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EXAMINING THE RELATION BETWEEN SOCIAL CAPITAL AND PHYSICAL ACTIVITY ACROSS LIFE STAGES

LEIGH ANN GANZAR

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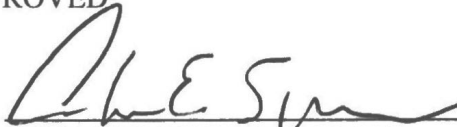
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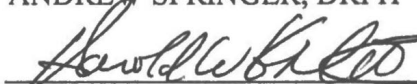
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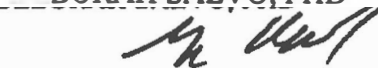
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ACTIVITY ACROSS LIFE STAGES

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EXAMINING THE RELATION BETWEEN SOCIAL CAPITAL AND PHYSICAL ACTIVITY ACROSS LIFE STAGES

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Physical inactivity in adults increases the risk for adverse health outcomes, including non-communicable diseases and premature death. Children who are not sufficiently physically active face increased risk for non-communicable disease risk factors, mental health issues, and poor academic performance. Despite these risks, the majority of people do not achieve sufficient physical activity levels. Social capital is an aspect of the social environment that can shape physical activity behavior throughout different life stages. The three studies of this dissertation sought to assess the association between social capital, from both the cohesion and network perspectives, and physical activity behavior in different life stages.

Paper 1 used a representative sample of Texas 2nd grade children to examine the cross-sectional association of neighborhood language-based social cohesion and outdoor play. Using data from the Census, language spoken at home at the school catchment area was determined for each student using Geographic Information Systems (GIS), and multilevel regression was used to assess association of neighborhood language composition and outdoor play with students nested within schools. Interaction models were used to determine if the relation between majority neighborhood language and outdoor play varies by language

spoken at home. Paper 2 looked at the interaction between social cohesion and the built environment on adolescent physical activity using a cross-sectional, internet-based study of U.S. adolescents and adults. Built environment features were measured using GIS based variables from GeoFLASHE, and linear regression was used to assess differences in the association of neighborhood social cohesion and out-of-school time MVPA in adolescents by built environment features. Paper 3 assessed network social capital and physical activity trajectories using the longitudinal MoNNET-HA dataset, a cohort of adults age 25 and older living in Montreal. Latent trajectory analysis and multinomial logistic regression was used to assess effect of network social capital on changes in physical activity.

Paper 1 found that neighborhood language-based social cohesion was a significant predictor of outdoor play in predominately English speaking neighborhoods. Findings from Paper 2 revealed that social cohesion was significantly associated with physical activity, and this association was stronger for males than females. The association between social cohesion and physical activity differed by built environment features in males, with stronger effects for neighborhoods with unsupportive built environments. Paper 3 found that physical activity trajectories differed by sex and age group, and there were no groups that had increasing levels of physical activity over the five year time period. Network social capital diversity was significantly associated with physical activity in adults, and was also significantly associated with physical activity trajectories. Network social capital reach was significantly associated with physical activity trajectories in adults over 55 years.

Overall, this dissertation provides important contributions to the literature base on social capital and physical activity, and these findings provide a foundation for future

research to further the field of social capital and physical activity. Interventions and policies that seek to increase physical activity should incorporate both bonding (among like individuals) and bridging (among individuals of different socioeconomic or demographic groups).

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BACKGROUND

Literature Review

Physical inactivity increases the risk for adverse health outcomes and is a significant contributor to the burden of disease worldwide, with 9% of premature deaths attributable to physical inactivity and 6-10% of several major non-communicable diseases.¹ In addition to these consequences of physical inactivity in adults, children who are not sufficiently physically active face increased risk for cardiovascular disease risk factors,² type II diabetes,³ sleep apnea,⁴ depression,³ and poor academic performance.⁵ Physical activity during childhood and adolescence also provides benefits into adulthood, including higher perceived general health, higher aerobic capacity, and lower risk of high blood pressure and obesity.⁶

Despite the known harmful effects of physical inactivity, many people do not achieve sufficient physical activity. In 2016, globally, 23.8% of adults over the age of 18 years do not meet the global recommendations for health promoting physical activity, with higher levels of physical inactivity in higher income countries.⁷ Additionally, 80.3% of adolescents age 13-15 do not achieve recommended levels of physical activity, underscoring the need for understanding of the determinants and correlates of physical activity and interventions to address these factors.⁸ Given that physical inactivity affects populations across many age groups, it is important to take a life stages perspective to better understand influences on physical inactivity from childhood to adolescence and adulthood.⁹ This perspective is especially important due to the influence of physical activity behavior at early life stages on physical activity later in life.¹⁰ Several longitudinal studies have reported that individuals

who are physically inactive during early life stages, such as adolescence, are more likely to be physically inactive as adults.¹¹⁻¹³

Ecological models of health behavior take a comprehensive approach to determining causal factors of physical activity behavior, and include the interactions of individuals with their social environment as contributors to physical inactivity.¹⁴ In the adapted ecological model of the determinants of physical activity from Bauman et al.,¹⁴ the social environment and social support are both included as determinants of physical activity throughout the life course. The social environment affects individuals by “shaping norms, enforcing patterns of social control, providing or not providing environmental opportunities to engage in particular behaviors, reducing or producing stress, and placing constraints on individual choice.”¹⁵ The social environment can influence physical activity through several mechanisms: interpersonal factors like social support and social networks, social inequalities such as socioeconomic position, income inequality, and racial discrimination, and neighborhood and community factors including social capital.¹⁶ Despite a large body of research on the role of social support and physical activity, less is known about the role of social capital on shaping physical activity behavior on different life stages.^{14,17}

While different research disciplines use variations of a definition of social capital, the construct has been generally defined as the “resources that are accessed by individuals as a result of their membership of a network or group.”^{18,19} Social capital has been studied in regards to a diverse array of outcomes, including schooling, community organization, criminology, economic development, and public health, where it has been associated with various mental and physical health outcomes at different stages of life.¹⁸ A systematic review

found that higher levels of social capital, either through parents, communities, or schools, are associated with better general health, quality of life, neighborhood safety, and developmental and behavioral scores in children.²⁰ Social capital is also important at later life stages, and in adulthood, higher social capital is associated with better self-rated health, lower rates of depression, and lower rates of all-cause mortality.^{21,22}

Resources, as they relate to physical activity, refer to the tangible resources found in social relationships, both material and psychological.²³ Although social capital is viewed as resources accessed by an individual through their network, previous literature has generally relied on proxy measures, such as generalized trust, to assess the relationship between social capital and health.²⁴ Further, previous research has used various forms of operationalization, dimensions, and subtypes of social capital, and this heterogeneity in conceptualization and measurement of the construct has created inconsistent results about the relationship between social capital and physical activity behavior.^{25,26}

Social capital research has historically fallen in one of two major schools of thought: cohesion and network approaches.²³ Social cohesion refers to the presence of strong social bonds, and has been defined as the “extent of connectedness and solidarity among groups in society.”¹⁸ As a component of social capital, social cohesion emphasizes the cognitive facets of trust, sense of social belonging, integration, and the structural components of social and civic participation.²³ Shared language use has been identified as a potential factor that can foster social cohesion among communities through integration because language is related to how health promoting social linkages are formed.²⁷ The role of language as a component of social cohesion has been shown to be especially strong among Latinos living in the United

States, where the language commonly spoken in the home is not the majority language of the society.²⁸ The bulk of literature on social capital and physical activity has utilized the social cohesion perspective, and most studies have used generalized trust as a measure, so although language is potentially an important component of social cohesion, there is very little literature explicitly identifying shared language and physical activity.¹⁸

Another factor that can influence social cohesion is the built environment, which “comprises urban design, land use, and the transportation system, and encompasses patterns of human activity within the physical environment.”²⁹ The built environment has the potential to influence human social activities and behaviors, including influencing the degree to which neighborhoods and communities are deemed to be safe, comfortable, and attractive places to be physically active.³⁰ Because social cohesion is characterized by a sense of trust and reciprocity within groups, the built environment has the potential to affect social cohesion.³¹ Social and physical environments interrelated and influence each other, yet to date, there has been little research on the interactions between social cohesion and the built environment, and its influence on physical activity behavior, especially in children and adolescent populations.^{32,33}

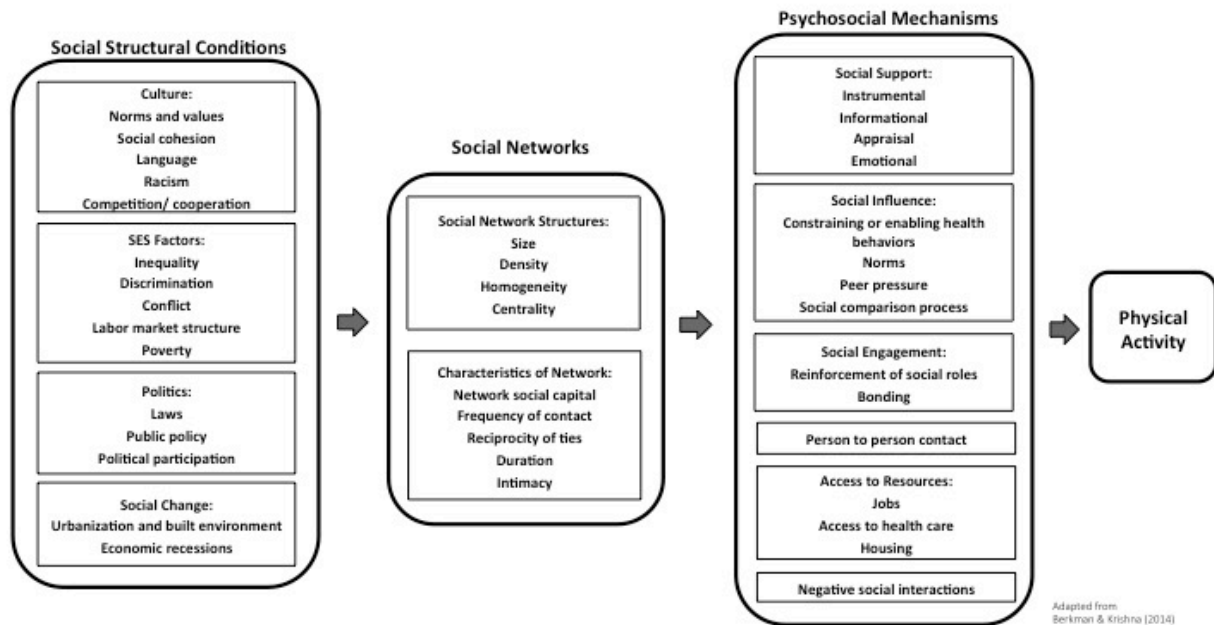
Network based approaches to social capital, in contrast to a social cohesion perspective of social capital, assess individual relationships, or ties, within a social network for their structure, such as density, their composition, such as the homophily of characteristics of the members of the network, and the resources that are embedded in the ties.¹⁸ The use of network social capital in studies relies on formal social network analysis.

To date, few studies assessing social capital and physical activity have used the network approach and even fewer have looked at such relationships longitudinally.³⁴

To further characterize social capital, the construct can be broken down into bonding and bridging social capital.³⁵ Bonding social capital refers to resources accessed by members of a homophilous group in terms of socio-demographic characteristics; bridging social capital refers to the resources available shared by members of a group composed of different socioeconomic classes, race/ethnicities, languages, or other characteristics.³⁶ It has been suggested that these two forms of social capital can elucidate different relationships between such community level constructs and health outcomes.³⁷

Social capital holds the potential to influence physical activity through a variety of mechanisms, including through the reinforcement of norms, provision of social support, access to information, or greater sense of belonging.^{16,38} Figure 1 depicts the conceptual framework of how the social environment, including both aspects of social capital, influences health, originally developed by Berkman and Krishna³⁹ and adapted by the author for physical activity as the health behavior outcome.

Figure 1: Conceptual framework of the influence of the social environment on physical activity, adapted from Berkman & Krishna (2014)



Public Health Significance

This research has important public health implications for interventions, policy, and directing future research. Findings from the studies in this dissertation can direct interventions aimed at increasing physical activity in children, adolescents, or adults, which can not only improve health outcomes and quality of life across all ages, but also affect total health care expenditures, 11.1% of which are associated with physical inactivity in the United States.^{40,41}

Children are engaging in less outdoor play, a key source of physical activity in this population, than previous generations, and it has been suggested this is due to parental values and safety concerns.⁴² Social cohesion has been shown to be a mediator between perceived

safety and physical activity in children,³³ and furthering this research by looking at the role of language spoken can provide important insight into developing and tailoring interventions, especially in the United States, where Hispanic and foreign born populations are two of the fastest growing segments of the population.⁴³

The Community Preventive Services Task Force recommends the use of built environment interventions to increase physical activity by creating or modifying environmental characteristics,⁴⁴ however ecological models of health behavior posit that multiple levels of influence affect physical activity and that built environment alone may not be enough to modify or promote physical activity.⁴⁵ Indeed, previous research has shown that built environment physical activity resources have no impact on physical activity for adults who are socially isolated.³⁴ For adolescents, little research exists on the interaction of social cohesion and the built environment on physical activity, and this research can have implications for built environment interventions and the need to incorporate multilevel components, including potentially neighborhood level activities designed to promote social cohesion.

Physical inactivity and sedentary behavior remain high in high-income nations, and current research on the association between social capital and physical activity in adults has shown higher levels of social capital are generally associated with higher levels of physical activity.⁴⁶ However, most research has been cross sectional and has looked at the cognitive aspects of social capital. Longitudinal studies that assess network social capital can enhance this research by providing causal evidence of the relationship between the two constructs. Findings from this research have implications for intervention design, and population-based

programs that seek to promote physical activity among adults could consider ecological-level interventions that use associational involvement and interpersonal relationships that provide resources to increase physical activity.

RESEARCH OBJECTIVE AND SPECIFIC AIMS

The purpose of this dissertation was to examine the association between social capital, from both the cohesion and network perspectives, and physical activity behavior in different life stages.

Specific Aims

Paper 1

- **Aim 1:** To determine the association between neighborhood language social cohesion and days of outdoor play in a representative sample of 2nd grade public school students.
 - **Hypothesis:** Neighborhood language social cohesion will be significantly associated with days per week with at least 30 minutes of outdoor play, with higher levels of neighborhood social cohesion predicting more days of outdoor play.
- **Aim 2:** To examine the association between the majority language in the neighborhood and days of outdoor play by language spoken at home.
 - **Hypothesis:** Children whose language spoken at home matched the majority language in the neighborhood will have significantly more mean days per week with at least 30 minutes of outdoor play than children whose language spoken at home does not match the majority language of the neighborhood.

- **Aim 3:** To explore differences in the association between language social cohesion and outdoor play by sex of the child.

Paper 2

- **Aim 1:** To determine the association between neighborhood social cohesion and weekly minutes of out-of-school time moderate-to-vigorous physical activity (MVPA) in a sample of U.S. adolescents aged 12-17.
 - **Hypothesis:** Higher reported levels of neighborhood social cohesion will be significantly associated with higher mean minutes of weekly out-of-school time MVPA.
- **Aim 2:** To examine differences in the association of neighborhood social cohesion and out-of-school time MVPA in adolescents by built environment features.
 - **Hypothesis:** The association between neighborhood social cohesion and out-of-school time MVPA will vary significantly by built environment features, with stronger effects for neighborhoods with unsupportive built environment features for physical activity.
- **Aim 3:** To assess whether the relations between the built environment, neighborhood social cohesion, and out-of-school-time MVPA vary by sex of the adolescent.

Paper 3

- **Aim 1:** To assess the association between baseline network social capital and physical activity in a cohort of adults residing in Montreal, Canada
- **Aim 2:** To assess the effects of network social capital on physical activity trajectories over a 5 year time period in a cohort of adults residing in Montreal, Canada

- **Hypothesis:** Network social capital will be directly associated with physical activity changes, with higher network social capital predicting maintenance of high levels of physical activity or increasing levels of physical activity over time.
- **Aim 3:** To assess if the association between network social capital and physical activity trajectories was moderated by sex or age of the participants.

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JOURNAL ARTICLE 1

Language Based Social Cohesion and Outdoor Play Behavior among Elementary School Children in Texas: A Representative Cross Sectional Analysis

Introduction

Outdoor play provides many benefits for children, including promoting physical, cognitive, social, and emotional wellbeing.¹⁻³ Both structured and unstructured outdoor play are important sources of physical activity for children, and previous studies have shown that parental-report measures of outdoor playtime were significantly associated with a direct measure of physical activity.^{4,5} A recent systematic review found that children were more likely to be physically active when outdoors compared to indoors.⁶ There is consistent evidence for the benefits of such physical activity among children, including facilitating energy balance,^{7,8} assisting in prevention of chronic disease,⁹ improving bone strength,¹⁰ and reducing depression and mental stress.¹¹ Despite the known value of outdoor play for children, there has been a decline over time in outdoor play among children in the United States ages 3 to 12 years.¹² Gender differences also exist in the prevalence and intensity of children's outdoor play, with boys engaging in not only more outdoor play, but also boys engage in more intense physical activity while playing outdoor than girls.¹³⁻¹⁵

Children's outdoor play behavior is influenced by individual factors, physical factors, and social factors.¹⁶ Previous research has focused on the role of parental influence and the physical environment on outdoor play, but there has been less of a focus on the social environment.¹⁷ The social environment encompasses social ties, social norms, patterns of social control, environmental opportunities, stress promoting or stress reducing factors, and

potential constraints on individual choice.¹⁸ One aspect of the social environment that has potential to influence outdoor play behavior in children is social cohesion, which has been defined as the “extent of connectedness and solidarity among groups in society.”¹⁹ Social cohesion emphasizes the cognitive facets of trust, sense of social belonging, integration, and the structural components of social and civic participation.²⁰ Social cohesion has the potential to affect physical activity behavior through several mechanisms: access to social resources such as informational or instructional social support, reinforcement of social norms, capacity to engage in collective efficacy, and ability to convey solidarity among a community.¹⁹ Social cohesion can also affect physical activity through the sense of social belonging and bonding, which can promote feelings of safety in the neighborhood, and safety has been shown to be a consistent predictor of physical activity behavior, especially in children.²¹

Previous research has shown that social cohesion is associated with physical activity behavior in children, with higher levels of social cohesion associated with higher levels of physical activity, but most of this literature does not differentiate between outdoor play and physical activity in other contexts and settings.^{22,23} Other studies have assessed the relationship between social cohesion and a physical-activity related behavior, such as one study looking at social cohesion and active commuting to school which found mixed results depending on the gender of the child.²⁴ Another study looked at the influence of social cohesion on children’s independent mobility, which is the degree to which children can travel or do other activities without an accompanying adult, and found a significant association between parental perceptions of social cohesion and independent mobility.²⁵ One study of Dutch children did assess outdoor play behavior, and results showed social cohesion was

directly associated with outdoor play in children of different ages and gender, however this sample was homogeneous in terms of language use among participants.²⁶

Shared language use has been identified as a potential factor that can foster social cohesion among communities through integration because language is related to how health promoting social ties and linkages are formed.²⁷ In the case of physical activity, previous research has shown neighborhood social ties are directly associated with physical activity.²⁸ Another construct, social support, which has been shown to be consistently related to physical activity, relies on shared language to enable the provision of emotional, informational, and instructional support.²⁹ Shared language is an especially important component of social cohesion among Latinos living in the United States, where the language commonly spoken in the home (Spanish) is not the mainstream language used by society (English).³⁰ Hispanic and foreign born populations are two of the fastest growing segments of the population in the United States, and with Hispanic populations achieving less physical activity than non-Hispanic White populations, it is important to determine factors that affect physical activity in these groups.^{31,32}

Although language is potentially an important component of social cohesion, there is very little literature explicitly assessing shared language and its association with physical activity. In this paper, we attempt to clarify the role of shared language in social cohesion by proposing the construct of “language social cohesion”, which we define as the level of language diversity within a neighborhood unit. While various facets of social cohesion have been examined in relation to children’s physical activity, including trust and perceived safety, no studies to date have assessed the association between *language social cohesion* and

outdoor play behavior among children, despite the central role of language in fostering social cohesion.²³ The purpose of the proposed study was to assess whether language social cohesion is associated with outdoor play behavior among 2nd grade children in Texas, and was assessed at both the individual and neighborhood levels.

Specific Aims

- **Aim 1:** To determine the association between neighborhood language-based social cohesion and days of outdoor play in a representative sample of 2nd grade public school students.
 - **Hypothesis:** Children living in neighborhoods with higher levels of neighborhood language social cohesion will have significantly more days per week with at least 30 minutes of outdoor play than children living in neighborhoods with lower levels of neighborhood language social cohesion.
- **Aim 2:** To examine the association between concordance of language at home with the majority language in the neighborhood and days of outdoor play (for the total sample and stratified by gender).
 - **Hypothesis:** Children whose language spoken at home matches the majority language in the neighborhood will have significantly more days per week with at least 30 minutes of outdoor play than children whose language spoken at home is different than the majority language of the neighborhood.

Methods

Study Design and Participants

Participants in this study were second grade public school students in Texas and their parents from the School Physical Activity and Nutrition (SPAN) project conducted during the 2015-2016 school year, which collected objective height and weight measures and surveyed participants about obesity-related behaviors (nutrition and physical activity), knowledge, and attitudes.³³ SPAN used a complex survey design that employed multi-stage probability sampling to provide representative estimates at the state level and when stratified by race/ethnicity, gender, and school grade. Methods for the SPAN project have been previously reported.^{33,34} Strata were designated by Texas Department of Health and Human Services (DSHS) Health Service Regions and by urban/rural status as defined by DSHS³⁵. The SPAN study was reviewed and approved by the University of Texas Health Science Center at Houston Committee for the Protection of Human Subject, the Texas Department of State Health Services, and by each participating school district. Parent consent and student assent was obtained prior to data collection. A request for use of the SPAN data was made and approved by the Principal Investigator, and data were de-identified.

Measures

Outdoor play of the child, the outcome behavior of interest for this study, was measured using responses from the parent to the following question: “Last week, on which of the following days did your 2nd grade child play outdoors for 30 minutes or more?” Parents selected the days of week, and responses did not include outdoor play during school hours. Responses were coded into a count variable with a scale of 0-7 days, as a measure of weekly frequency of outdoor play. This item was modified from previous SPAN questionnaires that

asked about physical activity in 4th grade children; the original survey item had acceptable reproducibility with a Kappa statistic of 0.71.³⁶

Language social cohesion at the neighborhood level was measured using a *neighborhood language homogeneity index*, which was developed using the school catchment area around the participants' geocoded school address. Because children attending public schools in the United States usually go to schools within a defined geographic area around their residence, the school catchment area was used a proxy for the individual neighborhood.³⁷ Data from the American Community Survey 2016 5-year estimates from the U.S. Census Bureau at the Census block group level was then used to develop neighborhood level proportions of language spoken at home within the school catchment area using geographic information system software ArcGIS Pro v2.3, from Environmental Systems Research Institute (ESRI).³⁸ A neighborhood language homogeneity index was developed following the method used by Putnam to create a Census tract Herfindahl index of ethnic homogeneity.^{39,40} Using the percentage of each language group (English, Spanish, Other), the language homogeneity index was developed with a range of 0 to 1, with a value of 1 implies complete homogeneity, i.e. the neighborhood speaks only one language, and a value close to zero means high diversity of languages spoken.

The percentage of each language group from the Census was used to identify the *majority language in the school catchment area*, which was used to measure language social cohesion at the individual level, using the following rules: 1) If 60% or more of the total population are of a given language, the neighborhood will be defined as being predominantly English, Spanish, or Other; 2) If there is no predominant language (no one language is 60%

or more of total population), the neighborhood will be defined as a linguistically diverse neighborhood. *Language use at home* was assessed from SPAN using the following question from the parent survey: “What language do you use at home with your 2nd grade child most of the time?” Responses will be classified into three categories: English, Spanish, and other.

Covariates used at the neighborhood level included *population density* within the school catchment area, taken from the American Community Survey 2016 5-year estimates from the U.S. Census Bureau at the Census block group level, and school level percentage eligible for free and reduced lunch as a measure for *neighborhood economic disadvantage* from the Texas Education Agency.^{41,42}

Covariates at the individual level included *age of the child*, *highest educational attainment of the household*, and *parental perceptions of neighborhood safety*, and *neighborhood physical activity opportunities*. Educational attainment was assessed using a categorical variable for highest level of education for the household, and used as a proxy for household level socioeconomic status, which previous research has shown is associated with outdoor play in children.⁴³

While the neighborhood language diversity measure, the neighborhood population density measure and the neighborhood economic disadvantage measure utilize the school catchment area to define neighborhood, neighborhood for parents, particularly as it relates to child play, needs a person-specific definition of perceived neighborhood. Accordingly, parental perceptions of safety and physical activity opportunities were included as covariates. Parental perception of neighborhood safety, which has also been shown to be associated with child outdoor physical activity and influences social cohesion,⁴⁴ was assessed using a

composite variable created from responses to 5 items assessed with 4-point Likert scale ranging from “not a problem” to “very serious problem.” Items asked parents’ perception of their neighborhood by asking how much of a problem the following things were: crime, gangs, drugs, noise, trash and litter, prejudice and discrimination. Opportunities for physical activity in the neighborhood, which previous literature has shown is associated with outdoor play and physical activity,⁴⁵ was assessed using responses to 2 items assessed with 4-point Likert scale ranging from “not a problem” to “very serious problem.” Items asked parents’ perception by asking how much of a problem the availability of safe parks, playgrounds, and community centers were in their neighborhood. The neighborhood characteristics items were developed from a measure of community stress with a Cronbach’s alpha of 0.88, and were developed for the Teen Health 2000 study, with a more detailed description of the measure presented by Roberts, Roberts, and Xing.⁴⁶

Statistical Analysis

Sample characteristics were calculated with weighted means for continuous variables and weighted proportions for categorical variables to provide representative estimates of 2nd grade children in Texas. Pearson chi square tests were used to test differences between sexes on categorical variables and adjusted Wald tests were used to test differences in continuous variables. For Aim 1, linear regression was used to assess neighborhood language homogeneity index and days of outdoor play, with individuals nested in school catchment areas, accounting for the complex survey design. Interaction terms were run in the linear models to assess potential moderation of the association between the homogeneity index and outdoor play by sex of the child, with Wald tests to assess significance of the interaction

term. For Aim 2, linear interaction regression models were used to assess whether the association of majority neighborhood language and days of outdoor play varies by language spoken at home, with Wald tests to assess significance of the interaction term. Model 1 for each analysis was a bivariate association, model 2 controlled for individual level covariates and model 3 controlled for individual and neighborhood level covariates. All analyses were performed using the *svy* suite of commands in Stata 14.2 (College Station, TX) to account for the clustering at the school level from the complex survey design and weighting. Figures were created using R (RStudio Version 1.0.153). Means and proportions were weighted to provide representative estimates of 2nd grade children in Texas.

Results

The sample size for this study was 2,317 children, which represents 320,800 children in Texas. Weighted sample characteristics are shown in Table 1. The mean age of the sample was 7.4 years (95% CI, 7.3, 7.5). There was a significant difference in the mean days per week with at least 30 minutes of outdoor play between boys and girls, with boys having higher levels of outdoor play than girls ($p=0.01$).

Paper 1 Table 1: Weighted descriptive characteristics of SPAN 2nd grade children in Texas (2015 -2016)

	Total	Boys (51.4%)	Girls (48.6%)	p value
Age in years, mean (95% CI)	7.4 (7.3, 7.5)	7.4 (7.3, 7.5)	7.4 (7.3, 7.5)	0.38
Race/ethnicity, proportion				
White	0.23	0.23	0.25	0.91
Hispanic	0.55	0.54	0.55	
African American	0.11	0.11	0.11	
Other	0.11	0.11	0.11	
Language spoken at home, proportion				
English	0.56	0.57	0.55	0.70
Spanish	0.26	0.26	0.27	
English and Spanish	0.10	0.10	0.10	
Other	0.08	0.07	0.08	
Parent education attainment, proportion				
Less than high school	0.16	0.15	0.16	0.74
High school or GED	0.25	0.26	0.23	
Some college	0.23	0.23	0.23	
College degree	0.21	0.20	0.23	
Graduate or professional degree	0.15	0.16	0.15	
Days per week with at least 30 minutes of outdoor play, mean (95% CI)	3.8 (3.6, 4.1)	4.0 (3.6, 4.3)	3.5 (3.2, 3.8)	0.01*
Notes: *p<.05, **p<.01, ***p<.001				

Neighborhood characteristics of the weighted sample are shown in Table 2. There were significant differences across neighborhood language categories in percentage of language spoken at home. Linguistically diverse neighborhoods had approximately equal percentages of English (44.2%) and Spanish (46.8%) speaking households. Linguistically diverse neighborhoods had an average language homogeneity index score of 0.44, significantly different than the language homogeneity index scores of majority English neighborhoods (0.65) and majority Spanish neighborhoods (0.69) ($p<.001$). There was also a

significant difference in the area-level economic disadvantage, calculated by the percent eligible for free/reduced lunch at the school, with majority English speaking neighborhoods having significantly less economically disadvantaged students (48.0%), compared to linguistically diverse (87.0%) and majority Spanish speaking neighborhoods (88.7%) ($p<.001$). There was no difference in population density between neighborhood language categories ($p=0.40$).

Paper 1 Table 2: Weighted neighborhood characteristics of SPAN 2nd grade children

	Total	Linguistically diverse (19.3%)	Majority English (41.9%)	Majority Spanish (38.8%)	p value
English Speaking Households	48.4 (39.5, 57.3)	44.2 (38.2, 50.2)	77.1 (72.4, 81.8)	18.7 (15.7, 21.6)	<.001 ***
Spanish Speaking Households	47.1 (37.5, 56.6)	46.8 (40.8, 52.7)	17.4 (12.2, 22.7)	80.1 (76.9, 83.3)	<.001 ***
Other Language Speaking Households	3.8 (2.4, 5.1)	5.3 (0.04, 10.5)	5.4 (3.7, 7.0)	1.2 (0.47, 2.0)	<.001 ***
Language Homogeneity (range 0-1)	0.62 (0.59, 0.66)	0.44 (0.39, 0.50)	0.65 (0.60, 0.70)	0.69 (0.65, 0.73)	<.001 ***
Eligible for free/reduced lunch	71.3 (60.6, 82.1)	87.0 (84.3, 89.7)	48.0 (30.3, 65.8)	88.7 (84.3, 93.2)	<.001 ***
Population density (population/sq. mile)	3970.5 (3212.6, 4728.3)	5135.2 (3217.8, 7052.6)	3634.6 (2131.7, 5137.4)	3746.9 (2884.1, 4609.8)	0.40
Notes: * $p<.05$, ** $p<.01$, *** $p<.001$					

Table 3 shows the predicted weekly days of outdoor play across levels of the neighborhood language homogeneity index from these. The levels of homogeneity index in the table were determined by tertiles of the sample. In analyses for Aim 1, linear regression models showed that neighborhood language homogeneity was a significant predictor of

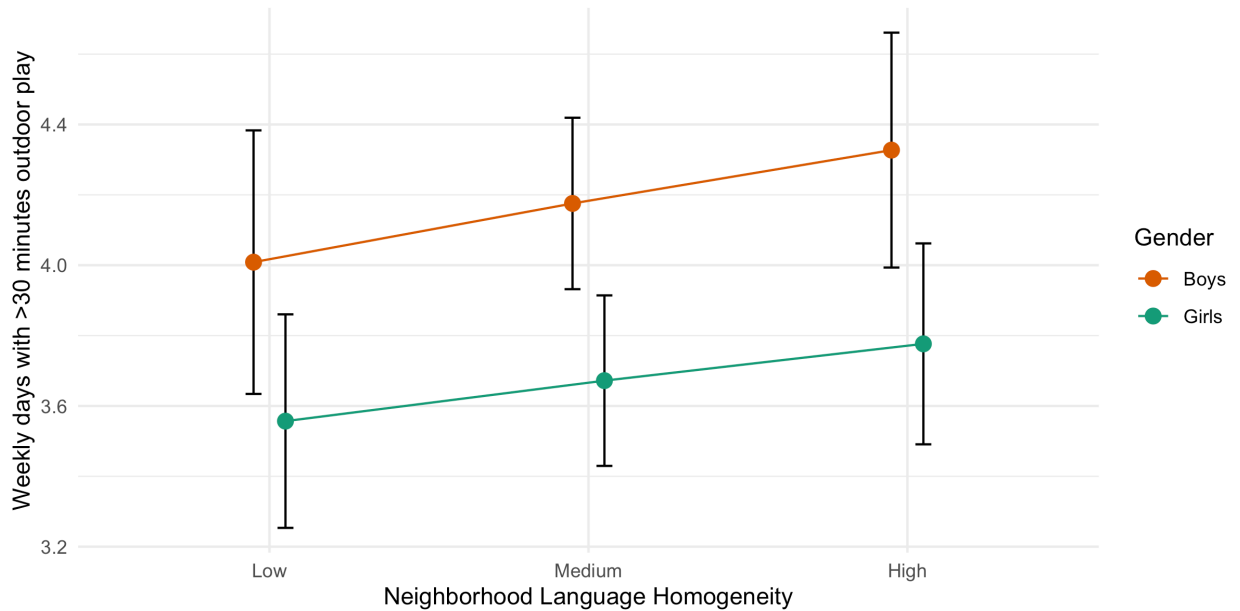
outdoor play in bivariate models (1.80 (0.74), $p=0.01$) (data not shown in tables). In multivariate models adjusted for individual and neighborhood level covariates, neighborhood language homogeneity was no longer a significant predictor of outdoor play ($p=0.15$).

Paper 1 Table 3: Linear regression models between neighborhood language homogeneity and outdoor physical activity behavior

	Predicted weekly days of outdoor play					
	Model 1 Mean (95% CI)	p value	Model 2^a Mean (95% CI)	p value	Model 3^b Mean (95% CI)	p value
Neighborhood language homogeneity index						
Low homogeneity (Index = 0.48)	3.52 (3.16, 3.87)		3.77 (3.47, 4.07)		3.79 (3.31, 4.07)	
Medium homogeneity (Index = 0.67)	3.85 (3.56, 4.15)	0.01*	3.94 (3.71, 4.16)	0.09	3.93 (3.73, 4.24)	0.15
High homogeneity (Index = 0.84)	4.16 (3.73, 4.58)		4.09 (3.81, 4.38)		4.05 (3.79, 4.32)	
Notes: * $p<.05$, ** $p<.01$, *** $p<.001$						
^a Model 2 adjusted for age, gender, race/ethnicity, perceived safety, and parental education level						
^b Model 3 adjusted for age, gender, race/ethnicity, perceived safety, parental education level, neighborhood economic disadvantage, and population density						

The interaction term for neighborhood language homogeneity and gender in the fully adjusted model was significant ($F(3, 72) = 5.67$, $p=0.001$) (data not shown in tables). Figure 1 shows the predicted values for weekly outdoor play at the three levels of the homogeneity index by gender, with stronger effects for boys than girls. There was a significant difference between days of outdoor play between boys and girls at the medium level of neighborhood language homogeneity ($p<0.05$), with 4.1 days (95% CI 4.9, 4.4) of outdoor play per week for boys, compared to 3.7 days (95% CI 3.4, 3.9).

Paper 1 Figure 1: Interaction plot of neighborhood language homogeneity and outdoor play
by gender

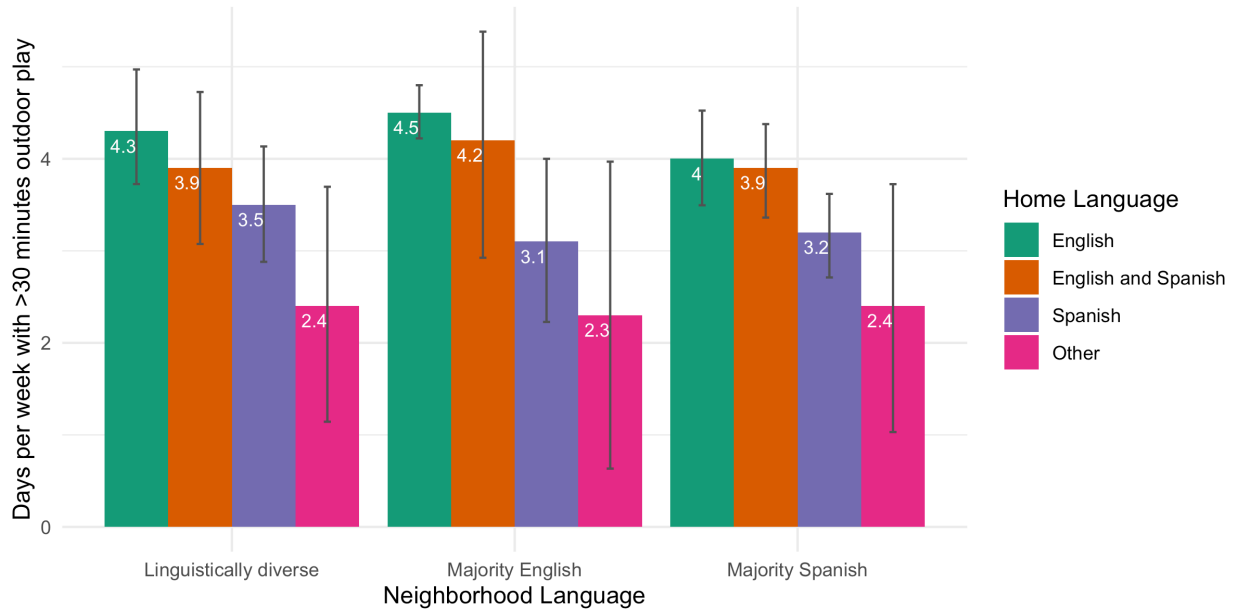


In analyses for Aim 3, fully adjusted main effects models showed a significant association between neighborhood majority language and outdoor play ($p < 0.05$), with children living in majority English-speaking neighborhoods having significantly higher predicted mean days of outdoor play (4.2 days, 95% CI 3.8, 4.6) than children living in majority Spanish-speaking neighborhoods (3.5 days, 95% CI 3.2, 3.8). Children living in linguistically diverse neighborhoods had an average of 3.9 (95% CI 3.5, 4.4) predicted days of outdoor play.

In models assessing the interaction between neighborhood majority language and language spoken at home, the interaction term was significant ($F(11, 63) = 7.54, p < 0.001$). Figure 2 presents the predicted mean days per week of outdoor play for the neighborhood majority language by language spoken at home. There was a significant difference in the

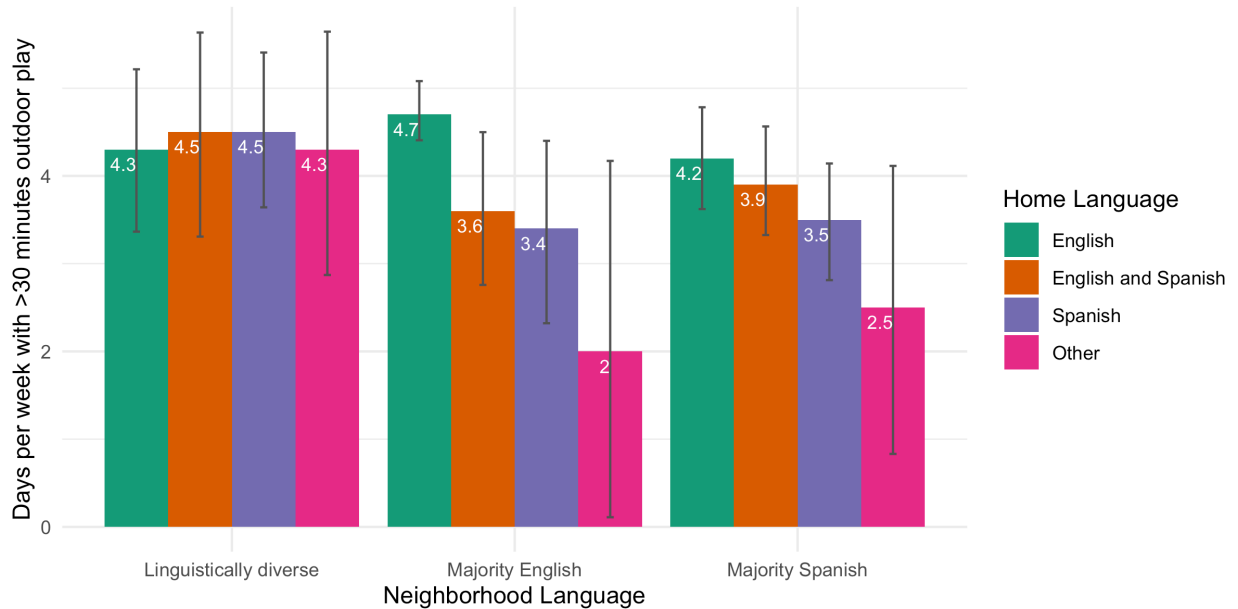
predicted days of outdoor play by language spoken at home in linguistically diverse neighborhoods between children who speak English (4.3 days, 95% CI 3.7, 5.0) and children who speak languages other than English or Spanish at home (2.4 days, 95% CI 1.1, 3.6). There were significant differences in predicted days of outdoor play in majority English speaking neighborhoods between children who speak English (4.5 days, 95% CI 4.2, 4.8), and children who speak Spanish at home (3.1 days, 95% CI 2.2, 4.0) and children who speak languages other than English or Spanish at home (2.3 days, 95% CI 0.6, 3.9). There were no significant differences in days of outdoor play between languages spoken at home for children living in majority Spanish speaking neighborhoods.

Paper 1 Figure 2: Children's predicted outdoor play for interaction of neighborhood language and language spoken at home



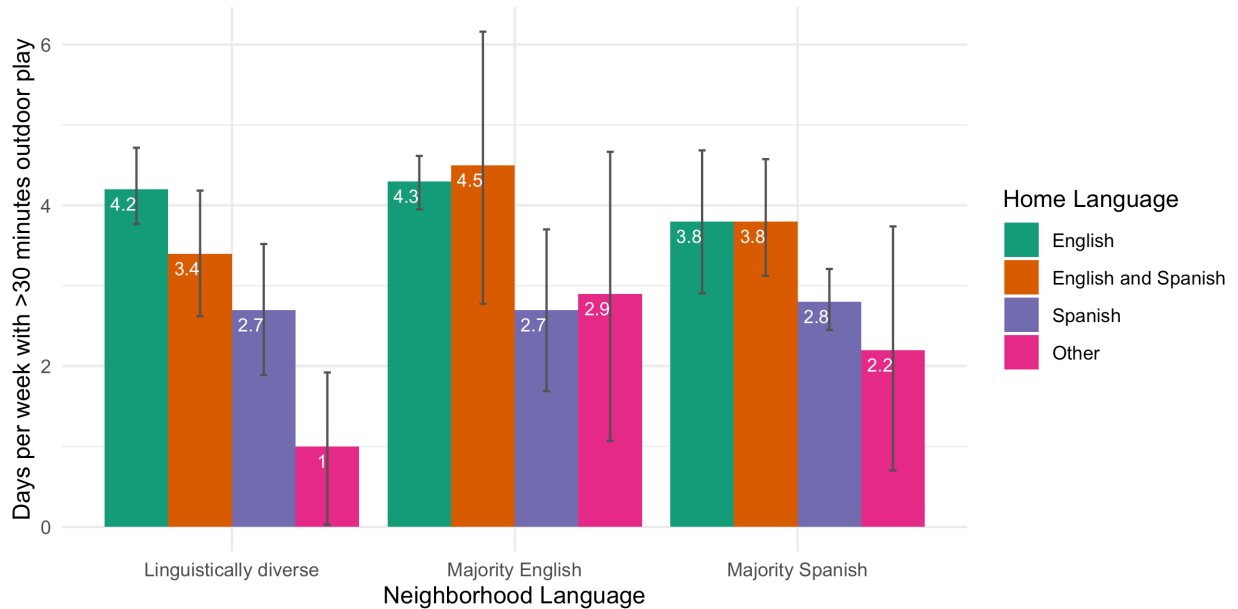
In fully adjusted models stratified by sex, the interaction of neighborhood majority language and language spoken at home was significant for boys ($F(11, 65) = 2.84, p=0.004$). Predicted days of outdoor play for boys for each neighborhood majority language across categories of language spoken at home are shown in Figure 3. There were no significant differences across categories of language spoken at home for boys living in linguistically diverse neighborhoods. In majority English speaking neighborhoods, boys who speak English at home had significantly higher days of outdoor play (4.7 days, 95% CI 4.4, 5.1) than boys who speak Spanish at home (3.4 days, 95% CI 2.3, 4.4) and boys who speak languages other than English and Spanish at home (2.0 days, 95% CI 0.1, 4.1).

Paper 1 Figure 3: **Boys'** predicted outdoor play for interaction of neighborhood language and language spoken at home



In girls, the interaction between neighborhood majority language and language spoken at home was significant in the fully adjusted model ($F(11, 65) = 8.72, p < .001$), and predicted days of outdoor play for the interaction are shown in Figure 4. In linguistically diverse neighborhoods, girls who speak English at home had significantly higher predicted mean days of outdoor play (4.2 days, 95% CI 3.8, 4.7) than girls who speak Spanish at home (2.7 days, 95% CI 1.9, 3.5) and girls who speak languages other than English and Spanish at home (1.0 day, 96% CI 0.3, 1.9). In majority English speaking neighborhoods, there was a significant difference in the predicted mean days of outdoor play between girls who speak English at home (4.3 days, 95% CI 3.9, 4.6) and girls who speak Spanish at home (2.7 days, 95% CI 1.7, 3.7). There were no significant differences in days of outdoor play across languages spoken at home in majority Spanish speaking neighborhoods.

Paper 1 Figure 4: **Girls'** predicted outdoor play for interaction of neighborhood language and language spoken at home



Discussion

This study examined the associations between neighborhood and individual level language social cohesion and outdoor play among a representative sample of Texas children, and several key findings emerged. Children living in majority Spanish speaking neighborhoods had significantly less days per week of outdoor play compared to majority English speaking neighborhoods. There were no differences in outdoor play by language spoken at home for boys or girls in Spanish speaking neighborhoods. In English speaking neighborhoods boys and girls who speak Spanish at home had significantly less days of outdoor play than children who speak English at home. In linguistically diverse neighborhoods, girls who speak English at home had significantly more days of outdoor play than girls who speak Spanish or other languages at home.

Aim 1 of this study was to assess the association between neighborhood language social cohesion, operationalized with a neighborhood language homogeneity index, and outdoor play. Contrary to this study's hypothesis, there was not a significant association between neighborhood language homogeneity and outdoor play in children (after adjusting for covariates). However, language homogeneity may influence outdoor play and physical activity differently in English speaking neighborhoods as compared to neighborhoods speaking other languages. Previous research has found that residents of Hispanic, Spanish-speaking enclaves have higher levels of physical inactivity compared to Hispanic residents of diverse neighborhoods, suggesting that social norms around physical activity within neighborhoods has the potential to influence behavior.⁴⁷ However, language homogeneity and outdoor play may have a different association in English-speaking neighborhoods, where there are higher levels of outdoor play in children as the percentage of English-speaking households increases.⁴⁸ Future research should examine the language homogeneity and outdoor play by majority neighborhood language to assess this potential differential association.

This study found a significant relationship between neighborhood language composition and outdoor play, with majority English speaking neighborhoods having higher average levels of weekly outdoor play than Spanish speaking. This finding is consistent with previous research, which has found that physical activity levels are lower for Hispanics living in immigrant enclave neighborhoods, where there are higher proportions of Spanish-speaking households, than Hispanics not living in such neighborhoods.⁴⁷ Similarly, this finding is consistent with previous outdoor play literature, where language spoken at home was

associated with outdoor play in children, with those speaking Spanish at home having lower levels of outdoor play than children speaking other languages.⁴⁹ Springer et al. proposed three potential social mechanisms explaining why language use can influence physical activity behaviors: exclusion from social participation, communication barriers, and socioeconomic status.⁵⁰ Social opportunities, such as someone to play outdoors with, has been shown to predict time spent outdoors,⁵¹ and if a child is living in a neighborhood where he or she is in the minority language group, parents of the children may be less likely to form social connections with other parents to create social opportunities for play. This may partially explain the results seen in the interaction models between home language and neighborhood language in majority English speaking neighborhoods, where Spanish and other language speaking children had lower levels of outdoor play.

This study also found differences in the association between language social cohesion and outdoor play for boys and girls, indicating that language and culture may function differently on neighborhood physical activity and outdoor play across genders. Levels of independent mobility, the ability for a child to move unsupervised by an adult through the neighborhood, differ between boys and girls, with boys having greater independent mobility, which has been shown to be associated with higher levels of outdoor play.⁵² When levels of independent mobility are low, there is a dependence on an adult to supervise or be available to take the child to a space to play.⁵³ Previous research has found that Hispanic children experience greater restrictions on independent mobility than non-Hispanic children, leading to the lack of adult supervision as a barrier to outdoor play, especially for Hispanic girls.²⁵ Higher perceived neighborhood social cohesion is associated with greater independent

mobility, leading to the potential that independent mobility is a mediator of the association between neighborhood language social cohesion and outdoor play.^{54,55}

While this study attempted to control for neighborhood and individual socioeconomic status using school-level economic disadvantage and individual-level educational attainment in analyses, there is still the potential that socioeconomic status played a role in explaining the findings between language social cohesion and outdoor play. In this study, linguistically diverse and predominately Spanish-speaking neighborhoods had higher levels of socioeconomic disadvantage than predominately English-speaking neighborhoods. Previous research by Richmond et al⁵⁶ has found that lower physical activity levels, especially in girls, were mainly attributable to the area level socioeconomic status of the schools they attended. There are several potential mechanisms by which area level economic disadvantage could affect outdoor play. First, parents of differing socioeconomic statuses may perceive neighborhood safety differently. Previous research has found that mothers in low socioeconomic status neighborhoods are primarily worried about crime, abandoned lots, and strangers, while mothers in high socioeconomic status were mostly concerned about strangers, leading to the potential that the majority Spanish speaking neighborhoods in this study face additional barriers to safety beyond what could be addressed through language social cohesion and social connections in the neighborhood.⁵⁷ Additionally, parents in low income neighborhoods have reported a lack of close social ties with neighbors that affects outdoor play of their children, and a lack of time to establish such relationships, while parents in high income areas report having more relationships with neighbors.⁵⁷ Indeed, those with low socioeconomic status often face the double burden of being income poor and time

poor due to potentially working multiple jobs, leading to less free time to engage in physical activity themselves a model for their children, or be available to supervise outdoor play.^{58,59}

Neighborhood segregation and socioeconomic status are closely tied, and neighborhood segregation between US born and foreign-born population has increased by two-thirds from 1960 to 2000.⁶⁰ Residential patterns of immigrants indicate that initially, immigrants tend to reside in segregated areas in urban cities for cultural reasons, such as developing social network and sense of belonging.⁶¹ As the proportion of the non-White population increased in the United States, the spatial patterns of ethnic segregation has changed, partly due to gentrification and rising housing prices in major metropolitan areas.⁶² These ethnic minority neighborhoods tend to be lower socioeconomic status than ethnic majority neighborhoods.⁶³ Residential trends have the potential to influence the social and physical environments that influence physical activity and outdoor play among the children who reside in these different neighborhoods. This study showed that linguistically segregated neighborhoods have different patterns of outdoor play based on language spoken at home, with the most striking disparity between non-English speaking households in majority English neighborhoods, suggesting that a lack of social inclusion for minorities in these neighborhoods may be responsible for lower levels of outdoor play.

Limitations

Despite the strengths of this study, there are limitations to note. First, the cross sectional nature of the study design does not allow for causal inferences to be made, limiting the findings of the influence of shared language on outdoor play behavior. Additionally, the neighborhood language composition used the elementary school as the buffer center. The

attendance zone for elementary schools are defined as the “geographic area from which the students are eligible to attend a local school.”⁶⁴ Some students may attend schools with open attendance and may reside outside the geographic area directly surrounding the school, and thus, may not live within the catchment area used in this study. Also, the proportion of language use was aggregated from the U.S. Census tract block group, the smallest unit of analysis provided by the Census bureau. However, even within the school catchment area, there can be significant diversity in terms of language use, leading the possibility that the proportions of language use within the school catchment area may not be representative of the language use in the child’s home neighborhood. Future research should assess neighborhood language social cohesion and outdoor play using the home neighborhood as the spatial unit of analysis. Another limitation is that though a neighborhood may predominately speak Spanish, this study did not include measures of English proficiency in Spanish speakers.

Conclusion

This study found that language social cohesion is associated with outdoor play, and the association differs for boys and girls. These findings contribute to the body of literature on social cohesion and physical activity in several ways, and have implications for both intervention and policy in public health and urban planning. First, the study design allowed for outdoor play estimates based on a representative sample of Texas students, an ethnically diverse state. Additionally, this study provides the first evidence for the association between language social cohesion and outdoor play, a topic of great importance due to the declining trend of outdoor play in children and the increasing trend of neighborhood ethnic and

linguistic segregation. These findings can influence the development of strategies to increase outdoor play. One intervention strategy is the provision of safe spaces to be physically active outdoors, while increase parental self-efficacy in allowing their children to be independently physically active. Given the potential social exclusion and lack of communication that Spanish-speaking parents may face, campaigns in Spanish that address negative stigmas of allowing children to play unsupervised may be helpful, especially in income poor and time poor areas. Additionally, providing settings for social connections to be formed among neighbors in all neighborhood types can build social cohesion. Previous research has suggested that initiatives to pull together groups of children may provide opportunities to build social norms and providing safe neighborhood routes can facilitate additional interaction among peers and their parents.⁵³ To promote outdoor play among children, parental concerns in all neighborhoods must be addressed, but especially among Spanish speaking households and other language speaking households, given findings of lower physical activity in these linguistically defined neighborhoods.

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JOURNAL ARTICLE 2

The Interaction of Social Cohesion and the Built Environment on Out of School Time Physical Activity among Adolescents

Introduction

Physical activity provides many short and long-term benefits in adolescents including improving cardiovascular fitness, controlling weight, reducing symptoms of anxiety and depression, strengthening bones, and reducing risk for chronic disease in adulthood.^{1,2} Additionally, physical activity habits in adolescence track into adulthood and are associated with adult physical activity behavior.^{3,4} In the United States, 46.5% of adolescents ages 13 to 18 years old were physically active for at least 60 minutes per day for at least five days per week, meeting recommended physical activity guidelines; however, more male adolescents met guidelines (56.9%) than females (36.8%).⁵ Adolescence is a critical period for understanding physical activity behavior because of the decline in physical activity levels during this life stage. In 2017, roughly in five adolescents (18.7%) in the U.S. reported they were not physically active for at least 60 minutes on at least 1 day the past week compared to 10.5% of 9th grade students.^{5,6} Even though adolescents spend the majority of their day in school, the majority of accumulated physical activity occurs outside the school day.^{7,8}

Physical activity behavior in adolescents is influenced by many factors, including physiologic, developmental, demographic, psychological, social, and environmental factors; in practice, however, it can difficult to isolate singular influences from these areas due to their interactions.^{9,10} The social environment is one environmental factor that has the potential to affect physical activity, and it does so through several mechanisms: interpersonal

factors like social support and social networks, social inequalities such as socioeconomic position, income inequality, and racial discrimination, and neighborhood and community factors including social cohesion.¹¹ Social cohesion is “a state of affairs concerning both the vertical and the horizontal interactions among members of society as characterized by a set of attitudes and norms that includes trust, a sense of belonging and the willingness to participate and help, as well as their behavioral manifestations.”¹² Social cohesion is typically assessed using measures of collective socialization or collective socialization, and cohesive neighborhoods have the ability to influence behavior by valuing shared goals.¹¹ One aspect of social cohesion is collective socialization, which is the ability of a network of adults in a neighborhood or community who have made social connections to watch out for each other’s children.¹³ Collective socialization can also influence behavior by shaping the types of role models that children are exposed to in their communities.¹⁴ Neighborhood disorder is another dimension of social cohesion, and it refers to people and their behavioral manifestations, such as litter on the streets, crime, graffiti, or drug dealing, that exemplify a lack of social control and cohesion.¹⁵

Social cohesion has the potential to influence physical activity behavior through several mechanisms, including through social influence and by constraining or enabling behavior.¹⁶ Social influence is the “either real or imagined pressure to change one's behavior, attitudes or beliefs,” and socially cohesive neighborhoods where residents feel a sense of belonging may be more susceptible to social influence for positive health behaviors, such as physical activity.^{17,18} Additionally, social cohesion can influence physical activity by

constraining or enabling the behavior through perceptions of safety, as neighborhood safety has been shown to be a barrier to physical activity.^{19,20}

Previous research assessing social cohesion and physical activity in adolescents, as well as other life stages, has shown consistent results across contexts of physical activity, with higher social cohesion being associated with higher physical activity.²¹⁻²³ One recent study assessed objectively measured physical activity over time in a sample of adolescents aged 11-15 years and found that parent reported neighborhood social cohesion was associated with both weekday and weekend physical activity.²⁴ Similarly, in a large and ethnically diverse sample of adolescents, neighborhood social cohesion was associated with higher odds of outdoor physical activity.²⁵

The built environment, which “comprises urban design, land use, and the transportation system, and encompasses patterns of human activity within the physical environment,” is another environmental factor that has the potential to influence physical activity behavior.²⁶ Previous research, including a 2011 systematic review on 103 papers, on built environment and physical activity in youth and adolescents provides evidence of the effects of built environment features including play facilities, parks, features that facilitate walking, land use mix and density on physical activity behavior.^{27,28} However, the results from these studies varied depending on the type of built environment variables used, with more significant associations between objective built environment variables and physical activity.²⁹ Selected aspects of the built environment have been found to affect the degree to which neighborhoods and communities are deemed to be safe, comfortable, and attractive places to be physically active,³⁰ and because social cohesion is characterized by a sense of

trust, safety, and reciprocity within groups, the built environment has the potential to affect social cohesion.³¹ The social and physical environments are interrelated, and the behaviors and social interactions of humans are related to the features of the built environment, such that certain neighborhoods design have the potential to encourage or facilitate social interactions and ties.³²

While previous research has examined the effect of the built environment on social cohesion,^{31,33} and the effect of social cohesion on physical activity (i.e. a mediated pathway between the built environment and physical activity),^{21,34} this research will look at the built environment as a potential moderator between the association of social cohesion and physical activity. The contextual effect of the built environment has the potential to influence the effect of social cohesion on physical activity, as social cohesion may play a more central role in perceptions of safety that drive physical activity behavior in neighborhoods with unsupportive built environments.³⁵ Additionally, social cohesion is potentially a more modifiable correlate of physical activity than the built environment, as built environment interventions are costly, so it is valuable to assess the main effects of social cohesion and the potential moderation by the built environment, rather than as a mediator.³⁶ To date, there has been little research on the interactions between social cohesion and the built environment, and its influence on physical activity behavior, and no known literature examining this relationship in adolescent populations.^{37,38} The objective of this paper was to determine whether built environment features moderate the relationship between neighborhood social cohesion and out-of-school time physical activity in a sample of adolescents ages 12-17.

Specific Aims

- **Aim 1:** To determine the association between neighborhood social cohesion and weekly minutes of out-of-school time moderate-to-vigorous physical activity (MVPA) in a sample of U.S. adolescents aged 12-17.
 - **Hypothesis:** Higher reported levels of neighborhood social cohesion will be significantly associated with higher mean minutes of weekly out-of-school time MVPA.
- **Aim 2:** To examine differences in the association of neighborhood social cohesion and out-of-school time MVPA in adolescents by built environment features.
 - **Hypothesis:** The association between neighborhood social cohesion and out-of-school time MVPA will vary significantly by built environment features, with stronger effects for neighborhoods with unsupportive built environment features for physical activity.
- **Aim 3:** To assess whether the relations between the built environment, neighborhood social cohesion, and out-of-school-time MVPA vary by sex of the adolescent.

Methods

This cross-sectional study used data from the Family Life, Activity, Sun, Health, and Eating (FLASHE) Study, a study conducted by the National Cancer Institute to assess generational and environmental influences on preventative health behaviors during adolescence.³⁹ The web-based study recruited 1,479 dyads of parents and their children between the ages of 12 and 17 years who completed all study procedures (overall study response rate=29.4%). Households were eligible if an adolescent between the ages of 12-17

years who lived in the house at least 50% of the time, and if there was more than one eligible adolescent in the household, one was randomly selected to participant. Each parent and adolescent completed two surveys between April and October 2014.⁴⁰ FLASHE data collection materials and procedures were approved by the U.S. Government's Office of Management and Budget (OMB), NCI's Special Studies Institutional Review Board (SSIRB), and Westat's Institutional Review Board (IRB). These data are de-identified and publicly available through the National Cancer Institute. In addition, this dissertation research will be submitted for review by the Committee for the Protection of Human Subjects at the UTHealth School of Public Health.

The main outcome for this study was *daily minutes of out-of-school time MVPA* in the adolescent participants. Adolescent physical activity was measured using the self-report Youth Activity Profile (YAP), which consists of 15 items that assess in-school MVPA, out-of-school time MVPA, and out-of-school time sedentary behavior.⁴¹ The YAP was calibrated and validated using a randomly selected sub-sample of adolescents from the FLASHE study (n=628) that wore accelerometers (GT3X+ ActiGraph) on the dominant wrist for seven days and also completed the YAP.⁴² Estimates of MVPA from the YAP were within 10-20% of the values derived from the objective accelerometer values. For analyses, daily minutes of out of school time MVPA will be treated as a continuous variable.

For the current study, the built environment variables came from GeoFLASHE, a set of neighborhood and contextual variables based on participants' home and school locations that linked to other FLASHE variables.⁴³ Geocoded residential points were developed from the home addresses for each participant dyad, were supplemented from the following

questions in the demographic section of the questionnaire: “Can you tell me just the name of the street/road you live on?” and “What is the name of the nearest cross street/road?” Both Euclidean and network buffers were developed at various radii between 400 meters and 1200 meters to characterize the walkability of neighborhoods through a principal component analysis (PCA) using data from 13 variables from the 2010 U.S Decennial Census and the 2010-2014 American Community Survey.^{44,45}

GeoFLASHE followed the method presented by Hoehner et al., and extracted three factors, which will be used as the primary built environment variables in this study: *high density, older neighborhoods, and short commutes*.⁴⁶ Population density is a widely used measure of the built environment and is defined as the amount of activity, or population, in a given area, and has implications for physical activity behavior due to its association with mixed use development.²⁶ The older neighborhoods variable was a proxy measure for neighborhood design and connectivity because median home age is associated with more dense street connectivity and more pedestrian-oriented streets.⁴⁷ The short commutes variable represented land use mix and level of urbanization, and is included as an independent variable due to the association between land mix use and high urbanization with physical activity.^{26,48} The three built environment variables were combined into a composite supportive built environment score, and dichotomized into high support and low support categories.

Two dimensions of neighborhood social cohesion were assessed: *collective socialization* and *neighborhood disorder*. Collective socialization was measured in the FLASHE study using two items asking parents to rate their agreement on a four point Likert

scale for the following statements: “People in this neighborhood help each other out,” and “We watch out for each other’s children in the neighborhood.” Neighborhood disorder will be measured using responses to the following items: “There is litter or garbage on the streets or sidewalks in my neighborhood,” and “The crime rate in my neighborhood makes it unsafe to go on walks at night.” Crime rates have been shown to be indirectly associated with both levels of social cohesion in neighborhoods and physical activity behavior of adolescents, and is a component of neighborhood disorder.^{49,50} The survey questions were originally developed and validated by Sampson et al⁵¹ to study the influence of collective efficacy and violent crime. Collective socialization was a sum score of the first two items listed above, and dichotomized into low and high categories. Neighborhood disorder was the sum score of the second two items, and treated as a separate variable in the same manner.

The following variables were used as covariates in the analyses due to their associations with adolescent physical activity: *child age*, *child race/ethnicity*, *parental educational attainment* as a proxy for individual level socioeconomic status, and *percent living below the poverty level* as a neighborhood level measure of economic disadvantage.^{52,53} For neighborhood disadvantage, GeoFLASHE used the percent of the population with annual incomes that were below the federal poverty level from Census American Community Survey 2010-2014 data, rounded to the nearest whole percent, within the buffer distance.

Statistical Analysis

Descriptive statistics were run on the characteristics of adolescent participants. Results are presented by sex, and significant differences between male and female

participants were determined using independent samples t-tests for continuous variables and chi-square tests for categorical variables. A bivariate linear regression model was used to determine association between social cohesion variables and minutes of out-of-school time MVPA. Multiple linear regression models were used to assess the association of the two social cohesion variables and minutes of out of school time MVPA with the inclusion of all covariates. These main effects models were also stratified by sex.

To assess interaction between social cohesion and built environment, the composite built environment score was run in interaction models (unadjusted and adjusted) with each social cohesion variable separately, with likelihood ratio tests to assess statistical significance. Finally, the fully adjusted interaction models were stratified by adolescent sex to assess whether these relationships vary by sex. Statistical analyses will be conducted using Stata statistical software (College Station, TX, v14.2). Statistical significance was set at $p < .05$.

Results

The final analytic sample was 1,347 participants, and Table 1 provides a summary of the sample characteristics by sex, as well as the distribution of the social cohesion and built environment variables and the average minutes of MVPA. There were no significant differences between male and female participants in any of the sample characteristics or in the distributions of social cohesion or built environment variables.

Paper 2 Table 1: FLASHE Study Teen Participant Characteristics and Frequency of Independent and Dependent Variables by Participant Sex

	Total (N= 1347) N (%)	Male (n=657) N (%)	Female (n=690) N (%)	p value
Age				
12 - 14 years	675 (50.1)	320 (48.7)	355 (51.5)	0.31
15 - 17 years	672 (49.9)	337 (51.3)	335 (48.5)	
Race/Ethnicity				
Hispanic	141 (10.5)	70 (10.7)	71 (10.3)	0.45
Black/African American only	224 (16.6)	118 (17.9)	117 (15.4)	
White only	866 (64.3)	409 (62.3)	488 (66.2)	
Other	116 (8.6)	60 (9.1)	64 (8.1)	
Parental Educational Attainment				
Less than a high school degree	19 (1.4)	12 (1.8)	7 (1.0)	0.50
High school degree/GED	237 (17.6)	117 (17.9)	120 (17.5)	
Some college	468 (34.9)	220 (33.5)	248 (36.1)	
Bachelor's degree or above	619 (46.1)	307 (46.8)	312 (45.4)	
Neighborhood Built Environment				
Low support	765 (56.8)	368 (56.0)	397 (57.5)	0.58
High support	582 (43.2)	289 (44.0)	293 (42.5)	
Collective Socialization				
Low	949 (70.5)	475 (72.3)	474 (68.7)	0.15
High	398 (29.6)	182 (27.7)	216 (31.3)	
Neighborhood Disorder				
Low	727 (54.1)	343 (52.3)	384 (55.7)	0.21
High	618 (45.9)	313 (47.7)	305 (44.3)	
Daily Minutes of Out of School time MVPA^a	57.9 (10.5)	58.1 (10.7)	57.7 (10.4)	0.55
Notes: ^a , presented as mean (standard deviation)				
Bold indicates p<0.05				

Table 2 presents the results from the main effects models as predicted mean daily minutes of out of school time MVPA for adolescents from linear regression models with social cohesion variables as predictor variables for the full sample and stratified by sex. The

first column includes unadjusted estimates, and collective socialization was directly associated with physical activity, with adolescents having high levels of neighborhood collective socialization having higher reported physical activity than low levels in both unadjusted and adjusted models ($p=0.03$ and $p<.001$, respectively). When stratified by sex, collective socialization was only associated with physical activity in male adolescents, and males with high neighborhood collective socialization having an average of 59.8 minutes of daily out of school time MVPA compared to 57.4 minutes for males with low neighborhood collective socialization ($p=0.01$). Neighborhood disorder was not significantly associated with physical activity.

Paper 2 Table 2: Linear Regression Predicted Mean Daily Minutes of Out-of-School Time MVPA

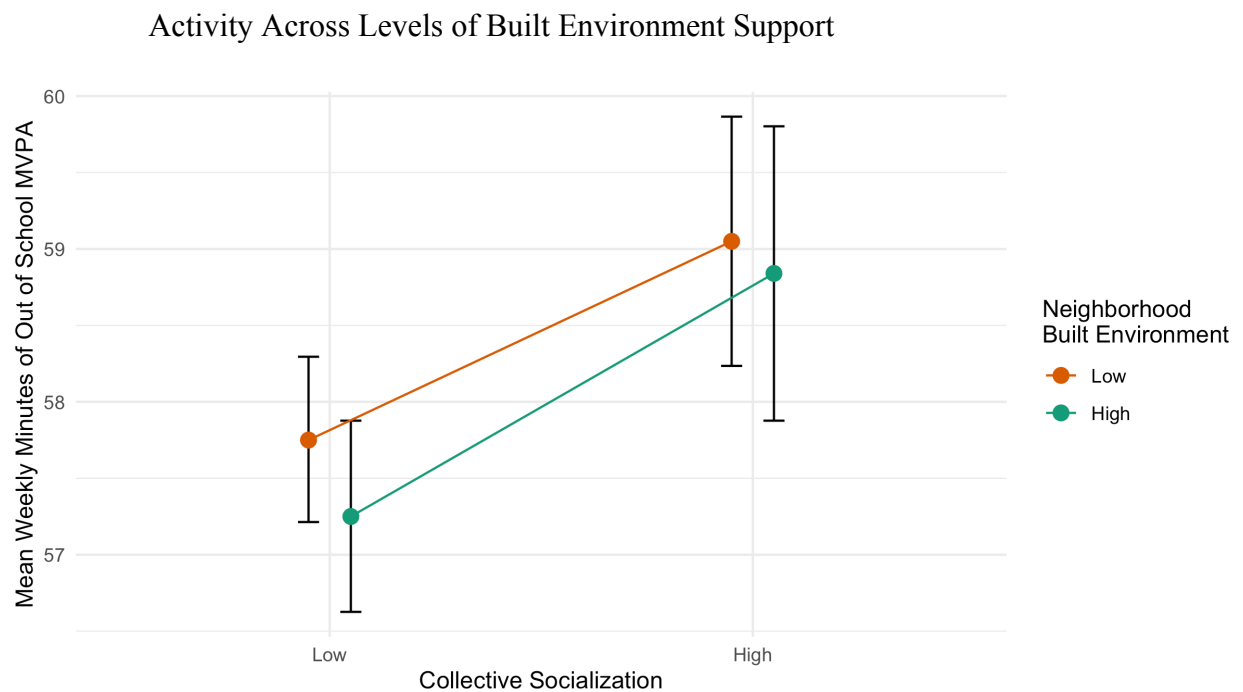
	Unadjusted models Minutes of MVPA (95% CI)	p value	Adjusted models ^a Minutes of MVPA (95% CI)	p value
Full Sample				
Collective socialization				
Low	57.5 (56.8, 58.2)	0.03	57.5 (57.2, 57.9)	< 0.001
High	58.9 (57.9, 59.9)		58.9 (58.3, 59.5)	
Neighborhood disorder				
Low	57.6 (56.8, 58.4)	0.25	58.3 (57.8, 58.7)	0.03
High	58.3 (57.4, 59.1)		57.4 (57.0, 57.8)	
Males				
Collective socialization				
Low	57.4 (56.5, 58.4)	0.01	57.5 (57.0, 58.1)	< 0.001
High	59.8 (58.3, 61.4)		59.6 (58.7, 60.5)	
Neighborhood disorder				
Low	57.8 (56.7, 58.9)	0.44	58.6 (58.0, 59.3)	0.04
High	58.4 (57.2, 59.6)		57.5 (56.3, 58.2)	
Females				
Collective socialization				
Low	57.6 (56.7, 58.5)	0.53	57.5 (56.9, 58.1)	0.10
High	58.1 (56.7, 59.5)		58.4 (57.5, 59.2)	
Neighborhood disorder				
Low	57.4 (56.4, 58.5)	0.40	58.0 (57.4, 58.7)	0.24
High	58.1 (56.9, 59.3)		57.4 (56.7, 58.2)	
Notes: ^a , adjusted for age, race/ethnicity, education attainment, and neighborhood disadvantage Bold indicates p<.05				

Next, multiple linear regression models were run with interaction terms. In the full sample, the interaction term of collective socialization and built environment was significant ($p= 0.001$), and Figure 1 shows the predicted daily mean minutes of out of school physical activity by level of built environment support. Adolescents with low levels of collective socialization living in neighborhoods with low support built environments had an average of 57.8 daily minutes of out of school time MVPA compared to 58.8 daily minutes for

adolescents with high collective socialization and low support built environments.

Adolescents with low levels of collective socialization living in neighborhoods with high support built environments had an average of 57.3 daily minutes of out of school time MVPA compared to 58.8 daily minutes for adolescents with high collective socialization and high support built environments. The interaction term of disorder and built environment was not significant in the full sample.

Paper 2 Figure 1: Association of Collective Socialization and Out of School Physical

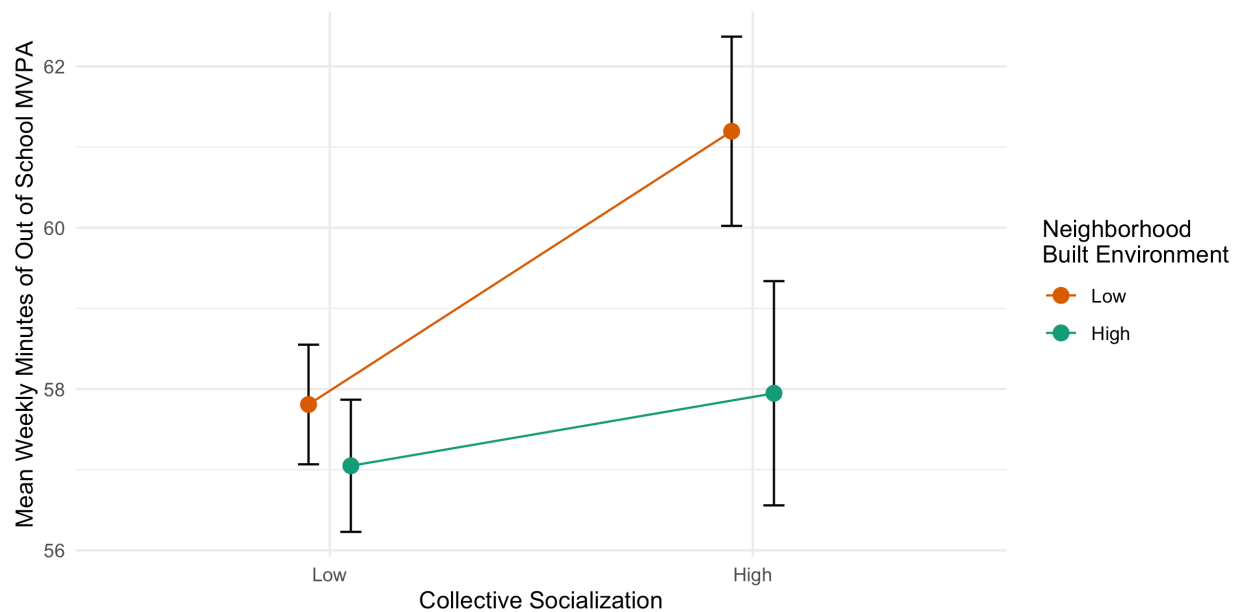


In the stratified analyses, the interaction term of collective socialization and built environment was significant among males ($p = 0.002$), and predicted means across levels of trust and built environment are shown in Figure 2. Male adolescents with low levels of collective socialization living in neighborhoods with low support built environments had an average of 57.8 daily minutes of out of school time MVPA compared to 61.2 daily minutes for adolescents with high collective socialization and low support built environments.

Adolescents with low levels of collective socialization living in neighborhoods with high support built environments had an average of 57.0 daily minutes of out of school time MVPA compared to 57.9 daily minutes for adolescents with high collective socialization and high support built environments. The interaction term of disorder and built environment was not significant among males. There were no significant interactions for either collective socialization or disorder among females.

Paper 2 Figure 2: Association of Collective Socialization and Out of School Physical

Activity Across Levels of Built Environment Support in Males



Discussion

This study assessed the association between neighborhood social cohesion and adolescent physical activity, and whether the association varied based on characteristics of built environment. Using a cross sectional dataset, three aims were assessed. First, it was hypothesized that higher reported levels of neighborhood social cohesion would be

significantly associated with higher mean minutes of daily out-of-school time MVPA. This study supported the hypothesis, as one facet of social cohesion, collective socialization, was directly associated with physical activity. High levels of collective socialization have been consistently linked to higher levels of physical activity in youth and adolescents.^{21,34,54} While the mechanisms of how social cohesion influences physical activity in adults are mostly related to social isolation and the provision of social support related to physical activity, it is also hypothesized that parental perceptions of safety play a role for adolescents.^{55,56} De Jesus and colleagues found that adults who reported high levels of social cohesion also perceived their neighborhood as safer compared to adults who reported low levels of social cohesion.³⁵ Given the influence of parents on adolescent physical activity, parents who perceive their neighborhood as more socially cohesive, and therefore safe, may be more likely to encourage, support, or allow out of school time physical activity for their adolescents.⁵⁷

In the stratified analyses, collective socialization was associated with physical activity in males, but not females. Previous research has also found gender-based differences in social environment influences on perceived safety, outdoor play, physical activity, and active travel.⁵⁸ Several mechanisms for these differences have been proposed, including that males and females perceive environments differently, and that vulnerability to aspects of the environment differ between males and females.⁵⁹ In adolescents, males tend to have higher levels of outdoor physical activity than females, and therefore, collective socialization in the neighborhood is more likely to influence physical activity in this context.⁶⁰ Similarly, adolescent males also have higher levels of independent mobility, and adolescents with parents who perceive their neighborhood as socially cohesive have higher numbers of

independently mobile trips.^{61,62} Additionally, previous research has shown that adolescent girls tend to perceive fewer opportunities to participate in sports clubs or teams and to play outside, indicating that collective socialization may not influence their physical activity behavior.⁶³

This study theorized that the association between neighborhood social cohesion and out of school time MVPA would vary significantly by built environment features, with stronger effects for neighborhoods with unsupportive built environment features for physical activity. Results from this study supported the hypothesis, and showed a significant interaction between perceived neighborhood trust and built environment features, especially in the stratified analysis among males. Social cohesion allows for more efficient use of existing physical activity opportunities and resources, which can diminish the effects of less supportive built environments on physical activity.²¹

Limitations

There were several limitations from this study to be acknowledged. The FLASHE study had a cross sectional design, and therefore, assumptions of causality from findings from this study are precluded. FLASHE was a web-based study with a response rate of 29%, leading to limitations to the generalizability of this study. Additionally, research questions that involve place risk the bias of self-selection of individual and families who are physically active into neighborhoods that have supportive built and social environments for physical activity. Another potential limitation for this study is that the independent variables that characterize the neighborhood built environment by using Census data may not capture all the features of the built environment that are important for physical activity, including micro

scale attributes, which have been shown to be associated with physical activity across multiple age groups.⁶⁴ Additionally, the physical activity measure used in the FLASHE study was self-report. Though the instrument was validated against an objective device-based measure of physical activity, estimates from self-report are typically higher than physical activity estimates from devices.⁶⁵

Despite these limitations, this study adds several important contributions, including the use of objective measures of the built environment, a large dyadic sample, and providing some of the first evidence for the interaction of social cohesion and built environment in adolescents. Findings from this study can be used in the development of programs and interventions to increase physical activity among adolescents. Interventions, such as neighborhood based group physical activity, can be effective for increasing adolescent physical activity while also having the potential to increase neighborhood social cohesion. Such programs could be effective in both supportive and unsupportive built environments.⁶⁶

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JOURNAL ARTICLE 3

Network Social Capital and Adult Physical Activity Trajectories: A Longitudinal Analysis

Background

Physical inactivity is a significant contributor to the burden of disease worldwide, with 9% of premature deaths and 6-10% of several major non-communicable diseases including cardiovascular disease, diabetes, and some cancers attributable to physical inactivity.¹ Despite these risks of adverse health outcomes, 31% of adults globally over the age of 18 years had insufficient amounts of physical activity in 2016. Prevalence of physical activity was lower in higher income countries, such as the United States and Canada.²

Ecological models of health behavior take a comprehensive approach to the determinants of physical activity behavior, including interactions of individuals with their social environment as contributors to physical inactivity.³ In the adapted ecological model of the determinants of physical activity from Bauman et al.,³ the social environment and social support are both included as determinants of physical activity throughout the life course. The social environment influences individuals by affecting social norms, determining environmental opportunities to engage in behaviors, provision of social support, social engagement, access to information and material resources, greater sense of belonging, and placing constraints on choice.^{4,5}

One facet of the social environment that influences physical activity is social capital, which refers to the resources that individuals and groups have access to within their social networks.⁶ There are two main approaches to operationalizing social capital: cohesion based

approaches and network-based approaches.⁷ Network based approaches to social capital assess individual relationships, or ties, within a social network for their structure, such as density, their composition, including the homophily of characteristics of the members of the network, and the resources that are embedded in the ties.⁸ Social capital has the potential to influence physical activity in a variety of mechanisms, most notably the access to resources and social support.⁹ Access to resources includes a “stock of trust within a collective is a type of ‘moral’ resource which lubricates collective action, mutual assistance, reciprocity exchanges and the ability to enforce norms.”¹⁰ These resources also include informational and instrumental social support, which has been shown to be associated with physical activity in adults.¹¹

There are several facets of network social capital that can be assessed, including the reach (refers to at the hierarchical nature of social capital), range (the degree to which individuals can access non-redundant information and influence by reaching out into their social structure), and diversity (variety of the types of people within a social network).¹² Network social capital diversity can help satisfy varied social, emotional and health-related needs through different types of social relations, and can also reflect the social network size.¹³ Networks of greater diversity may enable adults to draw from different and complementary resources that are accessed in response to specific needs or situations.

Despite a large body of research on the positive role of social support and social cohesion on physical activity, less is known about the role of network social capital in shaping physical activity behavior.¹¹ There is previous research, however, on the strong influence of social networks on various health outcomes and health behaviors, including

several systematic reviews on physical activity outcomes in children and adolescents.¹⁴⁻¹⁶

Structural characteristics of social networks, such as size, density, diversity and homogeneity, have been shown to be associated with physical activity, and the composition of a social network, such as socio-demographic characteristics and health behavior, has also been associated with physical activity.^{17,18} Evidence on the role of network diversity on influencing physical activity behavior is mixed; in a sample of older adults, respondents in diverse networks had the highest likelihood for engaging in physical activity,¹⁹ whereas in a study in African American adults, network diversity was significantly associated with reduced moderate to moderate to vigorous physical activity (MVPA).²⁰

In one longitudinal study by Josey and Moore that did assess network social capital,²¹ adults with higher network social capital had lower odds of physical inactivity, but this study did not assess changes in physical activity over time. Most other studies to date have been cross sectional, leading to the need for more longitudinal assessments of the relationship between social networks and physical activity behavior to provide evidence for a causal relationship.²² The objective of this study was to assess whether network social capital, including the reach, range, and diversity, influenced changes in physical activity in a cohort of adults living in the Montreal metro area.

Specific Aims

- **Aim 1:** To assess the association between baseline network social capital and physical activity in a cohort of adults residing in Montreal, Canada
- **Aim 2:** To assess the effects of network social capital on physical activity trajectories over a 5 year time period in a cohort of adults residing in Montreal, Canada

- **Hypothesis:** Network social capital will be directly associated with physical activity changes, with higher network social capital predicting maintenance of high levels of physical activity or increasing levels of physical activity over time.
- **Aim 3:** To assess if the association between network social capital and physical activity trajectories was moderated by sex or age of the participants.

Methods

Data for this study were from the Montreal Neighborhood Networks and Healthy Aging Panel (MoNNET-HA), which was a cohort of adult residents of the Montreal Metropolitan Area aged 25 years and older. The initial MoNNET-HA study sample was recruited in 2008 using a two-stage stratified cluster sampling design using census level income and age categories for the stages to obtain a representative sample of Montreal, Canada residents (N=2707).²³ The study used random digit dialing of listed numbers to recruit participants. Eligible participants included non-institutionalized adults who had lived in their current residence for at least one year, and were able to complete the computer-assisted telephone interviewing system questionnaire in either French or English. The response rate for the baseline participants was 38.7%. Data were collected from the MoNNET participants at three time points (2008, 2010, and 2013). De-identified data from the MoNNET-HA were provided by the investigators of the study after submission of a research proposal and completion of a data use agreement.

Measures

Weekly MET minutes of physical activity was the main outcome for this study and was assessed using the International Physical Activity Questionnaire (IPAQ) short form.²⁴ The IPAQ uses questions about the total volume of physical activity and the number of days per week the activities were conducted in order to calculate the energy costs of activities as the metabolic equivalent of task (MET). To calculate MET minutes per week, walking is considered 3.3 METS, moderate physical activity is considered equal to 4 METS and vigorous physical activity is considered equal to 8 METS.²⁵

Network social capital variables represented the primary exposure or independent variables and were measured using a position generator, in which participants are asked whether they know someone on a first-name basis who has a certain occupation in society.²⁶ These occupations are given a context-relevant prestige score to determine the diversity and potential value of a social network.^{8,27} The assumption of these measures is that knowing someone who holds these occupations is associated with the ability to access information, advice, and instrumental support.²⁸ Three measures of network social capital were derived from the position generator instrument at baseline: reach, range, and diversity. Network social capital reach is the highest prestige occupation reached, and range is the difference between the highest and lowest prestige occupations. Network social capital diversity is the number of different occupations identified by the participant and scores range from 0 to 10. Finally, a principal components analysis from the three variables was used to derive an overall network social capital variable.^{22,29}

Covariates for this study came from baseline, and included age group, sex, educational attainment, and marital status, all of which have been associated with physical

activity behavior in adults.^{30,31} Educational attainment was assessed as a categorical variable with the following levels: less than high school, high school degree/trade, some college, and university degree. Marital status was assessed as a binary variable (married/common law or not).

Statistical Analysis

This study used two analyses to assess the influence of network social capital variables on changes in physical activity over time. First, a binary outcome variable of meeting weekly recommended physical activity guidelines of 500 MET-minutes or not was used to assess whether baseline network social capital variables were associated with physical activity.³³ Baseline physical activity was assessed with logistic regression and multilevel logistic regression was conducted, for longitudinal analyses, with repeated measures nested within individuals. Second, latent trajectory models were developed with the continuous weekly MET-minutes outcome variable. Three sets of trajectory models were developed: full sample, stratified by sex, and stratified by age. For the age-stratified analysis, participants were divided into two categories (under 55 years of age and over 55 years of age) based on distribution. Model selection for the number of trajectory classes for each set of models was based on Bayesian Information Criterion (BIC) as a measure of goodness of fit and prior literature on physical activity trajectories.³² To assess whether network social capital was associated with changes in physical activity, multinomial logistic regression was used to identify whether network social capital variables assessed at baseline predicted trajectory group membership for models with more than two trajectory groups. For models with two physical activity trajectory groups, binomial logistic regression was used.

Unadjusted models were run, and then individual level covariates were added to the models to provide adjusted final models. Significance level for all analyses was set at $p < .05$.³⁴ All analyses were conducted in R (RStudio Version 1.0.153).

Results

The final sample size was 710 participants who had data from all three waves. Descriptive characteristics of the participants at baseline are presented in Table 1. The sample was highly educated, with 46.8% of cohort participants having a college degree or higher. The majority (62.2%) of participants were married. There were significant differences between males and females on levels of physical activity, with males having significantly higher baseline MET-minutes per week ($p < .001$) .

Paper 3 Table 1. Descriptive characteristics by sex of the MoNNET-HA cohort at baseline

	Total (N=710)	Male (n=263)	Female (n=447)	p-value for sex differences
Age in years, n (%)				
25 – 34	72 (10.1)	24 (9.1)	48 (10.7)	0.39
35 – 44	131 (18.5)	54 (20.7)	77 (17.1)	
45 – 54	177 (24.9)	68 (26.1)	109 (24.3)	
55 – 64	140 (19.7)	53 (20.3)	87 (19.4)	
65 – 74	154 (21.7)	54 (20.7)	100 (22.2)	
Over 75	36 (5.1)	8 (3.1)	28 (6.2)	
Education level, n (%)				
Less than high school	57 (8.0)	13 (4.9)	44 (9.9)	0.07
High school degree/trade	165 (23.3)	64 (24.3)	101 (22.6)	
Some college	155 (21.9)	53 (20.2)	102 (22.9)	
University degree	332 (46.8)	133 (50.6)	199 (44.6)	
Marital status, n (%)				
Married/common law	439 (62.2)	174 (66.4)	265 (59.7)	0.09
Overall Network Social Capital^a	0.15 (0.9)	0.16 (0.9)	0.14 (0.9)	0.86
Network Social Capital Reach^a	81.5 (20.8)	81.6 (20.4)	81.4 (21.1)	0.83
Network Social Capital Range^a	39.8 (19.3)	39.9 (19.8)	39.8 (19.0)	0.99
Network Social Capital Diversity (range 1-10)^a	4.8 (2.4)	4.9 (2.4)	4.7 (2.3)	0.55
Baseline MET-minutes/week^a	922.3 (703.5)	1141.7 (770.0)	793.0 (627.1)	<.001***

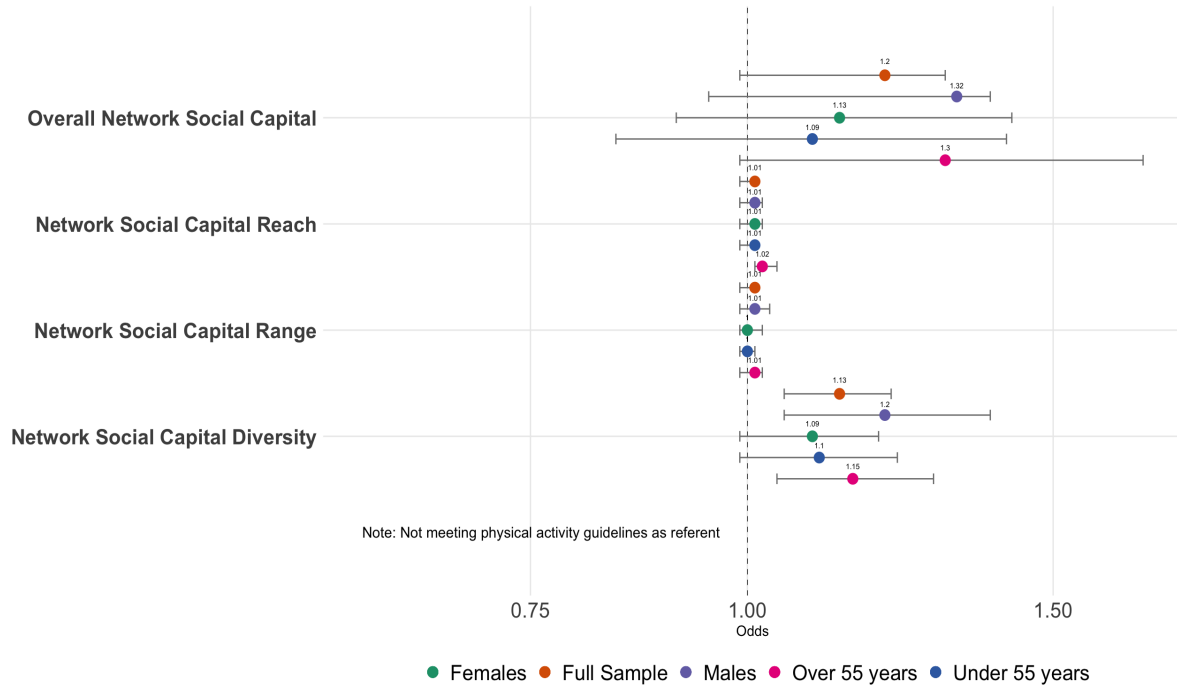
Notes: *p < 0.05, **p < 0.01, *** p < 0.001

^a Values reported as mean (standard deviation)

Multilevel Models of Meeting Physical Activity Guidelines

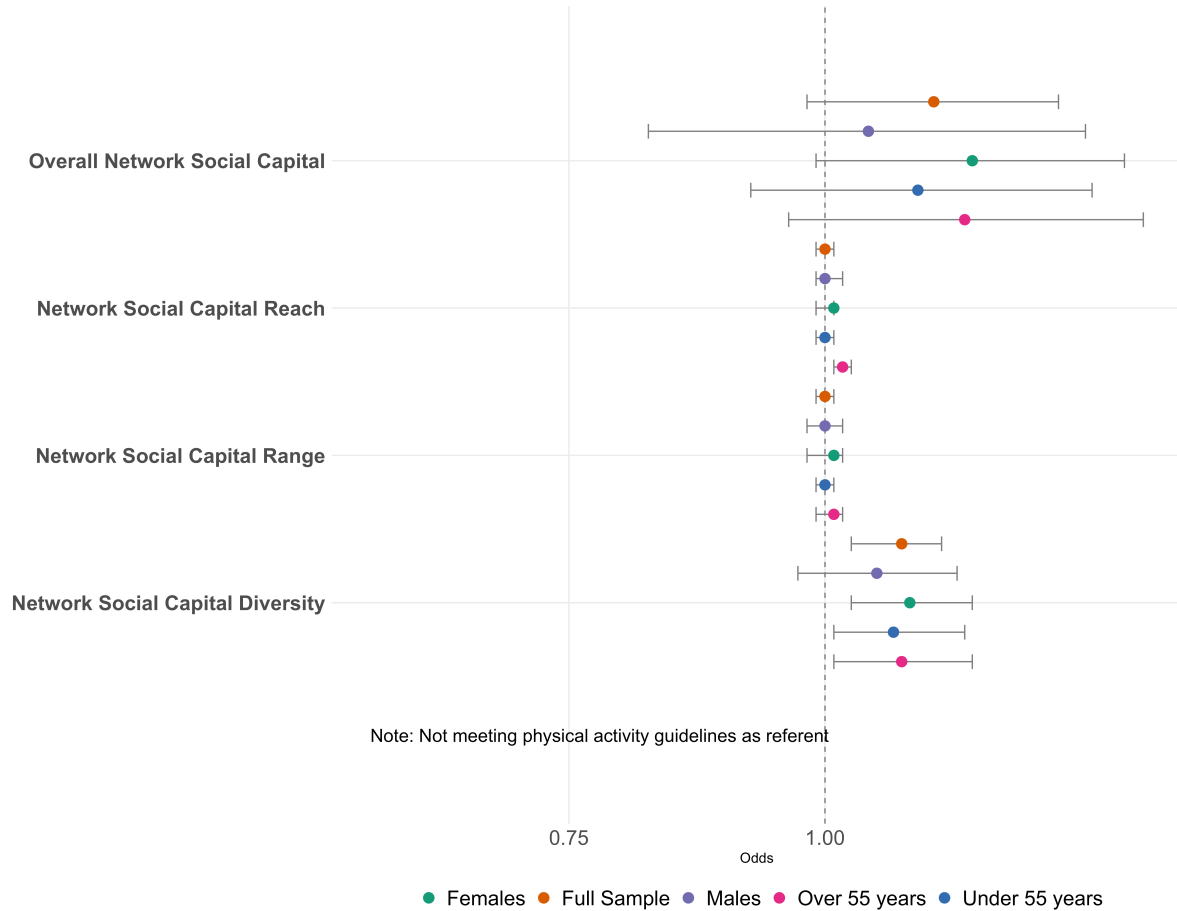
To assess whether baseline network social capital indicators were associated with physical activity, first, logistic regression was used to assess odds of meeting physical activity guidelines at baseline (Figure 1). In adjusted models, higher network social capital diversity was significantly associated with higher odds of meeting physical activity guidelines in the full sample (OR=1.13, 95% CI=1.05, 1.38), in males (OR=1.20, 95% CI=1.05, 1.38), and in individuals over 55 years of age (OR=1.15, 95% CI= 1.04, 1.28). Network social capital reach was significantly associated with meeting physical activity guidelines in individuals over 55 years (OR=1.02, 95% CI=1.01, 1.04).

Paper 3 Figure 1: Adjusted association of network social capital and meeting physical activity guidelines at baseline for MoNNET-HA cohort and selected demographic groups



Then, multilevel logistic regression was used to determine odds of meeting physical activity guidelines, with repeated measures nested within individuals (Figure 1). Network social capital diversity was the only network social capital indicator significantly associated with physical activity in the full sample, with each unit increase in network diversity being associated with 1.09 times higher odds of meeting physical activity guidelines in the adjusted model ($p=0.002$). In sex-stratified models, network social capital diversity was significantly associated with odds of meeting physical activity guidelines in females ($OR= 1.10$, $p=0.004$), but not in males ($OR= 1.06$, $p=0.21$). For individuals over the age of 55 years, network social capital reach was significantly associated with higher odds of meeting physical activity guidelines ($OR=1.02$, $p=0.02$).

Paper 3 Figure 2: Adjusted Multilevel Logistic Regression of Baseline Network Social Capital and Meeting Physical Activity Guidelines

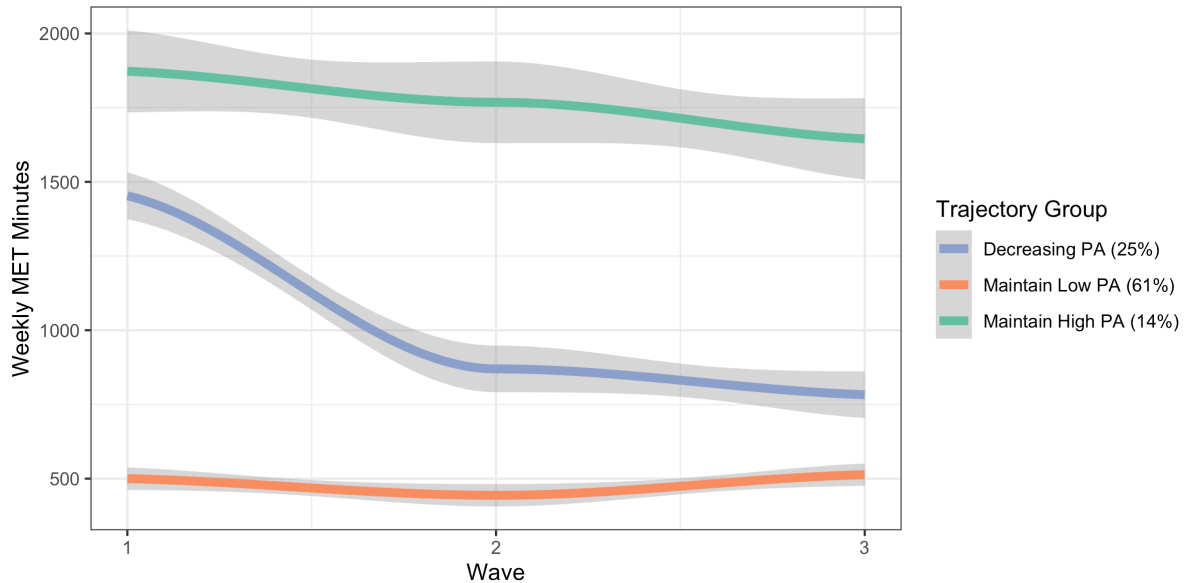


Model Selection for Trajectory Analyses

For each set of trajectory models (full sample, by sex, and by age), four models were run predicting different trajectory groups (2-5 groups). Final model selections were based on criteria established by Nagin and Odgers,³⁵ which include the Bayesian information criterion (BIC), with lower BIC values indicating better model fit, consideration of group sizes, and ensuring the means of posterior probabilities for individuals in each group are at least 0.7. Trajectory groups were labeled based on their shape (decreasing or maintaining). For the full

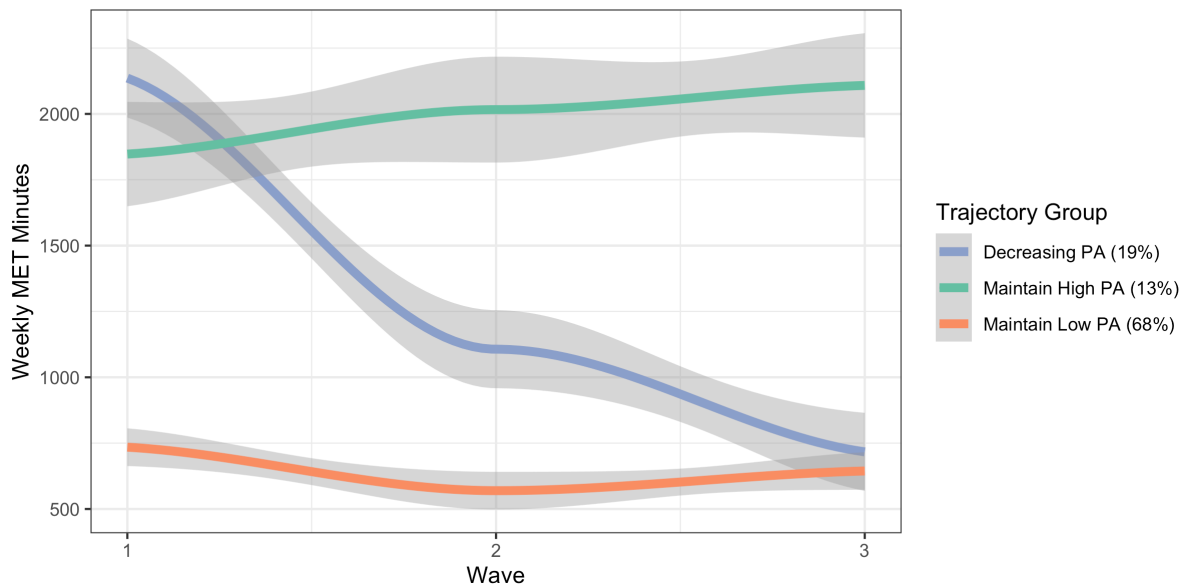
sample, three trajectory groups were identified, shown in Figure 2: Maintain Low PA(n=436), Maintain High PA (n=95), and Decreasing PA (n=179).

Paper 3 Figure 3: Trajectory models of physical activity over time for MoNNET-HA cohort

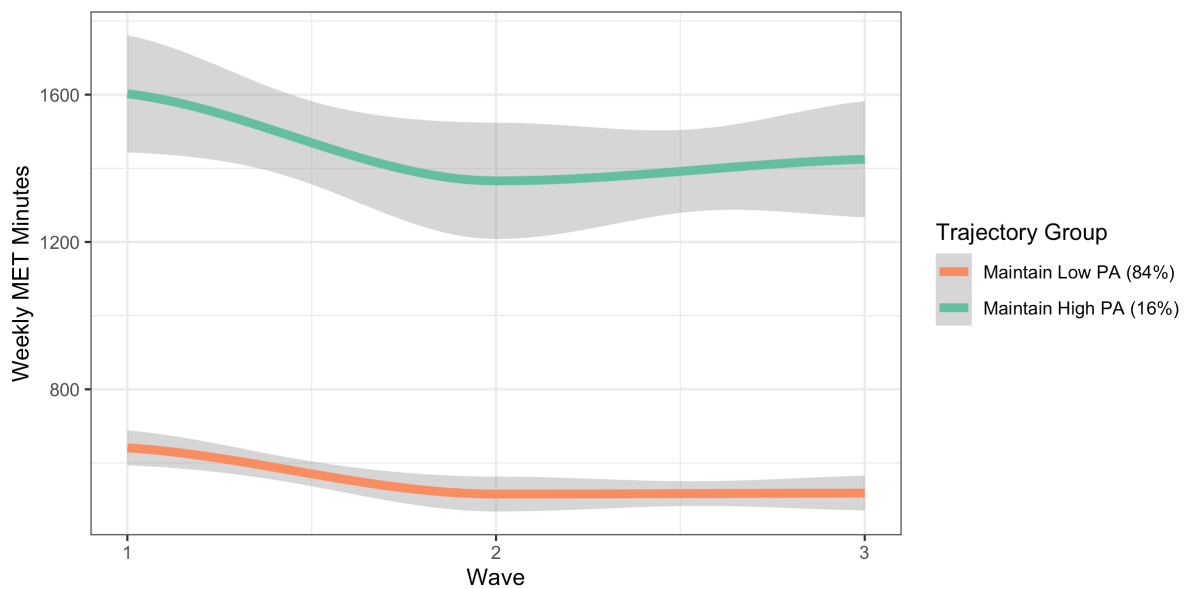


For the sex-stratified models, three trajectory groups were identified for males, while there were two trajectory groups for females. The male trajectory groups were Maintain Low PA (n=175), maintain high (n=35), and Decreasing PA (n=51), and are shown in Figure 3. The trajectory groups identified for females are shown in Figure 4, and are categorized as Maintain Low PA (n=380) and maintain high (n=69).

Paper 3 Figure 4: Trajectory models of physical activity over time for males



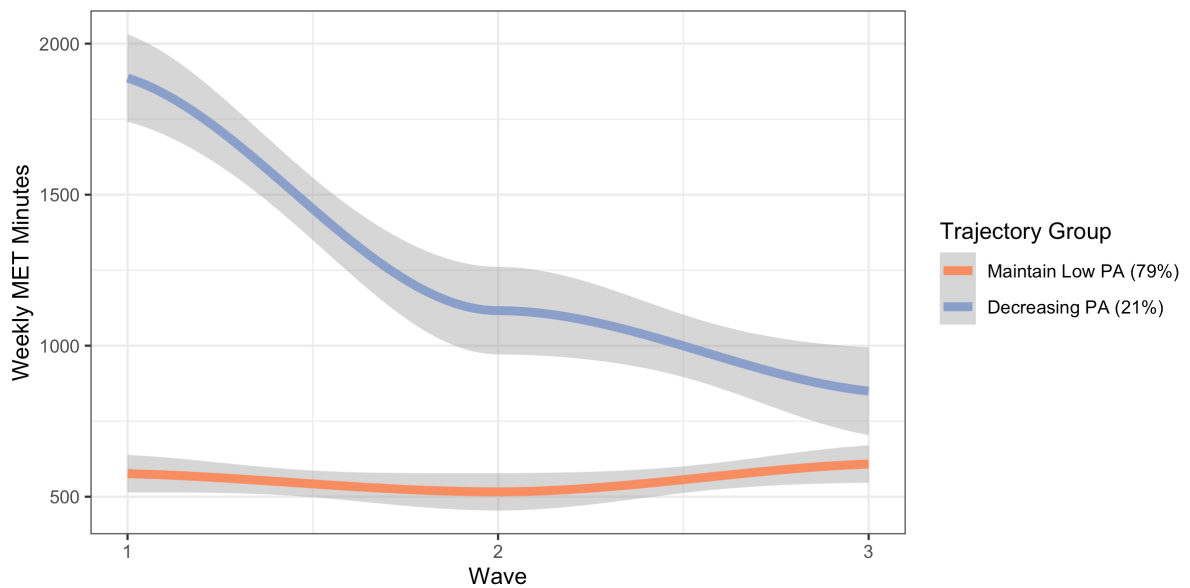
Paper 3 Figure 5: Trajectory models of physical activity over time for females



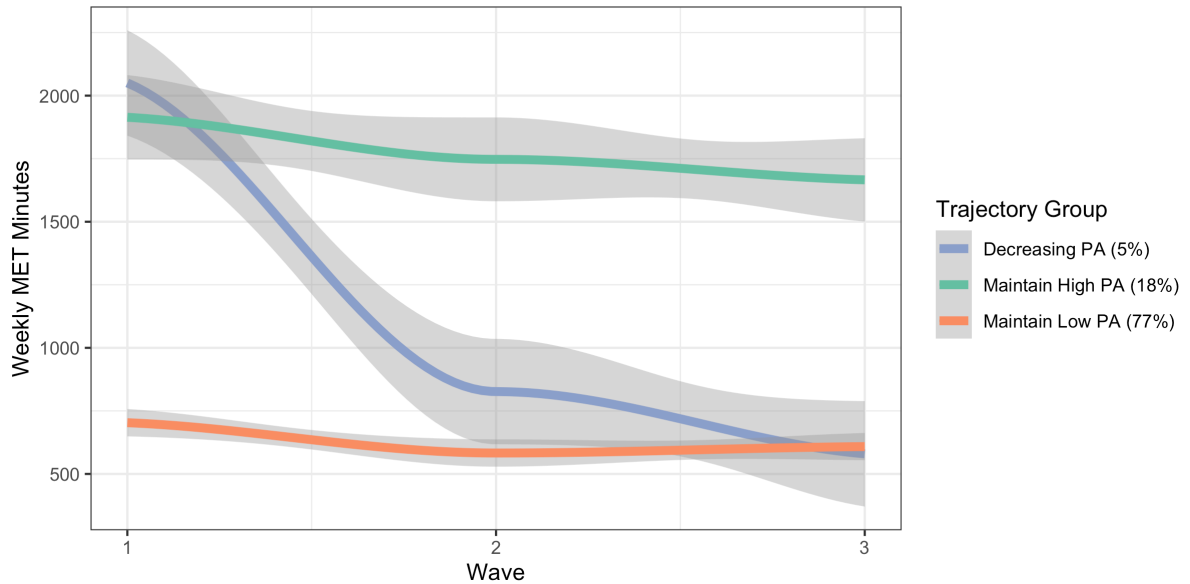
For the age-stratified analyses, two trajectory groups were identified for individuals under age 55 and three trajectory groups were identified for individuals' aged 55 or older. The two trajectory groups for the under 55 sample are shown in Figure 5, and are categorized

as Maintain Low PA (n=260) and Decreasing PA (n=70). The trajectory groups for the 55 years and over sample are shown in Figure 5 and are categorized as Maintain Low PA (n=294), maintain high (n=68), and Decreasing PA (n=18).

Paper 3 Figure 6: Trajectory models of physical activity over time for individuals under 55 years



Paper 3 Figure 7: Trajectory models of physical activity over time for individuals 55 years or older



Predictors of Group Membership

For each set of trajectory models, binomial or multinomial logistic regression was used to assess whether network social capital predicts physical activity trajectory group membership. Tables 2-6 show the unadjusted and adjusted odds ratios of group membership, and all analyses used the Maintain Low PA trajectory group as referent. In the full sample, network social capital diversity was significantly associated with physical activity trajectory group membership, with higher levels of diversity being associated with higher odds of being in the Decreasing PA group compared to the Maintain Low PA group ($p < .001$). In the stratified analyses, there were no significant associations between the network social capital variables and physical activity trajectory group.

Paper 3 Table 2: Multinomial logistic regression of network social capital on physical activity trajectory group membership for full MoNNET-HA cohort sample

	Maintain High PA (vs. Maintain Low PA) OR (95% CI)		Decreasing PA (vs. Maintain Low PA) OR (95% CI)	
	<u>Unadjusted</u>	<u>Adjusted^a</u>	<u>Unadjusted</u>	<u>Adjusted^a</u>
Overall Network Social Capital	0.94 (0.74, 1.19)	1.10 (0.85, 1.43)	1.28 (1.05, 1.57)*	1.24 (1.00, 1.54)
Reach	1.00 (0.99, 1.01)	1.00 (0.99, 1.02)	1.01 (1.00, 1.02)	1.00 (0.99, 1.01)
Range	0.99 (0.98, 1.01)	1.00 (0.99, 1.01)	1.01 (1.00, 1.02)	1.01 (1.00, 1.02)
Diversity	1.05 (0.95, 1.15)	1.10 (0.99, 1.22)	1.11 (1.03, 1.20)***	1.09 (1.01, 1.18)*
Notes: *p < 0.05, **p < 0.01, *** p < 0.001				
^a adjusted for age, sex, marital status, and educational attainment				

Paper 3 Table 3: Multinomial logistic regression of network social capital on physical activity trajectory group membership for males

	Maintain High PA (vs. Maintain Low PA) OR (95% CI)		Decreasing PA (vs. Maintain Low PA) OR (95% CI)	
	<u>Unadjusted</u>	<u>Adjusted^a</u>	<u>Unadjusted</u>	<u>Adjusted^a</u>
Overall Network Social Capital	0.80 (0.81, 1.64)	1.08 (0.71, 1.64)	1.15 (0.55, 1.16)	1.26 (0.86, 1.85)
Reach	1.00 (0.98, 1.01)	1.01 (0.99, 1.03)	1.01 (0.99, 1.03)	1.01 (0.99, 1.03)
Range	0.99 (0.97, 1.00)	1.00 (0.98, 1.02)	1.01 (0.99, 1.02)	1.01 (0.99, 1.03)
Diversity	1.04 (0.89, 1.20)	1.15 (0.98, 1.35)	1.07 (0.94, 1.22)	1.10 (0.96, 1.26)
Notes: *p < 0.05, **p < 0.01, *** p < 0.001				
^a adjusted for age, marital status, and educational attainment				

Paper 3 Table 4: Logistic regression of network social capital on physical activity trajectory group membership for females

	Maintain High PA (vs. Maintain Low PA)	
	OR (95% CI)	
	<u>Unadjusted</u>	<u>Adjusted^a</u>
Overall Network Social Capital	0.88 (0.61, 1.14)	0.86 (0.59, 1.13)
Reach	1.00 (0.98, 1.01)	1.00 (0.98, 1.01)
Range	0.99 (0.98, 1.01)	0.99 (0.98, 1.01)
Diversity	0.94 (0.84, 1.05)	0.93 (0.82, 1.04)
Notes: *p < 0.05, **p < 0.01, *** p < 0.001		
^a adjusted for age, marital status, and educational attainment		

Overall network social capital, range, and diversity were associated with physical activity trajectory group in unadjusted analyses among individuals under the age of 55. Higher network social capital was associated with lower odds of being in the Maintain High PA group compared to the Maintain Low PA group. These associations were attenuated in these adjusted models.

In unadjusted analyses for individuals over the age of 55, higher overall network social capital, reach, and range were significantly associated with lower odds of being in the Maintain High PA group compared to the Maintain Low PA. These associations were attenuated and non-significant in adjusted models. Higher network social capital reach was significantly associated with higher odds of being in the Decreasing PA group compared to the Maintain Low PA group in individuals aged over 55 years ($p < 0.05$).

Paper 3 Table 5: Logistic regression of network social capital on physical activity trajectory group membership for individuals under 55 years of age

	Decreasing PA (vs. Maintain Low PA)	
	OR (95% CI)	
	Unadjusted	Adjusted^a
Overall Network Social Capital	1.49 (1.09, 2.12)*	1.36 (0.97, 1.98)
Reach	1.02 (0.99, 1.03)	1.01 (0.99, 1.03)
Range	1.02 (1.00, 1.03)*	1.01 (0.99, 1.03)
Diversity	1.17 (1.04, 1.31)**	1.13 (0.99, 1.29)

Notes: *p < 0.05, **p < 0.01, *** p < 0.001
^a adjusted for sex, marital status, and educational attainment

Paper 3 Table 6: Multinomial logistic regression of network social capital on physical activity trajectory group membership for individuals aged 55 years or older

	Maintain High PA (vs. Maintain Low PA)		Decreasing PA (vs. Maintain Low PA)	
	OR (95% CI)		OR (95% CI)	
	Unadjusted	Adjusted^a	Unadjusted	Adjusted^a
Overall Network Social Capital	0.72 (0.54, 0.95)*	0.89 (0.65, 1.21)	1.40 (0.76, 2.61)	1.58 (0.83, 2.99)
Reach	0.98 (0.97, 0.99)*	0.99 (0.98, 1.01)	1.05 (0.99, 1.12)	1.06 (1.00, 1.12)*
Range	0.98 (0.97, 0.99)*	0.99 (0.98, 1.01)	1.01 (0.98, 1.04)	1.02 (0.99, 1.05)
Diversity	0.94 (0.84, 1.05)	1.01 (0.90, 1.14)	1.12 (0.91, 1.39)	1.17 (0.94, 1.44)

Notes: *p < 0.05, **p < 0.01, *** p < 0.001
^a adjusted for sex, marital status, and educational attainment

Discussion

To assess the association between network social capital and physical activity changes over time, this study developed three sets of physical activity trajectory models and examined predictors of group membership in a cohort of Canadian adults over a period of 3

years. Three distinct trajectory models emerged. The full sample, males and individuals aged 55 and older had three groups: highly active, decreasing, and active. This is consistent with previous research; a systematic review of physical activity trajectories across life stages reported that the most common number of physical activity trajectories is three.³⁶ Females had two physical activity trajectory groups: Maintain High PA and Maintain Low PA. Individuals under 55 years of age also had two physical activity trajectory groups: Decreasing PA and Maintain Low PA. Consistent with previous literature, there were no groups identified that had increasing levels of physical activity.³⁶

The first analysis in this study assessed the effects of baseline network social capital on meeting physical activity guidelines using multilevel logistic regression, and higher social network diversity was associated with higher odds of meeting physical activity guidelines. Access to diverse social resources may lead to greater knowledge of the benefits of physical activity or facilitators of physical activity from a wide range of informational, instrumental, and modeling social support sources, leading to higher levels of physical activity.⁹ Having access to diverse social resources such as those from high socioeconomic status individuals in a social network, can provide benefits for individuals of all socioeconomic statuses. In a study by Chetty et al,³⁷ low income individuals living in high income areas have higher levels of physical activity, lower levels of obesity, and greater life expectancy than low income individuals living in low income areas. Inequality, or a lack of social cohesion, has been posited as a source of stress for low income individuals and can lead to poor health behaviors and health outcomes.³⁸ While this study's sample was predominantly higher income individuals, future research should assess network social capital diversity and physical

activity in a low-income population to see if network social capital and access to social resources differentially affects physical activity behavior by socioeconomic status.

This study also revealed several aspects of network social capital that predicted physical activity trajectory group. Network diversity was significantly associated with physical activity trajectory group membership in the full sample, and individuals with higher network diversity, in other words, those who are connected with more people from different occupations, were more likely to be in the Decreasing PA group than the Maintain Low PA group. No other study has previously assessed network social capital as a predictor for physical activity trajectory, but several studies have also found a direct association between network diversity and physical activity.²² Even though individuals with higher network diversity were more likely to be in the Decreasing PA physical activity group than the Maintain Low PA group, the Decreasing PA group still had a higher average number of weekly MET-minutes at time point 3 than the Maintain Low PA group.

Network reach was significantly associated with physical activity trajectory group membership in individuals aged 55 and older, with higher network reach being associated with higher odds of being in the Decreasing PA physical activity group compared to the Maintain Low PA group. In this age group, the Decreasing PA group had the same average number of weekly MET-minutes at the third time point as the Maintain Low PA group. Because the trajectory group membership was based on baseline levels of network social capital, it is possible that high network social capital reach was significantly associated with baseline physical activity and that reach decreased over time with physical activity. Future research should assess the effect of changes in network social capital and changes in physical

activity. Previous research has not found a significant association between network social capital reach and physical activity.^{21,22} Older adults can potentially have greater levels of loneliness and decreasing size of social networks due to life events such as retirement, friends or family passing away, and moving into assisted care, leading to a higher importance of social networks in older adults compared to younger adults.³⁹

Limitations

There are several limitations of this study to acknowledge, including that the dependent variable for this study was self-report physical activity. Reported physical activity has been shown to overestimate actual behavior compared to objectively measured physical activity by accelerometer.^{40,41} Additionally, the IPAQ may not be the most suitable instrument for detecting change over time in individuals, and future research should aim to use objective measures to assess within person change over time.⁴² This study looked at the various components of social networks that influence physical activity behavior, though extricating these factors from social selection biases can be difficult since physically active people are more likely to select physically active people as friends.⁴³ The independent variable in this study will be network social capital as measured by a position generator, which emphasizes the prestige of occupations as the primary operationalization of social resources.⁴⁴ Finally, the MoNNET-HA sample had an initially low response rate, and the cohort experienced attrition over time, leading to limitation in the generalizability of results from this study. Analyses comparing participation across waves found that subjects participating in multiple waves tended to be French speaking, higher educated, between 35 and 74 years old, and living in their current address for comparatively longer.²⁹

This study provides several meaningful contributions to the knowledge base, including the longitudinal association of network social capital and trajectories of physical activity. Additionally, the use of several components of network social capital as independent variables in this study allows for the parsing out of which dimensions of network social capital are most associated with physical activity behavior. Results from this study can be used to inform social network interventions to increase physical activity by using network social capital as a channel for the influence of intervention components on outcomes.⁴⁵ To expand upon these findings, future research should use objective measures to assess physical activity trajectories and use a diverse population to examine whether these associations can be generalized to rural or populations with lower socioeconomic status.

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CONCLUSION

The overall objective of this dissertation was to examine the association between social capital, from both the cohesion and network perspectives, and physical activity behavior in different life stages. Each of the articles in the dissertation also examined the association of social capital and physical activity by gender. There were several key findings from each paper. In the first article, the association between language-based social cohesion and outdoor play among 2nd grade children in Texas was assessed at both the individual and neighborhood levels. Children living in majority Spanish speaking neighborhoods had significantly less days per week of outdoor play compared to majority English speaking neighborhoods. There were significant differences between English speaking children and other language groups in English speaking neighborhoods, but not in Spanish speaking neighborhoods. The neighborhood language mattered more for girls than for boys, and there were significant differences by language spoken at home in linguistically diverse neighborhoods for girls. The second article assessed whether the association between neighborhood social cohesion and out-of-school time physical activity differed by neighborhood built environment features in a sample of adolescents ages 12-17. Social cohesion was significantly associated with physical activity, and this association was stronger for males than females. The association between social cohesion and physical activity differed by built environment features in males, with stronger effects for neighborhoods with unsupportive built environments. The final article looked at whether network social capital, including the reach, range, and diversity, influenced changes in physical activity in a cohort of adults living in the Montreal metro area. Physical activity trajectories differed by sex and

age group, and there were no groups that had increasing levels of physical activity over the five year time period. Network social capital diversity was significantly associated with physical activity in adults, and was also significantly associated with physical activity trajectories. Network social capital reach was significantly associated with physical activity trajectories in adults over 55 years.

Throughout the three papers of this dissertation, there were several unifying themes and innovative strengths. First, the three papers add to the literature base by going beyond the usual measures of social capital, such as perceived trust, to examine different components of social capital, such as language based social cohesion, collective socialization, and network social capital. Additionally, the papers in this dissertation highlight the importance of both bonding and bridging social capital for physical activity behavior. While these two forms of social capital use different mechanisms to influence physical activity, both can be important due to providing individuals a sense of belonging (bonding), and providing diverse social resources such as social support and modeling (bridging).¹

Another strength of this dissertation was that each paper assessed the relation between social capital and physical activity by sex. In each paper, the association between social capital and physical activity was stronger among males. Previous research supports the notion of social capital inequality between men and women, with men typically having higher social capital than women.^{2,3} Men typically have larger social networks than women, while women's social networks typically have higher proportions of kin, so neighborhood social capital, like the kind examined in this dissertation, may exist in higher quantities for

men.⁴ Future research should investigate the types of social capital that may be more important in determining physical activity behavior in women.

Paper 2 of this dissertation also examined the innovative interaction between the social environment and the built environment and the importance of both for adolescent physical activity. Previous research has identified neighborhood factors, including local resources and opportunities for meeting others, as important in the creation of social capital, specifically in the development of social norms, trust in others, and collective efficacy, and the built environment can influence these.^{5,6} There is some evidence that residence in walkable, mixed-use neighborhoods have higher levels of social capital, however, more research is needed on which built environment features are consistently related to social capital.⁷

There are several limitations to this dissertation that should be acknowledged. All three papers used self-report physical activity measures, and such measures been shown to overestimate actual behavior compared to objectively measured physical activity by accelerometer.^{8,9} Additionally, the samples in this dissertation are limited in their generalizability due to selection bias (Papers 2 and 3) and attrition bias (Paper 3), which led to samples that may not be representative of the populations from which they were drawn. Two of the three studies within this dissertation were cross-sectional, and assumptions of causality should therefore be limited. Another limitation of this dissertation affects the findings for Papers 1 and 2, which assess the effects of area-based variables (neighborhood language in Paper 1 and built environment features in Paper 2). The Modifiable Areal Unit Problem (MAUP) describes the potential measurement error due to the spatial units at which

the exposure variables are classified, and is a common issue in built environment research.^{10,11} Future research on language-based social cohesion should use the home address as the spatial unit center to reflect the participant's proximal neighborhood more accurately.

Findings from this dissertation have important implications for physical activity interventions, policies, and future research in the field. Findings from Paper 1 provide strategies for intervention to increase outdoor play in children, an important source of physical activity in the age group. Language of marketing and program materials should be taken into consideration in physical activity intervention design, especially in predominately English-speaking neighborhoods, where this study found disparities in outdoor play between English and non-English speaking households. Additionally, linguistically diverse and Spanish-speaking neighborhoods should be prioritized for outdoor play interventions, such as the opening a school yard to the community and providing an attendant to watch over the play space, which has been shown to increase outdoor physical activity among children.¹²

The interaction between the built environment and the social environment is an important consideration for interventions, and the Community Preventive Services Task Force has recommended the use of built environment interventions to increase physical activity by creating or modifying environmental characteristics.¹³ Findings from Paper 2 suggest that such built environment interventions should be coupled with social resources to increase social cohesion, which may increase the uptake of the built environment interventions. Additionally, practitioners should prioritize physical activity interventions that seek to increase social cohesion in neighborhoods with unsupportive built environments, as this may diminish the disparities in physical activity due to differences in built environments

between low and high-income neighborhoods.¹⁴ Sport has been used to both increase social cohesion and connectedness and physical activity within communities, and such interventions would be particularly well suited in areas with limited access to other physical activity opportunities.¹⁵

Findings from Paper 3 support intervention strategies such as developing network social capital diversity within the workplace through physical activity interventions. In this setting, there can be different types of workers within one workplace that have varying socioeconomic statuses, and the National Physical Activity Plan encourages tactics such as promoting physical activity across socio-economic environments within the worksite setting.¹⁶ Additionally, interventions to increase physical activity can use social networks to better disseminate information from an intervention using pre-existing network social resources in a community.¹⁷

Overall, this dissertation provides important contributions to the literature base on social capital and physical activity in an era where both are decreasing in the United States, and these findings provide a foundation for future research to further the field of social capital and physical activity.^{18,19} Objective measures of physical activity, such as those provide by accelerometers, should be used to further assess how social capital can influence physical activity across life stages, and these measures can better detect change over time. Accelerometers, when combined with global positioning systems (GPS), can provide objective measures of intensity and duration of physical activity, as well as location, which especially for outdoor play as an outcome measure, can provide valuable information. Additionally, future research should seek to use more longitudinal methods to provide further

evidence of causality between social capital and physical activity. While this dissertation assessed social capital from both the social cohesion perspective (Papers 1 and 2) and the network perspective (Paper 3), future research should assess network social capital as a potential mediator for social cohesion and physical activity, as suggested by the conceptual framework from Berkman and Krishna.²⁰ Additionally, this dissertation highlights the importance of both bonding and bridging social capital, and future research should examine which components of social capital are more important for physical activity at different life stages.¹

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