the finding was consistent with another study of moderators of perceived safety and physical activity with a similar association among men (Carlson et al., 2014).

The finding that White non-Hispanics appeared to benefit more than minority adults from living in neighborhoods with high pedestrian safety parallels findings from other studies (Hooker et al., 2005; Carlson et al., 2012;). When taken together, these findings imply that White non-Hispanic participants' physical activity may be more influenced by their perceptions of neighborhood safety than other minorities. Therefore, an important next step is to identify other potential strategies for increasing physical activity in mostly-minority communities to use in targeted interventions.

Hispanic and/or the most obese participants appeared to derive no benefit from pedestrian safety infrastructure. Unexpectedly, in neighborhoods with low pedestrian safety, both Hispanic and the most obese participants had more minutes of total MVPA than participants of other races/ethnicities and/or less obese. A limitation of total MVPA measured via accelerometer was the inability to differentiate between neighborhood-based physical activities vs. other locations (e.g., work, gyms, inside the home). It is possible these high-risk participants engaged in physical activity at other locations. Another possible explanation is that the most obese participants chose not to engage in outdoor physical activity in their neighborhoods for fear of embarrassment, due to weight stigmatization (Lewis et al., 2011). If the most obese participants were less likely to be physically active in their neighborhood, then neighborhood safety would be irrelevant. It is possible that Hispanic and/or most obese participants were the most disadvantaged and were most active because they engaged in active transport out of necessity, which is consistent with transportation research (Ross, 2000; Miles et al., 2008; Turrell et al., 2013).

Findings with the Active Transport Outcome

Overall neighborhood walkability (non-safety related) had a significant positive main effect, with a large magnitude of nearly 2 more days of active transport reported for each SD increment in overall walkability. This increase was almost double the average days of active transport, which emphasized the importance of non-safety related built environment features related to active transport. The finding was consistent with the literature, in that those in more walkable neighborhoods (e.g., high street connectivity, proximal to commercial destinations) engaged in more active transport (Bracy et al., 2014; Sallis et al., 2004; Wang et all, 2016). A recent study from 10 countries identified walkability features, such as residential density and the number of public transit stops, as critical for adults to be physically active (Sallis et al., 2016). Though pedestrian safety infrastructure was not related with active transport in the current study, highly walkable areas typically have ample pedestrian infrastructure. The present study adds to the literature because there no moderation effects by overall non-safety realted walkability, which implies walkability benefitted all subgroups in this sample of overweight/obese adults.

Sex and BMI were moderators of perceived safety from crime and days/week of active transport, which paralleled the total MVPA findings. Specifically, men obtained almost 1 more day of active transport in safer neighborhoods, but there was no association for women. Again, this was counter to expectations, but findings from studies on safety from crime and physical activity were inconsistent. A recent review of the relation between the built environment, neighborhood crime and physical activity reported no association between physical activity and neighborhood crime, including no moderation by gender (da Silva et al., 2016). The authors noted that most studies focused on leisure-time physical activity, but of those that assessed active transport, 8.2% of the findings were in unexpected directions for active transport vs. 2.1% for leisure-time physical activity (da Silva et al., 2016). These differences could be largely because transportation based physical activity is not an individual choice in the same way that leisure-time physical activity is; rather, it may be the only way people can get from place to place.

In the interaction of safety from crime and BMI, the findings again paralleled the total MVPA findings, where overweight and obese Class I participants appeared to benefit in neighborhoods with high safety from crime. An unexpected finding was that the most obese participants (Class II/extreme obesity) reported almost a full day more active transport in neighborhoods with low safety from crime compared to neighborhoods with high or mid safety. The finding that the most at-risk participants (e.g., the most obese) reported the most active transport and total MVPA in unsafe neighborhoods lends support to the idea that the most obese have to engage in active transport because they tend to be economically disadvantaged. The full day decrement in active transport in neighborhoods with higher safety is difficult to explain, but a possible explanation is that neighborhoods with higher safety from crime were less conducive to active transport in terms of overall walkability. A possible explanation was that more urban and walkable areas have greater indicators of crime (e.g., graffiti) (Foster & Giles-Corti, 2008).

Findings with Leisure-time MVPA Outcome

Social support and self-efficacy for physical activity moderated the relation of perceived pedestrian infrastructure and leisure-time physical activity. Higher self-efficacy and social support may help participants in neighborhoods with low safety overcome safety-related barriers, which is consistent with a Dutch study that explored psychosocial moderators of perceived neighborhood safety and sports participation (similar to leisure-time MVPA) (Beenackers et al., 2011). It is unclear why leisure-time physical activity would be lower in safer neighborhoods, even when self-efficacy and social support were high. The similar pattern of findings for social support and self-efficacy moderators imply that these psychosocial variables are important for leisure-time physical activity when in unsafe environments, yet not in safe environments.

More home physical activity equipment was associated with higher leisure-time MVPA, but only in unsafe neighborhoods, which is consistent with a study from Brazil (Rech et al., 2012). It is logical that, in neighborhoods with high crime, having more physical activity equipment could help one engage in physical activity more in their home as opposed to going out into the neighborhood. Across all safety levels, more physical activity equipment was consistently associated with more leisure-time physical activity. However, high ownership of physical activity equipment in safer neighborhoods was associated with less MVPA compared to unsafe neighborhoods. It is unclear why participants would engage in less leisure-time MVPA when living in neighborhoods perceived as safe from crime.

Self-efficacy and home physical activity equipment were both also main effects and associated with slightly more leisure-time physical activity, which demonstrated that higher self-efficacy and having access to more physical activity equipment benefited all participants. In contrast, safety from crime was negatively associated with leisure-time physical activity. This finding that higher safety from crime crime was associated with less frequent leisure-time physical activity was unexpected. It is possible that higher safety from crime is an indicator of a less walkable environment with few destinations. Foster and Giles-Corti (2008) suggested that destinations in the neighborhood may facilitate walking for leisure, as well as walking for transport (Bracy et al., 2014; Sallis et al., 2004; Wang et al., 2016).

Theoretical Implications

Ecological models, which posit behaviors have multiple levels of influence, informed the original study design and present analytical approach. The principle that influences on behavior interact across levels (Sallis & Owen, 2015) was tested using moderator analyses. In the present study, at least one variable from each of the four levels of influence tested (individual/demographic, psychosocial, home environment and neighborhood environment) was significantly related to outcomes. The 8 significant moderators were from three levels (individual/demographic, psychosocial, and home environment), and a significant main effect was found from the fourth level (neighborhood environment). The relation between the perceived neighborhood safety environment and physical activity was complex, in line with inconsistent findings in the literature (Carlson et al., 2014; Bracy et al., 2014; Foster & Giles-Corti, 2008; Christian et al., 2011; da Silva et al., 2016). The current study demonstrated the utility of an ecological approach, specifically assessing multilevel moderators, to help better understand for whom and under what circumstances perceived neighborhood safety is related to physical activity. More studies need to be designed to include measures from multiple levels of influence to help interpret findings and explore moderators, which was how ConTxt was conceptualized.

Strengths & Limitations

Limitations included a relatively small sample size, unequal distribution of men vs. women, and a cross-sectional design that prohibits the establishment of temporal associations. A next step is to assess moderators of the intervention effect on physical activity variables (i.e., use the longitudinal data). Though it is a strength that the variables used in the current study were hypothesis-based for evaluating a weight loss intervention, they were not necessarily optimized to test the moderation of environmental and psychosocial variables with physical activity. Therefore, it is possible there are other variables that could be included and future studies should examine more variables (e.g., distance from work, seasonal influences, dog ownership/walking). Incorporating objective safety variables (e.g., crime rates, traffic volume, streetscape audits) may have added to the study, because it would have enabled exploration and comparison of objective and perceived neighborhood environment measures.

A strength of this study was the use of three physical activity outcomes, but having location-specific physical activity collected via GPS would allow for more conclusive statements about the role of perceived neighborhood safety on physical activity in the neighborhood. Specifically, GPS could be used to define physical activity in (and out of) the neighborhood, so a hypothesis could be tested that neighborhood safety would be more strongly related to physical activity in, than out of, the neighborhood. Other strengths included the use of objective and domain-specific self-report physical activity outcomes, an ethnically/racially diverse sample, sampling from a vulnerable population of overweight/obese individuals and exploring moderators from multiple levels of the ecological model.

Implications and Recommendations

Though some results from the present study were difficult to interpret, the patterns of moderators across the different outcomes suggested that at least some findings are robust. Being overweight and/or male were consistent, though unexpected, moderators of the relation between safety from crime and pedestrian infrastructure with physical activity, where those in safe neighborhoods had more physical activity than those in unsafe neighborhoods. There were also domain-specific findings, where demographic characteristics were significant for active transport, but psychosocial characteristics were significant for leisure-time physical activity. Therefore, strategies to increase physical activity for certain subgroups should vary based on the targeted physical activity domain. The large magnitude of the overall (non-safety related) walkability association with active transport finding emphasized the importance of a walkable environment to facilitate active transport that apparently applied across all subgroups.

Present results indicate that perceived safety concerns have subgroup-specific effects in terms of whom is physically active. The fact that 8 of the tested interactions were statistically significant in the final models and were distributed across the three physical activity outcomes, provides evidence for the need to explicitly consider moderators in future studies of safety and physical activity and when planning interventions. Pedestrian safety infrastructure was in 4 interactions involving both total and leisure-time MVPA. It is logical that pedestrian infrastructure in the neighborhood, like presence of sidewalks, may impact the likelihood of choosing to be physically active there. Neighborhoods with high pedestrian safety most benefited participants who were men, overweight and/or had low social support for physical activity.

The moderators of the relation between perceived neighborhood safety and leisure-time MVPA were psychosocial and home environment characteristics, which implied demographic differences were less important for engaging in leisure-time physical activity compared to the other outcomes. High self-efficacy, social support and/or physical activity equipment ownership appeared to help participants overcome the barrier of low perceived safety from crime. However, interpreting the association of those variables in neighborhoods with high safety from crime proved difficult. Future studies should better operationalize perceived crime, use consistent measures across studies and employ longitudinal designs to better understand how perceived crime influences physical activity and for whom (Foster & Giles-Corti, 2008).

Previous studies identified perceived traffic safety as an important correlate of physical activity (Duncan et al., 2005), yet in the current study, traffic safety was not significantly associated with physical activity for any outcome. Depending on how it is measured and defined, safety from traffic may be highly related to pedestrian infrastructure, as much of its function is to protect pedestrians from traffic (e.g., sidewalks, buffers). Interestingly, another study that assessed moderators and used the same NEWS scale found no interactive effects of perceived traffic safety (Carlson et al., 2014).

Because of the apparent importance of perceived neighborhood safety, environmental improvements that are large enough to be perceived could produce substantial benefits and could be targeted to subgroups that would benefit most. Another approach would be interventions designed to overcome environmental barriers by encouraging participants to get outside in their neighborhoods by creating walking routes, maps with destinations to walk to, assembling walking groups or advocating for environmental modifications (e.g., adding crosswalks or curb cuts).

Conclusion

Given the significant findings across outcomes in the current study, there is a demonstrated need to evaluate the role of perceived neighborhood safety in interventions that target physical activity. Before making conclusive intervention recommendations, studies that replicate the present findings are needed. Though moderator analyses using longitudinal data from the current study are planned, other longitudinal moderator analyses should also be explored. Conducting qualitative research with target populations could help clarify the unexpected findings of neighborhood perceptions of safety and physical activity within certain subgroups, and inform future interventions. Studies that include objective measures of neighborhood safety and location-specific physical activity would also strengthen the evidence and further clarify these findings.

ACKNOWLEDGEMENTS

Chapter 1 is currently being prepared for submission for the publication of the material. Co-authors include Dr. Job G. Godino, Dr. James F. Sallis, Dr. Terry L. Conway, Dr. Linda Hill, Dr. Hala Madanat, and Dr. Kevin Patrick. The dissertation author was the primary investigator and author of this material.

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Table 1.1: Summary of physical activity outcomes, perceived safety and moderator measures used in the cross-sectional analysis of ConTxt data

Ecologi-cal level	Construct / Variable	Number of Items (Response scale or Range)	Example items or methods	Psychometrics and reference
Physical Activity Outcomes				
--	Total Moderate-to-vigorous physical activity (MVPA) minutes/day	Minimum of 3 valid days (≥10 valid hours) were necessary to be included in analyses (n=279)	Methods: Participants wore an Actigraph accelerometer (model GT3X) on a belt securely around the waist). Participants were asked to wear the device for 7 consecutive days at baseline. Participants were given instructions on how to properly wear the device. Scoring: Data were cleaned and scored using Actilife software. The epoch was set at 60 seconds. Valid wear time was calculated using the Choi method: 1) zero-count threshold during a nonwear time interval, 2) 90-min time window for consecutive zero/nonzero counts, and 3) allowance of 2-min interval of nonzero counts with the up/downstream 30-min consecutive zero counts window for detection of artifactual movements. Total MVPA minutes per day were calculated using a cut point of ≥2020 counts per minute	ActiGraph, LLC; Pensacola, FL (Troiano et al., 2008; Choi et al., 2012)
--	Global Physical Activity Questionnaire (GPAQ): Leisure-time MVPA (self-report)	4 items (Yes or No; 1-7 days) Combined the 2 moderate items to represent days/week and then combined the 2 vigorous items to represent days/week [0-7]. Averaged both to represent days/week of leisure-time MVPA	*Moderate*: Do you do any moderate-intensity sports, fitness or recreational activities that cause a small increase in breathing or heart rate such as brisk walking, [cycling, swimming, volleyball] for at least 10 minutes continuously? *Vigorous*: Do you do any vigorous-intensity sports, fitness or recreational (leisure) activities that cause large increases in breathing or heart rate like [running or football] for at least 10 minutes continuously? If yes, how many days/week? Separate vigorous and moderate questions were averaged to represent days/week of MVPA (0-7)	Reliability coefficients were moderate- strong (Kappas 0.67-0.73) in a 9-country study (Armstrong & Bull, 2006; Bull et al., 2009). Acceptable criterion validity (r=.484) and ability to measure change (Cleland et al., 2014).
--	GPAQ: Active transport (self-report)	2 items (Yes or No; 1-7 days) Combined to represent days/week [0-7] of active transport	Do you walk or use a bicycle (pedal cycle) for at least 10 minutes continuously to get to and from places? If yes, how many days/week?	Reliability coefficients were moderate to strong (Kappas 0.67-0.73) in a 9-country study (Armstrong & Bull, 2006; Bull et al., 2009)

Table 1.1: Summary of measures used (continued)

Independent Variables: Perceived Neighborhood Safety Environment				
Ecolog-ical level	**Construct / Variable**	**Number of Items (Response scale or Range)**	1. **Example items or methods**	**Psychometrics and reference**
Neighborhood Safety Environment	Abbreviated Neighborhood Environment Walkability Scale (NEWS-A): 1: Neighborhood traffic safety	3 items (1 = strongly disagree, 4 = strongly agree)	2. There is so much traffic along nearby streets that makes it difficult or unpleasant to walk in my neighborhood. 3. The speed of traffic on most nearby streets is usually slow (30 mph or less) 4. Most drivers exceed the post speed limits while driving in my neighborhood (reverse-coded)	Original subscales had test- retest reliability ICC .77 (Sealens et al., 2003). Construct validity supported by correlations with PA (Cerin et al., 2006)
	2: Safety from Crime	3 items (1 = strongly disagree, 4 = strongly agree) Reverse coded and averaged to create the scale measure	1. There is a high crime rate in my neighborhood 2. The crime rate in my neighborhood makes it unsafe to go on walks during the day 3. The crime rate in my neighborhood makes it unsafe to go on walks at night	Original subscales had test- retest reliability ICC .80 (Sealens et al., 2003). Construct validity supported by correlations with PA (Cerin et al., 2009)
	3: Neighborhood pedestrian safety infrastructure	6 items (1 = strongly disagree, 4 = strongly agree) Averaged to create the scale measure	1. There are sidewalks on most of the streets in my neighborhood 2. Sidewalks are separated from the road/traffic in my neighborhood by parked cars 3. There is a grass/dirt strip that separates the streets from the sidewalks in my neighborhood 4. My neighborhood streets are well lit at night 5. Walkers and bikers on the streets in my neighborhood can be easily seen by people in their homes 6. There are crosswalks and pedestrian signals to help walkers cross busy streets in my neighborhood (RC)	Original subscales had test- retest reliability ICC .77 (Sealens et al., 2003). Construct validity supported by correlations with PA (Cerin et al., 2009)
Correlates of physical activity from different ecological levels explored as moderators				
Individual	Demographics	Age; Sex; Race/ethnicity; Education; Marital Status	Race/ethnicity was recoded to Hispanic, White non-Hispanic and other minority.	N/A
	Weight	Body Mass Index (BMI) (27-39.8)	BMI was calculated from height and weight as kg/m^2. Body weight was measured using a calibrated digital scale to 0.1 kg. Height was measured with a stadiometer to 0.1 cm.	N/A

Table 1.1: Summary of measures used (continued)

Ecological level	Construct / Variable	Number of Items (Response scale or Range)	Example items or methods	Psychometrics and reference
Psychosocial Characteristics:	Self-efficacy: 1. PA self-efficacy 2. Task self-efficacy for PA	1. 6 items (1 = not at all confident, 5 = extremely confident) Averaged to create the scale measure 2. 5 items (1 = not at all confident, 5 = extremely confident) Averaged to create the scale measure	1. "How confident are you that you would participate in regular exercise or PA in each of the following situations?" Example items included "when I am tired", "when I feel I do not have time" and "When the weather is bad." 2. Rate confidence in doing several tasks. Example task items included "walk for 15 minutes without stopping" and "use the stairs instead of the elevator."	Both scales adapted from published scales with evidence of acceptable test-retest reliability and construct validity (Robinson et al., 2008; Carlson et al., 2012)
	Social support for PA	5 items (1 = almost never, 5 = almost always) Averaged to create the scale measure	How often in the last 30 days the participant's family and friends have done instrumental and encouragement supportive behaviors (e.g. "encourage you to do PA", "do PA with you")	Acceptable internal consistency, test-retest reliability and construct validity (Carlson et al., 2012)
Home Environment	Home PA equipment	16-item inventory (Present: Yes or no) Sum of "yes" responses	Participants were asked to indicate which PA supplies or equipment they have in their home, yard, or apartment complex, such as stationary aerobic equipment, weight lifting equipment, and sports equipment	Test-retest of the summed index was .89 and scores correlated significantly with PA (Sallis et al., 1997)
Neighborhood walkability (non-safety related)	Abbreviated Neighborhood Environment Walkability Scale (NEWS-A)	Total of 53-items using 4 non-safety subscales [*aesthetics, street connectivity, residential density, mixed use-diversity*] to create a built environment walkability subscale. Aesthetics (4 items), mixed use-access (3 items), street connectivity (2 items) with response scale (1 = strongly disagree, 4 = strongly agree). Residential density (6 items) (1=none, 5=all). Mixed use-diversity (23 items) (1-5 min=1, 30+ min=5)	*Aesthetics* items (e.g., "there are trees along the streets in my neighborhood" and "there are attractive buildings/homes in my neighborhood"). *Street connectivity* items (e.g., "the distance between intersections in my neighborhood is usually short [100 yards or less]"). *Residential density* items (e.g., "how common are detached single-family residences in your immediate neighborhood?"). *Mixed land use* Mixed-use access items (e.g., stores are within easy walking distance (10-15 minute walk) of my home). Mixed-use diversity items ("how long would it take to get from your home to the nearest business listed below if you walked to them?" Locations included supermarket, clothing store, library, fast food restaurant, coffee place, park).	Most original subscales had test-retest reliability ICC's >.75 (Saelens et al., 2003). Construct validity for most scales supported by correlations with PA (Cerin et al., 2009).

Table 1.1: Summary of measures used (continued)

Ecologi-cal level	Construct / Variable	Number of Items (Response scale or Range)	Example items or methods	Psychometrics and reference
		The walkability features subscale was created by standardizing the four non-safety related NEWS-A subscales, summing them, and then taking the mean of these standardized subscales, similar to an activity-supportiveness scale used previously (47).		

Table 1.2: ConTxt descriptives & participant characteristics by ecological level (baseline measures) (N=298)

	Mean (SD) / N (percent)
Physical activity outcomes	
Average total MVPA/day (accelerometer) (n=279)	24.38 (16.92)
Transport PA: Number of days/week (n=126 who do PA for transport) [0-7]	1.83 (2.39)
Leisure-time MVPA: Number of days/week [0-7]	1.35 (1.32)
Independent Variables: Perceived neighborhood safety environment	
NEWS Safety from Crime [1-4]	3.35 (0.75)
NEWS Traffic Safety [1-4]	2.66 (0.66)
NEWS Pedestrian Safety Infrastructurrrre [1-4]	2.82 (0.62)
Individual/demographic variables	
Sex: Female	228 (76.5%)
Age (23-64)	44.57 (10.85)
Race/ethnicity	
White non-Hispanic	122 (42.2%)
Hispanic (any other race)	112 (38.8%)
Other minority	55 (19.0%)
Marital status: married or living with partner	162 (54.4%)
Education: college degree or higher	132 (44.3%)
BMI	32.68 (3.39)
Psychosocial variables	
Self-efficacy for PA [1-5]	2.39 (0.87)
Task self-efficacy for PA [1-5]	4.03 (0.87)
Overall PA self-efficacy [1-5]	3.14 (0.70)
Social Support for PA [1-5]	2.57 (1.06)
Home environment variables	
Home PA Equipment Index [0-15]	5.07 (2.83)
Perceived neighborhood environment (non-safety)	
NEWS overall walkability (non-safety) index [-1.5-1.75]	0.00 (1.00)

Table 1.3: Accelerometer derived MVPA minutes/day outcome-ConTxt cross-level ecological model of significant main effects and interactions that were significant from each NEWS scale (p<.05)

	Total MVPA (minutes/day)		
Variables based on ecological model levels	**B**	**95% CI**	**P value**
Intercept	22.950	18.618, 27.282	--
Demographic characteristics			
Sex (male vs. female)	3.975	-0.740, 8.690	.098
Race/ethnicity			
Hispanic vs. White non-Hispanic	1.267	-3.583, 6.116	.607
Other minority vs. White non-Hispanic	-3.293	-8.721, 2.135	.233
Education (no college vs. college degree)	-1.085	-5.189, 3.018	.603
Marital status (single vs. married/living with partner)	2.062	-1.842, 5.967	.299
Age (23-64)	-0.081	-0.269, 0.108	.400
BMI	-0.333	-0.913, 0.246	.258
Perceived Neighborhood Environment Variables (NEWS safety scales)			
Pedestrian Safety Infrastructure	8.458	2.961, 13.955	.003
Interactions with NEWS Safety scales			
Sex X Pedestrian Safety	11.322	3.932, 18.713	.003
Race/Ethnicity X Pedestrian Safety			
Hispanic vs. White non-Hispanic	-10.318	-17.475, -3.160	.005
Other minority vs. White non-Hispanic	-7.402	-16.054, 1.250	.093
BMI X Pedestrian Safety	-1.452	-2.475, -0.429	.006

Variables that were tested but ultimately removed include: Education X Traffic Safety, Sex X Safety from Crime, Education X Safety from Crime, Home PA Equipment X Safety from Crime, Home PA Equipment, Safety from Crime, Traffic Safety
All demographic characteristics were maintained as covariates.
All predictor variables were mean-centered to aid in interpretation of B.
B denotes unstandardized regression coefficient.

Table 1.4: Days/Week of active transport: ConTxt cross-level ecological model of significant main effects and interactions that were significant from each NEWS safety scale (p<.05)

	Active transport (days/week)		
Variables based on ecological model levels	**B**	**95% CI**	**P value**
Intercept	1.540	0.952, 2.128	--
Demographic characteristics			
Sex (male vs. female)	0.053	-0.575, 0.682	.867
Race/ethnicity			
Hispanic vs. White non-Hispanic (ref)	-0.184	-0.833, 0.465	.576
Other minority vs. White non-Hispanic (ref)	-0.444	-1.182, 0.294	.237
Education (no college vs. college degree)	0.440	-0.123, 1.002	.125
Marital status (single vs. married/living with partner)	0.336	-0.211, 0.882	.228
Age (23-64)	0.009	-0.017, 0.034	.507
BMI	-0.053	-0.131, 0.025	.185
Psychosocial characteristics			
PA self-efficacy	0.344	0.042, 0.646	.026
Perceived Neighborhood walkability environment (non-safety related NEWS index)			
Overall neighborhood walkability (non-safety)	1.700	1.132, 2.267	<.001
Perceived Neighborhood Safety Variables (NEWS safety scales)			
Safety from Crime	-0.403	-0.812, 0.006	.053
Interactions with NEWS Safety scales			
Sex X Safety from Crime	0.983	0.127, 1.838	.025
BMI X Safety from crime	-0.158	-0.259, -0.058	.002

Variables that were tested but ultimately removed include: Sex X Traffic Safety, PA Self-Efficacy X Pedestrian Safety, PA Social Support X Pedestrian Safety, Age X Safety from Crime, Race/ethnicity X Safety from Crime, PA Social Support, Traffic Safety, Pedestrian Safety
All demographic characteristics were maintained as covariates.
All predictor variables were mean-centered to aid in interpretation of B.
B denotes unstandardized regression coefficient.

Table 1.5: Days/Week of leisure-time moderate to vigorous physical activity: ConTxt cross-level ecological model of significant main effects and interactions that were significant from each NEWS safety scale (p<.05)

	Leisure-time MVPA (days/week)		
Variables based on ecological model levels	**B**	**95% CI**	**P value**
Intercept	1.564	1.238, 1.890	--
Demographic characteristics			
Sex (male vs. female)	0.175	-0.163, 0.513	.310
Race/ethnicity			
Hispanic vs. White non-Hispanic (ref)	0.029	-0.323, 0.381	.871
Other minority vs. White non-Hispanic (ref)	-0.162	-0.556, 0.233	.421
Education (no college vs. college degree)	-0.202	-0.507, 0.104	.195
Marital status (single vs. married/living with partner)	-0.096	-0.389, 0.197	.519
Age (23-64)	0.002	-0.011, 0.016	.736
BMI	-0.034	-0.077, 0.008	.111
Psychosocial characteristics			
Social Support for PA	0.132	-0.004, 0.269	.057
PA self-efficacy	0.377	0.208, 0.545	<.001
Home Environment			
Home PA Index	0.104	0.049, 0.159	<.001
Perceived Neighborhood Safety Variables (NEWS safety scales)			
Pedestrian Safety Infrastructure	0.090	-0.153, 0.332	.467
Safety from Crime	-0.396	-0.617, -0.175	<.001
Interactions with NEWS Safety scales			
Social Support for PA X Pedestrian Safety	-0.298	-0.498, -0.098	.004
PA self-efficacy X Safety from crime	-0.318	-0.521, -0.114	.002
Home PA equipment X Safety from crime	-0.095	-0.173, -0.017	.017

Variables that were tested but ultimately removed include: Marital Status X Safety from Crime, PA Task Self-Efficacy X Pedestrian Safety, PA Self-Efficacy X Pedestrian Safety, PA Task Self-Efficacy.
All demographic characteristics were maintained as covariates.
All predictor variables were mean-centered to aid in interpretation of B.
B denotes unstandardized regression coefficient.

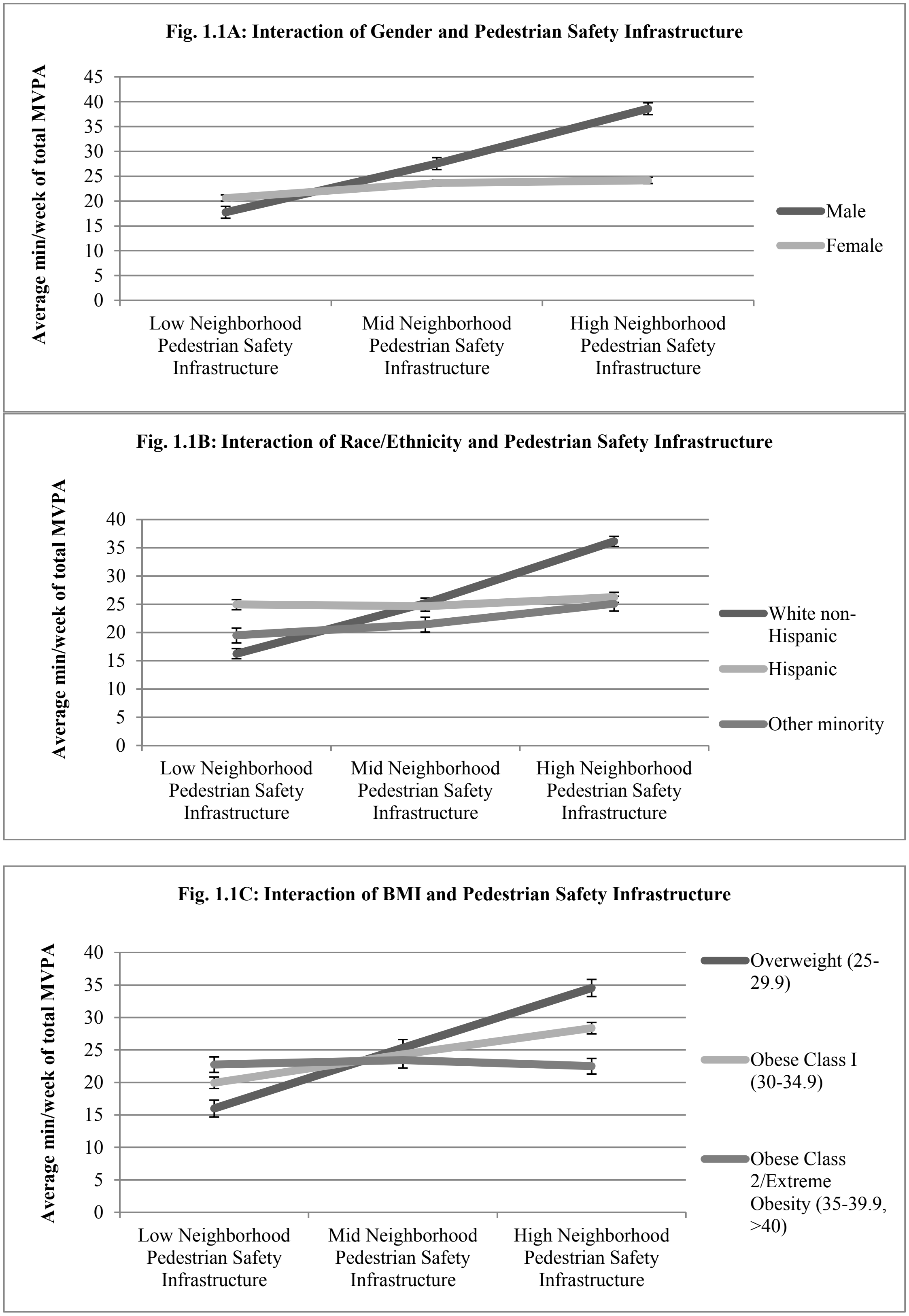
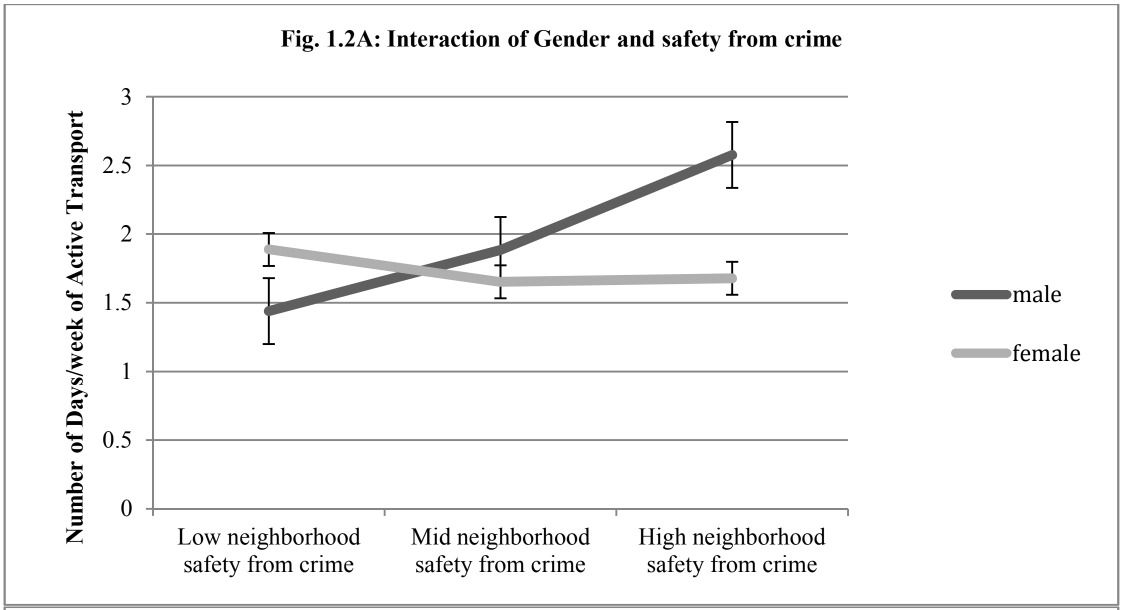


Figure 1.1: Gender (1.1A), Race/ethnicity (1.1B) and BMI (1.1C) as moderators of pedestrian safety and objective total MVPA among overweight/obese adults, graphed using equal tertiles.



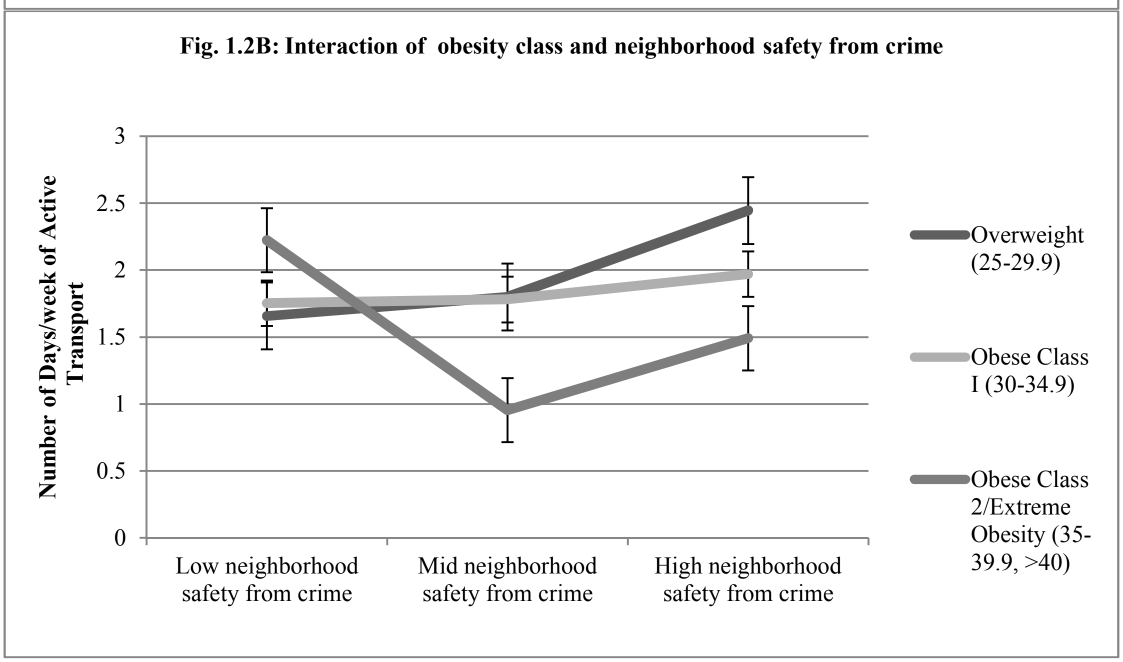


Figure 1.2: Gender (1.2A) and BMI (obesity class) (1.2B) as moderators of perceived safety from crime and days/week of active transport among overweight/obese adults, graphed using equal tertiles.

Fig. 1.3B: Interaction of PA self-efficacy and safety from crime

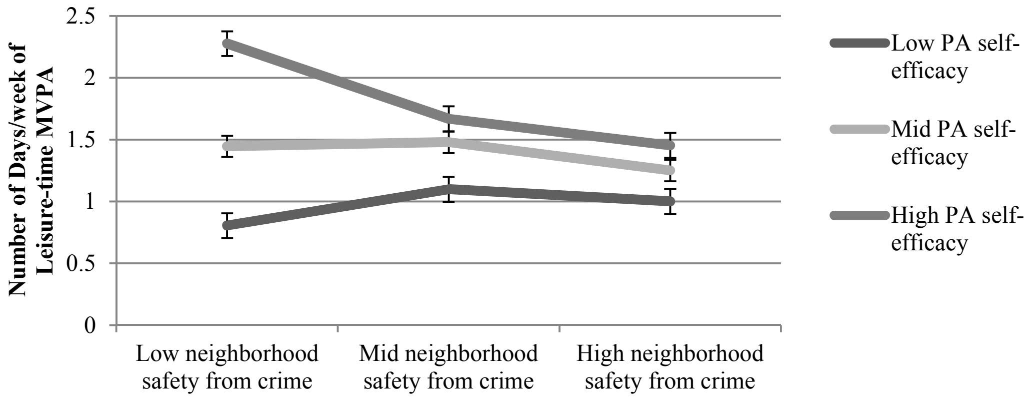


Fig. 1.3A: Interaction PA Social Support and pedestrian safety infrastructure

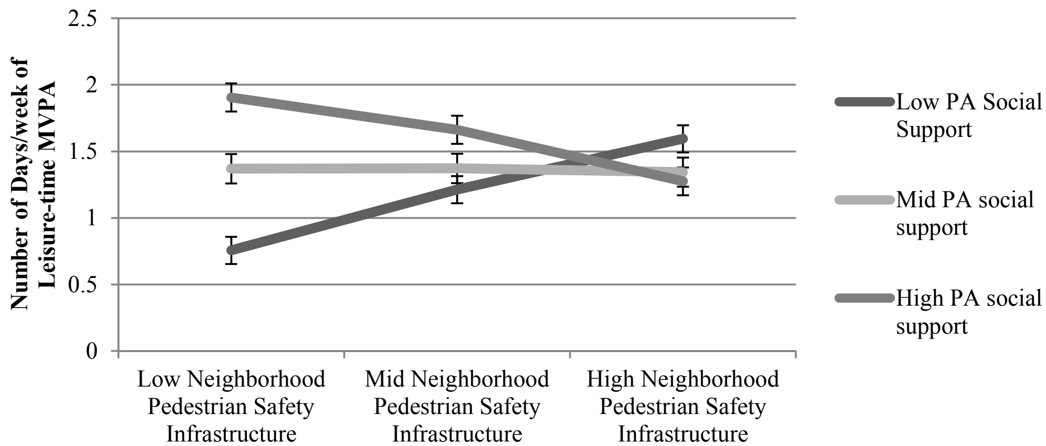


Fig. 1.3C: Interaction of Home PA Equipment and Safety from Crime

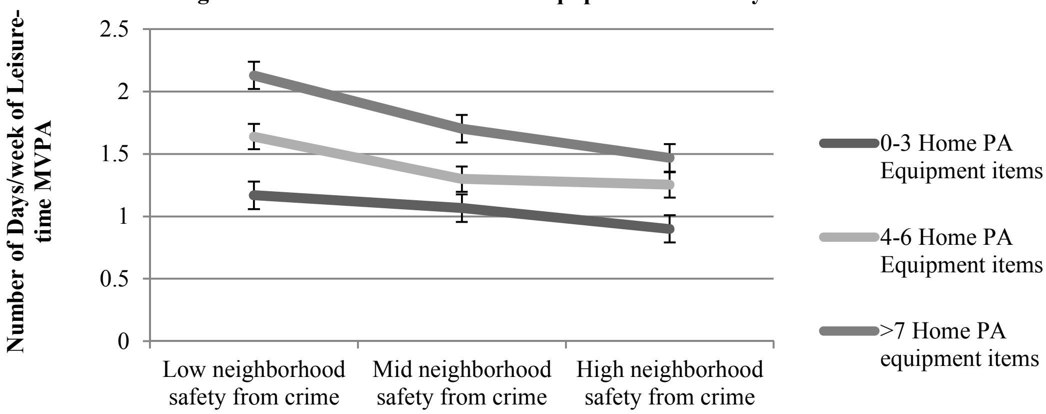


Figure 1.3: Social support (1.3A), PA self-efficacy (1.3B) and home PA equipment (1.3C) as moderators of neighborhood safety and days/week of leisure-time MVPA among overweight/obese adults graphed using equal tertiles.

CHAPTER 2

Objectively Measured Pedestrian Safety and Physical Activity among Adolescents: Multilevel Moderators

ABSTRACT

Objective: The relation between neighborhood safety and physical activity (PA) and the factors that moderate this relation are unclear. The current study examined moderators of this relation among adolescents.

Methods: Participants were aged 12-17 years (n=878) from the Baltimore, MD and Seattle, WA regions, with 50% male and 33% non-white. Three PA outcomes were used: objective moderate-to-vigorous PA (MVPA) in the home neighborhood (n=715) and self-reported active transport and leisure-time PA in the neighborhood. Objective neighborhood streetscape safety data were collected using a validated observational measure of streetscapes (MAPS). Survey-reported (from parent and adolescents) moderators at multiple ecological levels were examined: individual (e.g., sex, BMI), psychosocial (e.g. self-efficacy), home environment (e.g., home PA equipment) and perceived neighborhood safety (e.g., traffic safety). A final multilevel generalized linear regression model identified main and cross-level moderator effects.

Results: Objectively-assessed streetscape safety was significantly ($p<.05$) negatively associated with leisure-time PA in the neighborhood but was not independently associated with the other outcomes. There were 5 significant interactions with streetscape safety across the outcomes, from two ecological levels. High safety streetscapes were positively associated with greater MVPA in the neighborhood for White non-Hispanics participants with low social support and perceived low environmental barriers to walking/biking. Unexpectedly, low streetscape safety was associated with more MVPA for those with high social support and more perceived environmental barriers. Those who perceived low barriers to being active had slightly more active transport in safe vs. unsafe neighborhoods, and those with fewer parent-reported safety-related rules had less leisure-time PA in safe vs. unsafe neighborhoods. There were also main effect findings of significant correlates of PA from all ecological levels for all outcomes.

Conclusion: Moderators or main effects were identified from all tested levels of the ecological model, supporting the ecological approach and implying that multi-level interventions are promising. Findings suggest the relation with neighborhood safety and PA is complex but the use of objectively-assessed streetscape safety is promising.

INTRODUCTION

Though it is recommended adolescents obtain 60 minutes/day of moderate to vigorous physical activity (MVPA) (DNPAO, 2015; PAGA, 2015), according to self-report data 27% of adolescent meet the recommendations (CDC, 2015) but when using objective data as few as 8% meet the recommendations (Troianno et al., 2008). Understanding the variety of factors related to physical activity among adolescents can inform interventions to increase adolescents' physical activity. Because physical activity is a complex behavior, an ecological approach that considers multiple levels of influence (e.g. individual, psychosocial, home environment, neighborhood environment) can be helpful to explain variation in physical activity among adolescents (Sallis & Owen, 2015). Reviews of physical activity among adolescents have identified numerous correlates from multiple levels, including sociodemographic (e.g. age, sex), psychosocial (e.g. self-efficacy, social support) and environmental factors (e.g. perceived traffic safety, sidewalk infrastructure) (Sallis et al., 2000; Ferreira et al., 2007; McGrath et al., 2015). Safety is often studied because it is believed to be associated with physical activity, but has some of the least consistent findings (Carver et al., 2008; Ding et al., 2011; Foster & Giles-Corti, 2008), so further study is especially needed for this topic.

Safety is defined by the World Health Organization (WHO) as: "…a state in which hazards and conditions leading to physical, psychological or material harm are controlled in order to preserve the health and well-being of individuals and the community" (WHO, 1998, p. 5). Elements of both perceived safety and objectively measured safety include traffic (e.g., speed limits), pedestrian safety (e.g., marked crossings. street lights) and safety from crime (including stranger danger for youth).

However, the role of safety in physical activity is not well understood. Reviews showed safety-related correlates (e.g. heavy traffic, crime, stranger danger) were inconsistently associated with physical activity among youth (Ferreira et al., 2007; Ding et al., 2011; Carver et al., 2008).

The authors noted that a methodological limitation that may partially explain these findings is related to the use of crude and non-validated measures of safety that do not differentiate between types of safety (i.e., crime and traffic) (Ding et al., 2011). When studies used validated measures that differentiated elements of safety, there were more consistent associations between safety and physical activity (Ding et al., 2011; Esteban-Cornejo et al., 2016). Many studies used perceived safety measures and, as such, another identified limitation was the lack of objective measures of the safety environment (Carver et al., 2008).

Though few studies have used objective measures of both the neighborhood environment and physical activity among adolescents, the findings from those few studies identified important neighborhood factors. Pedestrian safety, specifically sidewalk presence and characteristics, was positively associated with light to moderate physical activity (Jago et al., 2005; Jago et al., 2006). A study that used accelerometers and GPS technology to determine where adolescents obtained physical activity found that adolescents were proportionally most active in their neighborhood and near school, when time spent in each location was taken into account (Carlson et al., 2015). These findings emphasize the need to study neighborhood features, including both macrolevel and microscale features. Macrolevel features include residential density, street connectivity, retail floor area ration and land use mix. Microscale features refer to small environmental features (e.g., aesthetics, street lights, sidewalk presence) (Brownson et al., 2009) that are often easily modified.

Safety-related variables are included in many microscale audit tools, but to date, they have not been studied independently. The Microscale Audit of Pedestrian Streetscapes (MAPS) is a validated tool that includes numerous safety-related features (Millstein et al., 2013). MAPS has been associated with physical activity among children, adolescents, adults and older adults (Cain et al., 2014), yet no composite index of safety-specific items was constructed or assessed.

It is likely the relation between neighborhood safety and physical activity varies by participant characteristics (e.g., age, sex, self-efficacy, perceived stranger danger), and, as such, it could be useful to examine moderators. A principle of ecological models is the idea that behaviors are influenced by interactions with correlates across multiple levels (Sallis & Owen, 2015). Understanding moderating effects of known correlates of physical activity from multiple levels may help clarify the relation of neighborhood safety and physical activity. Supporting the value of the moderator approach, one study found that parent encouragement moderated the association between parent and child physical activity (Tate et al., 2015). Esteban-Cornejo et al. (2016) found sex moderated the relation of adolescent perceived traffic safety and physical activity in parks, where lower perceived traffic safety was associated with greater reported physical activity, but only among males.

Because the association between neighborhood safety and physical activity among adolescents is unclear, the purpose of the current study was to better understand the association by assessing moderators of the relation. The study adds to the literature in three primary ways. First, the use of three specific physical activity outcomes (objective MVPA, self-reported active transport and leisure-time physical activity) helps to differentiate among physical activity domains. Second, the use of a validated, objective measure of the neighborhood safety environment at the microscale level addresses a gap in the literature, because the majority of existing studies relied on participants' self-reported perceptions of safety or macrolevel (e.g., GIS) data. Third, exploring moderators may help partially explain the inconsistencies in main effects across the literature. The specific aim was to explore the association of objectively measured neighborhood safety and physical activity, and assess if known correlates of physical activity moderate the relation.

METHODS

Study Design & Participants

The study used data from the Teen Environment and Neighborhood (TEAN) observational study (Sallis et al., under review; Sallis et al., 2011). Participants (N=878) were adolescents aged 12-17 living in suburban and urban neighborhoods in Seattle, WA or Baltimore, MD regions in 2009-2011. One parent per adolescent participant was enrolled.

Participants were selected from 4 quadrants of high or low walkability (based on GIS measures of walkability) stratified by high or low income (based on Census 2000 data), described for a previous study with similar design (Sallis et al., 2009; Frank et al., 2010). Households with adolescents in these block groups were identified from a marketing company list and recruited by mail and telephone. Adolescents were screened by phone and ineligible to participate if they had a condition affecting their physical ability, dietary habits (e.g. eating disorder) or ability to participate cognitively (e.g. developmental disability). Overall participation rate (i.e., returned surveys divided by eligible contacts) was 36% and did not vary by quadrant. Comparisons of participants' household demographics with census data indicated the study sample had higher education and household income compared to residents of the 447 census block groups in which participants lived. Regarding race/ethnicity, the study sample was comparable to census data for adolescent participants, with 34% being non-White or Hispanic versus 37% of adolescents in the census block groups from which participants were recruited.

Adolescent participants and one parent each completed a survey to assess demographics, psychosocial characteristics and the perceived neighborhood environment. Adolescents wore an accelerometer and GPS device for one week to determine daily minutes of moderate to vigorous physical activity (MVPA) and location of physical activity. Objective microscale environmental data were collected by trained observers. Further details of the study design have been described (Sallis et al., 2011; Sallis et al., under review). The Institutional Review Board of San Diego State University approved this study, all adolescents signed assent forms, and their parents signed informed consents.

Measures

Table 2.1 depicts details of all the measures used in the current study, including psychometrics. Brief overviews are included below.

Physical activity outcomes

Self-report frequency of leisure-time physical activity in the neighborhood

Adolescents reported how often they were physically active (0 = never to 5= four or more times a week) in five settings in the neighborhood (e.g., nearby street or cul-de-sac). The responses were averaged to represent the average frequency of leisure-time physical activity in the neighborhood.

Self-report frequency of active transport in the neighborhood

Adolescents reported how often they usually walked or biked (0 = never to 5 = four or more times/week) to 9 common locations in the neighborhood (e.g., a park or friend's house). Responses were averaged to represent the average frequency that adolescents engaged in active transport in their neighborhood.

Objective neighborhood MVPA: GPS-specific minutes per day of MVPA (accelerometer):

Participants were asked to wear an ActiGraph accelerometer (ActiGraph, Pensacola, FL) on a belt at their left hip for 7 days. A rewear was requested if <5 valid wearing days were recorded, including 1 weekend day. Participants also wore a GlobalSat DG-100 GPS tracker (GlobalSat, New Taipei City, Taiwan), with latitude and longitude data collected at 30-second epochs (i.e., 1 fix every 30 seconds when GPS signal was attainable). The Personal Activity and Location Measurement System (PALMS) Version 4 (Center for Wireless and Population Health Systems, La Jolla, CA) was used to merge GPS and accelerometer data. Only days with ≥8 hours of GPS signal during valid accelerometer wear time were included. A neighborhood buffer was created as a 1-km street network buffer around geocoded home point, excluding a 50-meter circular buffer around the home (i.e., excluding the PA that occurred within or very near the home). More details were reported in a previous study (Carlson et al., 2015). The current study is unique in that it used GPS data combined with accelerometer data to look at total minutes/day of MVPA that occurred within a specified 1-km neighborhood buffer around the home.

Objective Neighborhood Safety: Microscale Audit of Pedestrian Streetscapes (MAPS Streetscape Safety Index:

The current study created a streetscape safety index using existing items that were related to streetscape safety from different sections of MAPS, a validated tool (Millstein et al., 2013; Cain et al., 2014).

MAPS Background: Data collection and validity

Details about MAPS data collection, reliability, training, scoring and reliability were previously reported (Millstein et al., 2013). In brief, MAPS is an observational tool conducted by trained observers on a 0.25-mile route from their home address to a pre-selected non-residential destination (e.g., restaurant, school, retail, service). MAPS has four sections: route, street segments, crossings and cul-de-sacs (available at http://sallis.ucsd.edu/measure_maps.html). Route-level items included land use and destinations, street amenities, highest posted speed limit, traffic calming features, and aesthetic characteristics. Segment-level (street segments between intersections) items included sidewalk presence, buffers between street and sidewalk, trees, number of traffic lanes. Street crossing items included crosswalk markings, width of crossings, curb cuts and signalization. Cul-de-sac items included distance from home and amenities within cul-de-sacs (e.g., basketball hoops).

The inter-rater reliability of MAPS individual items and subscales demonstrated almost entirely moderate to excellent inter-rater reliability (ICC values ≥ 0.41 and ≥ 0.60, respectively). Cain et al. (2014) assessed MAPS validity by exploring the relation between physical activity (transport, leisure and MVPA from an accelerometer) with microscale environmental attributes, specifically by each MAPS item, subscale, section score, and total streetscape score. The study used 4 age groups (i.e. children, adolescents, adults and older adults) and found significant relationships with the physical activity outcomes, but they varied by age group (Cain et al., 2014). The grand score (i.e. total streetscape score) was significantly related to walking and biking for transport in all age groups, leisure and neighborhood physical activity among only children and adolescents, and MVPA among only children and older adults (Cain et al., 2014).

MAPS Streetscape Safety Index Development

Because safety-related attributes were collected there was no safety specific subscale or index created using MAPS items, though some items were included in the original subscales previously reported (Millstein et al., 2013; Cain et al., 2014). Therefore, the current study referred to the literature on pedestrian safety and used existing MAPS items to create a different subscale or index. The microscale features were related to pedestrian safety, with some influencing traffic conditions (e.g., speed limits) and others providing infrastructure for pedestrians to stay out of the road. The US Department of Transportation report on *Pedestrian facilities users guide: Providing safety and mobility* identified traffic speed, sidewalks, crosswalks, curb ramps, lighting, raised medians, crosswalk signalization and marking, refuge islands, speed humps, and curb extensions as important factors related to protecting pedestrians from traffic collisions (Zegeer et al., 2002). Additionally, other studies of microscale features and physical activity found well-maintained sidewalks, sidewalk infrastructure and traffic calming features (e.g. traffic humps) were positively associated with physical activity, particularly active transport (Brownson et al., 2009; Boarnet et al., 2011; Pikora et al., 2006).

The MAPS items used in the safety index were all previously assessed for inter-rater reliability and validity. Many of the items were included in subscales that created the MAPS grand score were also used in the safety index, but did not include ones like access to commercial destinations, building setbacks, building maintenance or landscaping. The grand score and MAPS streetscape safety index were correlated at .84. The streetscape safety index was unique from other MAPS scores because all the items reflect the presence or absence of pedestrian infrastructure related to safety, such as speed limits, marked crosswalks, refuge islands on crossings, presence and continuity of sidewalks and pedestrian signage. The MAPS streetscape safety index, including all items and scoring per section, is available in Appendix 1. There were a possible 52 points possible, where each item was worth 0-2 points, were averaged within the section (e.g., if there were three segments, the mean of each item would be calculated to represent an overall segment score for the item), and eventually summed together across sections.

Variables assessed as Moderators of neighborhood safety and physical activity associations

Moderators of physical activity from four levels of ecological models (individual/demographic, psychosocial, home environment and perceived neighborhood environment) (Sallis & Owen, 2015) were measured to investigate correlates of physical activity that might moderate the association between neighborhood safety and physical activity.

Individual/demographics level variables

Age, sex, race/ethnicity, highest education in household, and parent marital status were assessed via survey. Adolescent BMI and parent BMI were assessed by parents following detailed instructions on measuring and reporting height and weight.

Psychosocial level variables

Variables assessed as moderators included self-efficacy for physical activity, social support, environmental barriers to walking/biking, planning/psychosocial barriers to walking/biking, safety barriers to walking/biking, barriers to being active in neighborhood, number of friends in neighborhood, min/day of active transport by the parent, min/day of leisure-time MVPA of the parent, parent-reported safety-related activity rules and adolescent reported safety-related activity rules.

Home environment-level variables

The variables were home physical activity equipment index, personal electronic ownership, electronic devices in the bedroom, and the number of vehicles per driver in household.

Perceived neighborhood-level variables

Parent-reported variables included traffic safety, pedestrian safety, low crime risk, low stranger danger and overall walkability (non-safety related). Adolescent-reported variables included traffic safety, pedestrian safety, low crime risk and low stranger danger.

Additional covariates

In all models, study design variables (i.e., GIS-based walkability and census 2000 income categories) and site (i.e., Seattle or Baltimore region) were included as fixed effects and block group ID included as a random effect to adjust for participant clustering in neighborhoods. Additional covariates for the accelerometer MVPA outcome were average daily wear time and the accelerometer model worn (i.e.,7164, GT1M, GT3X).

Statistical Analyses

All models used mixed-effects linear regression in SPSS V.23.0 to adjust for nesting of participants within block groups as a random effect. The average frequency of leisure-time physical activity and active transport outcome variables were approximately normally distributed and did not need to be transformed. The average minutes/day of MVPA within the neighborhood buffer outcome was natural log-transformed (*ln*) to better approximate a normal distribution. However, data presented in tables were back-transformed (e^b) for meaningful interpretation as minutes per day.

Initial models with the same predictors were run for all three dependent variables. All models included individual-level demographic covariates (age, sex, race/ethnicity, parent marital status, parent education, adolescent BMI, parent BMI). The continuous independent variables were grand mean-centered to create orthogonal interaction terms, such that the intercept values would approximate the sample means for outcomes.

For each outcome the multilevel factors, the MAPS streetscape safety index score, and the interaction between each multilevel factor and the MAPS streetscape safety index score were first analyzed in four separate models based on each ecological level: (1) individual/demographic (7 variables), (2) psychosocial (11 variables), (3) home environment (4 variables), and (4) perceived neighborhood (9 variables), for a total of 93 interactions. All main effects and interactions with $p \leq 0.10$ were entered and tested in a cross-level model for each outcome. All models included the demographic variables (regardless of significance). To reach the final cross-level model for each outcome, interaction terms that did not retain their significance ($p<.05$) were manually removed, one at a time, starting with the highest p-value, until a model containing only significant ($p<.05$) interaction terms and main effects was achieved. Lastly, all removed interactions and main effects were re-entered into the final cross-level model one at a time to ensure that they were still not significant after other variables had been removed, similar to the approach described in Saelens et al. (2012).

Significant ($p<.05$) interactions were graphed using one standard deviation above and below the mean to represent high and low values of each moderator variable. Unstandardized regression coefficients (B) were reported and can be interpreted as the change in the dependent variable for a 1-unit change in the independent variable. Effect sizes were calculated and reported using Cohen's *d*, to provide practical significance and aid in comparability across outcomes.

RESULTS

Sample Characteristics

The study sample was comprised of adolescents (n=878) with a mean age of 14.1 years (Table 2.2). There was an equal split by gender. The sample was 67% White non-Hispanic and the average CDC-based BMI z-score was 0.461, which means the sample, on average, was not overweight or obese, according to CDC cut-points (DNPAO, 2015). Almost 85% of the adolescents lived with parents who were married or living with a partner, and 75% of the adolescents lived in households that had a parent with a college-degree or higher. The parents' average BMI was 27.6, which falls into the overweight category (N.O.E.I.E, 1998).

The participant's self-reported frequency of physical activity was fairly low, with an average of about once every other week for leisure-time physical activity and about once a month for active transport. The average minutes per day of MVPA in the home neighborhood was about 6 minutes (untransformed). The average MAPS streetscape index score was about 17 out of a possible 52 (though the range in the current sample was 4 to 32) and indicates relatively poor streetscape safety.

Perceived neighborhood safety subscale scores, reported by adolescents and parents, were generally higher (all above 2 on a 4-point scale), especially adolescent reported low stranger danger (about 3.4 out of 4 points). Related to psychosocial variables, in general perceived barriers were mostly low, self-efficacy was higher, adolescents had about an average of 7 friends in the neighborhood and parents' reporter high amounts of physical activity. At the home-environment level, adolescents reported an average of 6 (out of 10) physical activity items around the house and owned nearly 3 out of 4 personal electronic devices, though they had less than half of the possible electronic items in their bedroom.

Table 2.3: Association of streetscape safety with minutes/day of MVPA within neighborhood buffer and moderators of the relation

In the final cross-level model there were three significant ($p<.05$) interactions, one from the individual/demographic level and two from the psychosocial level (Table 2.3). All the effect sizes (Cohen's *d)* the significant interactions for minutes/day of MVPA in the neighborhood buffer were small ($d \geq 0.2$).

The significant interaction of the MAPS streetscape safety index with a demographic variable showed White non-Hispanic participants had nearly 3 more minutes/day of MVPA in home neighborhoods with high (+1 SD) vs. low (-1 SD) MAPS streetscape safety scores (Fig. 2.1A), but there were no differences for non-white participants. From the psychosocial level, there was an interaction between perceived environmental barriers to walking/biking and MAPS streetscape safety (Fig. 2.1B). Participants who perceived fewer environmental barriers had almost one more minute/day of MVPA in home neighborhoods with high vs. low MAPS streetscape safety. This finding was reversed for those who perceived higher barriers, as they had just under 1.5 more minutes/day of MVPA in neighborhoods with low vs. high streetscape safety. Another interaction from the psychosocial level showed those with high social support for physical activity had over 1.5 more minutes/day of MVPA in home neighborhoods with low vs. high MAPS streetscape safety (Fig. 2.1C). Participants with low social support showed an opposite trend, with just under one minute/day more of MVPA in home neighborhoods with high vs. low streetscape safety.

Table 2.4: Association of streetscape safety with average frequency of active transport in the neighborhood and moderators of the relation

In the final cross-level model for active transport, there was one significant ($p<.05$) interaction, with a small effect (d=0.153) (Table 2.4). In the interaction, barriers to being active in the neighborhood moderated the relation of the MAPS streetscape safety and active transport (Fig. 2.2). Participants who reported low barriers to being active in the neighborhood had more active transport in neighborhoods with high vs. low streetscape safety. There appeared to be no association between MAPS streetscape safety and active transport for those with high perceived barriers to being active in the neighborhood.

Table 2.5: Association of streetscape safety with average frequency of leisure-time physical activity in the neighborhood and moderators of the relation

There was a main effect finding where the MAPS streetscape safety variable was significantly ($p<.05$) negatively associated with average frequency of leisure-time physical activity in the neighborhood and one interaction, both with small to moderate effects (*d*=.387 and *d*=0.331, respectively) (Table 2.5). In the significant interaction, parent-reported safety-related rules moderated the relation between MAPS streetscape safety and average frequency of leisure-time physical activity in the neighborhood (Fig. 2.3). As illustrated in the graphed interaction, adolescents with parents that reported fewer safety-related rules had more leisure-time physical activity in neighborhoods with low streetscape safety compared to those with high streetscape safety. For adolescents with parents reporting higher levels of safety-related rules, streetscape safety was unrelated to leisure-time physical activity.

Table 2.6: Main effects: Correlates of physical activity

In the final cross-level models across outcomes, there were significant ($p<.05$) main effects identified with variables from all four ecological levels examined: demographics/individual, psychosocial, home environment and perceived neighborhood environment (Tables 2.3-2.6). Across all outcomes, only perceived barriers to activity in the neighborhood was negatively associated with physical activity. There were no other variables consistently associated with all outcomes, but eight other variables were associated with two outcomes in the same direction. Self-efficacy, social support and physical equipment around the home were positively associated with active transport and leisure-time physical activity, and parent-reported safety-related rules had a negative association with the self-reported outcomes. Parent reported overall walkability (non-safety) was positively associated with objective MVPA in the neighborhood and active transport, while adolescent reported low crime rate had a negative association with the same outcomes. Being male and having lower BMI z-scores was associated with more objective MVPA and leisure-time physical activity in the neighborhood. Effect sizes for all outcomes ranged from small to moderate/large, though variables significantly associated leisure-time physical activity consistently had the largest effect sizes, including the largest across outcomes (i.e., sex [*d*=.723]).

DISCUSSION

The hypothesis that multi-level correlates of physical activity would moderate the relation of objectively assessed neighborhood streetscape safety and physical activity among adolescents was partially supported. Though the study did not find substantial evidence of moderating effects, significant moderators were found for all outcomes. Four of the moderators were psychosocial correlates of physical activity and one was demographic (i.e., race/ethnicity), so the findings provide some support for the ecological principle of cross-level interactions (Sallis et al., 2015), especially for objective neighborhood based MVPA.

The new MAPS streetscape safety index appears useful as a measure of objective streetscape safety, though associations were domain or subgroup specific. The new MAPS streetscape safety item was significantly negatively associated with leisure-time physical activity in the neighborhood as a main effect, which is consistent with another study that found walkability-related measures were negatively associated with leisure-time physical activity (Cain et al., 2014). The negative associations may be partially explained due to greater leisure activity occurring in less walkable suburban-type areas, in contrast to active transport that occurs in areas that are more “walkable” in terms of destinations to walk to and greater pedestrian infrastructure. Though MAPS streetscape safety was not independently associated with the two other physical activity outcomes, the finding that there were significant moderators indicate that objective streetscape is still important to assess, but likely has subgroup-specific associations.

The present results add to the limited literature on objectively assessed neighborhood safety, and may help clarify the inconsistent findings of neighborhood safety and physical activity among adolescents in the literature (Ferreira et al., 2007; Ding et al., 2011; Carver et al., 2008). The current findings indicate there were few moderator effects of neighborhood safety and physical activity in the neighborhood, but there were enough to warrant future study with other samples of adolescents.

Moderators of streetscape safety and objective minutes/day of MVPA within the neighborhood

Accelerometer measured moderate-to-vigorous physical activity (MVPA) is strongly related to health (Atienza et al., 2011). The current study used only minutes/day of MVPA that occurred specifically within the neighborhood, enhancing the conceptual match with the objective streetscape safety measure. The MAPS streetscape safety index variable was not a significant main effect, but was involved in three interactions.

The race/ethnicity interaction showed White non-Hispanic participants benefitted most from safe neighborhoods compared to minorities (Fig 2.1A). Given that minority adolescents, are already at the greatest risk of being obese or overweight (Ogden et al., 2014) or becoming overweight (Ahn et al., 2008), future research should be focused on better understanding why increased safety was not associated with more physical activity among minorities. This finding is also consistent with some literature on adults' perceived safety and physical activity (Hooker et al., 2005; Carlson et al., 2014).

The authors hypothesized that adolescents with low perceived barriers would have the most MVPA, regardless of safety, and those with high perceived barriers would have less MVPA. It was further hypothesized that for adolescents with high barriers, physical activity would vary, such that they would have more physical activity in neighborhoods with high vs. low streetscape safety. However, the findings were opposite, where those who perceived high environmental barriers and were in neighborhoods with low versus high streetscape safety had the most physical activity (Fig 2.1B). It is unclear why this may be the case, though it is possible the adolescents who perceived higher environmental barriers may be active in the neighborhood out of necessity (e.g., to get from their home to other destinations), regardless of the barriers.

Another possible explanation because adolescents were only reporting environmental barriers to walking or biking to the nearest local park. It is possible that those participants who perceived greater barriers to getting to the nearest park had more physical activity in the neighborhood because they lived further from a local park and were more likely to stay within the neighborhood (1 km around home) to be active, compared to those who thought it was easy to get to the nearest park. Though a local park was within the 1-km neighborhood buffer for about two-thirds of the TEAN participants, the closest park was outside of this buffer for one-third of the participants. Although beyond the scope of this paper, it is worth noting that when adolescents' total and non-school MVPA (i.e., not limited to within 1-km neighborhood buffer around home) was assessed, the expected negative association between physical activity and environmental barriers to walking/biking to a local park was seen. This suggests that objective distance to a local park may be important to consider when examining environmental influences on PA within one's neighborhood, irrespective of safety considerations

In the social support interaction, participants in neighborhoods with low streetscape safety who reported high social support had over double the minutes of MVPA than those with low social support (Fig 2.1C). This implies that having greater social support may serve to help one overcome the barriers of low neighborhood safety. It is unclear why participants with high social support would have less physical activity in safe compared to unsafe neighborhoods.

Moderators of streetscape safety and average frequency of active transport in the neighborhood

The single significant interaction implied that for those in neighborhoods with low streetscape safety, regardless of their perception of barriers, adolescents obtained less active transport (Fig. 2.2). However, those with few perceived barriers and lived in neighborhood with high streetscape safety had the most active transport. Therefore, helping reduce perceived barriers among adolescents who live in neighborhoods with high streetscape safety may be a promising approach to help adolescents engage in more active transport.

Moderators of streetscape safety and average frequency of leisure-time physical activity in the neighborhood

Higher MAPS streetscape safety was associated with less leisure-time physical activity, which is counter to expectations. However, Cain et al. (2014) also found leisure-time physical activity and the MAPS grand score (which was correlated at .84 with the MAPS streetscape safety index) was significantly negatively associated with leisure-time physical activity. Cain et al. (2014) suggested that the negative association may be explained by design differences in neighborhoods, where the design of neighborhoods that facilitate active transport may be associated with less active play in the neighborhood. Given many safety related streetscape features (e.g., marked crossings, walking signals) are concentrated along commercial areas with higher vehicular traffic, those areas may not be conducive to active outdoor play, though they may have objectively safer built environment features. Because these components of streetscape safety components may not as be needed in suburban or low-walkable neighborhoods due to low vehicular traffic, the low streetscape score could be an indicator that it is a safer place for children to engage in leisure-time play.

Adolescents with many parent-reported safety restrictions had the same amount of leisure-time physical activity—regardless of the objective streetscape safety (Fig 2.3). However, adolescents with fewer safety-related rules had greater leisure-time physical activity in neighborhoods rated as unsafe compared to safe. A possible explanation is that low streetscape safety scores were found on many suburban streets that also have low traffic. Thus, parents may be comfortable letting adolescents be active outside in such neighborhoods and have fewer rules, or simply may not be as invested in their adolescent's whereabouts (particularly older ones).

Main Effects: Correlates of physical activity across three outcomes

The main effects identified in at least two or more outcomes were mostly consistent with the literature on correlates of physical activity (Sterdt et al., 2014; Ding et al., 2011). Being male, having greater self-efficacy, greater social support, fewer barriers to being active in the neighborhood and lower BMI were positively associated with more physical activity, which is mostly consistent with a recent review (Sterdt et al., 2014). The significant finding that greater parent-reported overall walkability (non-safety) was associated with more active transport and objective MVPA in the neighborhood is consistent with the literature (Ding et al., 2011) and logical that having a destination to visit would be associated with greater physical activity, particularly active transport. More parental safety-related rules and restrictions was associated with less active transport and leisure-time physical activity, which may be related to concerns about safety or the age of their child (Carver et al., 2010).

Theoretical Implications

An ecological approach informed which variables would be tested as moderators. The moderator analysis was based on a principle from ecological models that influences on behavior interact across levels (Sallis & Owen, 2015). The 5 significant moderators found in the current study were from two levels (demographic and psychosocial). Considering main effects were found from the four tested ecological levels, the findings support the utility of an ecological approach that considers multiple levels of influence on physical activity (Sallis & Owen, 2015). The findings emphasize that the relation between objectively assessed neighborhood safety environment and physical activity were complex, but findings were mostly in line with the reviews of correlates of physical activity (Sterdt et al., 2014). The current study demonstrated the utility of an ecological model approach and the need to explore correlates from multiple ecological levels as moderators. However, the scarcity of significant moderators implies that significant main effects may work similarly for most adolescents, which can help inform the design and implementation of targeted interventions.

Strengths & Limitations

Limitations included the format of the self-reported physical activity outcomes as average frequency (instead of days per week) and the cross-sectional design that prohibited the establishment of temporal associations. Another limitation was the reduced statistical power for the GPS-specific MVPA outcome, as the sample size for the GPS-specific outcome was smaller than the two self-report outcomes (n=715 vs. n=878).

The reviews of neighborhood environments and physical activity among youth emphasized the need to use objective measures of both physical activity and the neighborhood environment to advance the field (Ferreira et al., 2007; Ding et al., 2011), as was done in the current study. Using existing objective and reliable MAPS items conceptually related to pedestrian safety to develop the streetscape safety index was innovative and adds to the literature on objectively assessed safety features of the built environment and physical activity. The use of the GPS-specific accelerometer measured minutes/day of MVPA in the neighborhood was a novel contribution. By using a location-specific independent variable and outcome, the findings for this outcome help overcome a limitation of other studies that use accelerometer measures of total MVPA, but do not directly assess if the activity occurred within the neighborhood. Therefore, present findings about the relation of objectively assessed streetscape safety and physical activity in the neighborhood can be interpreted with greater confidence. Other strengths included the use of two self-reported domain-specific physical activity outcomes, a diverse sample, equal representation of sexes and exploring moderators identified from known correlates of physical activity across multiple levels influence.

Conclusion and Recommendations

Though some of the findings from the current study were difficult to interpret, there were several consistent patterns across outcomes. Males consistently had more physical activity and there were significant psychosocial moderators across the three outcomes. The fact that all tested ecological levels had significant correlates with at least one physical activity outcome reinforces the importance of applying an ecological approach.

The lack of main effects with active transport and MAPS streetscape safety was somewhat unexpected, as Cain et al. (2014) found a positive association with the MAPS grand score and active transport among adolescents. However, given the control of study design and numerous additional variables included in the current study (e.g., from multiple ecological levels), it is not completely unexpected. Furthermore, the items in the MAPS grand score that were not in the streetscape safety index included commercial destinations along the route, mixed land use, residential density and aesthetics. The finding from the current study suggests that the destinations and mixed land use drive the association with active transport among adolescents and not the safety elements. This hypothesis was further supported because perceived overall walkability (non-safety) was positively associated with greater activity for the active transport and minutes of MVPA outcomes. Having destinations nearby appeared to help all adolescents get more physical activity, regardless of the objectively assessed safety of their neighborhood and especially related to active transport.

It was unexpected that none of the perceived neighborhood safety variables moderated the relation of physical activity and streetscape safety in the neighborhood. It was hypothesized that the perceptions of neighborhood safety would be different from the objectively assessed safety. However, the hypothesis was not supported in the current study. An example of that moderator relation would be that if adolescents perceived high safety from traffic, they would have the same amount of physical activity in objectively safe and unsafe neighborhoods. Perceived traffic safety has been significantly associated with physical activity in several studies, though in inconsistent directions (Carver et al., 2008; Esteban-Cornejo et al., 2016; Davison et al., 2006), but perceived traffic safety was not a significant main effect or moderator in the present study.

The variables used to create the MAPS streetscape safety index were primarily related to pedestrian infrastructure, such as continuous sidewalks, marked crosswalks, low speed limits, streetlights and traffic calming measures (e.g., speed humps). Because these are primarily small and modifiable characteristics, adding these types of features can make the streets safer for pedestrians and facilitate more physical activity. Therefore, adding safety features to neighborhoods could have a double benefit, by helping reduce pedestrian involved crashes and increasing physical activity.

The relation between physical activity among adolescents and objectively assessed neighborhood streetscape safety was complex. The few moderating effects, but many main effects, across outcomes suggest that many characteristics are likely to affect physical activity of adolescents in general. There were several indications that adolescents' perceived safety may not heavily influence their physical activity, perhaps because they perceive themselves to be invincible (i.e., that the consequences of risky behaviors will not happen to them, including injury) (Monneuse et al., 2008; Killgore, Kelley & Balkin, 2010). If they do not think they are at risk, particularly from traffic or automobile crashes, their behaviors may not be influenced by the safety of the environment. Future qualitative research should be done to help clarify some of the findings and better understand thought processes behind the behaviors. However, encouraging mixed use, pedestrian-oriented development may help all adolescents get more physical activity by providing destinations to walk or bike to, and hopefully safety infrastructure will become more common to yield dual benefits through injury prevention and physical activity.

ACKNOWLEDGEMENTS

Chapter 2 is currently being prepared for submission for the publication of the material. Co-authors include Dr. Terry L. Conway, Dr. Jordan A. Carlson, Kelli L. Cain, Carrie Geremia, Dr. Brian E. Saelens, Dr. Karen Glanz, Dr. Lawrence D. Frank, Dr. Hala Madanat, Dr. Linda Hill and Dr. James F. Sallis. The dissertation author was the primary investigator and author of this material.

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Table 2.1: Summary of Measures used in the current study with TEAN data: outcomes, independent variables and moderator variables

Ecologi -cal level	**Variable**	**Number of Items (Response options)**	**Description/sample items**	**Psychometrics and references**
Physical Activity Outcomes				
	Moderate-to-vigorous physical activity (MVPA) minutes/day within 1-km neighborhood buffer	5+ days of valid wear time (>10 hours) for accelerometer were required to be included in analyses. Only days with ≥8 hours of GPS signal during accelerometer wear time were included (n=725)	Participants wore an Actigraph accelerometer (ActiGraph, LLC) on a belt securely around the waist during waking hours, with acceleration recorded at 30-second epochs. Multiple ActiGraph models were used and though model type was not associated with MVPA, it was controlled for in analyses. MVPA was scored with the Evenson cutoff points for youth (Evenson et al, 2008) divided by 2, which has been shown to have excellent classification accuracy (Trost et al., 2011). Groups of >60 sequential 30-second epochs with count = 0 were considered nonwear, thus excluding nonwear and nonwaking time from the data. Details of how the GPS buffer was calculated is described in a previous study (Carlson et al., 2015). A buffer of the neighborhood area was defined as 1-km street network buffer around geocoded home point, excluding a small at-home circular buffer. Next, accelerometer and GPS data were linked to determine whether the GPS point was in the neighborhood buffer. This information was used to calculate minutes per day of MVPA within the neighborhood.	ActiGraph, LLC, Pensacola, FL; Evenson et al., 2008; Trost et al., 2011 Carlson et al., 2015;
	Leisure-time PA in the neighborhood: average frequency of leisure-time PA in neighborhood (self-report)	6 items (6 settings out of 7 used in current analyses) (0 = never, 1 = once a month or less, 2 = once every other week, 3 = once a week, 4 = 2-3 times per week, 5 = four or more times/week). A mean of the 6 items was taken to represent average frequency of leisure-time PA (scores 0-5)	How often are you physically active in settings near your home? Examples were nearby street, sidewalk, or cul-de-sac	This scale was adapted from a measure with good test-retest reliability (Grow et al., 2008)

Table 2.1: Summary of measures used (continued)

Ecologi -cal level	**Construct / Variable**	**Number of Items (Response scale or Range)**	**Example items or methods**	**Psychometrics and reference**
	Active transport, non-school: average frequency of active transportation in neighborhood (self-report)	9 items (9 locations out of 12 used in current analyses) (0 = never, 1 = once a month or less, 2 = once every other week, 3 = once a week, 4 = 2-3 times per week, 5 = four or more times/week) A mean of the 9 items was taken to represent average frequency of active transport (Scores 0-5)	How often do you walk or bike to one of nine common locations? Examples included recreation centers, parks and a friend's house	Test–retest reliability for active use of, proximity to, and active transport to/from recreation sites ranged from fair to very good adolescents (ICC = 0.25 to 0.77) (Grow et al., 2008).
Independent Variable: MAPS Streetscape Safety				
Object-ive Neighborhood safety	Microscale Audit of Pedestrian Streetscapes (MAPS) Streetscape Safety Index	26 items (52 points possible; actual range 4-32); 8 items from the route section; 4 items from the segment section; 14 items from the crossing section (0 to 2, where 0=extremely unsafe and the 2=extremely safe). Summed to create an index	Data were collected along a 0.25-.45 mile route beginning at the participant's home and extending toward the nearest destination (e.g. stores, school or park). Route-level safety items included speed limits, street lights, and traffic calming and crosswalk signage. Segment-level (i.e. street segments between intersections) items included sidewalk presence, buffer presence and number of traffic lanes. Street crossing items assessed crosswalk markings, curb cuts, crossing signals, and pedestrian protection. Cul-de-sac items were collected but not included in present analyses. Higher scores reflected greater safety.	MAPS development and inter-rater reliability determined (Millstein et al., 2013). Validated by associations with PA in 4 age groups (Cain et al., 2014).
Moderators of neighborhood safety and physical activity association from multiple ecological levels				
Indivi-dual characteristics	Demograph-ics	1. Age 2. Sex 3. Race/ethnicity 4. Household highest education 5. Parent Marital Status	1-3: self-reported by adolescent Race/ethnicity was recoded to White non-Hispanic vs. other race/ethnicity 4-5: self-reported from the parent survey Education was recoded to college degree or higher vs. other Marital status was recoded to married/living together vs. other	N/A
	BMI	Adolescent Body Mass Index (used SAS Program for the 2000 CDC Growth Charts) Parent BMI	BMI was calculated from self-reported height and weight as kg/m^2. Parents were provided instructions on how to accurately measure and record their child's weight and height. Adolescent's BMI z-scores were based on CDC BMI-for-age growth charts.	Kuczmarski et al., 2000

Table 2.1: Summary of measures used (continued)

Psychosocial Characteristics:	Self-efficacy for physical activity	6 items (1 = "I'm sure I can't" to 5 = "I'm sure I can") Summed into a scale	"How sure are you that you can do physical activity in each situation?" Example items included "even when you feel sad or stressed", "even when it is raining or really hot outside" and "even when you have a lot of homework."	Alpha = .76; test-retest ICC = .71 (Norman, Sallis & Gaskins, 2005)
	Perceived barriers to walking and bicycling	3 subscales: 1.planning/psychosocial (7 items) 2. social/safety (3 items) 3. environmental factors (7 items) (1 = 'strongly disagree' to 4 = 'strongly agree') Averaged items to create each subscale measure	It is difficult for me to walk or bike to the closest local park because… 1. Planning/psychosocial example items included "no other teens walk or bike" and "I have too much stuff to carry" 2. Social/safety example items included "there is nowhere to leave a bike safely" and "I would have go through places that were unsafe because of crime or things sometimes related to crime" 3. Environmental example items included "there are no sidewalks or bike lanes" and "there are too many hills"	Alpha = 0.70–0.83; test–retest ICCs=0.60–0.75. Scales 1 and 3 were associated with PA (Forman et al., 2008)
	Barriers to activity in your neighbor-hood	9 items (1 = 'strongly disagree' to 4 = 'strongly agree')	"It's difficult for me to be active in the local park or streets/neighborhood near our home because…" Example items included "There is no choice of activities," "It is not safe because of traffic" and "I have been a victim of crime in my neighborhood"	Adapted from the Active Where? Questionnaire ICCs for items range = .35 - .73; percent agreement range for items = 44% - 81% (Joe, et al., n.d).
	Number of friends in the neighbor-hood	1 item (open response)	"How many friends do you have in the neighborhood" (i.e., within a 10-15 minute walk from your home)?	Not assessed for psychometric properties
	Social support for PA	5 items (0 = "never" to 4 = "very often") Averaged items to create the scale measure	"During a typical week, how often does an adult in your household OR brothers/sisters or friends:" Example items included "encourage you to do sports or activities" or "ask you to walk or bike to school or to a friend's house?"	The scale was adapted from a previous study (ICC=0.68-0.74) (Norman, Sallis & Gaskins, 2005)
	Parental restrictions and rules related to safety	1. Adolescents reported 10 items (out of 14) (Yes = 1, No = 0) 2. Parents reported 11 items (out of 18) (Yes = 1, No = 0) Summed into separate parent and adolescent scales	5. "Does your parent or guardian have the following rules, whether they remind you often or not?" Example items included "Carry a cell phone or 2-way radio," "watch out for cars" and "do not cross busy streets" 6. "Do you have the following rules for your child, whether you tell them often or not?" Example items included "Do not go places alone," "come in before dark" and "stay on paths, trails or sidewalk"	Scale with all items Alpha = 0.87; test–retest ICC=0.68; data from a prior sample not previously published. Percent agreement range = 50% - 78% (Joe et al., n.d.)

Table 2.1: Summary of measures used (continued)

Ecological level	**Construct / Variable**	**Number of Items (Response scale or Range)**	**Example items or methods**	**Psychometrics and reference**
Home Environment	PA Equipment around the Home Index [0-10]	10 items (0 = “don’t have” to 5 = “once a week or more”). Recoded as 0 = “don’t have” and 1 = “have access to.” Then summed to create an index	“How often do you use these items in or around your home (or in a common apartment area)?” Example items included bike, basketball hoop, home aerobic equipment (e.g., treadmill, stationary bike, workout videos), sports equipment (e.g., balls, racquets, bats, sticks). Recoded to assess “presence of” instead of “use of.”	Psychometrics on this are not available, but a PA index was shown to be reliable and associated with PA among adults (Sallis et al., 1997)
	Personal portable electronics ownership	4 items (Yes = 1, No = 0) Summed into a scale	“Do you have the following items for your own use?” Example items included “Cell phone” and “personal stereo (iPod, MP3 player, Discman)”	Test-retest ICC = >.60 (Rosenberg et al., 2010)
	Electronic devices in the bedroom	6 items (Yes = 1, No = 0) Summed into a scale	“Please indicate whether the following is in your bedroom.” Example items included “TV,” “computer,” and “video game access (non-handheld-Playstation, Xbox, etc.)	Test-retest ICC range .39-.87 (Rosenberg et al., 2010)
	Number of drivable motor vehicles per licensed driver in household [0-3] (Parent-reported)	1. Number of vehicles 2. Number of licensed drivers Computed by dividing number of vehicles by number of licensed drivers	1. “How many drivable motor vehicles (cars, motorcycles) are there at your household?” 2. “How many licensed drivers are in your household (including yourself)?”	N/A
Parent Perceived Neighborhood Safety Environment	Neighborhood Environment Walkability Scale for Youth (NEWS-Y) (Parent reported)	1. Neighborhood traffic safety (3 items) 2. Low crime rate (1 item) 3. Low stranger danger (4 items) 4. Pedestrian safety (3 items) For the safety subscales, (1 = strongly disagree, 4 = strongly agree) 5. Overall non-safety walkability scale (total of X-items using 7 z-scores of non-safety related subscales)	1. Neighborhood traffic safety (3 items) E.g., “The traffic makes it difficult or unpleasant for my child to walk.” 2. Crime rate (1 item) “There is high crime rate” (reverse coded) 3. Stranger danger (4 items) E.g., “I’m afraid of my child being taken or hurt by a stranger on local streets” 4. Pedestrian safety (3 items) E.g., “There are crosswalks and signals on busy streets” 5. The non-safety walkability scale was created from the following subscales and sample items: -residential density (6 items, e.g., “how common are detached single-family residences in your immediate neighborhood?”); -land use diversity (13 items; “how long does it take you to walk to the nearest places listed?” E.g., supermarket, clothing store, fast food”);	Based on original NEWS, where subscales had test-retest reliability ICC .77 (Saelens et al., 2003). Construct validity supported by correlations with physical activity (Cerin et al., 2009) For all NEWS-Y subscales, test-retest ICCs ranged from 0.61 to 0.78 (Rosenberg et al., 2009).

Table 2.1: Summary of measures used (continued)

Ecologi-cal level	**Construct / Variable**	**Number of Items (Response scale or Range)**	**Example items or methods**	**Psychometrics and reference**
			-neighborhood recreation facilities (9 items; "how long does it take you to walk to the nearest places listed?" E.g., basketball court, small public park, bike/hiking/walking trails/paths); -Land use mix access (6 items) E.g., "Stores are within easy walking distance of our home" -Street connectivity (3 items) E.g., "There are many different routes for getting from place to place in our neighborhood" -Walking/cycling facilities (3 items) E.g., "There is grass/dirt between the streets and the sidewalks in our neighborhood" -Aesthetics (4 items) E.g., "there are many beautiful things to look at")	
Adolescent Perceived Neighborhood Safety Environment	Neighborhood Environment Walkability Scale for Youth (NEWS-Y) (Adolescent reported)	1. Neighborhood traffic safety (3 items) 2. Low crime rate (1 item) 3. Low stranger danger (4 items) 4. Pedestrian safety (4 items) (1 = strongly disagree, 4 = strongly agree)	1. Neighborhood traffic safety (3 items) E.g., "The speed of traffic on most streets is usually slow (30 mph or less)." 2. Crime rate (1 item) "There is high crime rate" (reverse coded) 3. Stranger danger (4 items) E.g., "I'm afraid of my child being taken or hurt by a stranger on local streets" 4. Pedestrian safety (4 items) E.g., "There are crosswalks and signals on busy streets"	Based on original NEWS, where subscales had test-retest reliability ICC .77 (Saelens et al., 2003). Construct validity supported by correlations with physical activity (Cerin et al., 2009) For all NEWS-Y subscales, test-retest ICCs ranged from 0.61 to 0.78 (Rosenberg et al., 2009).

Table 2.2: Descriptives of PA outcomes, MAPS streetscape safety, and correlates of physical activity from multiple levels of ecological model using a sample adolescents living in the Seattle and Baltimore regions (N=878)

Variables	Mean (SD) / N (percent)
Physical Activity Outcomes	
Min/day of total MVPA (GPS specific)[A] (n=715)	
Back-transformed[A]	2.747 (n/a)
Untransformed [0-74.75]	6.0 (9.938)
Frequency of Leisure-time MVPA (self-report) [0-5]	1.806 (1.281)
Frequency of Active Transport (self-report) [0-5]	1.37 (0.962)
Independent variable: Objective Pedestrian Safety	
MAPS Streetscape Safety Index (N=878) [4-32]	16.723 (5.394)
Ecological variables explored as multilevel moderators	
Individual/demographic variables	
Sex (male)	442 (50.3%)
Race/ethnicity (White non-Hispanic)	584 (67.0%)
Marital Status (Married or living with partner)	736 (84.1%)
Household highest education (college degree or higher)	659 (75.3%)
Adolescent Age (12-17)	14.09 (1.407)
Adolescent BMI (z-score) [-5.30-2.97]	0.461 (1.012)
Parent BMI (16.14-73.16)	27.581 (6.188)
Psychosocial Variables	
Adolescent self-efficacy for PA [1-5]	3.534 (0.995)
Adolescent PA social support [0-4]	2.090 (0.884)
Adolescent Environmental barriers to walking and biking [1-4]	1.773 (0.698)
Adolescent Planning/psychosocial barriers to walking and biking [1-4]	1.735 (0.628)
Adolescent Safety barriers to walking and biking [1-4]	1.706 (0.706)
Adolescent Barriers to Activity in neighborhood	1.751 (0.579)
Adolescent number of friends in the neighborhood [0-65]	6.69 (7.468)
Parent reported safety-related activity rules [0-11]	7.747 (2.559)
Adolescent reported safety-related activity rules [0-10]	5.738 (2.496)
Parent's self-reported minutes of MVPA per week	254.94 (232.36)
Parent's self-reported minutes of active transport per week	249.46 (379.43)
Home Environment Variables	
PA Equipment around the Home Index [0-10]	6.225 (2.155)
Adolescent personal electronics ownership [0-4]	2.91 (0.958)
Adolescent electronic devices in the bedroom [0-6]	2.60 (1.702)
Number of drivable motor vehicles per licensed driver in household [0-3]	1.082 (0.395)
Perceived Neighborhood Environment (NEWS)	
Parent reported	
Traffic Safety [1-4]	2.581 (0.581)
Pedestrian Safety [1-4]	2.824 (0.651)
Low Crime Rate [1-4]	3.099 (0.879)
Low Stranger Danger [1-4]	3.007 (0.730)
Overall non-safety walkability scale [-2-2][B]	-0.010 (0.544)
Adolescent reported	
Traffic Safety [1-4]	2.730 (0.614)
Pedestrian Safety [1-4]	3.108 (0.523)
Low Crime Rate [1-4]	3.212 (0.744)
Low Stranger Danger [1-4]	3.378 (0.744)

[A]Back-transformed from skewed mean to report the geometric mean, however standard deviations cannot be back-transformed and were not reported

Table 2.3: Final cross-level model of multilevel moderators of the association of objective streetscape safety and average minutes/day of MVPA in the neighborhood buffer (GPS-derived) among adolescents

	Minutes/day of MVPA in the neighborhood buffer[A,B,C,D]			
	B	CI	P-value	Cohen's *d*
Intercept	2.297	-0.997, 4195.474	--	--
Independent variable: objective pedestrian safety				
MAPS Streetscape Safety	-0.037	-0.144, 0.083	.527	0.048
Individual/demographic variables				
Adolescent gender (Male)	9.881	3.233, 26.938	<.001	0.375
Adolescent Age	-0.193	-0.480, 0.023	.067	0.138
Adolescent race/ethnicity (Other vs. White non-Hispanic)	1.716	-0.029, 6.591	.057	0.144
Adolescent BMI (z-score)	-0.458	-0.672, -0.102	.017	0.180
Parent BMI	-0.007	-0.086, 0.080	.876	0.012
Parent Marital status (not married/living with partner)	0.027	-0.729, 2.896	.968	0.003
Highest Household education (less than college)	-0.128	-0.727, 1.804	.822	0.017
Psychosocial variables				
Social support for PA	0.433	-0.185, 1.519	.211	0.094
Environmental Walk and Bike Barriers	1.718	-0.423, 6.815	.063	0.140
Planning/Psychosocial Walk and Bike Barriers	-0.689	-0.892, -0.102	.031	0.163
Barriers to being active in neighborhood	-0.699	-0.894, -0.147	.024	0.171
Perceived Neighborhood variables (NEWS)				
Parent Low Stranger Danger	0.089	0.017, 3.655	.014	0.185
Parent Overall Walkability (non-safety)	2.622	0.239, 9.591	.019	0.178
Adolescent Low Crime Risk	-0.537	-0.746, -0.157	.012	0.190
Interactions				
Race/ethnicity X MAPS Streetscape Safety	0.239	0.021, 0.502	.030	0.164
Social support for PA X MAPS Streetscape Safety	-0.130	-0.215, -0.036	.008	0.201
Environment Walk Bike Barriers X MAPS Streetscape Safety	-0.157	-0.255, -0.047	.007	0.205

[A]All models contained all the individual/demographics level variables as controls, regardless of main effect significance. Also controlled for site and study design (macro walkability and block-group income quadrants)
[B]This outcome was natural log-transformed (ln) and then for back-transformed (e^b) for interpretation
[c]Controlled for accelerometer model and wear time
[D]Variables that were identified as significant at p<.1 in the level-specific models that were not significant in the final cross-level model: Psychosocial (Self efficacy, Parent Safety Rules, Parent Safety Rules X MAPS); Home environment (Home PA Index); Perceived Neighborhood Environment (Low Crime Risk X MAPS)

Table 2.4: Final cross-level model of multilevel moderators of the association of objective streetscape safety and adolescent-reported average frequency of active transport in the neighborhood among adolescents

	Frequency of Active Transport in the neighborhood[A,B]			
	B	CI	P-value	Cohen's *d*
Intercept	1.228	1.075, 1.381	--	--
Independent variable: objective pedestrian safety				
MAPS Streetscape Safety	0.004	-0.008, 0.016	.496	0.048
Individual/demographic variables				
Adolescent gender (Male)	0.153	0.036, 0.269	.010	0.176
Adolescent Age	0.024	-0.021, 0.068	.301	0.071
Adolescent race/ethnicity (Other vs. White non-Hispanic)	0.318	0.194, 0.443	<.001	0.346
Adolescent BMI (z-score)	0.006	-0.053, 0.065	.834	0.014
Parent BMI	-0.004	-0.014, 0.005	.373	0.061
Parent Marital status (not married/living with partner)	0.203	0.040, 0.366	.015	0.167
Highest Household education (less than college)	0.136	-0.008, 0.281	.064	0.127
Psychosocial variables				
Self-efficacy for PA	0.066	0.0002, 0.131	.049	0.134
Social support for PA	0.171	0.095, 0.247	<.001	0.302
Barriers to being active in neighborhood	-0.115	-0.224, -0.005	.040	0.140
Parent Safety-related activity rules	-0.055	-0.080, -0.031	<.001	0.302
Home Environment variables				
Home PA Equipment index	0.056	0.028, 0.085	<.001	0.265
Electronic devices in the bedroom	0.045	0.010, 0.081	.013	0.170
Perceived Neighborhood variables (NEWS)				
Parent Overall Walkability (non-safety)	0.280	0.153, 0.407	<.001	0.305
Adolescent Low Crime Risk	-0.096	-0.167, -0.026	.008	0.183
Interactions				
Barriers to being active in neighborhood X MAPS Streetscape Safety	-0.020	-0.038, -0.002	.026	0.153

[A]All models contained all the individual/demographics level variables as controls, regardless of main effect significance. Also controlled for site and study design (macro walkability and block-group income quadrants)
[B]Variables that were identified as significant at p<.1 in the level-specific models that were not significant in the final cross-level model: Individual (Age X MAPS Safety); Psychosocial (Parent minutes/week of active transport); Home environment (Personal Electronic Ownership); Perceived Neighborhood Environment (Parent Traffic Safety, Parent Pedestrian Safety, Parent Low Crime Risk, Adolescent Traffic Safety, Adolescent Pedestrian Safety, Parent Traffic Safety X MAPS Safety, Parent Pedestrian Safety X MAPS Safety, Adolescent Traffic Safety X MAPS Safety, Adolescent Pedestrian Safety X MAPS Safety)

Table 2.5: Final cross-level model of multilevel moderators of the association of objective streetscape safety and adolescent-reported average frequency of leisure-time physical activity in the neighborhood among adolescents

	Frequency of Leisure-time PA in the neighborhood[A,B]			
	B	CI	P-value	Cohen's *d*
Intercept	1.593	1.268, 1.918	--	--
Independent variable: objective pedestrian safety				
MAPS Streetscape Safety	-0.034	-0.063, -0.006	.017	0.387
Individual/demographic variables				
Adolescent gender (Male)	0.672	0.416, 0.928	<.001	0.723
Adolescent Age	-0.086	-0.184, 0.012	.084	0.241
Adolescent race/ethnicity (Other vs. White non-Hispanic)	0.247	-0.042, 0.536	.093	0.235
Adolescent BMI (z-score)	-0.181	-0.323, -0.040	.012	0.387
Parent BMI	0.012	-0.016, 0.0341	.333	0.135
Parent Marital status (not married/living with partner)	0.247	-0.097, 0.589	.158	0.200
Highest Household education (less than college)	-0.124	-0.488, 0.240	.504	0.093
Psychosocial variables				
Self-efficacy for PA	0.215	0.068, 0.363	.004	0.414
Social support for PA	0.238	0.063, 0.414	.008	0.377
Safety Walk and Bike Barriers	0.466	0.233, 0.699	<.001	0.563
Barriers to being active in neighborhood	-0.277	-0.539, -0.014	.039	0.292
Number of friends in neighborhood	0.038	0.020, 0.057	<.001	0.566
Parent min/day Active Transport	0.0004	0.0001, 0.001	.013	0.350
Parent Safety-related activity rules	-0.034	-0.092, 0.023	.243	0.176
Home environment variables				
Home PA Equipment index	0.122	0.061, 0.179	<.001	0.599
Interactions				
Parent Safety-related activity rules X MAPS Streetscape Safety	0.010	0.001, 0.020	.033	0.331

[A]All models contained all the individual/demographics level variables as controls, regardless of main effect significance. Also controlled for site and study design (macro walkability and block-group income quadrants)
[B]Variables that were identified as significant at p<.1 in the level-specific models that were not significant in the final cross-level model: Individual (Age X MAPS Safety); Home environment (Personal Electronic Ownership, Electronic devices in the bedroom); Perceived Neighborhood Environment (Parent Traffic Safety, Parent Overall Walkability (non-safety), Adolescent Traffic Safety, Adolescent Low Stranger Danger, Adolescent Traffic Safety X MAPS Safety, Adolescent Low Stranger Danger X MAPS Safety)

Table 2.6: Significant main effects (p<.05) across the three physical activity outcomes from the final cross-level models

	Total minutes/day of MVPA	Average frequency of active transport	Average frequency of leisure-time PA
Independent variable			
Objective pedestrian safety variable			
MAPS Streetscape Safety Index			–
Multi-level variables			
Individual/demographic variables			
Adolescent gender (Male)	+		+
Adolescent Age			
Adolescent race/ethnicity (Other vs. White non-Hispanic)		+	
Adolescent BMI (z-score)	–		–
Parent BMI			
Parent Marital status (not married/living with partner)		+	
Highest Household education (less than college)			
Psychosocial variables			
Adolescent self-efficacy for PA		+	+
Adolescent social support for PA		+	+
Adolescent Environmental barriers to walking and biking			
Adolescent Planning/psychosocial barriers to walking and biking	–		
Adolescent Safety barriers to walking and biking			+
Adolescent Barriers to Activity in neighborhood	–	–	–
Adolescent number of friends in the neighborhood			+
Parent reported safety-related activity rules		–	–
Adolescent reported safety-related activity rules			+
Parent's self-reported minutes of MVPA per week			
Parent's self-reported minutes of active transport per week			
Home Environment variables			
PA Equipment around the Home Index		+	+
Adolescent personal electronics ownership			
Adolescent electronic devices in the bedroom		+	
Number of drivable motor vehicles per licensed driver in household			
Perceived Neighborhood Environment (NEWS) variables			
Parent reported			
Traffic Safety			
Pedestrian Safety			
Low Crime Rate			
Low Stranger Danger	+		
Overall non-safety walkability scale	+	+	
Adolescent reported			
Traffic Safety			
Pedestrian Safety			
Low Crime Rate/risk	–	–	
Low Stranger Danger			

Key: + positive association, significant at p<.05; negative association, significant at p<.05; blank represents a null finding

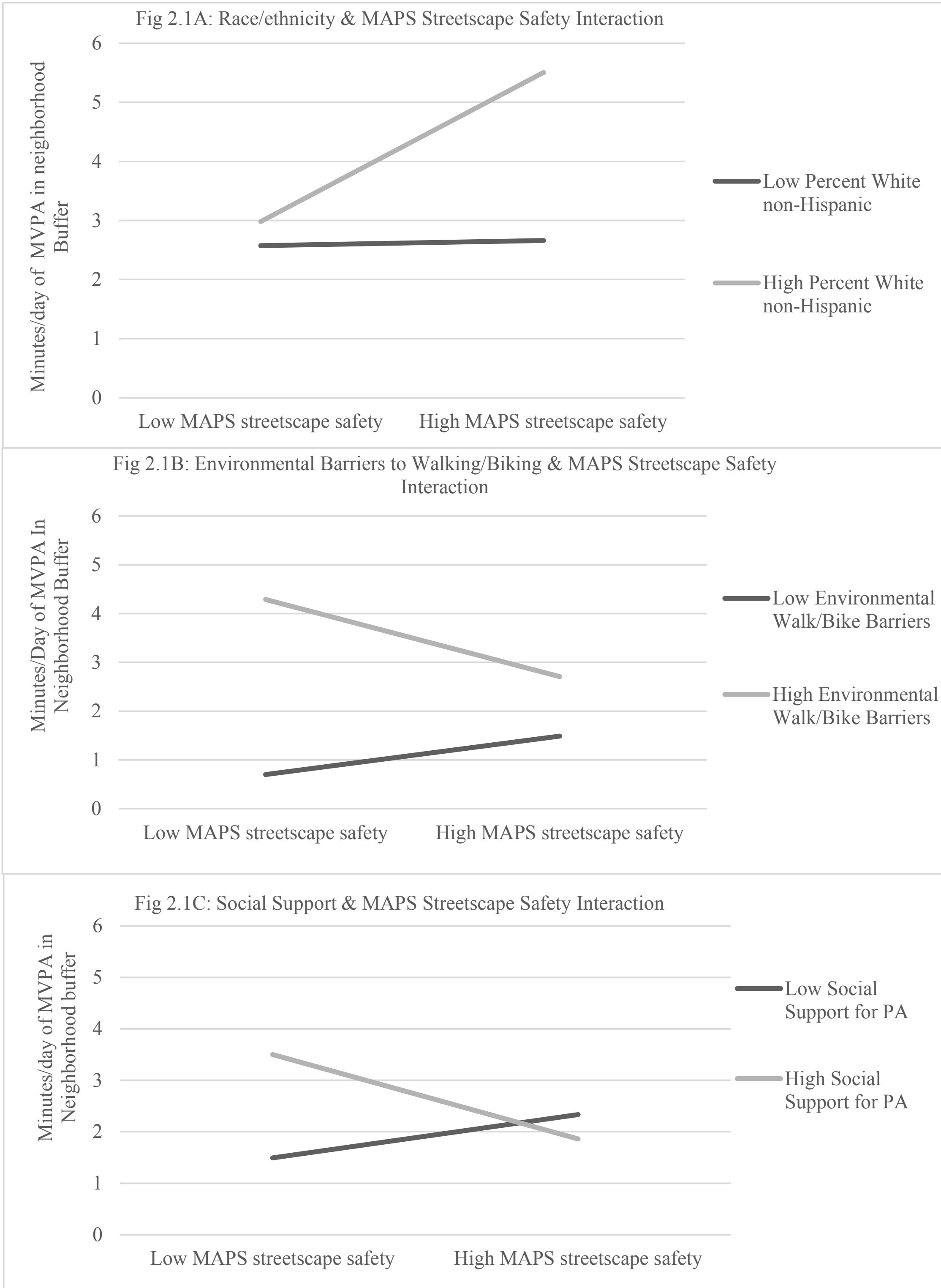

Figure 2.1: Race/ethnicity (2.1A), Environmental barriers to walking and biking (2.1B) and social support (2.1C) as moderators of the relation between objectively assessed neighborhood safety and daily minutes of MVPA in a neighborhood buffer among adolescents

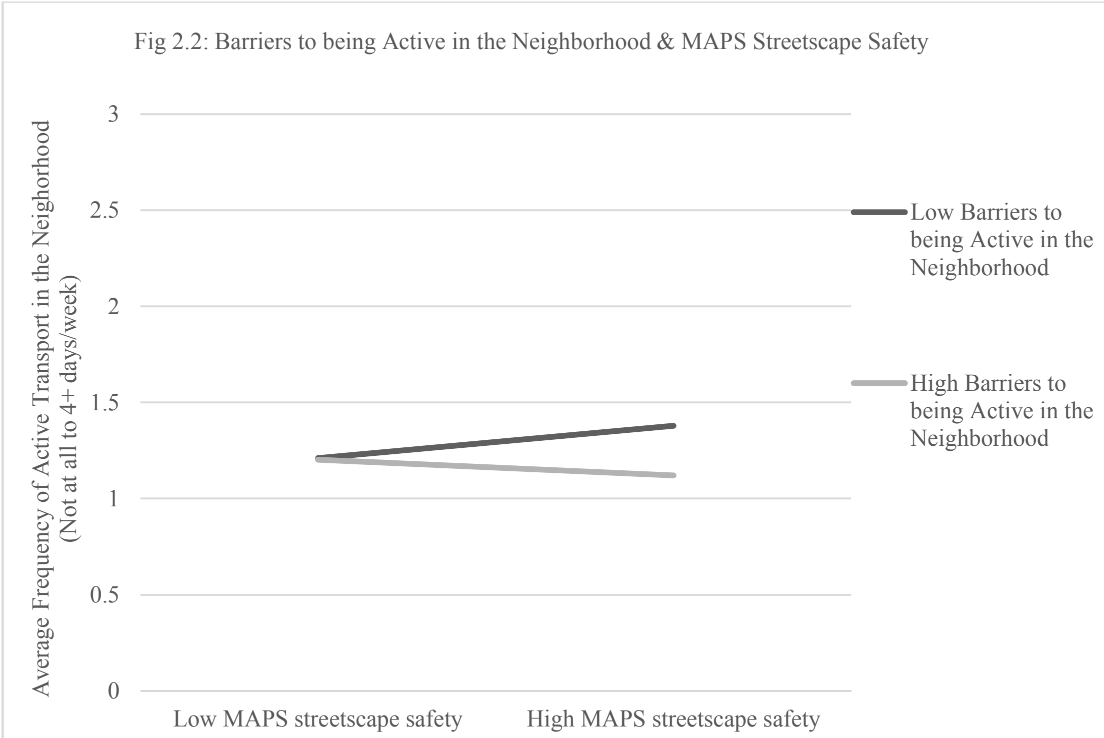

Figure 2.2: Adolescent perceived Barriers to being Active in the Neighborhood as a moderator of the relation of Average Frequency of Active Transport in the Neighborhood and objectively assessed MAPS Streetscape Safety among adolescents

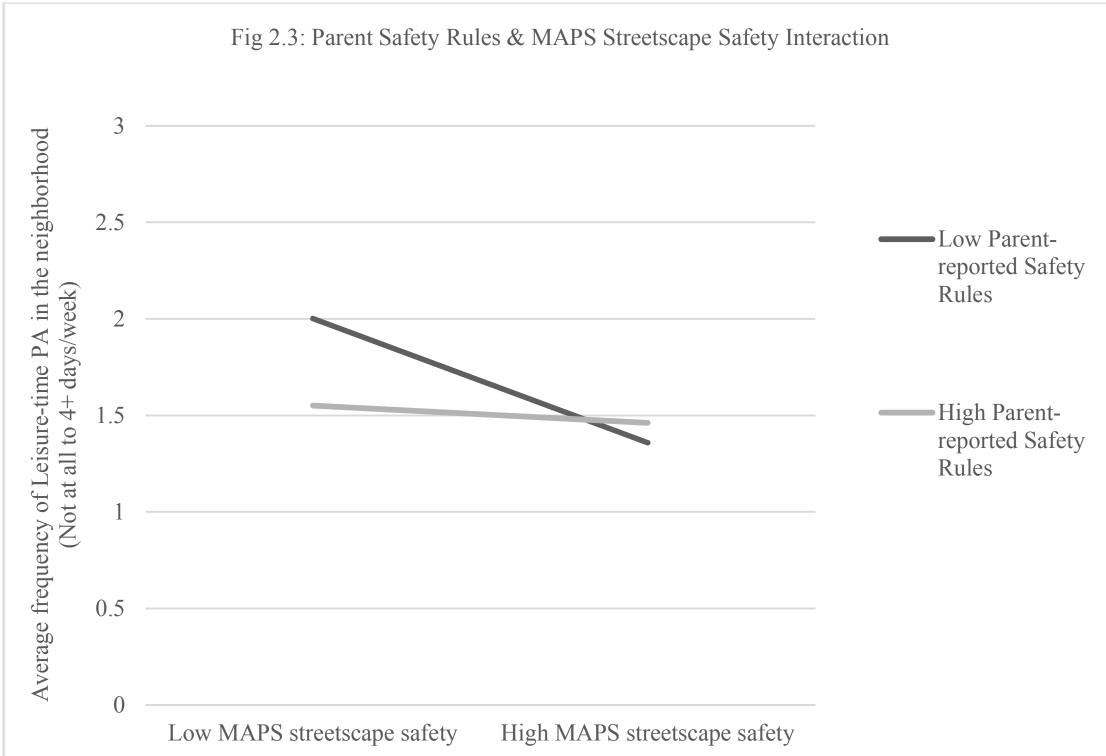

Figure 2.3: Parent-reported Safety-related rules and restrictions as a moderator of the relation of Average Frequency of Leisure-time PA in the Neighborhood and objectively assessed MAPS Streetscape Safety among adolescents

CHAPTER 3

Objectively Measured Pedestrian Safety and Physical Activity among Older Adults: Multilevel Moderators

ABSTRACT

Objective: The relation of neighborhood safety, specifically pedestrian infrastructure, with physical activity (PA) is not well understood. Older adults often do much of their PA in their neighborhoods, so pedestrian safety may be especially important for this population. The current study examined moderators of the relation of objectively-assessed pedestrian streetscape safety with PA.

Methods: Participants (N=367) were aged 65 years or older (average 75) from the Seattle, WA region, with 51% female and 84% White non-Hispanic. Three PA outcomes were used: self-reported minutes/week of active transport and leisure-time PA in the neighborhood, and accelerometer-measured minutes/day moderate-to-vigorous PA (MVPA). Objective pedestrian streetscape safety data were collected using a validated observational measure of streetscape features. Survey-reported moderators from multiple ecological levels were examined: individual (e.g., sex, driving status), psychosocial (e.g., self-efficacy), home environment (e.g., home PA equipment) and perceived neighborhood safety (e.g., traffic safety). A final multilevel generalized linear regression model identified main effects and cross-level interactions. Four self-reported health issues were assessed as confounders in the final models.

Results: Objectively-assessed pedestrian streetscape safety was significantly ($p<.05$) positively associated with greater active transport and walking for leisure in the neighborhood. There were 5 significant ($p<.10$) interactions with streetscape safety and PA, from 3 levels of influence. Those with high vs. low social support and without vs. with a college degree reported greater walking for leisure in safe vs. unsafe neighborhoods. Those with a college degree had more walking in unsafe vs. safe neighborhoods. Participants who were male, single and perceived high safety from traffic reported greater active transport in safe vs. unsafe neighborhoods. Females and those who

were married reported the same amount of active transport, regardless of safety. Health-related variables did not change the significance of any interactions.

Conclusion: Pedestrian streetscape safety was strongly associated with older adults' PA in their neighborhood, even when controlling for health status. The significant moderators from 3 levels support the utility of an ecological approach and the need to consider subgroup-specific effects when designing interventions. Designing neighborhoods to be pedestrian friendly could be a promising tactic to help older adults age in place.

INTRODUCTION:

The population of older adults in the US is expected to grow to nearly 84 million by 2050, which is nearly double what the population was in 2012 (Ortman, et al., 2014). In 2014, about 12% of older adults reported meeting the 2008 Physical Activity Guidelines (PAGA, 2015) and, as older adults aged, the proportion of people meeting the guidelines decreased (Federal Interagency Forum on Aging-Related Statistics, 2016). The well-established health benefits of physical activity (Warburton et al., 2006; PAGA, 2015) can be especially beneficial to older adults (Vogel et al., 2009; Nelson et al., 2007), as they are at a high risk of having or developing chronic diseases, including those associated with obesity and physical inactivity (Federal Interagency Forum on Aging-Related Statistics, 2016). Despite the low rates of older adults meeting guidelines and the documented benefits of physical activity, factors related to older adults' physical activity are not well understood.

Though interventions to increase physical activity have largely targeted individual and social characteristics (e.g., self-efficacy, barriers, social support) (Kahn et al., 2002; Marcus et al., 2006), data suggest environmental correlates are also related to physical activity in older adults. For example, elements of the neighborhood built environment, such as overall walkability, access to recreational facilities and home physical activity equipment, have been associated with physical activity in older adults (Yen et al., 2009; Van Cauwenberg et al., 2008; Frank et al., 2010). However, a recent systematic review of the 31 studies assessing the relation of environmental characteristics with physical activity among older adults found few consistently significant neighborhood environment factors. Limitations noted were related to measurement of correlates and physical activity outcomes, including the lack of domain-specific and objective measures of physical activity (Van Cauwenberg et al., 2011). Because physical activity is a complex behavior, an ecological approach, which considers multiple levels of influence (e.g.

individual, psychosocial, home environment, neighborhood environment), can be helpful to explain variation in physical activity among older adults (Sallis & Owen, 2015).

A component of the neighborhood environment is safety, which may be particularly important for older adults as they often get the majority of their daily physical activity inside their homes or neighborhood (Glass & Balfour, 2003). Safety is defined by the World Health Organization (WHO) as: "…a state in which hazards and conditions leading to physical, psychological or material harm are controlled in order to preserve the health and well-being of individuals and the community" (WHO, 1998, p. 5). The safety of a neighborhood can include both perceived (e.g., safety from traffic, walking infrastructure, and safety from crime) and objectively assessed safety-related microscale features of the built environment (e.g., sidewalk presence, curb cuts, speed humps). Safety from crime and safety from traffic (including pedestrian infrastructure) are separate constructs, and must be assessed as such. Given the higher rates of disability, greater fall risks and impaired mobility associated with physical inactivity among older adults (Nelson et al., 2007), the population of older adults is likely more influenced by the neighborhood built environment (i.e., safety from traffic and pedestrian infrastructure) than other age groups.

Despite the need to ensure communities remain accessible to older adults as they age (Micheal et al., 2006; Frank et al., 2010), the association between neighborhood safety and physical activity in the neighborhood remains unclear (Foster & Giles-Corti, 2008; Van Cauwenberg et al., 2011; Fleig et al., 2016). It is likely the relation between neighborhood safety and physical activity varies by participant characteristics (e.g., age, sex, self-efficacy, perceived safety from traffic), and as such, it could be useful to examine moderators. A principle of ecological models is that behaviors are influenced by interactions with variables from multiple levels (i.e., multilevel moderators) (Sallis & Owen, 2015). Given the unclear relation between safety and physical activity among older adults, moderator analyses that explore interactions across ecological levels could help clarify the findings.

There are limited studies that explore moderators of the relation between physical activity and neighborhood safety among older adults. The findings across the studies were inconsistent, and none utilized objective measures of neighborhood safety (Fleig et al., 2016; Tucker-Seeley et al., 2009; Bracy et al., 2014; Carlson et al., 2012). Only one study used both objectively assessed and domain-specific measures of physical activity (Carlson et al., 2014). One study found no relation with perceived safety measures and physical activity (Fleig et al., 2016) and a different study found the relation lost significance after controlling for self-rated health (Tucker-Seeley et al., 2009). The relation between perceived walking infrastructure and walking for leisure was moderated by the number of recreation facilities (Bracy et al., 2014) and self-efficacy (Carlson et al., 2012). A different study found over half of the significant interactions were with perceived safety from traffic, two with perceived pedestrian safety and one with perceived safety from crime among older adults (Carlson et al., 2014). Though the findings from the existing moderator analyses were inconsistent, they demonstrate the relation between neighborhood safety and physical activity among older adults is complicated and warrants further investigation.

Rather than relying on only perceptions of neighborhood safety from traffic, objectively measured neighborhood safety is important to include. The findings from studies that show perceived and objectively assessed data related to the environment and safety were inconsistent (Bailey et al., 2014; Kirtland et al., 2003; McGinn et al., 2007; Strath et al., 2012) support the need to incorporate objective measures. Though safety-related variables are included in many microscale measures, they are rarely analyzed on their own. A validated microscale tool, the Microscale Audit of Pedestrian Streetscapes (MAPS), included numerous safety-related features (Millstein et al., 2013) and was positively associated with physical activity among children, adolescents, adults and older adults (Cain et al., 2014), yet no safety-specific variable was constructed. A different study explored how both perceived and objective environmental characteristics were associated with accelerometer-measured physical activity among older adults and found objectively measured street safety was positively associated with physical activity, but perceived safety was not (Strath et al., 2012). The authors concluded, “A lack of concordance between perceived and measured attributes is likely indicative that other interesting interactions are present that warrant further investigation in an attempt to fully discern contributions to physical activity behavior” (Strath et al., 2012, p. 7).

The literature on physical activity among older adults and the relation to the neighborhood environment, particularly safety, is unclear and inconclusive. The aim of the present study was to help clarify the inconsistent findings by applying an ecological approach to explore multilevel moderators of the relation between objectively measured neighborhood safety and physical activity. The study adds to the literature in four primary ways. First, the use of three physical activity outcomes differentiates among physical activity domains, as two self-report and one objective measure were used. Second, the use of an objective measure of safety of the neighborhood environment at the microscale level addressed a gap in the literature, because the majority of the existing studies relied on self-reported perceived neighborhood safety. Third, analyses were conducted with and without covarying for measures of health status to examine if self-reported health factors were confounders. Fourth, the exploration of multilevel moderators can help illuminate subgroup-specific effects that may partially explain the inconsistent findings in the literature.

The specific aim of the current study was to explore moderators of the relation between objectively measured neighborhood safety and physical activity among older adults. The moderators were from multiple levels of influence according to an ecological approach. Given the lack of consistency in findings from the existing moderator analyses, it was hypothesized that sex and perceived neighborhood safety were likely moderators of the relation between objective neighborhood streetscape safety and physical activity in the current study. It was further hypothesized that the objectively assessed neighborhood safety variable would be independently associated with walking for leisure (i.e., main effects), given the significant findings of safety with walking for leisure among older adults.

METHODS

Study Design

The cross-sectional data used in the current study were collected from 367 older adult participants of the Senior Neighborhood Quality of Life Study (SNQLS), who were independently living in the Seattle/King County, WA region between 2005-2008 (King et al., 2011). SNQLS was simultaneously conducted in Baltimore, MD region (n=351), but there were concerns about the quality of the objective streetscape data collected there, and as such, only data from the Seattle, WA region were used. The purpose of SNQLS was to explore the relation between neighborhood built environment factors and physical activity among older adults. Census block groups were selected based on high- and low-walkability using GIS-data and high- and low-income using census data, which resulted in four quadrants (King et al., 2011). Participants were recruited from households within the four quadrants that a marketing company identified as having an adult 66 years or older residing there.

Potential participants were contacted via mail and then follow-up phone calls. Eligibility requirements included being 66 years or older, the ability to complete surveys in English and the ability to walk at least 10 feet. Though the response rate was low (21.4% of eligible contacts), the participants were still representative of the block groups they were recruited from. The low response rate is consistent with studies using an older sample with protocol that requires wearing an accelerometer or GPS device (Frank et al., 2005; Troiano et al., 2008). Recruited participants were mailed a survey and an accelerometer with instructions to fill out the survey after wearing the accelerometer for one week. The extensive survey included questions pertaining to different levels of the ecological model, such as demographics, psychosocial characteristics, perceived neighborhood environment, physical activity, and health-related questions (e.g. existing diseases, smoking behaviors). Greater details were reported in a previous study (King et al., 2011).

MEASURES

Table 3.1 depicts all measures used in the current study in detail, and brief descriptions are included below.

PHYSICAL ACTIVITY OUTCOMES

Objective minutes/day of moderate-to-vigorous physical activity (MVPA)

Objective physical activity was measured using ActiGraph accelerometers. Average daily minutes of total moderate-to-vigorous physical activity (MVPA) was calculated using the validated Freedson adult cut points (≥1952 counts/minute) (Freedson et al., 1998). The cut points have been used with these same SNQLS data in previous studies (King et al., 2011; Cain et al., 2014; Carlson et al., 2012; Carlson et al., 2104; Ding et al., 2014).

Minutes/week walking or biking for transport in the neighborhood

The Community Healthy Activities Model Program for Seniors (CHAMPS) survey, which has been validated with older adults (Stewart et al., 2001), was used. Active transport was assessed by summing the two items that asked about walking or biking in the neighborhood for errands. The outcome was skewed and was log-transformed for analyses, though back-transformed for interpretability.

Minutes/week of walking for leisure in the neighborhood

A single item asked about time spent walking for leisure in the neighborhood during an average week, also using CHAMPS (Stewart et al., 2001).

INDEPENDENT VARIABLE: OBJECTIVE PEDESTRIAN SAFETY

Background on the Microscale Audit of Pedestrian Streetscapes (MAPS)

Microscale Audit of Pedestrian Streetscapes (MAPS) (Millstein et al., 2013) is an observational tool conducted by trained observers on a 0.25-mile route from their home address to a pre-selected non-residential destination (e.g., restaurant, shops, service). Details on data collection, training, scoring and reliability were previously reported (Millstein et al., 2013), but a brief overview is included. MAPS has four sections: route, street segments, crossings and cul-de-sacs (available at http://sallis.ucsd.edu/measure_maps.html). Route-level items included land use and destinations, street amenities, highest posted speed limit, traffic calming features, and aesthetic characteristics. Segment-level (street segments between intersections) items included sidewalk presence, buffers between street and sidewalk, trees, number of traffic lanes. Street crossing items included crosswalk markings, width of crossings, curb cuts and signalization. Cul-de-sac items included distance from home, amenities within cul-de-sacs (e.g., basketball hoops), but were not used in the current study. The inter-rater reliability MAPS items and subscales demonstrated almost entirely moderate to excellent inter-rater reliability (ICC values ≥0.41 and ≥0.60, respectively).

Cain et al. (2014) assessed MAPS validity by exploring the relation between three physical activity outcomes (transport, leisure and MVPA from accelerometer) with MAPS items, subscales and a total streetscape score (i.e., grand score). The study used 4 age groups (i.e., children, adolescents, adults and older adults), and found the total streetscape score was significantly related to walking and biking for transport in all age groups, leisure and neighborhood physical activity among only children and adolescents, and MVPA among only children and older adults (Cain et al., 2014).

Development of the MAPS Streetscape Safety Index

Though safety-related attributes of the built environment were collected and some items were included in the grand score, no safety-specific subscale was created using MAPS items. A MAPS streetscape safety index was created with items from the route, segments and crossings sections of the tool. The MAPS items included in the index had acceptable inter-rater reliability (Millstein et al., 2013). The items included also reflect the presence or absence of pedestrian infrastructure related to safety, including speed limits, marked crosswalks, presence and continuity of sidewalks, and curb cuts (i.e., ramps). Well-maintained sidewalks, sidewalk infrastructure and traffic calming features (e.g. traffic humps) were positively associated with physical activity, particularly for transport, in one or more studies of microscale features and physical activity (Cain et al., 2014; Brownson et al., 2009; Boarnet et al., 2011; Pikora et al., 2006).

The microscale features selected for the safety index were conceptually related to injury prevention, specifically pedestrian safety. Some features selected influence traffic conditions (e.g., speed limits) and others provide infrastructure to protect pedestrians from traffic. The US Department of Transportation report on *Pedestrian facilities users guide: Providing safety and mobility* identified traffic speed, sidewalks, crosswalks, curb ramps, lighting, crosswalk signalization and marking, refuge islands, speed humps, and curb extensions as important factors related to protecting pedestrians from traffic collisions (Zegeer et al., 2002). These items were all included in the MAPS streetscape safety index, supporting content validity, and each item in the index was worth 0-2 points, with a maximum possible score of 52. All items in the MAPS streetscape safety index are in Appendix 1.

MULTI-LEVEL MODERATORS OF THE PHYSICAL ACTIVITY AND SAFETY RELATION

Individual/ Demographics level characteristics:

Variables included age, gender, race/ethnicity (White non-Hispanic vs. non-White), education (college degree vs. no college degree), marital status (married/living together vs. other), BMI, and driving status.

Psychosocial level characteristics:

Variables included self-efficacy for physical activity, social support, and barriers to physical activity in the neighborhood. All scales had acceptable psychometric properties (Marcus et al., 1992; Carlson et al., 2012; Sallis et al., 1987; Sallis et al., 1997).

Home environment-level characteristics:

The single variable assessed was an index of the presence of physical activity equipment around the home.

Perceived neighborhood-level characteristics:

The perceived environment was assessed using the Neighborhood Environment Walkability Scales-Senior Modified (NEWS-Senior), which was modified from the original NEWS scale which has demonstrated good to excellent psychometric properties in multiple studies (Saelens et al., 2003; De Bourdeaudhuij et al., Cerin et al., 2008). A recent review identified NEWS as the most frequently used measure to assess perceived neighborhood safety and physical activity (da Silva et al., 2016). The modifications included additional items related to older adults' pedestrian safety (e.g., if crosswalks were designed with markings for people with poor vision). Though there were 9 subscales in NEWS-Senior, the current study used the 3 safety ones (safety from traffic, safety from crime and pedestrian safety) and combined the remaining 6 into a single overall walkability index (non-safety related).

Additional Covariates:

Study design variables (i.e., GIS-based walkability and census 2000 income categories) were included as fixed effects and block group ID included as a random effect to adjust for participant clustering in neighborhoods. Additional covariates for the accelerometer MVPA outcome were average daily wear time and accelerometer model worn (7164, 71256).

Health-related variables:

The health variables were not tested in the initial models as moderators, but rather were added after final models were reached. These were included to assess if the health status of the participants was explaining much of the variance. The health variables were self-reported and included: hospitalizations in the past year (any vs. none), falls within the past year (any vs. none), any major visual or hearing impairments (any vs. none) and current medical conditions (none, 1, 2 or more).

STATISTICAL ANALYSES

All analyses were conducted in SPSS v.23.0 and mixed-effects linear regression models were used to adjust for nesting of participants within block groups for all models. The minutes/day of total MVPA and walking for leisure outcomes were approximately normally distributed and were not transformed. The active transport in the neighborhood outcome was skewed, and was natural log-transformed (*ln*) to better approximate a normal distribution. Data presented in the active transport outcome table were back-transformed (e^b) for meaningful interpretation as minutes per day. The correlations between all variables were assessed for collinearity, but no variables were correlated above 0.5. However, self-efficacy and self-rated mobility a previous study using these data found them to significantly correlated at 0.76 and used only self-efficacy (Thornton et al., 2016), which the current study did as well.

All models were run separately for the three outcome variables, but the components of the initial models were the same across outcomes. All models adjusted for the individual-level demographic variables (i.e., age, sex, race/ethnicity, marital status, education, BMI and driving status) and study design (macrolevel GIS derived walkability and block group income quadrants). The continuous variables were grand mean-centered, such that the intercept values would approximate the sample means for the outcomes and enable interpretation of the unstandardized regression coefficients (B).

The initial models for each outcome included the multilevel correlates, the MAPS streetscape safety index score, and the interaction term between each multilevel correlate and the MAPS streetscape safety index score. They were analyzed in four models per outcome based on each ecological level: (1) individual/demographics (7 variables), (2) psychosocial (3 variables), (3) home environment (1 variable), and (4) perceived neighborhood environment (4 variables). Fourteen possible interactions were tested per outcome, for a total of 42 tested across outcomes. Main effects and interactions with $p \leq 0.10$ were retained to be entered into a final cross-level model for each outcome. All models included the individual/demographic variables (regardless of significance).

To reach the final cross-level model, interaction terms that did not retain significance ($p < .10$) were manually removed, one at a time, starting the highest p-value, until only interactions significant at $p < .10$ remained. The same approach was then used with main effects, until only main effects significant at $p < .05$ remained. Lastly, all removed interactions and main effects were re-entered into the final cross-level model, one at a time, to ensure that they did not become significant after the other variables were removed, similar to approach described in Saelens et al. (2012). Significant or trending ($p < .10$) interactions were graphed using one standard deviation above and below the mean to represent high and low values of each moderator variable. Unstandardized regression coefficients (B) were reported for all final models and can be interpreted as the change in the dependent variable for a 1-unit change in the independent variable.

Given the importance of health status among older adults 4 health-related variables were added after a final model was reached for each outcome. These were not tested in the initial models as moderators, but rather were added after to assess if the health status of the participants confounded the relation and changed the significant findings of the final model. Both final models (i.e., without and with health variables) were reported.

RESULTS

Sample Characteristics

The study sample was comprised of older adults (n=367) with a mean age of 75 years (Table 3.2). There was an approximately equal split by gender (49.3% male). The majority of participants were white non-Hispanic (84%) and the mean BMI was 26, which falls into the low end of the overweight category. Over 58% were married or living with a partner, and nearly 52% had a college degree or higher. Nearly 90% of participants were categorized as active drivers.

The average amount of physical activity was low when measured by accelerometer, with an average of 14 minutes/day of MVPA. The self-reported walking for leisure in the neighborhood was similar, with about 1 hour 45 minutes/week. The mean minutes of active transport in the neighborhood was fairly low, with about 40 minutes/week (untransformed). The objectively assessed neighborhood streetscape safety was fairly low, with a mean score of 15 out of a possible 52 points (actual range = 4-32).

For the variables assessed as multilevel moderators, the psychosocial variables were mostly positive (e.g., high self-efficacy of over 8 on a 1-10 scale) and the home environment was low, with an average 3 out of 10 possible items. Overall, participants perceived neighborhood safety was high across all subscales, especially safety from crime (3.5 on a scale of 1-4). Participants' self-rated health was generally good, as only about 27% reported a major fall in the past year, 27% had a major visual or hearing impediment, and 15% had been hospitalized in the past year. Over 70% reported having one or more health condition, which was to be expected with older adults.

MODERATOR FINDINGS FROM FINAL CROSS-LEVEL MODELS

Results from the final cross-level models are reported separately for each outcome (Tables 3.3-3.5), where the MAPS streetscape safety index is first discussed and then interactions. Other main effects of correlates of physical activity are briefly summarized at the end (Table 3.6).

Average minutes/day of total MVPA (accelerometer) (Table 3.3)

The MAPS streetscape safety index was neither a significant main effect or involved in any interactions for total daily MVPA.

Self-reported minutes/week of active transport in the neighborhood (Table 3.4)

The MAPS streetscape safety index was significantly associated with more minutes/week of active transport in the neighborhood as a main effect ($p<.05$) and was involved in two interactions ($p<.10$). Greater streetscape safety was significantly associated with more minutes/week of active transport for all participants, though the magnitude was small (about 0.06 more per unit increase in the safety scale). Social support and household education interacted with MAPS streetscape safety ($p=.057$ and $p=.011$, respectively) (Fig. 3.1). The streetscape safety main effect and interactions stayed significant ($p<.10$) after health variables were added.

In the interaction with social support, those who reported high support had more active transport in neighborhoods with high vs. low streetscape safety (Fig. 3.1A). There was no difference in active transport for those with low social support. In the household education interaction, participants without a college degree had about one more minute of active transport in safe vs. unsafe neighborhoods (Fig. 3.1B). Those with higher education had a slightly over 2 minutes of active transport, regardless of streetscape safety.

Self-reported average minutes/week of walking for leisure in the neighborhood (Table 3.5)

Streetscape safety was significantly associated with walking for leisure in the neighborhood as a main effect ($p<.05$) and was involved in three interactions ($p<.10$). For each unit increase in streetscape safety, participants reported nearly 6 more minutes/week of walking for leisure in the neighborhood. The relation between streetscape safety and walking for leisure was moderated by sex, marital status and perceived safety from traffic (Fig. 3.2). The MAPS safety main effect and interactions stayed significant after health variables were added in.

In the sex interaction, males benefitted more than females, with nearly double the minutes/week (from 80 to 150 minutes) of walking for leisure in neighborhoods with high vs. low streetscape safety (Fig. 3.2A). However, females reported about 105 minutes/week of walking in neighborhoods with low safety, but only reported about 8 more minutes/week in safer neighborhoods. In the marital status interaction, those who were single (i.e., not married or not living with a partner) benefitted most in neighborhoods with high streetscape safety, compared to married participants (Fig. 3.2B). Similar to the sex interaction, single participants had nearly double the minutes/week of walking for leisure, while married participants' walking was only about 12 minutes greater in safe vs. unsafe neighborhoods.

Those who perceived poor safety from traffic had about 70 minutes of walking for leisure in neighborhoods with low streetscape safety, but over 165 minutes in neighborhood with high streetscape safety (Fig. 3.2C). Those who perceived higher traffic safety had a similar pattern and reported more walking in neighborhoods, but with a smaller magnitude, from about 85 to 135 minutes/week in neighborhoods with low vs. high streetscape safety.

MAIN EFFECTS ACROSS OUTCOMES

Table 3.6 depicts significant main effects ($p<.05$) across outcomes, with all correlates listed and presented for the analyses, both with and without health variables included. Significant correlates from the individual/demographic level that were significant for at least two of the outcomes included race/ethnicity and age, where minorities (non-white non-Hispanic) and older age were associated with less physical activity. Self-efficacy was consistently positively associated with more physical activity (for all three outcomes), but there were no other consistent psychosocial main effects.

When the health variables were added to the models, most of the correlates retained significance. Having 2 or more medical conditions (vs. none) was significantly associated with the minutes/day of total MVPA and active transport outcomes.

DISCUSSION

Findings from the current study demonstrated a positive association between objectively measured neighborhood streetscape safety and physical activity among older adults. The hypothesis that there would be multilevel moderators of the association was supported, as there were significant moderators from three of the four tested ecological levels. All significant main and interactive findings were from the self-reported physical activity outcomes that were specific to the neighborhood (i.e., active transport and waling for leisure). The findings showed that greater pedestrian safety in neighborhoods appeared to facilitate older adults be more active in their neighborhoods, whether they were walking for leisure or engaging in active transport. However, there were important subgroup-specific distinctions that can inform targeted interventions to reach the older adults who could benefit most from greater streetscape safety (e.g., single males with low social support). These findings emphasize the need to objectively measure micro-level safety-related features in more studies and suggest that older adults' physical activity may be especially influenced by the pedestrian infrastructure in their neighborhoods.

The use of an objective measure of neighborhood safety was novel and addressed a gap in the literature, particularly because perceived and objectively assessed measures of neighborhood safety are typically not interchangeable (Bailey et al., 2014; Kirtland et al., 2003; McGinn et al., 2007). As such, it was important to explore the MAPS streetscape safety index as a main effect and then to assess multilevel moderators of the relation. The significant finding that objectively assessed streetscape safety was positively associated with active transport and walking for leisure in the neighborhood demonstrated the utility of the measure. It is noteworthy that microscale streetscape safety was significant despite controlling for study design (i.e., macrolevel GIS-based walkability and block group income) and remained significant after health variables were added. It is likely that interventions to increase physical activity among older adults should include components targeted to improving neighborhood safety and helping participants overcome safety-related barriers.

Objective total MVPA, MAPS streetscape safety and moderators of the association

Objective streetscape safety was not significantly associated with daily total MVPA. The finding was unexpected because two studies found total MVPA among SNQLS participants to be significantly associated with walkability or perceived safety. Cain et al. (2014) found that the MAPS grand score was positively associated with total MVPA among older adults, and Carlson et al. (2012; 2014) found several moderators with total MVPA and macrolevel GIS walkability or perceived neighborhood safety. However, the MAPS grand score included other features of the neighborhood environment, including aesthetics, mixed land use, residential density and social disorder. The current findings imply that the association with the MAPS grand score may be primarily driven by the non-safety items or that other variables included in the models in the current study accounted for the variance (e.g., self-efficacy, driving status). Similarly, there were no significant moderators of the relation between objective streetscape safety and total MVPA.

Active transport, MAPS streetscape safety and moderators of the association

There was a significant positive association of streetscape safety with minutes/week of active transport, which was also moderated by social support and household education. Interestingly, the Cain et al. (2014) study also found a significant association with the MAPS grand score and active transport in all age groups, but because the grand score incorporates many other elements of walkability (e.g., commercial destinations), the present finding indicates streetscape safety may influence older adults decision to engage in active transport.

The interaction with social support was synergistic in its relation with active transport, where participants with high vs. low social support living in neighborhoods with high streetscape safety had the most active transport. There was no benefit of greater streetscape safety for those with low social support. The finding that social support was a moderator is consistent with another study that found older adults with high social support had more active transport in neighborhoods with high vs. low objective GIS-based walkability scores (Carlson et al., 2012). The findings can inform future interventions because they illustrate that older adults in safe neighborhoods with high social support have a greater likelihood of engaging in more active transport, especially because high social support alone did not help overcome the barrier of low streetscape safety. Interventions should work with older adult residents of neighborhoods to identify the safest routes in the neighborhood, create neighborhood walking groups and have the older adults engage in advocacy to get targeted changes in the neighborhood (e.g., curb cuts).

The finding that greater streetscape safety benefitted those without a college degree is inconsistent with another study that also used SNQLS data but found more affluent/advantaged participants (i.e., higher income, education and white non-Hispanic) benefitted most in neighborhoods with greater perceived safety from traffic and pedestrian safety (Carlson et al., 2014). The finding suggests improvements in streetscape safety in low socioeconomic status (SES) neighborhoods may help more at-risk older adults engage in greater active transport. In the current study, the amount of active transport did not vary significantly for highly educated participants by streetscape safety, though there was slightly more active transport in neighborhoods measured as unsafe. This may be partially explained because highly dense and walkable neighborhoods often have more traffic (even in high SES areas), which is also consistent with the main effect finding that greater perceived walkability was associated with more physical activity. However, the finding was unexpected because the literature often shows that those who are of a lower SES, and are thus at higher risk for health disparities, often get more active transport out of necessity (Lachapelle et al., 2016), regardless of neighborhood safety. The finding was difficult to explain, but the association is not as well studied among older adults, and thus the type of active transport may be one that is out of choice rather than necessity. Future studies should directly assess if older adults engage in walking for transport in the neighborhood out of necessity or choice and convenience.

Walking for leisure, MAPS streetscape safety and moderators of the association

Similarly to the active transport outcome, the MAPS safety index was positively associated with walking for leisure as a main effect, which was unlike what Cain et al. (2014) found using the MAPS grand score and walking for leisure. This discrepancy suggests that elements of streetscape safety may be especially influential for older adults deciding to walk for leisure in their neighborhoods, even more so than other components of walkability (e.g., access to destinations and aesthetics). This explanation is further supported by another study that found that GIS-based mixed land use was not associated with walking for leisure among older adults (Thornton et al., 2016).The idea that greater streetscape safety influenced the physical activity of older adults in their neighborhood is logical because of their limited mobility, greater fall risks and other health related issues (Nelson et al., 2007).

Summarizing across the three interactions, living in an objectively rated safe (vs. unsafe) neighborhood was associated with about 70-95 more minutes/week of walking for leisure among participants who were male, single and perceived low traffic safety. In contrast, safe (vs. unsafe) neighborhoods were only associated with about 8-50 minutes/week for participants who were female, married and perceived high safety from traffic. Interventions should be tailored to specific subgroups with unmodifiable characteristics (i.e., sex and marital status), and include components to help older adults overcome barriers to walk for leisure in their neighborhoods.

The finding that males benefitted most was counter to hypotheses but is consistent with a study that also used SNQLS data and found sex moderated the relation of perceived traffic safety and leisure-time physical activity in the same unexpected direction (Carlson et al., 2014). It is difficult to explain because it was hypothesized females would be more sensitive to the safety of the neighborhood, but in the current study females had the same amount of walking in the neighborhood regardless of streetscape safety. The pattern was similar for those who were single living in neighborhoods with high vs. low streetscape safety. A possible explanation is streetscape safety may benefit single participants because it makes them feel safer when walking alone, while those who are married have a partner to walk with and likely the presence of the other person makes them feel safer. Living in neighborhoods with high vs. low streetscape benefited all participants, regardless of their perceived safety from traffic. However, those who perceived low safety from traffic reported the most walking for leisure in neighborhoods with high vs. low pedestrian streetscape safety. The importance of traffic safety with older adults is consistent with a study that found a significant interaction with perceived safety from traffic for the leisure-time physical activity outcome (Carlson et al., 2014), though as noted earlier, this study also used SNQLS data (from both regions) which limits generalizability.

Patterns of significant main effects as correlates of physical activity across all outcomes

Self-efficacy was consistently positively associated with more physical activity, which is consistent with the literature (Baumann et al., 2014; Trost et al., 2002). The finding is also consistent with a study that assessed mediators and moderators of the intervention effect on increasing walking in the neighborhood among older adults. The intervention found self-efficacy was the only significant mediator of the intervention effect, and neither perceived safety of the neighborhood or objective macrolevel walkability were significant mediators or moderators (Michael & Carlson, 2009).

The other main effect findings of correlates with physical activity outcomes were less consistent, though being a minority (i.e., non-white non-Hispanic) was negatively associated with walking for leisure and active transport. The positive association of greater perceived walkability (non-safety related) with active transport was expected, as having more destinations to walk to has been associated with greater physical activity among older adults (Yen et al., 2009; Van Cauwenberg et al., 2008; Frank et al., 2010). Those who were not active drivers had more active transport, which is logical and consistent with another study that reported a similar main effect for active transport and no interactions between the perceived environment and driving status (Ding et al., 2014). The finding that higher social support was associated with more walking for leisure is also aligned with the literature (Resnick et al., 2002; Baumann et al., 2010).

Variables related to participants' health status were added to the final model of each outcome to assess for confounders. Having no current medical conditions at the time (compared to 2 or more) was positively associated with more total MVPA and active transport. Though over 70% of the participants reported having one or more medical conditions, adding the health status variables did not change the significance of the MAPS streetscape safety index or the moderators. In contrast, another study that assessed SES (e.g., income, education) as moderators of the relation with perceived neighborhood safety and physical activity found the association did not remain significant after adding in self-rated health variables (Tucker-Seeley et al., 2009).

Strengths and Limitations

Limitations included the cross-sectional design of the study, which prohibits any causal interpretations. The reduced statistical power associated with the modest sample size is a limitation, especially because the current study was unable to use the full sample due to questionable quality data from the Baltimore region. This also reduced heterogeneity, as over 80% of included participants were White non-Hispanic, and generalizability may be limited. The objective total MVPA outcome was not specific to the neighborhood, and the lack of significant findings with neighborhood streetscape safety may be due to the lack of specificity of where the physical activity occurred. Future studies should incorporate GPS with the accelerometer data to better understand associations with measures of safety in the neighborhood. Though walking for leisure in the neighborhood was domain and location specific, it did not include other forms of leisure-time physical activity one may do in the neighborhood (e.g., jogging or biking), which could also be associated with streetscape safety.

There were multiple strengths in the present study, including equal representation of males and females in the sample, objective and domain-specific measures of physical activity, using known correlates of physical activity as potential multilevel moderators, assessing the influence of health issues, controlling for macrolevel walkability, and the use of both objective and perceived measures of neighborhood safety. The creation of an objective measure specific to neighborhood streetscape safety adds to the field, particularly because it was based on previously validated items from MAPS (Millstein et al., 2013; Cain et al., 2014) and features of the built environment that were identified as important within the field of injury prevention and pedestrian safety (Zegeer et al., 2002). The significant findings with the MAPS streetscape safety index were only found with the active transport and walking for leisure outcomes, which supports the use of both domain and location specific physical activity outcomes.

Theoretical implications

The findings of the present study support the utility of an ecological model. The correlates of physical activity that were tested as moderators were informed by an ecological approach, and significant main effects and moderators were identified from multiple levels of influence. The ecological model principle that influences on behavior interact across levels (Sallis & Owen, 2015) was supported with 5 significant moderators found from 3 levels (individual/demographic, psychosocial and perceived environment). There were fewer significant moderators than expected, implying targeting main effects, such as self-efficacy and pedestrian streetscape safety, could benefit all older adults, rather than benefitting only specific subgroups. Overall, the findings indicated the relation between objective streetscape safety and physical activity is complex and varied by type of physical activity, but applying an ecological approach can be useful to identify influences from numerous levels.

Conclusion and recommendations

The findings from the current study are generally aligned with a systematic review of the qualitative literature on the physical activity among older adults and the neighborhood environment. The review found common features in neighborhoods conducive to physical activity were the presence of high-quality pedestrian infrastructure, safety from crime and traffic, and access to destinations (Moran et al., 2014). Many features of high-quality pedestrian infrastructure were included in the MAPS streetscape safety index, such as sidewalk presence, continuity and buffers, as well as crossing ramps and crosswalk markings (Zegeer et al., 2002).

The findings supported the need to assess moderators to better understand the complex relation of physical activity and neighborhood safety, as the current study demonstrated some subgroup-specific effects among older adults. Improving understanding about specific differences among participants, including from the individual and psychosocial levels, can inform and help tailor future interventions to increase physical activity among older adults. However, despite the promising findings related to streetscape safety and neighborhood-specific physical activity, more studies are needed that replicate these findings.

Though there are studies that use a variety of objective microscale measures of neighborhood environments and walkability (Winters et al., 2015; Brownson et al., 2009; Manaugh & El-Geneidy, 2011), the findings from the current study demonstrate features specific to pedestrian safety should be assessed and analyzed separately. Neighborhood streetscape safety appears to be particularly influential for older adults, and designing neighborhoods accordingly can ensure communities remain accessible to older adults (Micheal et al., 2006; Frank et al., 2010). Because older adults frequently get the majority of their physical activity in their homes or neighborhoods (Glass & Balfour, 2003), targeted improvements in pedestrian streetscape features could have a large impact the physical activity behaviors of older adults, and ultimately help them age in place. Future studies using objective measures of safety and an ecological approach are needed to build on these findings, and prospective studies are needed to make causal inferences.

ACKNOWLEDGEMENTS

Chapter 3 is currently being prepared for submission for the publication of the material. Co-authors include Dr. Terry L. Conway, Kelli L. Cain, Carrie Geremia, Dr. Brian E. Saelens, Dr. Karen Glanz, Dr. Lawrence D. Frank, Dr. Abby C. King, Dr. Hala Madanat, Dr. Linda Hill, Dr. Sherry Ryan, Dr. John P. Elder and Dr. James F. Sallis. The dissertation author was the primary investigator and author of this material.

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Table 3.1: Summary of measures used in the study using SNQLS data: outcomes, independent variables and multi-level moderators

Ecologi-cal level	**Variable**	**Number of Items (Response options)**	**Description/sample items**	**Psychometrics and references**
Physical Activity Outcomes				
	Moderate-to-vigorous physical activity (MVPA) minutes/day	5+ days of valid wear time (>10 hours) for accelerometer were required to be included in analyses	Participants wore an Actigraph accelerometer (ActiGraph, LLC) on a belt securely around the waist during waking hours, with acceleration recorded at 60-second epochs. A valid hour could contain a maximum of 45 consecutive zero counts. Actigraph models 7164/71256 were used and though model type was not associated with MVPA, it was controlled for in analyses. MVPA was scored with the Freedson cutoff points for adults (≥1952 counts/minute) (Freedson et al, 1998). There is no consensus on cutpoints for older adults and these were the cutoff points used in the Cain et al. (2014) study with MAPS, and other studies with these data (e.g., Carlson et al., 2014; Ding et al., 2014; King et al., 2011)	ActiGraph, LLC, Pensacola, FL; Freedson et al., 1998; Cain et al., 2014; Carlson et al., 2014; Ding et al., 2014; King et al., 2011
	Walking & Biking for trans-port in neighbor-hood	2 items (Minutes/week)	Indicate how many times during an average week did you… "Walk to do errands (such as to/from a store)" and "Bike to do errands (such as to/from a store"	Acceptable 6-month stability (ICCs 0.58-0.65), and validity among older adults (Stewart et al., 2001)
	Walking for Leisure in the neighbor-hood	1 item (1= less than 1 hour/week to 6=9 or more hours/week) Recoded into minutes/week	If you did the activity at least once a week, how many hours you did the activity in an average week… "Walk leisurely for pleasure or exercise" Recoded into minutes/week by taking a midpoint from each range of time category options to estimate the time spent in each activity (e.g. 1-2.5 hours/week=105 minutes/week)	Acceptable 6-month stability (ICCs 0.58-0.65), and validity among older adults (Stewart et al., 2001)
Independent Variable: Objective pedestrian safety (MAPS Streetscape Safety)				
Objective pedestrian safety	Micro-scale Audit of Pedestrian Street-scapes (MAPS) Street-scape Safety Index	26 items (52 points possible; actual range 4-28.7) 8 items from the route section; 4 items from the segment section; 14 items from the crossing section (0 to 2, where 0=extremely unsafe and the 2=extremely safe). Summed to create an index	Data were collected along a 0.25-.45 mile route beginning at the participant's home and extending toward the nearest destination (e.g. stores, school or park). Route-level safety items included speed limits, street lights, and traffic calming and crosswalk signage. Segment-level (i.e. street segments between intersections) items included sidewalk presence, buffer presence and number of traffic lanes. Street crossing items assessed crosswalk markings, curb cuts, crossing signals, and pedestrian protection. Higher scores reflected greater safety.	MAPS development and inter-rater reliability determined (Millstein et al., 2013). Validated by associations with PA in 4 age groups (Cain et al., 2014).

Table 3.1: Summary of measures used (continued)

Ecological level	Variable	Number of Items (Response options)	Description/sample items	Psychometrics and references
Correlates of physical activity from multiple ecological levels explored as moderators				
Individual variables	Demo-graphics	1. Age 2. Sex 3. Race/ethnicity 4. Household highest education 5. Marital Status	1-5: self-reported Race/ethnicity was recoded to White non-Hispanic vs. other race/ethnicity Education was recoded to college degree or higher vs. other Marital status was recoded to married/living together vs. single/living alone	N/A
	BMI	Body Mass Index	BMI was calculated from self-reported height and weight as kg/m². Participants were provided instructions on how to accurately measure and record their weight and height.	N. O. E. I. E., 1998
	Driving Status	3 items	Driving status was defined on the basis of having a valid driver's license, owning at least 1 car, and feel comfortable to drive at least 1 mile from home Categorized as "active driver" vs. "inactive driver"	Demonstrated concurrent validity and association with active transport (Ding et al., 2014)
Psycho-social variables	Self-efficacy for physical activity	3 items (10-point scale where 1 = "not at all confident" to 10 = "absolutely confident")	"Rate how confident you are that you currently can walk each of the following distances without slowing down or stopping to rest" Distance options were ½ block, 4 blocks and 10 blocks Averaged items into single scale	Alpha = .87 (Marcus et al., 1992)
	Social Support for Physical Activity	8 items (0 = never to 4 = very often)	Rate how frequently within the past 6-months family and friends (separately) encouraged physical activity. Example items included "Walk or exercise with me" and "Give me encouragement to do physical activity" Averaged items into a single scale	Alpha = 0.67 (Carlson et al., 2012). Two-week ICCs were 0.67 and the correlation with physical activity was .12 in women (Sallis et al., 1987)
	Barriers to activity in your neighbor hood	4 items (1 = not important to 5 = extremely important)	"Rate how important each statement is to your decision whether or not to be more active." Example items included "regular physical activity would take too much of my time" and "I would feel self-conscious about how I look if people saw me doing physical activity."	Alpha = 0.53 (Carlson et al., 2012). Two-week ICCs were 0.61 and the correlation with physical activity was -.19 in women (Sallis et al., 1987)

Table 3.1: Summary of measures used (continued)

Ecological level	**Variable**	**Number of Items (Response options)**	**Description/sample items**	**Psychometrics and references**
Home Environ-ment variables	PA Equip-ment around the Home Index [0-12]	12-item inventory (Present: Yes or no) Sum of "yes" responses	Participants were asked to indicate which PA supplies or equipment they have in their home, yard, or apartment complex, such as stationary aerobic equipment, weight lifting equipment, and swimming pool	Test-retest of the summed index was .89 and scores correlated significantly with PA (Sallis et al., 1997)
Perceived Neighbor-hood Safety Enviro-nment variables	Neighbor hood Environ ment Walkabil ity Scale-Senior Modified (NEWS-Senior)	1. Safety from traffic (3 items) 2. Safety from crime (6 items) 3. Pedestrian safety (7 items) For the safety subscales, (1 = strongly disagree, 4 = strongly agree) 4. Overall non-safety walkability scale (total of 49-items using 6 z-scores of non-safety related subscales)	1. Safety from traffic (3 items): E.g., "There is so much traffic along nearby streets that it makes it difficult or unpleasant to walk in my neighborhood." 2. Safety from crime: E.g., "There is high crime rate in my neighborhood" (reverse coded) 3. Pedestrian safety (9 items): E.g., "There are curb cuts (ramps) that go from sidewalk level to road level in my neighborhood" 4. The non-safety walkability scale was created from the following subscales (and sample items): -residential density (6 items, e.g., "how common are detached single-family residences in your immediate neighborhood?"); -land use diversity (26 items; "how long does it take you to walk to the nearest places listed?" E.g., supermarket, clothing store, fast food")-reverse coded; -Land use mix access (6 items) E.g., "Stores are within easy walking distance of our home" -Street connectivity (3 items) E.g., "There are many different routes for getting from place to place in my neighborhood" -Walking/cycling facilities (3 items) E.g., "There is grass/dirt between the streets and the sidewalks in our neighborhood" -Aesthetics (4 items) E.g., "There are attractive buildings/homes in my neighborhood."	The original NEWS scale test-retest reliability ranged from .58-.80, though most were above .75 for all the subscales, and Cronbach's Alpha = 0.74 (Saelens et al., 2003). Construct validity supported by correlations with physical activity (Cerin et al., 2008)

Table 3.2: Descriptives of PA outcomes, MAPS streetscape safety, and variables from multiple levels of ecological model explored as moderators among a sample of older adults living in the Seattle, WA region (N=367)

	Mean (SD) / Frequency (%)
Physical activity outcomes	
Accelerometer-derived Moderate to Vigorous Physical Activity (MVPA) minutes/day [0-118]	14.025 (17.317)
Minutes/week of active transport in the neighborhood	
Back-transformed[A]	4.629 (n/a)
Untransformed)	40.14 (79.699)
Average total minutes/week of leisure-time physical activity in the neighborhood [0-585]	106.62 (126.966)
Independent Variable: Objective Pedestrian Safety	
MAPS Streetscape Safety [0-52]	15.396 (6.066)
Ecological variables explored as multilevel moderators	
Individual/demographic variables	
Sex	
Male	181 (49.3%)
Female	186 (50.7%)
Age [66-97]	74.98 (6.623)
Race/ethnicity	
White non-Hispanic	306 (83.8%)
Other minority race/ethnicity	59 (16.2%)
BMI [16-50]	26.137 (4.706)
Marital status	
Not married/living with a partner	150 (41.7%)
Married/living with a partner	210 (58.3%)
Highest Household education	
Less than a college degree	186 (51.5%)
College degree or higher	175 (48.5%)
Driving status	
Does not drive	41 (11.2%)
Active driver	326 (88.8%)
Psychosocial variables	
Self-efficacy for PA [1-10]	8.601 (2.440)
Barriers to physical activity [1-4]	1.596 (0.613)
Social support for PA (friends & family) [0-4]	1.495 (1.033)
Home environment variables	
Home PA Equipment index [0-10]	3.11 (2.104)
Perceived neighborhood environment variables	
Traffic Safety [1-4]	2.822 (0.659)
Pedestrian Safety [1-4]	2.609 (0.462)
Personal Safety [1-4]	3.507 (0.506)
Overall Walkability (non-safety z-score) [-1.45-1.85]	0.001 (0.638)
Health status variables	
Hospitalizations in past year (Yes)	57 (15.8%)
Falls within past year (Yes)	97 (27.0%)
Major seeing or hearing impairments (Yes, 1 or more)	98 (27.3%)
Current medical conditions	
None	104 (29%)
One condition	139 (38.7%)
Two or more conditions	116 (32.3%)

[A]Back-transformed from skewed mean to report the geometric mean, however standard deviations cannot be back-transformed and were not reported

Table 3.3: Minutes/day of total MVPA: SNQLS cross-level ecological model of significant main effects (p<.05) and interactions (p<.10) with the objectively assessed streetscape safety (MAPS)

	Minutes/day Total MVPA[A,B,C]			Minutes/day Total MVPA[A,B,C] With health variables		
	B	CI	P-value	B	CI	P-value
Intercept	-13.848	9.177, 18.519	--	10.940	3.990, 17.890	--
Independent variable: Objective pedestrian safety						
MAPS Streetscape Safety	0.238	-0.067, 0.543	.126	0.227	-0.077, 0.532	.143
Individual/demographic variables						
Sex (Female)	4.236	0.721, 7.752	.018	4.293	0.795, 7.788	.016
Age	-0.855	-1.121, -0.590	<.001	-0.846	-1.110, -0.581	<.001
Race/ethnicity (Other vs. White non-Hispanic)	-1.327	-5.983, 3.339	.575	-0.759	-5.467, 3.949	.751
BMI	-0.411	-0.782, -0.041	.030	-0.324	-0.692, 0.045	.085
Marital status (not married/living with partner)	2.394	-1.502, 6.290	.228	2.007	-1.859, 5.874	.308
Highest Household education (less than college)	0.323	-3.052, 3.698	.851	-0.098	-3.433, 3.237	.954
Driving status (does not drive)	-2.025	-8.014, 3.963	.506	-1.013	-6.993, 4.966	.739
Psychosocial variables						
Self-efficacy for PA	1.201	0.415, 1.987	.003	1.048	0.254, 1.841	.010
Health status variables						
Hospitalizations in past year	--	--	--	2.064	-2.273, 6.402	.350
Falls within past year	--	--	--	-0.111	-3.740, 3.518	.953
Major seeing or hearing problems	--	--	--	-1.110	-4.688, 2.458	.542
Current medical conditions						
None vs. 2 or more	--	--	--	6.396	2.183, 10.609	.003
1 vs. 2 or more	--	--	--	1.637	-2.186, 5.460	.400
Interactions						
None	--	--	--	--	--	--

[A]All models contained all the individual/demographics level variables as controls, regardless of main effect significance. Also controlled for site and study design (macro walkability and block-group income quadrants)
[B]Variables that were identified as significant at p<.1 in the level-specific models were tested but did not maintain significance in the final cross-level
[C]Average accelerometer wear time per day was included as a covariate

Table 3.4: Minutes/week of active transport: SNQLS cross-level ecological model of significant main effects (p<.05) and interactions (p<.10) with the objectively assessed streetscape safety (MAPS)

	Minutes/week Active Transport[A,B,C]			Minutes/week Active Transport[A,B,C] With health variables		
	B	CI	P-value	B	CI	P-value
Intercept	8.410	4.359, 15.523	--	3.442	0.912. 9.319	--
Independent variable: objective pedestrian safety						
MAPS Streetscape Safety	0.067	0.016, 0.121	.009	0.065	0.015, 0.117	.010
Individual/demographic variables						
Sex (Female)	-0.154	-0.445, 0.290	.437	-0.076	-0.391, 0.402	.709
Age	-0.034	-0.064, -0.003	.031	-0.027	-0.056, 0.004	.097
Race/ethnicity (Other vs. White non-Hispanic)	-0.510	-0.715, -0.160	.010	-0.541	-0.734, -0.207	.005
BMI	0.004	-0.039, 0.049	.867	0.010	-0.032, 0.055	.637
Marital status (not married/living with partner)	0.151	-0.274, 0.826	.548	0.186	-0.247, 0.891	.459
Highest Household education (less than college)	0.145	-0.237, 0.682	.534	0.163	-0.211. 0.716	.445
Driving status (does not drive)	1.910	0.462, 4.789	.002	2.271	0.650, 5.482	.001
Psychosocial variables						
Self-efficacy for PA	0.161	0.062, 0.269	.001	0.134	0.037, 0.241	.006
Social Support	0.177	-0.030, 0.428	.097	0.191	-0.017, 0.445	.074
Perceived neighborhood variables						
Overall Walkability (non-safety)	1.077	0.381, 2.121	<.001	1.032	0.355, 2.047	.001
Health status variables						
Hospitalizations in past year	--	--	--	-0.076	-0.449, 0.550	.764
Falls within past year	--	--	--	0.065	-0.305, 0.645	.759
Major seeing or hearing problems	--	--	--	0.844	0.019, 1.807	.004
Current medical conditions						
None vs. 2 or more	--	--	--	0.707	0.045, 1.790	.033
1 vs. 2 or more	--	--	--	0.394	-0.109, 1.177	.145
Interactions						
Social Support X MAPS Streetscape Safety	0.030	-0.001, 0.063	.057	0.040	-0.001, 0.062	.060
Household Education X MAPS Streetscape Safety	-0.079	-0.134, -0.019	.011	-0.080	-0.134, 0.021	.009

[A]All models contained all the individual/demographics level variables as controls, regardless of main effect significance. Also controlled for site and study design (macro walkability and block-group income quadrants)
[B]Variables that were identified as significant at p<.1 in the level-specific models were tested and all maintained significance at p<.10.
[C]Natural log transformed to better approximate a normal distribution and then back-transformed for interpretation

Table 3.5: Minutes/Week of Walking for Leisure: SNQLS cross-level ecological model of significant main effects (p<.05) and interactions (p<.10) with the objectively assessed streetscape safety (MAPS)

	Minutes/week Self-report Leisure-time PA[A,B]			Minutes/week Self-report Leisure-time PA[A,B] With health variables		
	B	CI	P-value	B	CI	P-value
Intercept	115.323	79.766, 150.880	--	122.048	66.098, 177.998	--
Independent variable: Objective pedestrian safety						
MAPS Streetscape Safety	5.950	0.953, 10.947	.020	5.979	0.977, 10.982	.019
Individual/demographic variables						
Sex (Female)	-4.941	-33.916, 23.933	.737	-3.973	-33.090, 25.145	.789
Age	0.016	-2.140, 2.172	.988	0.007	-2.186, 2.200	.995
Race/ethnicity (Other vs. White non-Hispanic)	-40.669	-76.617	.027	-41.080	-77.744, -4.415	.028
BMI	-0.334	-3.290, 2.622	.824	-0.269	-3.256, 2.718	.859
Marital status (not married/living with partner)	-15.252	-46.869, 16.365	.343	-14.031	-45.769, 17.708	.385
Highest Household education (less than college)	-3.742	-30.649, 23.165	.785	-3.900	-20.868, 23.068	.776
Driving status (does not drive)	20.907	-25.839, 67.653	.343	21.605	-25.591, 68.802	.369
Psychosocial variables						
Self-efficacy for PA	7.012	1.001, 13.022	.022	6.798	0.631, 12.964	.031
Social Support for PA (friends & family)	22.832	9.847, 35.818	.001	22.612	9.399, 35.824	.001
Perceived neighborhood variables						
Traffic Safety	-5.279	-10.478, -0.052	.048	-5.628	-25.217, 13.961	.572
Health status variables						
Hospitalizations in past year	--	--	--	-17.925	-53.477, 17.628	.322
Falls within past year	--	--	--	1.664	-27.744, 31.071	.911
Major seeing or hearing problems	--	--	--	0.071	-28.885, 29.028	.996
Current medical conditions						
None vs. 2 or more	--	--	--	13.697	-19.967, 47.361	.424
1 vs. 2 or more	--	--	--	5.859	-25.043, 36.760	.709
Interactions						
Sex X MAPS Streetscape Safety	-5.265	-10.478, -0.052	.048	-5.145	-10.370, 0.081	.054
Marital status X MAPS Streetscape Safety	-4.714	-9.928, 0.501	.076	-4.839	-10.077, 0.399	.070
Traffic Safety X MAPS Streetscape Safety	-2.837	-5.966, 0.291	.075	-2.783	-5.911, 0.345	.081

[A]All models contained all the individual/demographics level variables as controls, regardless of main effect significance. Also controlled for site and study design (macro walkability and block-group income quadrants)
[B]Variables that were identified as significant at p<.1 in the level-specific models were tested and all maintained significance at p<.10

Table 3.6: Significant main effects (p<.05) across outcomes from the final cross-level models from a sample of older adults

	Total minutes/day of MVPA		**Minutes/week of active transport**		**Minutes/week walking for leisure**	
	Without Health Vars	With Health Vars	Without Health Vars	With Health Vars	Without Health Vars	With Health Vars
Independent variable: Objective pedestrian safety						
MAPS Streetscape Safety	--	--	+	+	+	+
Individual/demographic variables						
Sex (Female vs. male)	+	+	--	--	--	--
Age	-	-	–	--	--	--
Race/ethnicity (Other vs. White non-Hispanic)	--	--	–	–	–	–
BMI	–	–	--	--	--	--
Marital status (Not married/living with partner vs. married)	--	--	--	--	--	--
Highest Household education (Less than college degree vs. college degree)	--	--	--	--	--	--
Driving status (does not drive vs. drives)	--	--	+	+		
Psychosocial variables						
Self-efficacy for PA	+	+	+	+	+	+
Barriers to physical activity	--	--	--	--	--	--
Social support for PA (friends & family)	--	--	--	--	+	+
Home Environment variable						
Home PA Equipment index	--	--	--	--	--	--
Perceived Neighborhood Environment variables						
Traffic Safety	--	--	--	--	–	--
Pedestrian Safety	--	--	--	--	--	--
Personal Safety	--	--	--	--	--	--
Overall Walkability (non-safety)	--	--	+	+	--	--
Health status variables						
Hospitalizations in past year (Yes)	n/a	--	n/a	--	n/a	--
Falls within past year (Yes)	n/a	--	n/a	--	n/a	--
Major seeing or hearing impairments (Yes, 1 or more)	n/a	--	n/a	+	n/a	--
Current medical conditions						
None vs. 2 or more	n/a	+	n/a	+	n/a	--
1 vs. 2 or more	n/a	--	n/a	--	n/a	--

Key: + positive association, significant at p<.05; – negative association, significant at p<.05; -- null

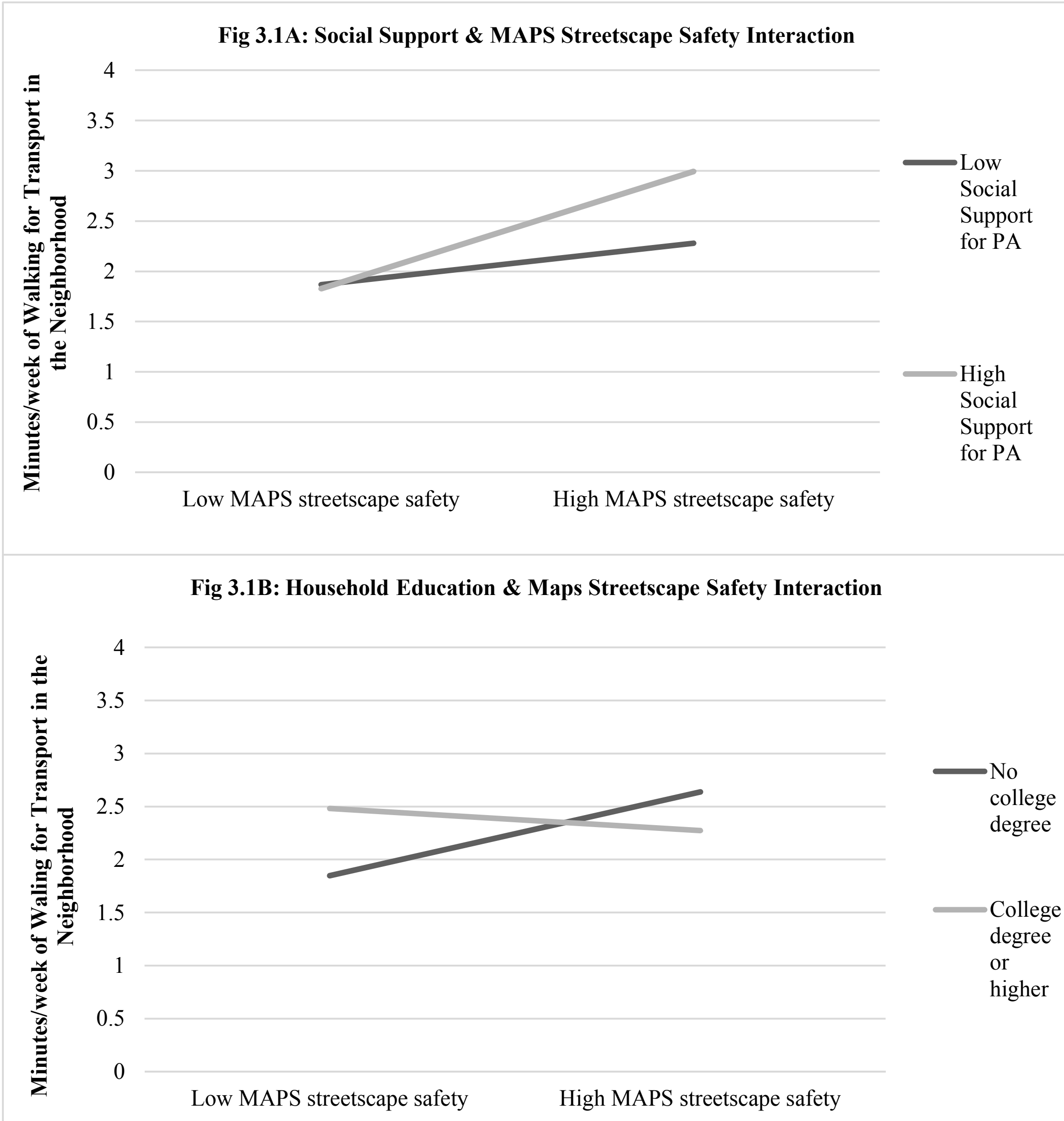

Figure 3.1: Social support (3.1A) and household education (3.1B) as moderators of the relation between objectively assessed streetscape safety and minutes/week of active transport in the neighborhood among older adults living in the Seattle, WA region

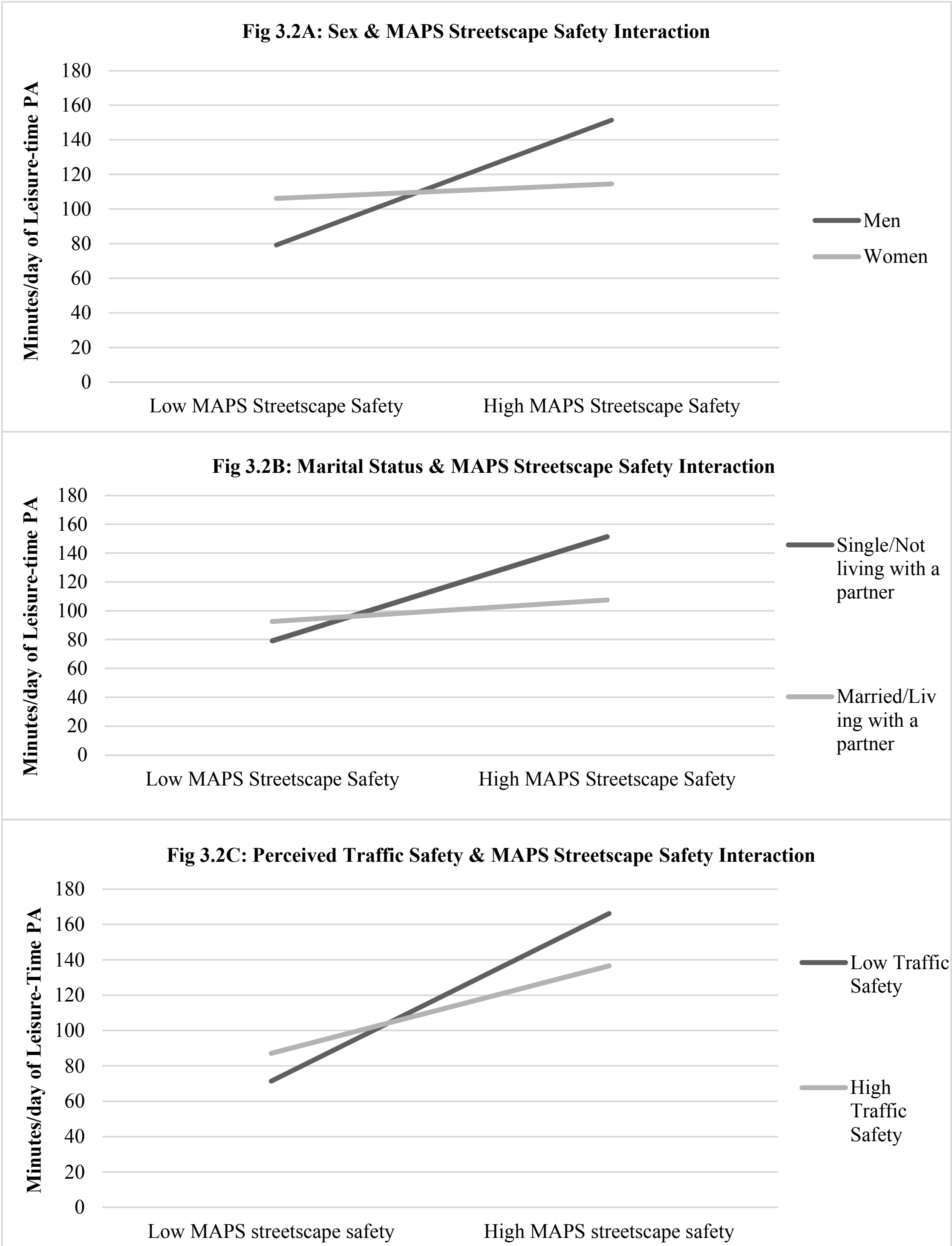

Figure 3.2: Sex (3.2A), marital status (3.2B) and perceived safety from traffic (3.2C) as moderators of the relation between objectively assessed streetscape safety and reported minutes/week of leisure-time physical activity in the neighborhood among older adults living in the neighborhood.

GENERAL DISCUSSION

Common Themes, Key Lessons and Implications for Intervention from Studies 1-3

This dissertation was based on the premise of integrating goals, concepts and methods from the field of injury prevention and safety with the fields of physical activity and the built environment, with an emphasis on exploring moderators of the relation between neighborhood safety and physical activity. Practically speaking, moderators are critical to consider because they help elucidate for whom and under what conditions associations exist. Data from these three studies can inform future interventions for different population subgroups, which would likely increase the effectiveness of an intervention.

The current dissertation applied an ecological approach and explored multilevel moderators of the association between neighborhood safety and physical activity among three diverse samples: (1) overweight/obese adults living in San Diego, CA, (2) adolescents living in the Seattle, WA and Baltimore, MD regions, and (3) older adults living in the Seattle, WA region. Though different datasets were used, the three studies shared the specific aim of assessing ecological cross-level interactions with neighborhood safety and the same three physical activity outcomes. The aim of the current chapter was to highlight patterns across studies, provide direction for future research and propose how the current findings can inform targeted interventions. The section was organized to first discuss patterns of moderators of the association with neighborhood safety and physical activity by each physical activity outcome (Studies 1-3) and then the contribution of the newly-developed objective measure of streetscape safety (Studies 2-3). The conclusion section highlighted how the current dissertation helped bridge the fields of injury prevention and physical activity and situated the findings within the greater context of policy in the US.

The findings across the three studies illustrated that the association of neighborhood safety with physical activity was complex and varied by population subgroup. The findings supported the utility of an ecological approach, which considered multiple levels of influence on a behavior, including cross-level interactions (Sallis & Owen, 2015). An important commonality was that all three studies had significant moderators from both individual/demographic and psychosocial levels. Though it was difficult to generalize across studies because the specific variables that moderated the relation varied by study and physical activity outcome, the findings taken as whole emphasize the need for interventions to consider segmenting by individual/demographic and psychosocial factors to reach specific subgroups. It would be simple if the same significant moderators had been replicated across subgroups, but it is consistent with expectations that the association of safety with physical activity would vary based on the population subgroups. For example, it would be unexpected if adolescents and older adults had similar patterns of physical activity in neighborhoods with high pedestrian infrastructure. Adolescents typically have greater mobility and less of a need to consider pedestrian infrastructure compared to older adults, who may need that infrastructure (e.g., curb cuts and sidewalks) to be mobile in the neighborhood. The findings emphasized the need to consider subgroup-specific differences to create more tailored interventions and to avoid overgeneralizing (e.g., assuming neighborhood safety would influence all age groups uniformly).

STUDIES 1-3. THE ASSOCIATION OF SAFETY WITH PHYSICAL ACTIVITY AND MODERATORS OF THE ASSOCIATION: PATTERNS ACROSS 3 PHYSICAL ACTIVITY OUTCOMES

Tables D.1-D.3 depict the significant associations between neighborhood safety (perceived and objective) variables and the three physical activity outcomes, as well as significant moderators of the association. It is important to note that though similar multilevel moderator variables were used in all the studies, the exact variables assessed varied and the number of variables ranged from 11 (Study 1) to 14 (Study 3) to 31 (Study 2). The neighborhood safety independent variables were also different in Study 1 vs. Studies 2 and 3. In Study 1, the independent variables were the perceived neighborhood safety variables (i.e., pedestrian safety,

safety from crime, traffic safety), but in Studies 2 and 3 the independent variable was objective pedestrian streetscape data.

Objective minutes/day of total moderate-to-vigorous physical activity (MVPA) (Table D.1)

The relation between neighborhood safety and the accelerometer-derived MVPA outcome was significantly ($p<.05$) moderated by 3 individual/demographic characteristics among overweight/obese adults (Study 1), and 1 demographic and 2 psychosocial characteristics among adolescents (Study 2). The significant shared moderator between studies was race/ethnicity, where those who were White non-Hispanic benefitted most in neighborhoods with higher safety in both studies. There were few or no apparent benefits of safety characteristics for minority participants, which could be partially explained by the fact that minorities are often more disadvantaged and have fewer options of places to be physically active. Though Hispanic and African American racial/ethnic groups make up less than 28% of the US population, they accounted for nearly 36% of the pedestrian fatalities in 2014 in the US (NHTSA, 2016a; DOT, 2016), which is disproportionately high.

Race/ethnicity was not a significant moderator among older adults, which could be attributed to a lack of racial/ethnic diversity in the sample (i.e., 84% White non-Hispanic in Study 1, compared to 42% in Study 1 and 67% in Study 2). Future interventions could implement pedestrian safety improvements in neighborhoods that are mostly White non-Hispanic and include advocacy from neighborhood residents. Because neighborhood streetscape safety does was not associated with physical activity of racial/ethnic minorities, different intervention strategies may be more effective and beneficial. For example, improved access to parks and recreational facilities or providing free/low cost physical activity programs in the neighborhood could have a greater impact at increasing rates of physical activity among racial/ethnic minorities. Given the disparities in pedestrian fatality rates by race/ethnicity, the pedestrian safety of high-minority neighborhoods should still be improved, even if the intent is not to increase physical activity. If people are going to be active in neighborhoods regardless of pedestrian streetscape safety, increasing the safety to reduce their risks of traffic fatalities and injuries would still be beneficial.

Table D.1: Multilevel moderators and main effects for the association between neighborhood safety and objective total minutes/day of MVPA

	Study 1: Overweight/obese adults (ConTxt)	Study 2[B]: Adolescents (TEAN)	Study 3[B]: Older adults (SNQLS)
Significant moderators: Ecological variables			
Individual/Demographic variables			
Sex[A]	**	--	--
BMI[A]	**	--	--
Race/ethnicity[A]	*	*	--
Psychosocial variables			
Social support for physical activity	--	**	--
Environmental walk/bike barriers	--	**	--
Home environment variables	--	--	--
Perceived neighborhood environment variables	--	--	--
Main effects: Neighborhood Safety			
Perceived neighborhood environment			
Pedestrian safety	**	--	--
Safety from crime/low crime rate[D]	--	*~	--
Safety from traffic	--	--	--
Low stranger danger[C,E]	n/a	*	n/a
Overall walkability (non-safety)	--	*	--
Objective pedestrian safety			
MAPS streetscape safety	n/a	--	--

+ p<.10, * p<.05, **p<.01,***p<.001
~Finding was in the unexpected direction
[A]In Study 1, the 3 significant interactions terms were with perceived pedestrian safety
[B]All tested interaction terms were with the objective MAPS streetscape safety index
[C]Assessed only among adolescents; both parent and adolescent reported
[D]Adolescent reported in the significant interaction for Study 2
[E]Parent-reported in the significant interaction for Study 2
Bolded names represent variables that were significant in 2 or more of the studies

The 2 other significant moderators among overweight/obese adults were individual/demographic factors that are unmodifiable, but future interventions can use the information to target different subgroups and better understand the relation between safety and physical activity. Among adolescents, 2 psychosocial characteristics moderated the relation of objective streetscape safety and MVPA within the neighborhood. Interventions tailored to adolescents should incorporate intervention components that specifically target psychosocial characteristics but also evaluate their relation to safety, as more research is needed to clarify the subgroup-specific findings.

There were no significant main effects of neighborhood safety and minutes/day of MVPA that were shared across studies, and no significant safety-related findings among older adults. Because the objective measure of total minutes/day MVPA was not specific to the neighborhood, a potential explanation for the lack of findings may be that older adults are not getting their MVPA within their neighborhood. This hypothesis is supported because the other two outcomes, which assessed self-reported physical activity specifically within the neighborhood, had numerous interactive and main effect findings in Study 3. Another possible explanation may be that physical activity that occurred within the neighborhood, such as walking for leisure, did not meet the moderate-to-vigorous cut points.

Active Transport in the Neighborhood (Table D.2)

There were 4 significant ($p<.05$) and one trending ($p<.10$) moderators of the relation between neighborhood safety and active transport across the three studies. Though all the moderators were from demographic and psychosocial ecological levels, there were no specific variables shared across studies. The relation of active transport with safety varied most by demographic/individual (i.e., unmodifiable) characteristics among overweight/obese adults and by psychosocial (i.e., modifiable) characteristics among adolescents. The relation among older adults varied by both demographic and psychosocial characteristics. These findings further support the need to tailor interventions to specific subgroups, and the intervention components need to consider the different individual characteristics that cannot be modified (e.g., race/ethnicity, household education), while also targeting modifiable (e.g., perceived barriers and social support) characteristics.

The most consistent main effect was that perceived overall walkability (non-safety) was positively associated with more active transport for all age groups. It is logical that accessible destinations (e.g., stores, recreation centers) and other indicators of walkability not related to safety (e.g., greater street connectivity) would be important contributors in the decision to engage in active transport. The finding was also consistent with the literature that found walkability was significantly associated with active transport ((Bauman et al., 2012; Ding et al., 2011; Grow et al., 2008; Sallis et al., 2012; Van Cauwenberg et al., 2012). Safety from crime was also negatively associated with active transport among overweight/obese adults and adolescents. Though greater perceived safety from crime was associated with less active transport, a review of crime and the built environment with physical activity noted that indicators of crime (e.g., graffiti) were often

Table D.2: Multilevel moderators and main effects for the association between neighborhood safety and self-reported active transport

	Study 1: Overweight/obese adults (ConTxt)	Study 2[B]: Adolescents (TEAN)	Study 3[B]: Older adults (SNQLS)
Significant moderators: Ecological variables			
Individual/Demographic variables			
Sex[A]	*	--	--
BMI[A]	**	--	--
Household education	--	--	*
Psychosocial variables			
Barriers to being active in neighborhood	--	*	--
Social support	--	--	+
Home environment variables	--	--	--
Perceived neighborhood environment variables	--	--	--
Main effects: Neighborhood Safety			
Perceived neighborhood environment			
Pedestrian safety	--	--	--
Safety from Crime /Low crime risk[D]	+~	**~	--
Safety from traffic	--	--	--
Low stranger danger[C]	n/a	--	n/a
Overall walkability (non-safety)	***	***	***
Objective pedestrian safety			
MAPS Streetscape Safety Index	n/a	--	**

+ p<.10, * p<.05, **p<.01,***p<.001

[A]In Study 1, the 2 significant interactions terms were with perceived safety from crime

[B]All tested interaction terms were with the objective MAPS streetscape safety index

[C] Assessed only among adolescents; both parent and adolescent reported

[D]Adolescent reported in the significant interaction for Study 2

Bolded names represent variables that were significant in 2 or more of the studies found in more "walkable" and denser urban areas (Foster & Giles-Corti, 2008). This association was not found among older adults but there was a significant positive association with objective pedestrian streetscape among older adults (which was not found for the other two studies). The findings imply that among overweight/obese adults and adolescents, greater safety from crime may not influence their decision to engage in active transport, though this might be explained if they are using active transport out of necessity or despite greater indicators of crime in more urban, walkable areas.

Leisure-time Physical Activity in the neighborhood (Table D.3)

Significant or trending moderators of neighborhood safety and leisure-time physical activity were found for all 4 tested ecological levels, though no moderators were shared across studies. The majority of moderators were psychosocial characteristics for overweight/obese adults and adolescents, but individual/demographic characteristics for older adults. Targeting psychosocial characteristics, such as increasing self-efficacy or social support, are often included in interventions but should be assessed in combination with neighborhood safety as well, given the moderating effects found in the current studies. There were no consistent patterns across studies in terms of synergistic effects, though it did appear that higher psychosocial scores may contribute to helping participants overcome the barriers of lower neighborhood safety (e.g., high social support and self-efficacy in Study 1). Leisure-time physical activity was the only outcome where variables from the tested environmental levels (i.e., home environment in Study 1and perceived neighborhood environment in Study 2) were moderators. Surrounding environments may be more influential for people choosing when and where they will be active in their free time, when compared to the other PA outcomes. Based on present findings, interventions that target increasing leisure-time physical activity should include components that address safety concerns and objective streetscape safety, and then help participants overcome those barriers. For example, interventions could attempt to make the home environment more conducive to physical activity (i.e., provide equipment) or help participants locate places to be physically active, which could be further supported by assembling neighborhood exercise or walking groups (i.e., increase social support).

Table D.3. Multilevel moderators and main effects for the association between neighborhood safety and self-reported leisure-time physical activity

	Study 1: Overweight/obese adults (ConTxt)	**Study 2[C]: Adolescents (TEAN)**	**Study 3[C]: Older adults (SNQLS)**
Significant moderators: Ecological variables			
Individual/Demographic			
Sex	--	--	*
Marital status	--	--	+
Psychosocial			
Self-efficacy[A]	**	--	--
Social support[B]	**	--	--
Parent safety related rules	--	*	--
Home Environment			
Home PA Equipment[A]	*	--	--
Perceived Neighborhood Environment			
Safety from Traffic	--	--	+
Main effects: Neighborhood Safety			
Perceived neighborhood environment			
Pedestrian Safety	--	--	--
Safety from Crime/Low crime risk	***~	--	--
Traffic Safety	--	--	*~
Low stranger danger[D]	n/a	--	n/a
Overall walkability (non-safety)	--	--	--
Objective pedestrian safety			
MAPS Streetscape safety index	n/a	*	**

+ p<.10, * p<.05, **p<.01,***p<.001
[A]In study 1, significant interaction terms with perceived safety from crime
[B]In study 1, significant interaction term with perceived pedestrian safety
[C]All tested interaction terms were with the objective MAPS streetscape safety index
[D]Assessed only among adolescents; both parent and adolescent reported
Bolded names represent variables that were significant in 2 or more of the studies

STUDIES 2 & 3: CONTRIBUTION OF OBJECTIVELY ASSESSED STREETSCAPE SAFETY

Despite the evidence that perceived and objective measures of the built environment (including safety-related features) do not align and are discordant (Bailey et al., 2014; Kirtland et al., 2003; McGinn et al., 2007; Strath et al., 2012), there were few studies that included both types of measures, and even more infrequent were objective measures at the micro-level. Assessing microscale features is especially important because they are usually somewhat modifiable.

Microscale refers to small streetscape characteristics, such as traffic calming features, sidewalk presence, speed limits, marked crossings (Brownson et al., 2009). In contrast, macrolevel features of walkability are measured by GIS and include mixed-land use, residential density and street connectivity (Brownson et al., 2009; Frank et al., 2010), which are difficult to modify and often require changes to zoning laws. Though people are often physically active and walk in the streets of their neighborhood, the association of microscale features with physical activity has been infrequently examined.

Studies 2 and 3 addressed the dearth of studies that explore the association of objectively assessed streetscape safety and physical activity. The MAPS streetscape safety index created for these studies used existing items from MAPS that have acceptable reliability (Millstein et al., 2013) and were previously validated by associations with physical activity in multiple age groups, mainly active transport (Cain et al., 2014). The US Department of Transportation (DOT) funded reports (DOT, 2002; Zegeer et al., 2009) and the National Cooperative Highway Research Program (NCHRP) report (Toole, 2010) add content validity, because they identified pedestrian facilities that help make pedestrians safer, while also providing mobility. The reports identified traffic speed, sidewalks, buffers, crosswalks, curb ramps, lighting, crosswalk signalization and marking, refuge islands, speed humps, and curb extensions as important factors related to pedestrian safety from traffic, all of which were included in the MAPS streetscape safety index and support the content validity (available in Appendix 1).

Main effect findings with objective streetscape safety

There were 3 main effects, where objectively measured pedestrian streetscape safety was independently associated with physical activity, even while controlling for multiple covariates. The relation of streetscape safety and physical activity was moderated by 5 variables in both studies, where 4 moderators were individual/demographic characteristic, 5 psychosocial characteristics and 1 perceived neighborhood safety variable. The utility of the MAPS streetscape measure is demonstrated through these significant interactive and main effects, and future research that includes built environment features should directly assess objectively measured safety. Furthermore, current findings emphasized that perceived neighborhood safety and objective streetscape safety are often discordant and as such, both should be measured in studies. Next steps for the objective streetscape measure is to leverage data from studies that are collecting or have collected MAPS data, and explore interventions that directly target modifying the neighborhood or target the modifiable significant moderators (e.g., psychosocial characteristics).

As was hypothesized, the independent association between objective streetscape safety and physical activity varied by outcome and population subgroup. It is logical that older adults would be more influenced by the safety features of their neighborhood, as they are more likely to have health problems, limited mobility and be at greater fall risk (Nelson et al., 2007) than adolescents. Higher streetscape safety scores were *positively* associated with walking for leisure and active transport in the neighborhood for older adults, but *negatively* associated with leisure-time physical activity among adolescents. A possible explanation is that though more residential and suburban areas often have poorer pedestrian infrastructure, these could be streets that adolescents use more due to lower traffic volume and speed. Additionally, pedestrian safety may not factor into adolescents' decisions to be active in the neighborhood, as there are some studies that suggest adolescents may perceive themselves to be "invincible" (i.e., that the consequences of the behavior will not happen to them) (Killgore et al., 2010; Monneuse et al., 2008). Pedestrian infrastructure is likely an important consideration for older adults deciding to be active in their neighborhoods. Because older adults are a rapidly growing population in the US, improving the understanding of factors that may help them age successfully and remain in their communities is critical. More research focused on identifying pedestrian safety features that facilitate physical activity among older adults can inform tailored interventions for this important and vulnerable age group. Interventions could help older adults to identify key safety related characteristics in their neighborhoods and then advocate to modify them. However, the findings demonstrated that successful interventions should also target those who have the potential to benefit most (e.g., those who are single, have a lower education, are male and perceive low traffic safety).

STRENGTHS

A strength of this dissertation was the commonalities across the three datasets that enabled some comparisons to be made across studies. The use of the same three outcomes, two domain-specific physical activity outcomes (i.e., active transport and leisure-time) and one objective accelerometer-assessed outcome (i.e., minutes/day of MVPA), is a strength and adds to the literature that calls for the use of domain-specific and objective measures of physical activity (Bauman et al., 2012). Self-reported perceived safety and overall walkability (non-safety) subscales were assessed in the three studies using validated age-appropriate versions of the same measure (NEWS) (Cerin et al., 2009; Cerin et al., 2006; Rosenberg et al. 2009; Sallis et al., 2010). Another strength was the application of an ecological approach, which informed the variables assessed and the analysis, including testing for cross-level interactions (Sallis & Owen, 2015). The studies all explored multilevel moderators from the same 4 ecological levels (individual/demographic, psychosocial, home environment, perceived neighborhood environment), using variables that were previously recognized as correlates of physical activity (Bauman et al., 2012; Ding et al., 2011; Saelens et al., 2012; Van Cauwenberg et al., 2011).

Two of the studies used the same objective measure of streetscape safety that was developed specifically for this dissertation, and its content validity was supported. The objective measures advance the field by explicitly assessing the relation of pedestrian safety-related attributes of the neighborhood built environment with physical activity in the neighborhood. Because study design, including macrolevel walkability, was controlled for in both studies, the significant associations carry more weight as they demonstrated that microscale features of safety are related to physical activity independently of overall macrolevel walkability. The majority of the significant findings with objective streetscape safety and physical activity were found with the neighborhood-specific outcomes (i.e., self-reported active transport and leisure-time physical activity constrained within the neighborhood [Study 3] or MVPA within a GPS-derived neighborhood buffer [Study 2]).

LIMITATIONS

Despite these strengths, there are several limitations. The lack of longitudinal data precludes any statements about causality, and future studies should explore moderators using prospective study designs. There were likely other factors that were unmeasured that contributed to participants' decisions to engage in physical activity in their neighborhood. For example, some factors that should be assessed include if participants were active in the neighborhood out of obligation (e.g., no access to a car), if they had a large dog to walk or if they had close neighbors who walked together. Study 3 included a variable about active driver status and found those who were *not* active drivers had significantly more active transport in the neighborhood, which supports the idea that non-drivers were engaging in active transport out of necessity.

Though improved measures were used for the outcomes and neighborhood safety variables, the measures across studies were not directly comparable. It was impossible to directly compare findings across studies because all used different, though validated, measures to assess self-reported physical activity. Both domain-specific physical activity outcomes for the adolescents (Study 2) relied on computing the average frequency per month, unlike the other two studies (Studies 1 and 3) which asked participants about their physical activity in the past week. However, these cannot be directly compared either, because they were not the same measure (i.e., GPAQ vs. IPAQ) and due to a misprint on the survey, the data for Study 1 had to be assessed as days/week for both self-reported outcomes. For greater comparability across studies and a more sensitive measure, using minutes/week would have been preferred. Finally, the objective accelerometer-derived MVPA outcome was within a specific neighborhood buffer for adolescents (Study 2), but in Studies 1 and 3, average minutes/day of total MVPA was used.

The neighborhood safety variables were collected using validated measures (both self-reported [NEWS] and objective [MAPS]), but there were still limitations. There was limited variation in participants' self-reported perceived safety, where most participants rated their neighborhoods as relatively safe (especially for safety from crime). Using more refined measures of perceived safety, which directly ask about the relation of different components of safety and physical activity in the neighborhood, could help clarify current findings. The objective MAPS streetscape safety measure represented only a small portion of the participants' neighborhoods (i.e., a .25-.45-mile route from their home to the nearest commercial destination), and may not be representative of the entire neighborhood. The route was drawn towards the nearest commercial destination, which is likely to be more associated active transport. It is possible that those engaging in leisure-time physical activity (e.g., walking the dog in the neighborhood) intentionally avoided commercial destinations, and thus the safety items used in the objective measure may not have been representative of the parts of the neighborhood where participants were engaging in leisure-time physical activity.

IMPLICATIONS & FUTURE RESEARCH DIRECTIONS

A review of correlates of walking found personal safety (i.e., safety from crime) and pedestrian infrastructure were significantly associated with walking for leisure, but only personal safety was associated with walking for transport (Saelens & Handy, 2008). The findings of perceived pedestrian infrastructure and safety from crime and objective streetscape safety from the three current studies mostly lend support for this conclusion. Studies 1 and 2 both found that greater perceived safety from crime was consistently negatively associated with physical activity for several outcomes, but both found main effects with the active transport outcome. However, Study 1 also found subgroup-specific associations that imply safety from crime may be influential to only certain subgroups. Perceived safety from crime and the association with physical activity is not well understood (Foster & Giles-Corti, 2008) and warrants further investigation. The safety of the built environment may be especially important among older adults, given the significant finding of objective streetscape safety with both the active transport and walking for leisure outcomes.

The findings from the current studies demonstrated that neighborhood safety was related to physical activity, though there were subgroup-specific effects that could be considered when designing interventions. Though present results are promising, studies with similar specific aims, measures, and population subgroups are needed to ensure the findings are replicable before concrete recommendations for interventions can be made. More studies should utilize objective micro-level measures of streetscape safety, as the findings from Studies 1 and 2 demonstrated that macrolevel GIS walkability and perceived neighborhood safety may be related constructs but are separate from micro-level features. Studies should incorporate all three types of measures when possible, as all seem to explain different factors of safety and walkability. Because the data were mostly inconsistent across studies, a crucial next step is to conduct qualitative research with representative samples to help interpret the current findings, especially to better understand the moderating effects.

Future studies should stratify study areas based on high- and low-safety, specifically by crime rates and pedestrian injury/fatality rates. Stratifying in this way would increase variability in the safety measures (both perceived and objective). Additionally, the neighborhood should be clearly defined for participants to report their perceptions of safety and physical activity in the neighborhood. The objective measures (i.e., accelerometer-measured MVPA and streetscape safety) should match the same buffer used to define the neighborhood for the self-reported measures, and all streets within the buffer should be objectively measured for streetscape safety.

Finally, prospective studies are needed, including natural experiments that enhance the streetscape safety features in neighborhoods and assess physical activity before and after. These studies should conduct pre- and post- audits of streetscape characteristics (e.g., MAPS) related to safety to document changes and their effects on neighborhood-based physical activity and injury or fatality rates. However, the audits should ideally be more extensive (i.e., audit all neighborhood blocks) and could even be collected in partnership with the community to help with advocacy efforts. Though physical activity in one's neighborhood is conceptually relevant to explain pedestrian injuries, to date no interventions have been designed to target both physical activity and traffic fatalities/injuries outcomes. There is a need for research that emphasizes co-benefits to enhance the policy relevance (e.g., studies that demonstrate people in neighborhoods with greater pedestrian safety are more physically active, better health associated with greater outdoor physical activity and fewer traffic injuries/fatalities).

There were relatively few significant moderators, with only an average of 14% of the tested moderators significant across studies (24% Study 1, 5% Study 2, 12% Study 3). The scarcity of moderators implies population-wide interventions may be generally effective, and extremely narrow and tailored interventions are unnecessary. The multiple main effect findings should be used to guide population-wide interventions. Though there were few shared moderators across studies, there was an overall pattern that most moderators were from the demographic or psychosocial levels (15 out of 17). The 2 variables that came from the home environment or perceived neighborhood environment were moderators of the leisure-time physical activity outcome and neighborhood safety association. The findings emphasized that though there were some similarities across age groups, in general there were subgroup-specific effects that cannot be generalized to other age groups or population subgroups. An important finding was that race/ethnicity was a significant moderator for overweight/obese adults and adolescents with pedestrian safety (self-reported and objectively measured), particularly given the disproportionately high rates of pedestrian fatalities among racial/ethnic minorities (NHTSA, 2016a; DOT, 2016). Understanding for whom and under what conditions neighborhood safety is associated with physical activity can inform future targeted interventions, where creating small modifications in neighborhood pedestrian safety has the potential to help specific population subgroups be more active in their neighborhoods.

CONCLUSION

Physical activity is complex behavior that requires an ecological approach to better understand the factors that facilitate or inhibit the behavior, and factors related to the safety of one's neighborhood are not well understood. Though the fields of injury prevention and safety are conceptually related to physical activity and the built environment, this dissertation helped bridge the gap between the fields. The results demonstrated that both perceived and objective measures of neighborhood and pedestrian safety were associated with physical activity among different age groups, and that were further subgroup-specific effects. The findings are promising, they underscore the need for further research that considers the influence of safety on physical activity.

The topic of the current dissertation is timely, especially because pedestrian fatalities in the US are at a nearly 20-year high (NHTSA, 2016b) and a recent Department of Transportation led "Safer People, Safer Streets: Pedestrian and Bicycle Initiative" included a specific Mayor's Challenge for cities across the US to improve pedestrian and bicyclist safety (DOT, 2016). Vision Zero, which originated in Sweden, is an initiative based on the premise that deaths from traffic are preventable, and city design, infrastructure and enforcement should be designed to be conducive to safety and mobility for all (Belin et al., 2012; Tingvall & Haworth, 1999; White, 2016). Many cities in the US are adopting Vision Zero or "complete streets" policies (DOT, 2016; White, 2016), with the aim of improving safety and ensuring mobility for all community members (i.e., not just drivers). Designing cities and enforcing laws or policies that help pedestrians be safer in the streets may reduce or eliminate traffic-related fatalities among pedestrians, but may also have a dual benefit of facilitating greater physical activity in neighborhoods. However, more research is needed to assess for whom and under what circumstances the policies and design of streetscape features would be most beneficial in promoting both safety and physical activity. Evaluations of the effectiveness of these policies are needed, and there is potential for evaluations of physical activity in the same neighborhoods to be conducted in conjunction with the streetscape safety improvements. The three studies in this dissertation helped bridge the fields of injury prevention and physical activity by using physical activity as an outcome, neighborhood safety as the independent variable and assessing multilevel moderators of the association.

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APPENDIX 1
MAPS Streetscape Safety Subscale

Individual items on the scale ranged from 0 to 2, where 0=extremely unsafe and the 2=extremely safe. Higher scores reflect greater safety. The items all had 2 possible points to avoid overweighting any items and were summed to create an index. The maximum possible score was 52.

<u>From the route section:</u>
16 points possible from the route section

SS3: Is there a posted speed limit along the route?*
-Scoring: ≤25mph=2, 25-40mph=1, >40mph=0, none=0

SS4: Street characteristics:
a) Traffic calming (signs, circles, speed humps, etc.) =# (assessed range in data to decide cut-points, and used none=0, ≤1=1, ≤2=2)
b) Roll-over curbs=any (0) vs. none (2)
d) Instructional signs for pedestrians=any (2) vs. none (0)
e) Crosswalk signage or other pedestrian signage for drivers=any (2) vs. none (0)

SS5: Street lights
None=0, some=1, ample=2

SS6: Presence of driveways or alleys
None=2, 1-5=1, 6+=0

SS8: Presence of any mid–segment street crossing for pedestrians (Y=2, N=0)

<u>From the segment section</u>
8 points possible for segment section
*For routes with multiple segments, a mean was taken for each item (thus, scores ranged between 0-2).
*Note: if there was no sidewalk, items S3 and S4=0

S1: Is a sidewalk present? Y=2, N=0

S3: Is there a buffer present? Y=2, N=0

S4: Is the sidewalk continuous? Y=2, N=0

S10: # of traffic lanes present
1-2 lanes=2, 3-5 lanes=1, 6+ lanes=0

<u>From the crossing section:</u>
28 points possible for crossing section
*Similar to the segment approach, a mean was taken for each item and added to the index
*Note: if there is no crossing, they would get a 0 for the whole section (this is rare to have no crossing

C1: Intersection control
- b) stop signs=1
- c) traffic signal=2
- d) traffic circle=1
  none=0

C3: Signalization
- b) pedestrian walk signals=2
- c) push buttons=2
- d) countdown signal=2
  none=0

C5: Pre- and post-crossing curb cuts.
- a) Pre: Yes and lines up with crossing=2, Yes but does not line up with crossing=1, No=0
- b) Post: Yes and lines up with crossing=2, Yes but does not line up with crossing=1, No=0

C7: Other characteristics of crossing:
- c) crossing aids (e.g. flags): Y=2, N=0

C8: Crosswalk treatment
- a) marked crosswalk (Y=2, N=0
- b) high-visibility striping (Y=2, N=0)
- d) raised crosswalk (Y=2, N=0).
- e) diff material than road (Y=2, N=0)

C10: Road width (# of traffic lanes in crossing)
1-2=2, 3-4=1, 5+=0

C11: Features
- c) Protected refuge islands (Y=2, N=0)
- e) Curb extension (Y=2, N=0)

<u>From the cul-de-sac section:</u>
None (the relationship with the cul-de-sac is unclear)