ABSTRACT

Title of Dissertation: **ENVIRONMENTAL INFLUENCES ON PHYSICAL ACTIVITY AND OBESITY IN AFRICAN AMERICAN ADOLESCENTS-A MULTILEVEL PERSPECTIVE**

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Background: Prevalence of obesity among adolescents is increasing at an alarming rate. Currently, 34% of all 12-19 year olds are either at risk for overweight or are overweight. Without a comprehensive understanding of the myriad of environmental factors that influence physical activity, we cannot effectively curb the rising rates.

Methods: The objective of this study was to evaluate the direct and indirect effects of individual, built, and psychosocial environmental factors on the body mass index (BMI) of African American adolescents, and to assess how the relationships may be mediated by physical activity (PA) levels in an urban setting. A cross-sectional sample of 350 Students (grades 9-12) was drawn from two urban magnet high schools in Baltimore City. The outcome measurements cover a broad array of variables, including BMI, walking behavior, and overall PA. The independent variables are measures of three environments and individual socio-demographic status. The hierarchical linear model analyses were employed. In addition, the mediation analyses were conducted to examine the mediating effect of PA levels.

Results: The majority of the sample was African American (69%) and female (58%) with 40% at risk of overweight or overweight. After adjustment for individual sociodemographic factors, living in more hazardous neighborhoods was positively associated with moderate-to-vigorous physical activity (MVPA) and walking for transportation but not with BMI. Densities and proximities of destinations were not associated with BMI. Access to school and museums within 0.25 mile, and grocery stores, retail and shopping, post offices and mix of destinations within 0.5 mile and beyond was positively associated with participation in walking. In addition, densities of fast food restaurants, parks and recreation within 1 mile and 1.5 mile were associated with increased walking. Closer proximity to schools and museums increased both student's MVPA level and their walking trips. Green space coverage within 0.25 mile distance was associated with decreased BMI. In addition, the percentage of green space coverage around homes was not associated with physical activity. Physical activity did not mediate either the destination densities and proximity or the greenness on BMI.

Conclusion: The findings support the importance of focusing on places rather than the individuals who live in those places. Increasing the diversity of walkable destinations may contribute to adolescents doing more transport-related walking and achieving recommended levels of physical activity. In general, ecologic approaches to obesity prevention need to focus on urban design and food availability.

ENVIRONMENTAL INFLUENCES ON PHYSICAL ACTIVITY AND OBESITY IN AFRICAN AMERICAN ADOLESCENTS-A MULTILEVEL PERSPECTIVE

By

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Dissertation submitted to the Faculty of the Graduate School of the
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DEDICATION

This dissertation is dedicated to my beloved grandmother, Professor Emeritus of Pharmacy in China. She could not attend my doctoral dissertation defense and my graduation ceremony. Her love and support and her successful stories in academia have always encouraged me to move forward. I would like to dedicate this dissertation to her.

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I also owe thanks to my friends and family who have shared this journey with me. Finally, I would like to thank my sponsors, the Robert Wood Johnson Foundation Active Living Research Program, Dr. Jim Sallis, the Program Director of Active Living Research, and the Maryland School of Public Health Department of Public and Community Health, who provided funding and support for this research.

CHAPTER ONE: INTRODUCTION

This chapter will begin with an overview of the Robert Wood Johnson Foundation's Active Living Research program which funded this dissertation and the Baltimore Active Living Teens Study (BALTS, PI: Carolyn Voorhees) from which parts of the data were obtained. Rationale, the goals and the aims of the study will also be provided. Finally, this chapter will summarize the unique contributions of this dissertation study and how it will contribute to the literature and the research on childhood obesity.

1.1 Overview of Active Living Research Program

In order to reverse the childhood obesity epidemic by improving access to affordable, healthy foods and increasing opportunities for physical activity in schools and communities across the nation, the Robert Wood Johnson Foundation (RWJF) has announced plans to spend more than $500 million over the next five years. Active Living Research is a national program of the Robert Wood Johnson Foundation (RWJF) managing a $15.4- million authorization over five years (2007-2012). This national program supports research to identify environmental factors and policies that influence physical activity. With an interested on reversing the rise of childhood obesity, Active Living research focuses on active living related to youth in low-income and high-risk communities. Findings from this research will be used to help inform policy, design of the built environment, and other factors to promote active living. James F. Sallis, professor of Psychology at San Diego State University, is the Program Director of Active Living Research.

1.2 Overview of Baltimore Active Living Teens Study (BALTS)

Baltimore Active Living Teens study (BALTS), funded by the Robert Wood Johnson Foundation Active Living Research program was the parent study for this dissertation research. Carolyn C. Voorhees at the University of Maryland Department of Public and Community Health is the principal investigator for BALTS. The aim of BALTS is to investigate the complex relationship between objective measures of physical activity and community, family, social and individual variables among urban adolescents. The study was conducted during 2006-2007 in Baltimore city. The author has worked in collaboration with Dr. Voorhees as well as other co-investigators from the fields of public health, kinesiology, urban planning, and biostatistics, including Kelly Clifton, Min Qi Wang, Michelle Harris, Gerrit Knaap, and Deborah Rohm Young. Both BALTS study and this dissertation work were approved by the Institutional Review Board (IRB) at the University of Maryland (Application number: 04-0553).

1.3 Brief introduction of the current study

Funding specifically for this dissertation research was provided by a dissertation grant (63530) from the Robert Wood Johnson Foundation's Active Living Research Program. The competitions have been very intense in the past few years. According to ALR, 180 brief proposals were received in Round 2 and only 15 were funded (including dissertation proposals). In 2007 (Round 7), only 3 dissertation proposals, including this study were funded throughout the national competition.

1.4 Problem statement and the initial motivation of this proposal

Childhood obesity rates in the United States have reached epidemic proportions. Over the past three decades, the prevalence of overweight among young people in the United States more than tripled among children aged 6 to 11 years and more than doubled among adolescents aged 12 to 19 years(Ogden, et al., 2006). Racial/ethnic disparities in overweight are growing as rates increase faster among black children, with 27% of African American girls aged 12-19 being overweight compared to 15.5% nationally in the same age group(Ogden, et al., 2006). Public health interventions have traditionally focused on increasing individual knowledge and awareness about physical activity through educational approaches (Wadden & Butryn, 2003). These individual approaches have demonstrated limited success in promoting long-term maintenance (Kumanyika, et al., 2000; Wadden & Butryn, 2003). Without a comprehensive understanding of the myriad of environmental factors that influence physical activity, we cannot effectively curb the rising obesity rates. Individual behavior that has been altered will return to earlier behavior once the intervention is over (Gauvin & Spence, 1996; B. H. Marcus & Stanton, 1993; Ritchie, Welk, Styne, Gerstein, & Crawford, 2005). This proposal responds to the Active Living Research (ALR) program's main objective: establishing a transdisciplinary field to identify environmental factors that could substantially increase levels of physical activity among Americans.

1.5 Purpose of the study

The purpose of this study was to evaluate the direct and indirect effects of individual, built, and psychosocial environmental factors on African American adolescents' body mass indexes (BMI), and to assess how the relationships may be mediated by physical activity (PA) levels in an urban setting.

1.6 Specific Aims and Hypotheses

The specific aims of the study were the following. Specifically, the following hypotheses for each aim will be tested.

Aim1. To estimate the effects of multi-dimension factors (i.e., sociodemographic and three neighborhood environments: residential, commercial, and recreation) on PA levels.

Hypothesis 1. A- Living in a neighborhood with increased psychosocial hazards is associated with decreased levels of physical activity (e.g., walking and moderate-vigorous physical activity), independent of known social economic risk factors (education, and income).

Hypothesis 1.B- Walkable commercial neighborhoods as being centered on basic daily retail and food-related activities and presences of a variety of destinations (grocery stores/supermarkets, restaurants, and to a lesser extent, banks) are significantly associated with walking.

Hypothesis 1.B1- The proximity and density of a variety of destinations are related to utilitarian walking (e.g., walking for transportation) but not associated with walking for recreation.

Hypothesis 1.C1-After controlling for individual socio-demographic and neighborhood socioeconomic status (e.g., percentage of families in poverty, percentage of African American in a census block), measures of vegetation will predict physical activity levels.

Hypothesis 1.C2-The proximity and density of parks and recreation facilities are associated with physical activity levels.

Aim2: To estimate the effects of multi-dimension factors on BMI and assess how the relationships may be mediated by PA levels.

Hypothesis 2. A- Living in a neighborhood with increased psychosocial hazards is associated with overweight (including at risk for overweight), independent of known social economic risk factors (education, and income).

Hypothesis 2.B- Walkable commercial neighborhoods as being centered on basic daily retail and food-related activities and proximity and density of a variety of destinations (grocery stores/supermarkets, restaurants, and to a lesser extent, banks) are associated with overweight and at risk for overweight.

Hypothesis 2.C1-After controlling for individual socio-demographic and neighborhood socioeconomic status (e.g., percentage of families in poverty, percentage of African American in a census block), measures of vegetation are associated with overweight and at risk for overweight.

Hypothesis 2.C2-The proximity and density of parks and recreation facilities are associated with overweight and at risk for overweight.

To achieve the goal and specific aims of this study, three environments (<u>residential</u>, <u>commercial</u>, and <u>recreation</u>) were investigated, within which PA behaviors occur. To investigate the first environment, the participants' residential neighborhoods in an inner city will be examined under the framework that prolonged exposure to environments that evoke vigilance, threat, and alarm will decrease the likelihood of adolescents engaging in outdoor physical activity. Consequently, living in neighborhoods with psychosocial hazards makes an important, but modifiable, contributor to childhood obesity. The investigation of the commercial environment involves *linking* data related to various types of destinations (this is referred to as walkability and is obtained through GIS network analysis) within the walkable neighborhood areas, and examining the facilitators and barriers to walking. For the third environment, recreation, we will investigate the associations between the neighborhood greenness (e.g., vegetation), density of and proximity to parks, playgrounds, and recreation facilities, adolescents' perceptions of open space, park utilizations, and adolescents' PA levels.

1.7 Unique contributions of the study

This proposed study leverages funds by using data collected in a larger Robert Wood Johnson/Active Living Research (RWJF-ALR) funded study and expands the research to examine the complex environmental features that encourage sedentary behaviors and discourage physical activity in an urban setting among African American population. This study overcomes the limitation of existing studies, and will provide unique contributions to the current literature at minimal cost. The contributions can be expressed in the following three areas:

First, although several individual-level obesity risk factors have been identified, treatment and prevention efforts continue to be costly and of limited effect (C. Doak, 2002). Population rates of obesity are determined by a complex interplay of genetic, environmental, behavioral, and cultural factors (Glass, Rasmussen, & Schwartz, 2006). Research that aims to get a comprehensive understanding of how these factors interact is currently lacking and is being strongly encouraged by both the National Institutes of Health(United States Public Health, Office of the Surgeon, Office of Disease Prevention and Health, Centers for Disease Control and, & National Institutes of, 2001) and the Robert Wood Johnson Foundation (Active Living Research program, 2007). The proposed study fills in this critical gap by examining these complex relationships via structure equation modeling (SEM) analysis. This study simultaneously looks at various characteristics of three environments in an urban setting, such as greenness of neighborhood, access to parks and recreational facilities, crime rates and street conditions of residential areas, and the distribution of different walkable destinations which are typical elements of "town centers." This study not only includes the traditional sociologic measures of physical activity (PA) in the neighborhood, such as behavior (e.g., walking), domains (personal, physical environment), and outcome of interest (e.g., increase in walking), but also looks at the temporal dimension of PA in the neighborhood: the time of day, weekday versus weekend, and specific activities (e.g., PE class, playing basketball in the community) in school and out of school. This study seeks to confirm that multi-dimension neighborhoods exist. By exploring complex relationships among individual and built environmental variables, and comparing differential responses to the built environment by different age groups, our study will be able to answer the following questions: 1) Do adolescents and older adults respond similarly or differently to built environment characteristics? 2) Why are some built environment measures associated with walking but not with overall activity? 3) What are the relationships among travel activity, recreational activity and overall activity? Findings derived from the temporal and dynamic measuring of neighborhood environments will likely to result in stronger implication for public health intervention and for policymakers.

Second, precise measurements of one specific aspect of urban neighborhood condition will be used. By using sociologically real neighborhoods rather than administrative units (most studies use Census units or ZIP codes as proxies for neighborhoods), this study overcomes the limitation of previous studies by linking the real psychosocial index of "city neighborhood" to decreased physical activity and increased BMI at an individual's residential level using GIS modeling.

Third, this study is one of the first studies, that aims to investigate the association between recreation environments, physical activity levels and overweight. Both subjective and objective measures of one neighborhood aesthetic characteristics (vegetation) will be used.

In conclusion, this study addresses the objectives of the ALR program. It will help build a transdisciplinary field as the PI will collaborate with faculty mentors in adolescent health, geography, and statistics. The research findings based upon methodological triangulation will better inform policy change efforts that encourage physical activity in African American adolescents.

1.8 Definition of key variables or terms

The following terms were defined to clarify their use as applied in this investigation:

Obesity and overweight in children and adolescents

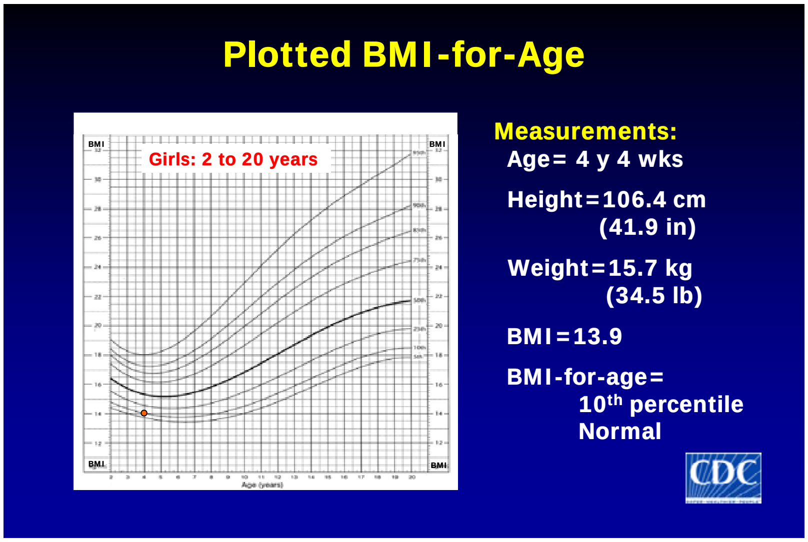
Obesity is a chronic, metabolic disease caused by multiple and complex factors, including increased calorie intake, decreased physical activity and genetic influence. BMI is used to measure weight. BMI ranges for children and adolescents are defined so that they take into account normal differences in body fat between boys and girls and differences in body fat at various ages. Therefore, adolescent body weight status was usually classified on the basis of the age- and sex- specific BMI percentile provided in the NCHS-CDC 2000 growth charts (Kuczmarski, et al., 2002). Objective weight status was based on respondents' BMI percentile and the following were cut-points for weight classification: underweight (less than 5^{th} percentile); normal weight (5^{th} percentile to less than the 85^{th} percentile); at-risk overweight (85^{th} to less than 95^{th} percentile); overweight ($\geq 95^{th}$ percentile).

Table 1: Weight status and corresponding BMI percentile (sex and age specific)

Weight status category	Percentile range
Underweight	Less than the 5^{th} percentile
Normal weight	5^{th} percentile to less than the 85^{th} percentile
At risk of overweight	85^{th} to less than the 95^{th} percentile
Overweight	Equal to or greater than the 95^{th} percentile

Following is an example of using CDC growth chart to identify at risk individuals. This girl is 4 years, 4 weeks old. Is her BMI-for-age at the risk for overweight? This girl's height is 41.9 inches and her weight is 34.5 pounds. Using her height and weight I calculated BMI to be 13.9. Plotted on the BMI-for-age chart for girls, her BMI-for-age falls on the 10th percentile, which falls on the normal weight category.

Table 2: Example of CDC growth chart



<u>Active living</u> is a way of life that integrates physical activity into daily routines. Individuals may do this in a variety of ways, such as walking or bicycling for transportation, exercise for pleasure; playing in the park; working in the yard; taking the stairs; and using recreation facilities. The goal for children and adolescents is to accumulate at least 60 minutes of moderate-to-vigorous activity each day, and the goal for adults is 30 minutes per day. This level of physical activity promotes energy balance needed to maintain healthy weight and improves physical and mental health.

<u>Built environment</u> refers to all buildings, spaces and products that are created, or modified, by people. It includes homes, schools, workplaces, park/recreation areas, greenways, shopping areas and transportation systems. The built environment is affected by land-use and transportation planning and policies in urban, rural and suburban areas. These environments and the policies that govern them affect opportunities for physical activity for recreation and transportation purposes. Built environment changes of particular relevance to youth include park development and renovation, installation of playgrounds in apartment complexes, improvements to playground equipment or school activity facilities, traffic calming, and improvements to sidewalk and crosswalks.

Environmental interventions involve: 1) changing physical surroundings or settings; 2) changing access to or availability of foods, physical activities, or sedentary behaviors; or 3) changing a publicly accessible information environment about physical activity or dietary behavior (in contrast to information presented to small group or classes). Examples of environmental interventions include building sidewalk, adding a salad bar to the school cafeteria, removing televisions from day care settings, opening gates so children can use playground after school, increasing stock of fresh fruits and vegetables in corner stores, signs promoting stair use, menu labeling.

Natural experiments are opportunistic studies that evaluate changes in real-world environments or policies and include pre- and post-assessments. In many natural experiments, researchers cannot control the allocation of an intervention to particular groups or communities, but naturally occurring or pre-determined variations in policy or environmental change can be evaluated with quasi-experimental designs.

Physical activity environments refer to places where children or teens can be physically active, such as homes; child=care, school and after-school settings; public and private recreation facilities; youth sports locations; sidewalks and trails; neighborhoods; and recreational settings where children and their families walk, bike and play.

<u>Physical activity and policies</u> refer to regulations, laws, policy-making actions or formal or informal rules established by organizations or government units that can affect physical activity. Policies affecting zoning, land use, recreation facilities, transportation, and crime and traffic safety can alter youth access to safe places to walk, bike and play (e.g., parks, playgrounds, sidewalks) for recreation and transportation purposes. Policies can affect access or quality of youth physical activity programs, including school physical education, recess, after-school programs, youth sports, promotion of active commuting to school, and costs of community recreational programs.

CHAPTER TWO: LITERATURE REVIEW

This chapter is mainly composed of five sections. First, it will begin with an overview of the prevalence of overweight and obesity in children and adolescents. Second, it will provide reviews of social ecological framework and a series of theoretical approaches for obesity preventions will be discussed. In Healthy people 2010, physical activity is ranked as a leading health indicator. Third, this chapter will provide the reviews of effective physical activity interventions. Fourth, the author will discuss the previous studies related to three physical activity related environments (psychosocial, commercial, and recreation) that will be investigated in the current study. Finally, this chapter will summarize the Baltimore Active Living Teens Study (BALTS, PI: Voorhees) and will present the unique characteristics of the current study and its conceptual model.

2.1 The Obesity and overweight in children and adolescents

Prevalence of overweight and obesity

Overweight prevalence. Based on YRBSS 2007 Survey (CDC, 2008), 15.8% of students in grades 9 – 12 were overweight nationwide. The prevalence of overweight was higher among white male (15.7%) and black female (21.4%) than white female (12.8%) and black male (16.6%) students, respectively. Overall, the prevalence of overweight was higher among black (19.0%) and Hispanic (18.1%) than white (14.3%) students and higher among black female (21.4%) and Hispanic female (17.9%) than white female (12.8%) students. Prevalence of overweight ranged from 11.4% to 18.2% across state surveys (median: 15.0%) and from 12.5% to 22.2% across local surveys (median: 17.7%).

Obese prevalence. Based on YRBSS 2007 survey (CDC, 2008), 13% of students in grades 9 – 12 were obese nationwide. Overall, the prevalence of obesity was higher among male (16.3%) than female (9.6%) students. Overall, the prevalence of obesity was higher among black (18.3%) and Hispanic (16.6%) than White (10.8%) students; higher among black female (17.8%) and Hispanic female (12.7%) than white female (6.8%) students; and higher among black male (18.9%) and Hispanic male (20.3%) than white male (14.6%) students. The prevalence of obesity ranged from 8.7% to 17.9% across state surveys (median: 12.0%) and from 8.4% to 19.3% across local surveys (median: 14.8%).

Risk times for the development of obesity

There are defined periods during the growth cycle where there is an increased risk of obesity – early infancy, the adiposity rebound in prepuberty, and adolescence – which need to be taken into account. The latter two periods are particularly relevant to intervention. Low birth weight is a risk for adult obesity and/or the metabolic syndrome. If low birth weight is the result of early gestational deprivation, then adiposity, hypertension and diabetes are more prevalent (Ravelli, Stein, & Susser, 1976). The earlier the adiposity rebound occurs, which is a universal phenomenon in mid-childhood, the greater the degree of adiposity in adolescence and adulthood (Rolland-Cachera, Deheeger, Sempe, Guilloud-Bataille, & Patois, 1984; Whitaker, Pepe, Wright, Seidel, & Dietz, 1998). Adolescence is a further risk time, particularly in females where increased body fat deposition is normal, with already obese adolescents experiencing a body fat gain which is threefold greater than that of lean adolescents (Dietz, 1994).

Physical activity in childhood and adolescence

Physical activity is taken to mean any time that the child is not asleep or completely sedentary. Physical activity in children can be planned or incidental – observation would suggest that in a 'time poor' society the emphasis is placed on planned activity for children.

Secular trends in physical activity in children, many of which are related also to safety of play, where freedom of activity is curtailed because of perceived or real danger, are not documented in traditional scientific literature. Such trend data may well be available, but not accessible. For example, the Transport Department of Western Australia has performed detailed transport studies of school car trips (James, 2000).

Limited episodes of vigorous activity may produce increased fitness, increased skill and increased strength, but will not produce a consistent increase in more general physical activity, which has been termed lifestyle or incidental activity. Incidental activity also includes spontaneous physical activity (SPA) or non-exercise activity. This type of activity, which includes wriggling and fidgeting, may serve a role to resist weight gain despite overeating (Levine, Eberhardt, & Jensen, 1999).

Children's activity varies in type, duration and intensity. Unlike adults there is no established grading system of intensity (metabolic equivalents or METs[1]) for various

[1] The measure of the rate of energy expended while doing work or exercise is known as metabolic equivalents or METs (Goran, 2000). Understanding your METs will not only help you understand how to prevent disease, doing so can help you train effectively. Exercise produces heat. We all get hot and sweaty after we run a certain distance. The amount of heat produced is directly proportional to the rate of energy

activities. Children's play is one category but may represent varied energy expenditure. Vigorous play will increase with age, strength and skill development (Pellegrini & Smith, 1998). Small children spend up to 50% of their time in sedentary play and much more active play is stop-start in nature (Pellegrini & Smith, 1998) and difficult to characterize. There is a decline in physical activity during adolescence, with the decline more apparent in female than in males and with a significant proportion of adolescents inactive. In 2007 YRBS (CDC, 2008), only 38.4% of adolescents spend at least 50% of school physical education class time being physically active, far away behind the goal of 50% from Healthy People 2010.

2.2 Social Ecological framework for obesity prevention

It has been suggested that environments that promote sedentary behaviors may be a strong contributor to the current obesity epidemic (Blanchard, et al., 2005; Ewing, Schmid, Killingsworth, Zlot, & Raudenbush, 2003; J. O. Hill & Peters, 1998; Swinburn, Egger, & Raza, 1999a). Indeed, several studies have been conducted on the role of built environment in shaping physical activity (PA) patterns. Distribution and quality of local sport and recreational facilities, community clubs and churches, as well as features of the

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expended, measured in METs. At rest, everyone expends energy at the same rate, measured as one MET, regardless of age or fitness level. As you expend energy, your body also uses oxygen. At rest, everyone uses the same amount of oxygen for each kilogram (or pound) of body weight. We use 3.5ml/kg/min. That is 3.5 milliliters (metric measurement of volume of oxygen used) per kilogram (metric measurement of standardized body weight) per minute. This rate of oxygen consumption at rest is equivalent to the rate of energy expenditure of one MET (3.5ml/kg/min=1 MET).

physical environment (e.g., safety, access to PA and recreation facilities) have been shown to have an influence on PA (Humpel, Owen, & Leslie, 2002; J.F. Sallis, Kraft, & Linton, 2002).

Based on the evidence, a social ecological approach is suitable for addressing the current obesity epidemic and low levels of PA in adolescents. The general thesis of social ecological approaches is that environments and particular social factors enable or constrain the range of behavior by promoting certain actions (e.g., sedentary behavior) and by discouraging other behavior (e.g., PA) (Wicker, 1979). This means that the "behavior setting" (i.e., physical and social context) could frame individual cognitions and perceptions (e.g., self-efficacy (SE) for PA) that either encourage or discourage PA. The ecological model (McLeroy, Bibeau, Steckler, & Glanz, 1988) systematically categorizing various of protective and risk factors into five levels of influences (Newes-Adeyi, Helitzer, Caulfield, & Bronner, 2000): (1) the individual level, including belief, values, education level, skills and other individual factors; (2) the interpersonal level, including interpersonal relationships between individuals; (3) the organizational level, which covers the way relevant institutes are organized and managed; (4) the community level, including the communities that individuals operate in (e.g., professional network, associations, neighborhoods), community attitudes, and the relationship among different institutions within communities; and (5) the policy level, which refers to policies and regulations affecting intervention participants and the institutions in which they function.

Figure 1: Social-Ecological Model

Source: http://www.cdc.gov/nccdphp/dnpa/obesity/state_programs/se_model.htm

The ecological models have gained increased recognition in the field of health promotion (Green, Richard, & Potvin, 1996; McLeroy, et al., 1988; Richard, Potvin, Kishchuk, Prlic, & Green, 1996; Stokols, 1996; Stokols, Allen, & Bellingham, 1996) and have been applied to investigations of many different health issues (Newes-Adeyi, et al., 2000; Stokols, Pelletier, & Fielding, 1996; Wandersman, et al., 1996). Some researchers have used social ecological models to guide program development. Goodman et al., (R.M. Goodman, Wandersman, Chinman, Imm, & Morrissey, 1996) for example, applied the ecological approach to their evaluation of how well a community-based intervention to prevent alcohol, tobacco, drug abuse and related risky behavior intervened at multiple levels, and how appropriate each set of strategies was for the community's stage of readiness. In developing, implementing and evaluating the community-based North Carolina Breast Cancer Screening Program, Viadro et al. (Viadro, Earp, & Altpeter, 1997) used a variety of instruments to collect progress data about organizational, program and individual service deliverer characteristics, as well as about external environmental influences. These data were used both for formative (advising program development and refinement) and for summative (assessing program effect) purposes.

Social ecological models describe the complex physical activity behavior as a dynamic process that is simultaneously influenced by a multitude of variables, including those at personal, social, and built environment levels (McLeroy, et al., 1988; J. F. Sallis & Owen, 1997). However, few studies have explicitly assessed how environmental and individual factors interrelate and how such interactions may have different influences on walking and physical activity in a broader socioecological context. To date, even fewer studies have exclusively examined aforementioned interplays in youth. With an adult sample, McNeill et al (McNeill, Wyrwich, Brownson, Clark, & Kreuter, 2006) found that social features (social support) of the environment and individual level factors (self efficacy) could mediate the relationship between physical environment and walking (J. Owen, Humpel, Leslie, Bauman, & Sallis, 2004). However, their study was limited by the self-reported measurements of physical activity and the findings may not apply to adolescents. This proposed study used a socio-ecological model of physical activity to examine direct and indirect effects of individual, social, and three built environmental factors (e.g., recreation, residential and commercial) in a sample of urban, predominately minority youth. This study combined both subjective and objective measures of physical activity outcomes and is theoretically and empirically justified.

2.3 Review of theoretical approaches to the physical activity promotion programs

Although some genetic predispositions contribute to the development of childhood obesity, its rapid increase in generically stable population points at the importance of environmental factors. Food commercialism, technology, urban and socioeconomic development are contributing to the creation of what is termed "obesogenic environments" that are nurturing over-eating and inactive lifestyle. Within these wider environmental influences, certain populations and communities can be more prone to obesogenic lifestyles. For example, the African American girls and Hispanic boys in the USA stand out as being more affected by the obesity epidemic (Ogden, et al., 2006), which may reflect underlying behavioral susceptibility patterns. Understanding these complex behaviors is important for the formulation of research and intervention strategies that will address the needs and circumstances of different groups of the society. Given the scale of the problem and what we already know about its root causes, it is surprising how little we have been able to alter its course. The following will briefly review the current strengths and limitations of the personal-level theoretical literature that has traditionally dominated the physical activity behavior field, and to introduce concepts and perspectives from other fields, including the social-ecology and urban planning fields, of potential relevance to the physical activity areas.

<u>Personal-level theoretical perspectives in the physical activity field</u>

Over the past two decades, a growing literature has focused on the application of theory to the physical activity field. The majority of theories have focused on the cognitive, affective, and social influences surrounding the individual and his/her choice to be active (i.e., personal-level perspective) (Dishman, 1994). Among the most prominent theories that focus primarily on intrapersonal processes (e.g., attitudes, beliefs, and affect) that have received at least some empirical support in the physical activity literature are the theories of reasoned action and planned behavior (Ajzen, 1991; Hausenblas, Carron, & Mack, 1997); expectancy-value or decisional theories (Hoyt & Janis, 1975; Kendzierski & Lamastro, 1988; Wankel, 1984); relapse-prevention models (A. C. King & Fredriksen, 1984; B. H. Marcus & Stanton, 1993; Marlatt & George, 1990); the transtheoretical model (B. H. Marcus & Simkin, 1994; Prochaska & Diclemente, 1984); and more recently, self-determination theory (Chatzisarantis & Biddle, 1998; Abby C. King, Friedman, et al., 2002). In addition to such theories, theoretical perspectives that have explicitly emphasized the dynamic interplay among intrapersonal factors, the behavior in question, and immediate or micro[2] environmental influences, have gained increasing empirical support. Such personal-plus-micro-environmental approaches include social cognitive theory (Bandura, 2001; Dzewaltowski, 1994).

In addition, a number of potential mediators of physical activity participation (i.e., intervention mechanisms contributing to physical activity change) have been identified through application of these personal-level theories. Yet, the mediators that have been

[2] Micro-environments (W. Wendel-Vos, 2007) are defined as environmental settings where group of people meet and gather. Such settings are often geographically distinct and there is often room for direct mutual influence between individuals and the environment. Examples of micro-environments are homes, schools, work places, supermarkets, bars and restaurants, and other recreational facilities.

most frequently studied have generally been found to explain a relatively small percentage of the variance in physical activity levels. It has become evident that the expansion of relevant targets for investigation has become increasingly pertinent. Targets that are particularly deserving of attention include the following:

1. The need to investigate understudied segments of the population, such as ethnic minorities, low-income people, people with disabilities, and older adults (A. C. King, Rejeski, & Buchner, 1998; W. C. Taylor, Baranowski, & Young, 1998). By evaluating which mediating influences may be particularly important for different population segments, more effectively tailored interventions may ensue.
2. The need to place more emphasis on the micro-environmental factors, such as social support , that form an important part of social cognitive theory and similar perspectives (Bandura, 2001), yet have received less systematic attention relative to other, more cognitive influences. For example, social support has been shown to consistently influence physical activity participation across an array of studies and populations (Dishman & Sallis, 1994; Oka, King, & Young, 1995).
3. Finally, it is critical that current investigation of theories and mediators be expanded beyond traditional psychosocial domains. That is to say, to include a greater array of behavioral and environmental factors that may well serve as potential mediators of physical activity change. We need to combine theoretical perspectives on the personal level, which are aimed at individuals' choices and decisions to be active, with more "choice-persuasive" or "choice-enabling" environmental perspectives implicit in broader-level meso- and macro-environmental approaches (Mckinlay, 1995).

The Macro-Environments: Social-Ecologic Perspective

Macro-environments include the broader, more anonymous infrastructure (sectors) that may support or hinder health behaviors. Examples of macro-environments are the town planning, the transport infrastructure, the health system, how products are marketed and distributed and the media (Swinburn, Egger, & Raza, 1999b). Social ecologic models of health promotion (McLeroy, et al., 1988; J. F. Sallis & Owen, 1997; Stokols, 1996) emphasize certain conceptual principles that are pertinent to understanding and influencing physical activity, and include the following:

1. Intrapersonal, interpersonal, physical environmental, and sociocultural variables function interactively to promote or hinder an individual's engagement in physical activity (A. C. King, et al., 2000).
2. Environment-behavior relationships are transactional in nature – that is, they are characterized by recurring cycles of reciprocal/mutual influence between people and their surroundings, rather than by unidirectional effects of environmental conditions on behavior (Proshansky, Ittelson, & Rivlin, 1976; Stokols, 1987).
3. Situational influences on physical activity patterns should be analyzed at different levels of the environment, ranging from micro to meso to macro scales (e.g., immediate-local conditions within one's home or workplace; meso-scale influence at the neighborhood level; and more distal or global feathers of whole communities such as the design of transit system, land use zoning laws, pervasive cultural values,

and wide spread economic or political conditions) (Bronfenbrenner, 1992; Killingsworth & Lamming, 2001).

4. Interventions to promote physical activity should address micro and macro levels of the environment and engage several sectors of society (A. C. King, Jeffery, & Fridinger, 1995; J. F. Sallis & N. Owen, 1999).

The principles underlying an ecologic analysis of individuals' activity patterns, outlined above, can be combined with several theories drawn from the fields of environmental and community psychology to establish a basis for identifying high-leverage features of micro and macro environments – each of which are hypothesized to influence individuals' physical activities, in conjunction with other situational and intrapersonal variables (e.g., family income, psychological readiness for health behavior change, self efficacy, and individuals' mental maps of their neighborhood and community environments).

Theories from Environmental and Community Psychology

The following theories, drawn from the fields of environmental and community psychology, suggest important mediators and moderators of physical activity that have received little attention in prior research.

Theories of environmental stress (including residential crowding, noise, traffic congestion, information overload, and threat of violence and crime). According to these theories, chronic exposure to environmental stressors can lead to feelings of fatigue, diminished sense of control over one's daily routines, and reduced social support within residential and work settings (C. Cohen, Evans, Stokols, & Krantz, 1986; Evans, 1999; Evans & Lepore, 1993; Glass, et al., 2006; Lazarus, 1966). At the neighborhood level, high levels of vehicular traffic have been found to reduce levels of social contact among neighbors and residents' use of sidewalks and front yards (Appleyard, 1981). Similarly, chronic exposure to community violence at the neighborhood level decreases residents' motivation to adopt and sustain healthy behaviors (Sanders-Phillips, 2000).

Theories of neighborhood disorder. At least two theories of environment and behavior have focused on physical and social features of neighborhood environments that are associated with a particular form of environmental stress, namely, heightened fear of crime among residents: Newman's theory (Newman, 1973) of defensible space and Perkins et al.'s (Perkins, Meeks, & Taylor, 1992; Perkins, Wandersman, Rich, & Taylor, 1993) and Taylor's theory of environmental incivilities (R. B. Taylor, 1988). Newman's (Newman, 1973) theory asserts that the physical design features of residential environments (e.g., the height of apartment buildings, number and density of dwelling units within an apartment complex, and poor site planning of structures that prevents inhabitants from exercising surveillance over outside areas adjacent to their building) can diminish residents ' sense of *defensible space*, or the extent to which they believe they have jurisdiction and control over their environment. Lower levels of defensible space are associated with heightened fear of crime and reduced use of open spaces adjacent to residential buildings. Taylor's theory of environmental incivilities (R. B. Taylor, 1988) further suggests that the overt presence of certain environmental cues in neighborhood areas (e.g., broken windows, poor street repair, graffiti, litter, and pornographic signage) convey a sense of disorder to occupants which, in turn, decrease their inclination to use sidewalks and open spaces for socializing with neighbors and engaging in recreational physical activities.

Restorative environments theory. The theories of environmental stress and incivilities, mentioned above, highlight certain potential constraints on individuals' engagement in physical activity. The theory of restorative environments (S. Kaplan, 1995), by contrast, identifies a set of environmental circumstances associated with stress reduction that may facilitate individuals' efforts to engage in physical activities – especially those undertaken for recreational purposes. Restorative environments are characterized by a high prevalence of natural features, such as water, foliage, extended vistas of open space, and other aesthetic elements that afford occupants a sense of novelty and the experience of "getting away" from one's usual work routines. Exposure to restorative environments has been found to reduce subjective and physiological levels of stress (R. Kaplan & kaplan, 1989; Korpela & Hartig, 1996; Ulrich, 1983). Residential and community environments that incorporate restorative physical features have the capacity to reduce stress and promote relaxation. Accordingly, those settings can be expected to facilitate individuals' engagement in a variety of recreational physical activities.

Ecologic psychology and the theory of behavior settings. Behavior settings are regions of the physical environment that are associated with recurring patterns of organized social activities (Barker, 1968; Schoggen, 1989; Wicker, 1979). Examples of behavior settings include classroom, neighborhood restaurants and retail stores, healthcare settings, and recreational venues, such as sports stadia and ice skating rinks. Behavior settings are situated in particular physical locations and are characterized by a predominant behavioral program or organized set of activities, such as instructional and learning activities that occur in classrooms, or the athletic events that take place in particular stadia.

Behavior setting theory is relevant to understanding and influencing physical activity in two respects. First, residents of communities that incorporate a larger number of recreational settings and facilities are more likely to engage in physical activities on a regular basis than individuals living in areas that offer fewer recreational opportunities (Corti, Holman, Donovan, & Broomhall, 1997; J. Sallis & N. Owen, 1999). Second, behavior settings can be thought of as meso-scale environmental units that contribute to the cultivation of social connections among citizens at the community levels, sometimes referred to as "social capital" (Putnam, 2000). Neighborhoods that incorporate a variety of well-organized behaviors settings are likely to be associated with high levels of social trust and civic engagement and , consequently, should be more conducive to residents active use of community open spaces and transit system for both creational and transportation purposes.

Given the short-time frame in which the obesity prevalence has increased to epidemic scales, many scientists postulate that this is more likely due to changes in environments than in biology. Environmental influences can be especially relevant to children and adolescents because they have less autonomy in their behavioral choices (Freedson & Evenson, 1991). Little empirical work has been undertaken to evaluate the application of these environmental and community psychology theories. An important direction for future research, suggested by theories outlined above, is to conduct prospective field-experimental studies of changes in physical activity levels in communities where potential environmental mediators of physical activity have been modified intentionally, as compared to case-control communities in which these environmental changes have not been made.

In conclusion, systematically identifying the most important social ecologic factors affecting physical activity participation is discussed above. In addition, exploring ways of combining such environmental approaches with empirically supported personal-level approaches may serve to enhance the reach and potency of physical activity interventions while mitigating any untoward effects on the individual.

The Macro-Environment: Urban Planning perspectives

In addition to social-ecologic perspectives, a growing interest has developed in understanding how features of city design can facilitate or impede physical activity. To analyze the relationship between city design and physical activity it makes sense to separate human environments into two types. The first type, which could be termed "car-oriented," is structured to ensure the safe and efficient movement of cars. The second type, which can be termed "pedestrian-oriented," is structured to ensure the safe and pleasurable movement of people. These two types of environments can be compared by discussion their structural differences, their relative conduciveness to human activity, and the obstacles that exist in trying to implement pedestrian-oriented environments.

Table 3 represents a summary of the fundamental differences between car-oriented and pedestrian-oriented environments. The former are relatively recent and are characterized by low-density, dispersed development that generally occurs on the fringes of existing urban areas. These areas, commonly termed "sprawl", are highly land consumptive. Spurred in part by a perception of limit-less, inexpensive land, development is random and often noncontiguous, resulting in vast areas of "lost space" comprised of parking areas, vacant lots, and empty strip malls, which make pedestrian activity undesirable as well as unsafe. The design of these places is focused on roads and aims to provide for the safe and efficient movement of cars. Diligent attention is paid to where cars are to be parked, with little consideration given to the effects of vast acres of asphalt on pedestrian activity. Land uses are kept separated (e.g., residential, commercial), which has the effect of further increasing the need for motorized travel. Because street connectivity (i.e., continuity) is restricted – via devices such as collector streets (larger streets that "collect" traffic from smaller streets) and cul-de-sacs – residents often lake the option of walking.

Pedestrian-oriented environments are fundamentally different. They are compact, mixed in use, focused on the public realm, and their streets and sidewalks are designed to encourage walking and other forms of pedestrian activity.

Most cities are composed of some combination of car-oriented and pedestrian-oriented environments. People can live in either types of environment, and still walk or drive depending on a variety of other factors. Yet, with respect to the effect of city design on physical activity, there is an essential, intrinsic difference between the two: one provides choices for physical activity associated with daily life, while the other does not.

The difference becomes clear when the reasons why people engage in physical activity area examined. The reasons generally are twofold: in built environments, people engage in physical activity either for the purpose of leisure and recreation or for the purpose of work or satisfying other daily life needs. While both automobile-oriented and pedestrian-oriented environments allow the possibility of engaging in physical activity for leisure, pedestrian-oriented environments accommodate the possibility of engaging in physical activity for daily needs, such as commuting or shopping. Whether or not residents actually do engage in physical activity in either type of environment has been traditionally treated as relatively unimportant in matters of city design. The important consideration is that automobile-oriented environments often restrict the choice of engaging in utilitarian forms of physical activity (i.e., physical activity as part of daily life needs) that can add to daily energy expenditure, and, consequently, influence physical activity-related health outcomes.

Table 3: Characteristics of two types of human environments

Automobile-oriented environments	Pedestrian-oriented environments
Past 50 years	Past 5500 years
Low-density, dispersed development	Compact development
Design of traffic flow primary concern	Design of public space primacy concern
Separation of land uses into mono-functional zone	Mixed land uses
Street connectivity limited	Street connectivity maximized
"lost space"	"Infill space"

Resource: (Abby C. King, Stokols, Talen, Brassington, & Killingsworth, 2002)

2.4 Review of effective physical activity interventions

Physical activity has many health benefits, including reduced risk of cardiovascular disease, ischemic stroke, non-insulin-dependent (type 2) diabetes, colon cancers, osteoporosis, depression, and fall-related injuries (Kahn, et al., 2002). Despite the benefits of regular physical activity, only 25% of adults in the United States report engaging in the recommended amounts of physical activity (i.e., 30 minutes of moderate-intensity activity on 5 or more days per week, or 20 minutes of vigorous-intensity activity on 3 or more days per week); 29% report no leisure-time regular physical activity; and only 27% of students (grades 9 through 12) engage in moderate-intensity physical activity (30 minutes, 5 or more days per week).

In Healthy people 2010, physical activity is ranked as a leading health indicator. The Healthy people 2010 has developed goals to improve levels of physical activity among adults, adolescents, and children and to reduce sedentary behavior among adolescents (Table 4). Recommendations to increase physical activity have been made for individuals and clinical settings but not for community settings. Increased physical activity has been linked not only to behavioral and social correlates but also to physical and social environmental correlates. Therefore, the role of community-based interventions to promote physical activity has emerged as a critical piece of an overall strategy to increase physical activity behaviors among the people of the United States. In 1996, the American College of Sports Medicine and the Centers for Disease Control and Prevention (CDC) recommended that every adult in the United States accumulate 30 minutes or more of moderate-intensity physical activity on most, preferably all, days of the week. That same year, the U.S. Preventive Services task Force recommended that healthcare providers counsel all patients on the importance of incorporating physical activity into their daily routines. This section of the review will give an update summary of interventions to increase physical activity.

Table 4: Selected objectives for increasing physical activity (PA), ***healthy people 2010***

Objective	Population	Percentage of population	
		Baseline[a]	2010 objective
No leisure-time PA	Adult	40% (1997)	Reduce to 20%
At least 30 minutes of moderate physical activity regularly, preferably daily	Adult	15% (1997)	Increase to 30%
At least 30 minutes of moderate physical activity on ≥5 of previous 7 days	Adolescents	27% (1999)	Increase to 35%
Vigorous PA that promotes the development and maintenance of cardiorespiratory fitness ≥3 days per week for 20 minutes/occasion	Adult	23% (1997)	Increase to 30%
Vigorous PA that promotes the development and maintenance of cardiorespiratory fitness ≥3 days per week for 20 minutes/occasion	Adolescents	65% (1999)	Increase to 85%
Daily school physical education	Adolescents	29% (1999)	Increase to 50%
View television ≤2 hours on a school day	Adolescents	57% (1999)	Increase to 75%
Trips of ≤1 mile made by walking	Adults	17% (1995)	Increase to 25%
Trips to school of ≤1 mile made by walking	Children and adolescents	31% (1995)	Increase to 50%
Trips of ≤5 miles made by bicycling	Adults	0.6% (1995)	Increase to 2%
Trips to school of ≤2 miles made by bicycling	Children and adolescents	2.4% (1995)	Increase to 5%

[a]Years indicate when the data were analyzed to establish baseline estimates. Some of the estimates are age adjusted to the year 2000 standard population.
Source: U.S. Department of Health and Human Services. Healthy people 2010: conference edition. Washington, DC: U.S. Department of Health and Human Services, 2000.[32]

The interventions reviewed in this section are useful in reaching the objectives set in Healthy People 2010. The strategies and strength and weakness reviewed here can be used to guide interventions to help increase levels of exercises and fitness. The two main foci of the Healthy People prevention objectives are to increase (1) the amount of moderate or vigorous physical activity performed by people in all population subgroups and (2) opportunities for physical activity through creating and enhancing access to places and facilities where people can be physically active. Three categories of interventions were reviewed in this section:

- Individual level information approaches: behavior modification, social learning, and individually tailored programs to change knowledge and attitudes about the benefits of and opportunities for physical activity within a community.
- Setting-specific, behavioral and social approaches to teach people the behavioral management skills necessary both for successful adoption and maintenance of behavior change and for creating social environments that facilitate and enhance

behavioral changes including school-based, worksite-based, health facility-based, and faith-based interventions.

- Environmental and policy approaches to change the structure of physical and organizational environments to provide safe, attractive, and convenient places for physical activity.

I. Informational approaches to increasing physical activity

Informational approaches are designed to increase physical activity by providing information necessary to motivate and enable people to change their behavior, as well as to maintain that change over time. The focus is mainly on the cognitive skills thought to precede behavior. The interventions use primarily educational approaches to present both general health information, including information about cardiovascular disease prevention and risk reduction, as well as specific information about physical activity and exercise. These programs were originally developed to complement a medical model of disease management by involving communities in understanding the cognitive antecedents of behavior.

The provision of information is intended to change knowledge about the benefits of physical activity, increase awareness of opportunities within a community for increasing physical activity, explain methods for overcoming barriers and negative attitudes about physical activity, and increase participation in community-based activities. Interventions reviewed here are **(1) Point-of-decision prompts and (2) classroom-based health education** focused on information provision and skills related to decision making.

Point-of-decision prompts

Point-of-decision prompts are signs placed by elevators and escalators to motivate people to use nearby stairs. Messages on the signs recommend stair use for health benefits or weight loss. Signs are thought to be effective in one of two ways: by reminding people already predisposed to becoming more active, for health or other reasons, about an opportunity at hand to be more active or by informing them of a health benefit from taking the stairs. All interventions evaluated in this category were single-component interventions, in which placement of the sign was the only intervention activity.

Reviews of evidence

Effectiveness

This search identified six reports (one paper reported two studies)(Andersen, Franckowiak, Snyder, Bartlett, & Fontaine, 1998; Blamey, Mutrie, & Aitchison, 1995; Brownell, 2004; Kerr, Eves, & Carroll, 2000; Nader, et al., 1999) on the effectiveness of point-of-decision prompts. All studies were of moderate suitability, using time-series designs. All were conducted between 1980 and 2000. Two of the studies (reported in one paper)(Brownell, 2004) were of good execution; the remaining four were rated as fair. All were included in the body of evidence.

Baseline rates of stair use were generally low, with all but one under 12% (range, 4.8% to 39.6%). In five studies (Andersen, et al., 1998; Blamey, et al., 1995; Brownell, 2004; Nader, et al., 1999) the median increase in stair-climbing was 53.9%. The remaining study showed an unspecified increase in stair-climbing and also found that the signs were effective in getting those who were less active (as measured by responses to a brief survey) to take the stairs. The range of effect sizes varied from a 5.5% net increase to 128.6%.

Classroom-based health education focused on information provision

Health education classes that provide information and skills related to decision making are usually multi-component, with the curriculum typically addressing physical activity, nutrition, smoking, and cardiovascular disease. Health education classes, taught in elementary, middle, or high schools, are designed to effect behavior change through personal and behavioral factors that provide students with the skills they need for rational decision making. Many of the classes in the studies reviewed had a behavioral skills component (e.g., role-play, goal-setting, contingency planning) but did not add time spent in physical activity to the curriculum. In most cases, comparison groups received the standard health education curriculum.

Reviews of evidence

Effectiveness

This search identified 13 studies (Bush, et al., 1989; Coates, Jeffery, & Slinkard, 1981; Eaton, Davis, Barrios, Brener, & Noonan, 2007; Holcomb, et al., 1998; Homel, Daniels, Reid, & Lawson, 1981; Killen, et al., 1989; F. E. Kuo, Bacaicoa, & Sullivan, 1998; A. C. Marcus, Wheeler, Cullen, & Crane, 1987; Moon, et al., 1999; Nader, et al., 1999; Park, et al., 2005; Petchers, Hirsch, & Bloch, 1988) evaluating the effectiveness of classroom-based health education focused on information provision. Most of the interventions were designed to reduce the risk of developing chronic disease. Four interventions (Bush, et al., 1989; Park, et al., 2005; Petchers, et al., 1988) were designed with the use of the Know Your Body curriculum. (The Know Your Body curriculum is designed to provide children with the skills needed to adopt behaviors that reduce the risk of developing cardiovascular disease. The classes focus on nutrition, physical fitness, and preventing cigarette smoking.) One intervention (Holcomb, et al., 1998) focused on prevention of type 2 diabetes by encouraging students to eat low-fat foods and to exercise regularly. The duration of the intervention activities ranged from 3 months to 5 years.

The studies reviewed showed variable effects of these interventions on time spent in physical activity outside the school setting: two studies showed increases in activity (Eaton, et al., 2007; Holcomb, et al., 1998; F. E. Kuo, et al., 1998), and two studies showed decreases in self-reported activity (F. E. Kuo, et al., 1998; Nader, et al., 1999). Other measures of physical activity were also varied: one study found positive changes in self-reported behavior (F. E. Kuo, et al., 1998), and two studies found no change or negative changes in self-reported behavior (F. E. Kuo, et al., 1998; Nader, et al., 1999). Aerobic capacity was not measured in any of these studies.

II. Behavioral and Social Approaches to Increasing physical Activity

Behavioral and social approaches focus on increasing physical activity by teaching widely applicable behavioral management skills and by structuring the social environment to provide support for people trying to initiate or maintain behavior change. Interventions often involve individual or group behavioral counseling and typically include the friends or family members that constitute an individual's social environment. Skills focus on recognizing cues and opportunities for physical activity, ways to manage high-risk situations, and ways to maintain behavior and prevent relapse. Interventions also involve making changes in the home, family, school, and work environments. Interventions reviewed here are (1) school-based physical education (PE), (2) college-based health education and PE, (3) classroom-based health education focused on reducing television viewing and video game playing, (4) family-based social support interventions, (5) social support interventions in community settings, and (6) individually-adapted health behavior change programs.

School-based PE

Interventions that used this approach modified curricula and policies to increase the amount of time students spend in moderate or vigorous activity while in PE classes. This can be done in a variety of ways, including (1) adding new (or additional) PE classes, (2) lengthening existing PE classes, or (3) increasing moderate to vigorous physical activity (MVPA) of students during PE class without necessarily lengthening class time. Examples of the last approach include changing the activities taught (e.g., substituting soccer for softball) or modifying the rules of the game so that students are more active (e.g., having the entire team run the bases together if the batter makes a hit). Many of these interventions also included the presentation of information on cardiovascular disease prevention, rendering it difficult to separate the effects of health education and modified PE.

Reviews of evidence

<u>Effectiveness</u>

This search identified 16 articles (one study was reported in two papers) (Donnelly, et al., 1996; Duncan & Mummery, 2005; Elder, et al., 2007; Fardy, et al., 1996; Flores, 1995; Glanz, et al., 2007; Halfon & Bronner, 1988; Harrell, McMurray, Gansky, Bangdiwala, & Bradley, 1999; Hopper, Gruber, Munoz, & Herb, 1992; Hopper, Munoz, Gruber, & MacConnie, 1996; MacKinnon & Dwyer, 1993; Manios, Moschandreas, Hatzis, & Kafatos, 1999; McKenzie, et al., 1996; Nader, et al., 1999; J. F. Sallis & Owen, 1997; Tell & Vellar, 1987; Vandongen, et al., 1995) reporting on 17 studies that evaluated the effectiveness of modified school-based PE curricula and policies.

Reported behavioral outcomes were energy expenditure (McKenzie, et al., 1996; Nader, et al., 1999; J. F. Sallis & Owen, 1997), percentage of class time spent in MVPA (Elder, et al., 2007; McKenzie, et al., 1996; Nader, et al., 1999; J. F. Sallis & Owen, 1997), minutes spent in MVPA (Elder, et al., 2007; McKenzie, et al., 1996; Nader, et al., 1999; J. F. Sallis & Owen, 1997), observed activity score (Donnelly, et al., 1996; Elder, et al., 2007), and self-reported type and frequency of physical activities outside of school (Basen-Engquist, Edmundson, & Parcel, 1996; Harrell, et al., 1999; Manios, et al., 1999; McKenzie, et al., 1996; Nader, et al., 1999; J. F. Sallis & Owen, 1997). Eleven studies also reported aerobic capacity as estimated maximal oxygen uptake (VO2 max) (Homel, et al., 1981; MacKinnon & Dwyer, 1993), results from timed runs (Donnelly, et al., 1996; Hopper, et al., 1996; McKenzie, et al., 1996; Nader, et al., 1999; J. F. Sallis & Owen, 1997; Vandongen, et al., 1995), or endurance testing (step test or shuttle runs) (Glanz, et al., 2007; Manios, et al., 1999; Vandongen, et al., 1995). These studies showed consistent increases in time spent in physical activity at school. Four studies showed increases in the amount (Basen-Engquist, et al., 1996; Donnelly, et al., 1996; Elder, et al., 2007) and percentage of time spent in MVPA in PE classes (Elder, et al., 2007; McKenzie, et al., 1996; Nader, et al., 1999; J. F. Sallis & Owen, 1997) . The median increase in the amount of PE class time spent in MVPA was 50.3% (range from 6.0% to 125.3%). The median increase in the percentage of class time in MVPA was 10% (range, 3.3% to 15.7%), with an additional study reporting a 762% increase from a very small baseline value. Two studies (McKenzie, et al., 1996; Nader, et al., 1999; J. F. Sallis & Owen, 1997) showed increases in energy expenditure as well. Eleven studies (Donnelly, et al., 1996; Fardy, et al., 1996; Flores, 1995; Glanz, et al., 2007; Hopper, et al., 1996; MacKinnon & Dwyer, 1993; Manios, et al., 1999; McKenzie, et al., 1996; Nader, et al., 1999; J. F. Sallis & Owen, 1997; Vandongen, et al., 1995) showed increases in aerobic capacity with a median of 8.4% .

College-based health education and PE

College-based health education and PE interventions aim to set long-term behavioral patterns during the transition to adulthood. To this end, they use didactic and behavioral education efforts to increase physical activity levels among college students. The physical education classes do not have to be offered by PE or wellness departments in college and university settings, but they do include supervised physical activity in the class.

The studies in this review included lecture classes that addressed the benefits and potential risks of physical activity, the current recommendations about the amount and type of physical activity one should get, and behavioral management techniques. Students applied these lessons in "laboratory"-type sessions in which they engaged in supervised physical activity, developed goals and activity plans, and wrote term papers based on their experiences. Students also received social support and phone calls from each other and made behavioral contracts for an agreed-on amount of physical activity.

Reviews of evidence

Effectiveness

This literature search identified five studies (one study was reported in two papers) (Block, Scribner, & DeSalvo, 2004; Brynteson & Adams, 1993; Epstein, Wing, Thompson, & Griffin, 1980; J.F. Sallis, Johnson, Calfas, Caparosa, & Nichols, 1997; J. F. Sallis & N. Owen, 1999; Slava, Laurie, & Corbin, 1984) evaluating the effectiveness of college-based health education and PE classes. The studies generally showed consistent increases in physical activity and aerobic capacity in the short term. The 2-year follow-up showed declines in activity back to previous levels and did not find the desired effects on the proposed mediators of behavioral change. According to Community Guide rules of evidence (Briss, Zaza, & Pappaioanou, 2000), because of the small number of qualifying studies, limitations in some of the studies' design and execution, and some inconsistency in the results (with positive results mostly limited to very short follow-up times), insufficient evidence was available to assess the effectiveness of college-based health education and PE interventions to increase physical activity behavior and fitness.

Classroom-based health education focused on reducing television viewing and video game playing

In elementary school classrooms, as part of a general health curriculum, regular classroom teachers taught classes that specifically emphasized decreasing the amount of time spent watching television and playing video games. Classes included instruction in behavioral management techniques or strategies such as self-monitoring of viewing behavior, limiting access to television and video games, and budgeting time for television and video. All studies included a "TV turnoff challenge" in which the students were encouraged not to watch television for a specified number of days. Activities that required greater energy expenditure than watching television or playing video games were not specifically recommended. Parental involvement was a prominent part of the intervention, and all households were given automatic television use monitors.

Reviews of evidence

Effectiveness

This literature search identified three studies (T. N. Robinson, 1999; Slava, et al., 1984) evaluating health education focused on reducing television viewing and video game playing. Two studies (Gortmaker, Cheung, et al., 1999; Gortmaker, Peterson, et al., 1999) occurred over a 2-year intervention period, and one study (T. N. Robinson, 1999) took place during a 6-month intervention period. All studies measured the time spent watching television and playing video games as the primary outcome of interest. One study (T. N. Robinson, 1999) also measured time spent in other sedentary behavior. The main effectiveness measure from these studies used in this review was the time spent in vigorous (Gortmaker, Cheung, et al., 1999), moderate or vigorous (R. M. Goodman, Wheeler, & Lee, 1995), or unspecified (T. N. Robinson, 1999) physical activity per day.

The studies showed a consistent decrease in television viewing and video game playing for both boys and girls according to children's self-report (Gortmaker, Peterson, et al., 1999; T. N. Robinson, 1999; Slava, et al., 1984) and parental report (T. N. Robinson, 1999). Time spent in other sedentary behaviors also decreased in a single study (T. N. Robinson, 1999). Reductions in television viewing and video game playing did not, however, consistently correspond with increases in physical activity. Six measures of physical activity showed inconsistent results, with two measures showing increases and four measures showing decreases.

Family-based social support

Family-based interventions attempt to change health behavior through the use of techniques that increase the support of family members for behavior change. The family is a major source of influence for children in the modeling of health behaviors and is, therefore, an appropriate target for intervention. Many disease risk factors, both behavioral and physiologic, aggregate within families. Moreover, a supportive social environment has been shown to increase maintenance of behavior change.

These interventions target factors in the social environment and interpersonal and behavioral patterns that are likely to influence physical activity behaviors. Interventions may be targeted to families with children or to spouses or partners without children. Programs typically include joint or separate educational sessions on health, goal-setting, problem-solving, or family behavioral management and will often incorporate some physical activities.

Interventions in this category targeted to children and their families are often implemented as part of a larger strategy that includes other school-based interventions, such as school-based PE or classroom-based health education. In this setting, the family component is often conceptualized as an adjunct home curriculum to the school activities, involving take-home packets, reward systems, and family record keeping. They may also include family-oriented special events (e.g., the CATCH [Child and Adolescent Trial for Cardiovascular Health] program has Family Fun Nights, which are “mini-health fairs” for family and peers that offer games, prizes, food, and beverages).

Reviews of evidence

Effectiveness

This literature search identified 12 studies (Eaton, et al., 2007; Hopper, et al., 1992; Hopper, et al., 1996; Manios, et al., 1999; McKenzie, et al., 1996; Nader, et al., 1999; J. F. Sallis & Owen, 1997) (Bishop & Donelly, 1987; Jason, Greiner, Naylor, Johnson, & Van Egeren, 1991; Nader, et al., 1999; Simons-Morton, Parcel, Baranowski, Forthofer, & O'Hara, 1991; Zimmerman, Gerace, Smith, & Benezra, 1988) of family-based social support interventions. Of these, 11 studies (Bishop & Donelly, 1987; Eaton, et al., 2007; Hopper, et al., 1992; Hopper, et al., 1996; Jason, et al., 1991; Manios, et al., 1999; McKenzie, et al., 1996; Nader, et al., 1999; J. F. Sallis & Owen, 1997; Simons-Morton, et al., 1991) indicated no change, with some studies showing increases in activity and others showing decreases. This inconsistency of results across the body of evidence can also be seen in the physiologic measures. Both increases and decreases were seen in energy expenditure, aerobic capacity and flexibility.

The 11 studies included in this review can be broadly divided into those that were implemented as part of a school-based program (Basen-Engquist, et al., 1996; Eaton, et al., 2007; Hopper, et al., 1992; Hopper, et al., 1996; Jason, et al., 1991; Manios, et al., 1999; J. F. Sallis & Owen, 1997) and those that were implemented as independent studies in the community setting (Bishop & Donelly, 1987; Nader, et al., 1999; Simons-Morton, et al., 1991). Studies that were implemented as part of a school-based program had slightly greater evidence of effectiveness, but the combination of techniques makes it impossible to attribute that success to the family-based social support intervention. In addition, studies that compared home and school interventions with school-only interventions showed no differences in effectiveness.

Social support interventions in community settings

These interventions focus on changing physical activity behavior through building, strengthening, and maintaining social networks that provide supportive relationships for behavior change. This change can be achieved either by creating new social networks or working within pre-existing networks in a social setting outside the family, such as the workplace. Interventions typically involved setting up a “buddy” system, making a “contract” with others to achieve specified levels of physical activity, or setting up walking or other groups to provide companionship and support while being physically active.

Reviews of evidence

<u>Effectiveness</u>

This literature search identified nine reports on the effectiveness of social support interventions in community settings. The typical intervention reviewed involved recruiting people into voluntary groups in which members provided companionship and support for attaining self-selected activity goals. Each study participant received phone calls from other participants and from study staff members to monitor progress and to encourage continuation of activities. The measured outcomes were varied and included the frequency and duration of exercise episodes (e.g., blocks walked daily, flights of stairs climbed daily, frequency of attendance at exercise sessions, frequency of jogging episodes, participation in exercise and organized sports, or minutes spent in activity).

Four studies (Avila & Hovell, 1994; Gill, Veigl, Shuster, & Notelovitz, 1984; Timperio, et al., 2006; D. R. Young, Haskell, Taylor, & Fortmann, 1996) measured change in time spent in physical activity with a median net increase of 44.2% (interquartile range, 19.9% to 45.6%). Three studies (Avila & Hovell, 1994; A. C. King & Fredriksen, 1984; Wankel, 1984) measured change in frequency of exercise or physical activity with a median net increase of 19.6% (interquartile range, 14.6% to 57.6%). Fitness also improved: three studies (Avila & Hovell, 1994; Gill, et al., 1984; A. C. King, Taylor, Haskell, & Debusk, 1988) showed a median net increase in aerobic capacity of

4.7% (interquartile range, 3.3% to 6.1%). One study (Lombard, Lombard, & Winett, 1995) found that those who received more frequent support were more active than those who received less frequent support, although both highly structured and less formal support were equally effective in getting people to be more active.

Individually-adapted health behavior change programs

Individually-adapted health behavior change programs are tailored to the individual's readiness for change, specific interests, and preferences. These programs teach participants specific behavioral skills that enable them to incorporate moderate-intensity physical activity into daily routines. Behaviors may be planned (e.g., a daily scheduled walk) or unplanned (e.g., taking the stairs when the opportunity arises). Many or most of these interventions use constructs from one or more established health behavior change models such as Social Cognitive Theory (Bandura, 2001), the Health Belief Model(Rosenstock, 1990), or the Transtheoretical Model of Change (Prochaska & Diclemente, 1984). All programs incorporated the following behavioral approaches: (1) setting goals for physical activity and self-monitoring of progress toward goals, (2) building social support for new behavioral patterns, (3) behavioral reinforcement through self-reward and positive self-talk, (4) structured problem-solving geared to maintenance of the behavior change, and (5) prevention of relapse into sedentary behaviors. All of the interventions evaluated were delivered to people either in group settings or by mail, telephone, or directed media.

Reviews of evidence

<u>Effectiveness</u>

This literature search identified 20 reports on the effectiveness of individually-adapted health behavior change programs (Coates, et al., 1981; Coleman, et al., 1999; Dunn, et al., 1999; Foreyt, Goodrick, Reeves, & Raynaud, 1993; Garcia-Reid, Reid, & Peterson, 2005; Jette, et al., 1999; Kanders, et al., 1994; A. C. King, Haskell, Taylor, Kraemer, & DeBusk, 1991; Lantz, et al., 1998; A. C. Marcus, et al., 1987; Mayer, et al., 1994; Morris, McAuley, & Motl, 2007; Noland, 1989; N. Owen, Bauman, Booth, Oldenburg, & Magnus, 1995; Paffenbarger, Hyde, Wing, & Steinmetz, 1984; Pate, Pratt, & Blair, 1995; J. I. Robinson, Rogers, & Carlson, 1992; Schwartz, Zamboanga, & Jarvis, 2007; Taggart, Taggart, & Siedentop, 1986). The typical intervention reviewed involved recruiting people into voluntary groups working toward physical activity goals. Members provided companionship and support for attaining self-selected activity goals. Study participants received phone calls from each other and from study staff members to monitor progress and to encourage continuation of activities. Some studies involved formal discussion groups in which barriers to exercise and negative perceptions about activity were addressed. The measured outcomes were varied and included the frequency and duration of exercise episodes (i.e., blocks walked daily, flights of stairs climbed daily, frequency of attendance at exercise sessions, frequency of jogging episodes, participation in exercise and organized sports, and minutes spent in activity).

Ten studies (Coleman, et al., 1999; Dunn, et al., 1999; Foreyt, et al., 1993; Kanders, et al., 1994; Lantz, et al., 1998; Mayer, et al., 1994; Morris, et al., 2007; Noland, 1989; N. Owen, Lee, Naccarella, & Haag, 1987; Schwartz, et al., 2007) measured change in the time spent in physical activity with a median net increase of 35.4% (interquartile range, 16.7% to 83.3%). Four studies (Coleman, et al., 1999; Dunn, et al., 1999; A. C. King, et al., 1991; Noland, 1989) measured change in VO2 max with a median increase of 6.3% (interquartile range, 5.1% to 9.8%). Four studies (Coates, et al., 1981; Coleman, et al., 1999; Foreyt, et al., 1993) measured change in energy expenditure with a net median increase of 64.3% (interquartile range, 31.2% to 85.5%). Other measures of physical activity, including attendance at exercise sessions (Morris, et al., 2007), the number of prescribed exercise sessions completed (A. C. King, et al., 1991), the percentage of people starting exercise programs (Pate, et al., 1995), and the frequency of physical activity (Noland, 1989; N. Owen, et al., 1987) increased as well.

The results of the various effect measures support a generally similar conclusion: the evidence suggests that this type of intervention is effective in increasing physical activity.

III. Environmental and policy approaches to increasing physical activity

Environmental and policy approaches are designed to provide environmental opportunities, support, and cues to help people develop healthier behaviors. The creation of healthful physical and organizational environments is attempted through development of policy that lends itself to creating supportive environments and strengthening community action. Correlational studies have shown that physical activity levels are associated with factors such as the availability of exercise equipment in the home and the proximity and density of places for physical activity within neighborhoods. Other neighborhood and environmental characteristics such as safety lighting, weather, and air pollution also affect physical activity levels, regardless of individual motivation and knowledge.

To affect entire populations, interventions in this category are not directed to individuals but rather to physical and organizational structures. The interventions are implemented and evaluated over a longer period of time than more individually oriented interventions. Interventions are conducted by traditional health professionals, but they also involve many sectors that have not previously been associated with public health, such as community agencies and organizations, legislators, and the mass media. The goal is to increase physical activity through changing social networks, organizational norms and policies, the physical environment, resources and facilities, and laws.

Creation of or enhanced access to places for physical activity combined with informational outreach activities

These interventions involve the efforts of worksites, coalitions, agencies, and communities to create or provide access to places and facilities where people can be physically active. For example, interventions in the body of evidence include providing access to weight and aerobic fitness equipment in fitness centers or community centers, creating walking trails, and providing access to nearby fitness centers.

In addition to promoting access, many of these studies incorporated components such as training on equipment, health behavior education and techniques, seminars, counseling, risk screening, health forums and workshops, referrals to physicians or additional services, health and fitness programs, and support or buddy systems. These multicomponent interventions were evaluated together because it was not possible to separate out the incremental benefits of each component.

Reviews of evidence

Effectiveness

This literature search identified a total of 12 studies (Bertera, 1993; Bowne, et al., 1984; R. C. Brownson, et al., 1996; Cady, Thomas, & Karwasky, 1985; Eddy, Eynon, Nagy, & Paradossi, 1990; Heirich, Foote, Erfurt, & Konopka, 1993; Henritze, Brammell, & McGloin, 1992; A.C. King, Carl, Birkel, & Haskell, 1988; Larsen & Simons, 1993; Lewis & Fremouw, 2001; Linenger, Chesson, & Nice, 1991; Ostwald, 1989; Pate, et al., 1995) evaluating the effectiveness of creation of or enhanced access to places for physical activity combined with informational outreach activities. Of these studies, five studies (Bertera, 1993; A.C. King, et al., 1988; Larsen & Simons, 1993; Linenger, et al., 1991; Ostwald, 1989) measured change in aerobic capacity: the median increase was 5.1% (interquartile range, 2.8% to 9.6%). Two studies (Linenger, et al., 1991; Pate, et al., 1995) measured change in energy expenditure: the median increase was 8.2% (range, −2.0% to 24.6%). Two studies (R. C. Brownson, et al., 1996; Heirich, et al., 1993) measured change in the percentage reporting some leisure-time physical activity: the median increase was 2.9% (interquartile range, −6.0 to 8.5%). One study (Lewis & Fremouw, 2001) measured exercise score: the median increase was 13.7% (interquartile range, −1.8% to 69.6%). Three studies (Bertera, 1993; Heirich, et al., 1993; Larsen & Simons, 1993) measured the percentage reporting three or more exercise sessions per week, and two studies (Henritze, et al., 1992; A.C. King, et al., 1988) measured frequency of physical activity; the median increase was 48.4% (interquartile range, 21.0% to 83.8%). The results of the various effect measures support a generally similar conclusion: the evidence suggests that this type of intervention is effective in increasing physical activity.

2.5 Emergent need to examine environmental factors influencing physical activity in adolescents

The dramatic increase in overweight and obesity in the US during the past decade is clear and easily quantifiable. Many youth today are physically inactive. Considerable evidence documents that nearly 35% of youth in the US fail to meet the minimum physical activity guidelines, and another 14% are completely inactive (CDC, 1997; USDHHS, 2000). Engagement in physical activity declines significantly during the high school years (Berrigan & Troiano, 2002). Low levels of physical activity and the failure to meet physical activity recommendations have notable consequences among children including increased risk of obesity (S.G. Trost, L.M Kerr, D.S. Ward, & R.R. Pate, 2001b), low bone density (C. M. Doak, Visscher, Renders, & Seidell, 2006), and low physical fitness (Maziak, Ward, & Stockton, 2008). Furthermore, children who are not physically active are denied the positive social and emotional benefits of physical activity including higher self esteem, lower anxiety, and lower stress (Pretty, Peacock, Sellens, & Griffin, 2005). The observed increasing prevalence of obesity and overweight is particularly striking for minority adolescents (Ogden, Flegal, Carroll, & Johnson, 2002). Studies have documented that inner-city youth experience high levels of life stress, poverty, and exposure to violence (Garbarino, Dubrow, Kostelny, & Pardo, 1992; Weist, Acosta, & Youngstrom, 2001). These stressors can negatively affect healthy adolescent development, and are associated with higher rates of emotional and behavioral problems and psychopathology (Tolan & Henry, 1996). Thus, research efforts must focus on identifying contributing environmental factors that contribute to inactivity and obesity, particularly in urban inner-city, minority populations who are more likely to suffer adverse health consequences. A comprehensive understanding of the determinants of physical activity among minority urban youth is essential for the identification of appropriate points of intervention to promote active lifestyles and their associated health benefits.

2.6 Residential psychosocial environment and physical activity

Studies have documented that inner-city youth experience high levels of life stress, poverty, and exposure to violence (Garbarino, et al., 1992; Weist, et al., 2001). These stressors can negatively affect healthy adolescent development, and are associated with higher rates of emotional and behavioral problems and psychopathology (Tolan & Henry, 1996). Glass and colleagues (Glass, et al., 2006) found among a cohort of older adults (50 to 70 years of age) in Baltimore City that living in a neighborhood with greater psychosocial hazards was independently associated with obesity. Their study was based on the theory that prolonged exposure to environments that evoke vigilance, threat, and alarm may be an important and modifiable contributor to the epidemic of obesity. **The unique contribution of our study** is (1) to examine whether the impact of neighborhood psychosocial hazards differs in a younger cohort with regard to PA level and obesity in a similar study setting, and (2) to test how residential psychosocial environments interact with other neighborhood environments to influence adolescents' PA levels.

2.7 Commercial environment and physical activity

Commercial environments are defined as walkable areas where sidewalks are present around stores (Active Living Research program, 2007). Promoting increased moderate-intensity physical activity to adolescents is a public health priority (USDHHS, 1996). Walking is the most common moderate-intensity activity for adolescents and recent studies have demonstrated the potential of active transport to and from school to increase overall physical activity levels for both elementary (Sirard, Ainsworth, McIver, & Pate, 2005; Sirard, Riner, Mciver, & Pate, 2005) and middle school students (Saksvig, et al., 2007). Transportation-related activity combined with other forms of moderate/vigorous physical activity throughout the day has the potential to reduce the chronic health risks associated with an inactive lifestyle. Improved understanding of the correlates of walking and other forms of moderate/vigorous physical activity can lead to evidence-based policies and programs.

There are **several domains of walking**, such as walking for transportation and walking for recreation. Built environments that **support utilitarian walking by having destinations (e.g., shops, services) in closer proximity** to residential areas have been associated with physical activity behaviors, primarily walking (Cervero, 1996; L. D. Frank, Schmid, Sallis, Chapman, & Saelens, 2005; B. Giles-Corti & R. J. Donovan, 2002; Handy, 1996; Hoehner, Brennan Ramirez, Elliott, Handy, & Brownson, 2005a; W. C. King, et al., 2005; Lee & Moudon, 2004). Furthermore, Moudon and colleagues (Moudon, et al., 2007) found walkable neighborhoods being centered on basic daily retail and food-related activities. Proximate presences of grocery stores/supermarkets, restaurants, and to a lesser extent, banks are significant attractors of walking. Their findings concurred with contemporary theories claiming commercially focused "town centers" as a necessary element of a community that is conducive to walking (Moudon, et al., 2006). However, some neighborhood walkability measurement issues may arise. Features such as connectivity, mixed use, density, and proximity of destinations often co-occur in studies, although they are highly correlated by nature. In addition, many research questions remain unresolved. For instance, what explains the findings that sidewalks are associated with walking but not necessarily with overall activity (e.g., meeting recommendations for moderate-to-vigorous physical activity [MVPA])? What explains the finding that walkability attributes are related mainly to active transportation? Additional research is needed to address more nuanced questions about how features of the built environment are associated with discrete measures of activity and with meeting physical guidelines. Our study, with comprehensive measures of outcome variables (e.g., walking for recreation, for transportation; overall PA (including MVPA), travel mode, etc.) will enable the investigator to address these questions.

2.8 Recreation environment and physical activity

There is a growing need to study how the aesthetics of environments are associated with active recreation or total physical activity. Many of these urgent physical health challenges, including obesity and coronary heart disease, are connected to sedentary and indoor lifestyle (CDC, 1996; DCMS, 2002). Physical active people have lower risk of dying from coronary disease type II diabetes, hypertension and colon cancer. Activity also enhances mental health, fosters healthy muscles and bones. Previous research suggests that exposure to green landscapes plays a role in promoting psychological and physiological well-being that can explain, at least in part, spatial patterns of overweight and obesity in children. Time spent outdoors is one of the strongest predictors of young adolescents' activity (J. F. Sallis, Prochaska, & Taylor, 2000); access to parks or other outdoor play space has also been associated with increased physical activity in youth (Baranowski, Thompson, DuRant, Baranowski, & Puhl, 1993; Giles-Corti, et al., 2005). Several studies have shown that proximity to recreational facilities and parks is one of the most important predictors of physical activity (J. Sallis, M. Hovell, & C. Hofstetter, 1990; James F. Sallis, Bauman, & Pratt, 1998). It was found in a recent study that adolescent girls who live near more parks, particularly near those with amenities that are conducive to walking and with active features, engaged in more non-school moderate/vigorous physical activity than those with fewer parks (D. A. Cohen, et al., 2006). Whether this is because of actual use of the parks or neighborhood choice could not be determined because the prevalence of living near a park or playground declined with decreasing income or education and increasing age. Although the magnitude of the association between parks and additional minutes of moderate/vigorous physical activity was small for an individual, amounting to an average of 4%-6% of a girl's total non-school moderate/vigorous physical activity, it is likely to have a large population-level association. Because of the potential population level impact, the use of parks to promote physical activity should be further studied.

Studies of inner-city neighborhoods have shown that outdoor spaces with trees are used with higher frequency by youth and adults than treeless outdoor spaces; moreover, the greater the number of trees, the more simultaneous users (Coley, 1997; F. E. Kuo, et al., 1998; A. F. Taylor, Wiley, Kuo, & Sullivan, 1998). Liu and colleagues (Liu, Wilson, Qi, & Ying, 2007) also found that after controlling for individual socio-demographics and neighborhood socioeconomic status, measures of vegetation significantly predicted overweight in children. That is, increased neighborhood vegetation was associated with decreased risk for overweight. Survey research has offered several reasons that could explain the positive effect of vegetation on use of outdoor spaces. Shade from tree canopy and scenery in the form of flowers and shrubs are associated with increased walking (James F. Sallis, et al., 1998). Vegetation may also promote activity in less direct modes (Liu, et al., 2007). For example, presence and maintenance of landscaping has been shown to be a strong indicator of territorial personalization, with implications that inhabitants actively care about their homes (Chaudhury, 1994). Such neighborhoods may display increased community cohesion and surveillance that deters crime and ultimately increases outdoor physical activity.

The evidence is growing on the importance of aesthetics of recreation facilities and neighborhoods in general for walking, running, and total leisure time physical activity. This study extends the findings that green spaces are associated with positive health outcomes. In addition, it aims to investigate the association between neighborhood vegetation, physical activity, and childhood overweight. It is one of the first investigations which includes both subjective and objective measures of an aesthetic characteristic (vegetation) of neighborhood recreation environment.

2.9 Overview of Baltimore Active Living Teens Study (BALTS)

The figure below depicts the conceptual model of BALTS study. It was hypothesized that individual, local physical environment and the social environment (i.e., family, friends) are associated with moderate/vigorous physical activity.

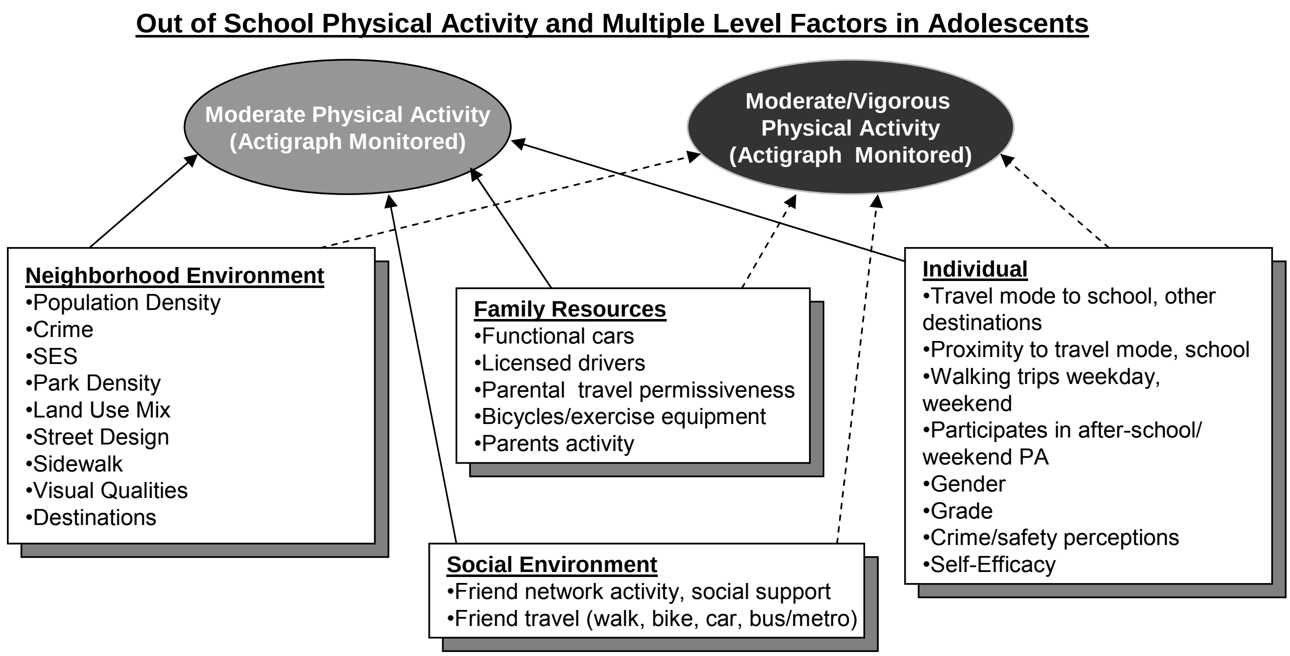


Figure 1

The key characteristics and unique contributions that distinguish the current dissertation are:

- Investigate three specific types of physical activity related built environments highlighted by Active Living Research program.
- Testing the mediating effects of physical activity.

CHAPTER THREE: METHODOLOGY

3.1 Background setting and population to be studied

Study site and population characteristics

The proposed study site is Baltimore city, Maryland. Based on 2000 US census data, the population in Baltimore is 64.3% African American, 31.6% White, 1.5% Asian and 2.6% other racial/ethnic groups. Ranked as the 6th of highest percentage of African American alone, the African American population in Baltimore is 418,951(2000 US census). Youth 10 to 24 make up about one-fifth of the total population. The distribution of youth across age groups (10-14, 15-19, 20-24) is fairly even at roughly one-third of each age group (2000 US census). Poverty continues to be a major problem for Baltimore. The percent of residents living in concentrated poverty is around 13% and female-headed families with children make up roughly one-third of all households (2000 US census). The wide variation in the sociodemographic characteristics of Baltimore City residents is shown in Table 5, which summarizes Census tract information for several demographic variables.

Table 5: Baltimore city, MD selected demographic variables versus Maryland

	Baltimore city	Maryland
Total Population, 2006	631,366	5,615,727
Persons per square mile, 2000	8,038.9	541.9
Median Household Income, 2004	$29,792	$57,019
% African-American, 2006	64.8	29.5
Persons per Household, 2000	2.42	2.61
Persons below poverty (%), 2004	21.5	9.2
Without Vehicle, 2004	72,318	N/A

In addition to the US census statistics of Baltimore city, studies have documented that inner-city youth experience high levels of life stress, poverty, and exposure to violence (Garbarino, et al., 1992; Weist, et al., 2001). These stressors can negatively affect healthy adolescent development, and are associated with higher rates of emotional and behavioral problems and psychopathology (Tolan & Henry, 1996).

3.2 Participants and data collection procedure for BALTS study

BALTS is a cross-sectional study investigating the effects of multi-level risk and protective factors on walking behavior and MVPA in a sample of 350 African American urban high school students (aged 14-18). The sample represents a broad geographic area of Baltimore city (participants distributed in 70 Census block groups and 139 traditional city neighborhoods). Participants were recruited in two magnet high schools located in Baltimore City, Maryland. A detailed description of recruitment can be seen elsewhere (Ries, Voorhees, Gittelsohn, Roche, & Astone, 2008). A magnet school is a public school that draws students who are interested in specific subjects from surrounding regions. In Baltimore city, admittance to magnet schools is depending upon test scores. One of the study schools focuses on math and engineering. Its student body is 70% African American, 26% White, 3% Asian, 1% Hispanic, and 0.4% American Indian. Twenty-five percent of students receive free student lunch, and 10% receive reduced school lunch ("Baltimore City Public School System Comprehensive School Profile Report: Baltimore Polytechnic Institute (on-line) "). The other study school has a liberal arts focus. The student body is 84% African American, 13% White, 2% Asian, 0.5% Hispanic, and 0.4%

American Indian. Thirty-two percent of students receive free school lunch, and 11% receive reduced school lunch ("Baltimore City Public School System Comprehensive School Profile Report: Western School (on-line) "). At both schools, students in twenty-nine non-core classes (biology, health, physical education, engineering practicum, science, chemistry, psychology, and sociology) were recruited for participation in BALTS. These classes were selected by the school administration. In deciding which classes would participate, they chose to include non-core classes in order to avoid using class time during required courses. They also aimed to address the principal investigator (Dr. Voorhees)'s request to recruit students from all four grades. Participation was then solicited through in-class presentations about the project and the purpose of the study.

A geographically stratified sampling method was used to recruit students based upon built environment characteristics to ensure variation in the students' home environments. Students were eligible for the study if they could read and understand English. Those who returned both a signed parental consent form and a signed child assent form were enrolled. Of 649 students that were recruited, 350 agreed to participate. Participation involved engaging in several data collection activities, including (1) a web based survey assessing students' self-reported perceptions of neighborhood built environment related to physical activities, (2) objective measure of physical activity using Actigraph accelerometer and the subjective measure of physical activity using the International Physical Activity Questionnaire (IPAQ), (3) travel dairy.

Web-based survey used subscales from the Neighborhood Environment Walkability Scale (NEWS) (Saelens, Sallis, Black, & Chen, 2003) and collected sociodemographic data. The Participants completed the web survey from school PCs and were able to redo the survey if any technical problems prevented them from continuing. Thus the response rate was 100%. The survey took approximately one hour to administer. The other data collection tools that were relevant to this dissertation study (e.g., objective measure of physical activity, travel dairy) and their development, validations and reliability are discussed in the instrument section. Each participant received incentives valued at $15-$30 for participation. The institutional review board of University of Maryland College Park approved the study (IRB: 04-0553). The data were collected during the 2006-07 school year.

3.3 Sampling frame

The sampling strategy of this study is based on that of the parent study (PI: Voorhees) examining the relationship between the built environment and physical activity in adolescents. A sample of 350 Students (in grades 9-12) was drawn from two urban magnet high schools. Students are distributed across 90 Census blocks. The geographic dispersion of the students provided the variability needed in population density and socioeconomic status to investigate the complex factors proposed. Only students with informed parental consent were eligible to participate in the study. The study team has been working with these schools for 13 years and has developed a rapport allowing for the recruitment of a representative sample of students (RWJ: BALTS study, PI: Dr Voorhees; NHLBI: Project HEART, PI: Dr Young).

3.4 Research Design

This cross-sectional study examined the direct and indirect effects of individual, built, and psychosocial environmental factors on African American adolescents' body mass index (BMI), and to assess how the relationships may be mediated by physical activity (PA) levels in a sample of grades 9 to 12 in Baltimore City. Several data sources were combined, including (1) individual-level PA and BMI measurements (main outcomes in the study), (2) self-reported sociodemographic data from each participant, (3) Maryland Property View 2006, ADS data from Maryland State Geospatial Data Archive (a measure of commercial environment), (4) 2000 Baltimore City Neighborhood Statistical Areas (NSAs) data (a measure of residential environment), and (5) 2002 Maryland Land use Land cover data (a measure of greenness), in order to estimate the effects of multi-level, multi-dimension factors on PA and childhood obesity.

3.5 Instrument

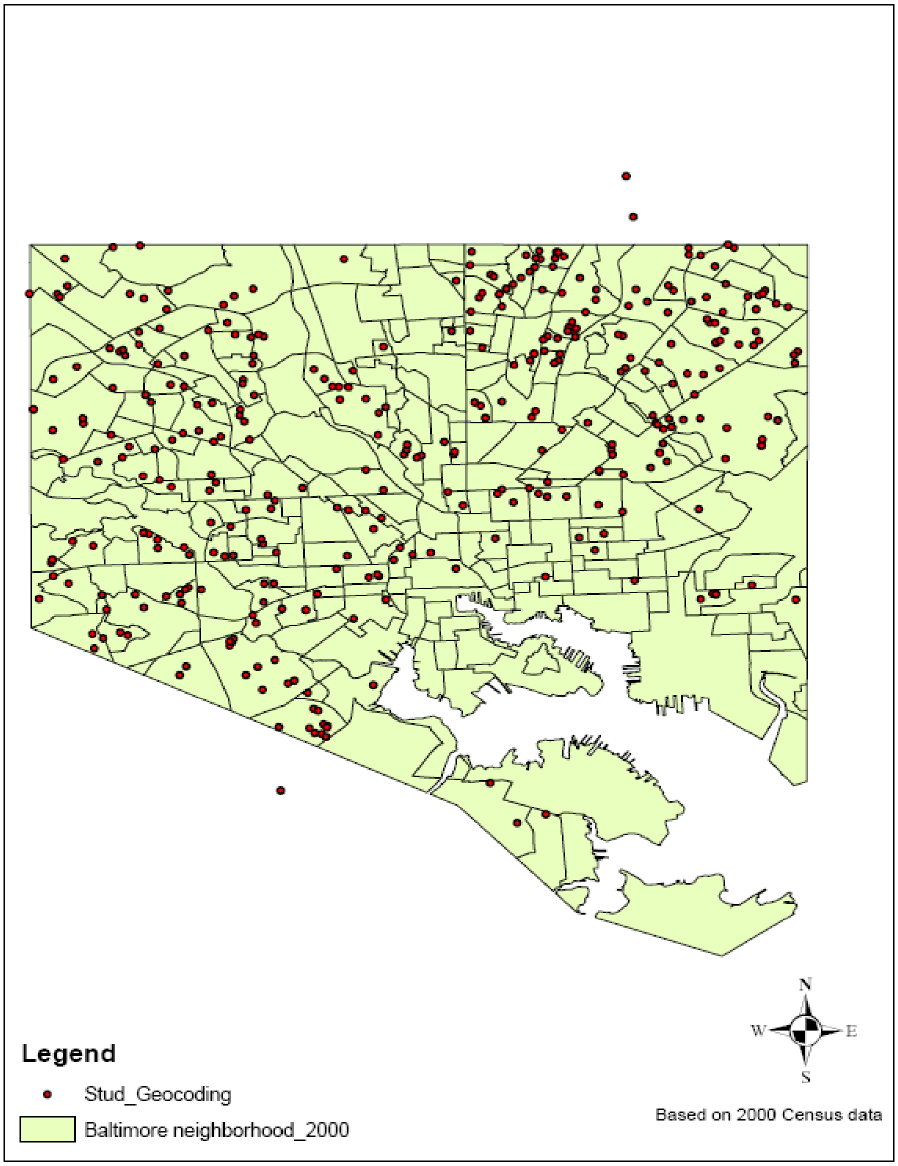
Independent variable

A. Measures of three environments. Three out of four Active Living Research program listed environments were measured. They are residential, commercial, and recreation environments. The complete list of study variables is shown in **Appendix A.**

a. Residential environment. The focus was on the psychosocial measurements of participant's residential neighborhood. Neighborhood boundaries were created by the

Baltimore City Department of Planning based on community definitions of existing neighborhoods. Thus, the spatial unit is the actual "city neighborhood" on neighborhood characteristics came from the 2000 U.S Census, and the Baltimore City Department of Planning, Public Works, and Police. Block-level Census data within precise boundaries of the Baltimore neighborhoods was obtained and recombined into neighborhoods by special request to U.S. Census Bureau. A complete list of indicators is shown in Appendix A. Number and location of violent crimes (the following are the types of violent crimes reported by Baltimore Police department: murder, rape, robbery, aggravated assault, burglary, larceny from vehicle, and stolen vehicle) and 911 emergency calls were individually mapped and aggregated at the residential neighborhood level using GIS. Participants were linked to their neighborhood of residence by their primary home address. The final 6 indicators were used to measure psychosocial hazards, defined as stable and visible features of neighborhood environments that give rise to a heightened state of vigilance, alarm, or fear in residents (Glass et al., 2006). Each indicator was standardized (z-score) and the sum of all standardized scores was used to create the final Neighborhood Psychosocial Hazards Scale (NPH). For modeling, the NPH was divided into quartiles (low, low-moderate, high-moderate, and high) to test across levels of neighborhood psychosocial hazards. Baltimore has 55 Community Statistical Areas (CSAs) (Source: Baltimore Neighborhood Indicator Alliance, http://www.ubalt.edu/bnia/indicators/statistical_profiles.html). The residential environment study was based upon those CSAs. Figure 2 also demonstrates the distribution of students in those community statistical areas.

Figure 2: Students distribution in Baltimore City Community Statistical Areas



In general, the neighborhoods fell into two categories: census-based and address based. The senses-based were the census tract and census block group. In this study, the actual “city neighborhood” was census-based and was used to define the broader residential neighborhood level analysis, in which students were nested. The address-based neighborhoods in this study are chosen to defined objective measured commercial and recreational environment.

There are several different definitions of address-based neighborhood in the literature. More recently buffers around the participant's home are used as a proxy for an address based neighborhood (Porter, Kirtland, Neet, Williams, & Ainsworth, 2004). Commonly used distances for creating these buffers in the adolescent physical activity literature are 0.5–0.6 miles (800 – 1000 meters) (Braza M, Shoemaker W, & A., 2004; Kerr, et al., 2006; Timperio, et al., 2006) or a 1 mile (1500–1600 meters) buffer around the home (D. A. Cohen, et al., 2006; Jago, Baranowski, & Baranowski, 2006; Norman, et al., 2006). However buffers as small as 0.25 miles (400 meters) (Jago, Baranowski, Zakeri, & Harris, 2005) and as large as 5 miles (8.05 kilometers) have been used (Gordon-Larsen, Nelson, Page, & Popkin, 2006). 0.25-mile distance (400m or approximately a five-block radius) from each person's residence has been widely used in urban planning literature to specify the scale of residential neighborhoods based on relatively easy walkability (Krizek, 2003). Gordon-Larsen and colleagues chose 5-mile (8.05 kilometers) to define buffer on the basis of empirical evidence that this distance would likely capture relevant physical activity facilities (Antonakos, 1995; J. F. Sallis, M. F. Hovell, & C. R. Hofstetter, 1990). Most studies acknowledge the lack of empirical data for selecting these distances and suggest additional research. One rationale for selecting these geographies is that they correspond to an easy walking distance (Jago, et al., 2005; Timperio, et al., 2006) though little empirical evidence exists for defining an easy walking distance. Larger buffers are sometimes employed to represent a reasonable driving distance (Kirtland, et al., 2003).

Defining the neighborhood for commercial and recreational environment measures

Because there are several neighborhood boundaries in the literature, I decide to create four neighborhood feature layers based on different definitions of neighborhood commonly reported: (1) ¼ – mile circular buffer, (2) ½–mile circular buffer, (3)1–mile , and (4) 1.5-mile circular buffer around each address. The same methodology and protocol have been used in a nationwide, multi-site randomized controlled intervention trial funded by the National Heart, Lung and Blood Institution of NIH (Trial of Activity for Adolescent Girls- TAAG) (D. Cohen & Ashwood, 2006) and an ancillary study of TAAG conducted by RAND (Overton & Ashwood, 2003). Once after creating the neighborhood boundaries, several measures from the geo-coded data containing the measures of commercial environment and recreation environment [discussed in the following (b and c)] were generated.

b. ***Commercial environment.*** The commercial environment refers to walkable areas where sidewalks are present around stores and commercial/public destinations. The following destination types: (1) Grocery stores, (2) retail and shopping centers, (3) fast food restaurants, (4) post offices, (5) schools and museums, (6) theaters and swimming pools, and (7) parks and recreation were used for the current study. Destinations were obtained from MD Property view. Destination/address data were used to geo-code the business and identify those that fall within each buffer centered on student's home address.

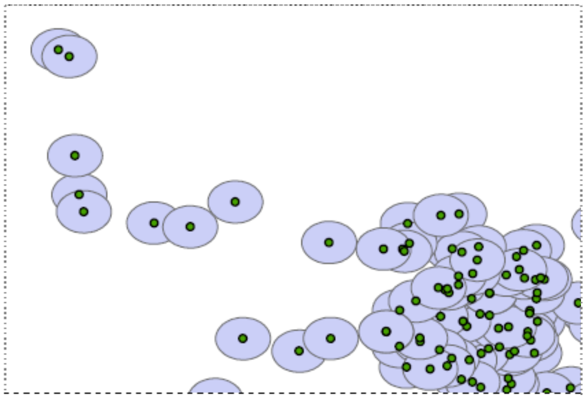
Destination proximity and density

Four different buffer sizes were created (0.25 mile-, 0.5 mile, 1mile, and 1.5 mile) around each student's home address. Proximity to each type of destination location was calculated using GIS network distance along street centerlines. Then the counts (density) of various types of destinations that are within certain miles of walking distance of each student's residence were calculated, hereafter referred to as objective accessibility. For example, the number of grocery stores, or swimming pools that were located within each buffer was calculated. Finally, the destination mix was created by using a calculated cumulative opportunity measure (Handy & Clifton, 2001; McCormack, Giles-Corti, & Bulsara, 2008). This measure included a total count of different types of destination within a variety of buffers of student's home. All analytic buffers were centered on the student's home address.

In Geographical Information System, the units of buffering are points, lines, and polygons. Buffer operation refers the creation of a zone of a specified width around a point or a line or a polygon. Buffering point data involves the creation of a circular polygon about the point of interest. The radius of this circular polygon is called the buffer distance. In this study the buffer is a point buffering operation. For example, a 0.5-mile buffer is 0.5-mile radius zone around a point (student's home address in the map). Figure

3 demonstrates an example of buffering multiple points (students address) in 0.5-miles radius.

Figure 3: Buffering Multiple Points



Note. Buffering multiple points (students address) in 0.5-miles radius.

c. ***<u>Recreation environment</u>.*** Neighborhood greenness was objectively measured by the percent green area coverage within 0.25-, 0.5-, 1.0-, and 1.5- mile radius buffer for each student. The measures of neighborhood vegetation were obtained from recent Maryland Land use land cover data (2002) archived at the University of Maryland's Global Land cover Data Facility. The Mid-Atlantic Regional Earth Science Application Center (RESAC) at the University of Maryland has mapped the entire Chesapeake watershed, including the study area, using Landsat data and a sophisticated regression tree statistical approach. This map forms the initial basis of research as it provides detailed spatial information on a variety of land cover classes and has been extensively validated. **<u>Appendix C</u>** gives a demonstration of 1) technical supports the PI is assured from the University of Maryland and 2) examples of a land cover map and a tree cover density map on which greenness analyses is based. Other objective measures include percentage of open space (i.e., playground, recreation centers) coverage within 0.25, 0.5, 1, and 1.5 mile radius buffer around each student's home.

B. Individual socio-demographic measures.

Individual data on demographic and socioeconomic variables, such as sex, age, and ethnicity were obtained through the web-based survey and are described in **Appendix A.**

Dependent variables

The main outcome variables were collected through a larger ALR study (PI: Voorhees). The outcome measurements cover a broad array of variables **(Appendix A)** from both public health and transportation perspectives, including **BMI, walking trips, and overall Physical activity.**

Body Mass Index (BMI)

Both objective measured weight and height were obtained to calculate body mass index (BMI). Weight was measured in kilograms to the nearest 0.1 kg using a medical weight scale (Tanita Digital Medical Scale), zeroed and calibrated before each weight. A stadiometer (Schorr Board), calibrated in 0.1-cm intervals, was used to determine height. The NCHS-CDC 2000 growth charts were used to calculate BMI and BMI percentile for age and sex.

Body mass index [BMI = weight (kg)/height^2 (m)] was calculated for each individual on the basis of measured weight and height. The adolescents' body weight status was classified on the basis of the age- and sex-specific BMI percentiles provided in the 2000 growth charts of the Centers for Disease Control and Prevention. *Overweight* was defined as a BMI≥ 95th percentile, and *at risk of overweight* was defined as a BMI ≥ 85th percentile (i.e., it included overweight). BMI is categorized as a binary variable (i.e., BMI ≥ 85th percentile is defined as at risk of overweight or overweight) in the analyses.

Walking behavior

Walking was defined as the frequency of walking trips for school, work, recreation, and exercise, or to get to places. It was measured by the household travel diaries. During the measurement week students were oriented to the process of completing a one-week travel diary. A paper travel diary was filled out to record destinations visited, time, and mode of travel in one-week. Household travel diary (L. D. Frank, Kerr, Chapman, & Sallis, 2007) is a standard tool used within the transportation industry to capture and assess the movement between and time spend at habitual (home and work) and other locations. When assessing the walking behavior, I selected the travel mode to be "walking" and then student-reported seven-day walking data were reduced to the individual level of walking trips per day and per week.

Overall Physical Activity measurement and Data reduction

Physical activity was measured by Actigraph accelerometers (Computer Science Applications). The Actigraph accelerometer is widely accepted as a valid means of physical activity assessment (Ainsworth, Wilcox, Thompson, Richter, & Henderson, 2003; Pate, et al., 2002; Thompson, et al., 2005; S.G. Trost, L.M. Kerr, D.S. Ward, &

R.R. Pate, 2001a; Trost, et al., 2003; Trueth, et al., 2004). Actigraph accelerometer has been proven to correlate reasonably with doubly labeled water (DLW)-derived energy expenditure (Plasqui & Westerterp, 2007). DLW technique is considered the gold standard for measuring energy expenditure under free-living conditions. Following a standardized protocol, each monitor was initialized prior to placing it on a belt to be worn on each participant's waist on their right hip. They were asked to wear it all the time, except at night while sleeping and while bathing or swimming during the seven consecutive monitoring days. Activity counts were stored in 30-second time intervals. Students who failed to comply with minimal wear, had a monitor malfunction, or left fewer than 7 days of data (or non useable data) were asked to wear the monitor again until useable data were collected.

Actigraph counts were summarized by quantifying the time (minutes) spent at different intensity levels. The BALTS thresholds for the activity intensities were less than 50.99 counts for sedentary activity, 51 to 578.99 counts for light activity, and 579 or more counts for MVPA. The threshold of 579 or more counts for MVPA corresponds approximately to the lower bound for a 2.5-mph walk, representing an activity intensity level of three metabolic equivalents (METs). A 3-MET cut point to define MVPA was used because it has been used as the threshold for MVPA in previous studies of youth (Ainsworth, et al., 2003; Pate, et al., 2002; Thompson, et al., 2005; Trost, et al., 2001a; Trost, et al., 2003; Trueth, et al., 2004). Accelerometer data reduction methods incorporated the following data processing issues suggested by literature: (Mâsse, et al., 2005)(1) individual record that either has value greater than 16,000 counts (max value for accelerometer) or constant and consecutive non-zero records for 10 minutes were excluded from the analysis, (2) valid wearing time was determined by subtracting the invalid minutes (i.e., interruption) from the total wearing minutes. The total weekday out of school minutes were the accumulated valid wearing minutes using before (5 a.m. – 8:30 a.m) and after school (3 p.m. – 10 p.m) combined. Interruption was estimated using 20 minutes (Saksvig, et al., 2007; Treuth, Sherwood, & Baranowski, 2004; Treuth, Sherwood, & Butte, 2003) of continuous zero counts. (3) The minimal wear requirement for a valid out of school day was 6 hours (Jackson, et al., 2003). Accordingly, the percentage of time spend in MVPA was defined as the combined valid moderate and vigorous physical activity minutes divided by the total *valid* physical activity time in each intensity category (i.e., sedentary, light, moderate, and vigorous physical activity). Moderate physical activity, moderate-to-vigorous physical activity, and vigorous physical activity were used as outcomes for this study. Aaccelerometers data were only used before (5 a.m. – 8:30 a.m) and after school (3 p.m. – 10 p.m) and on weekdays because we hypothesized that the neighborhood environmental factors would only affect non-school activity.

3.6 Data Analyses

Power and sample size estimation

The statistical power for this study depends on four factors: statistical test, alpha level, sample size, and effect size (Lipsey, 1990). The effect size represents the magnitude of the "real" effect to be detected (Lipsey, 1990). Based on data from the parent study (RWJ: BALTS study, PI: Dr Voorhees), it has been estimated that the effect size of this study for most independent variables is considered medium, ranging from .47 to .55. The statistical power is therefore found to be between .85 - .90 with the existing sample size. In other words, there is an 85 to 90% chance that the differences in the dependent variable accounted for by independent variables can be detected.

<u>Preliminary descriptive analyses</u>

This study examined the descriptive statistics of all variables including means, and standard deviation as well as the frequencies of all outcome measures to determine the distribution of variables. Bivariate association was assessed through correlation matrices for continuous variables, chi-squared tests for independence for pairs of categorical variables, and one-way ANOVA for continuous dependent variables and categorical independent variables.

<u>Inferential analyses corresponding to each aim</u>

Aim1. To estimate the effects of multi-dimension factors (i.e., sociodemographic status and three neighborhood environments) on PA levels among African American adolescents.

<u>Dependent variables (DVs)</u>: The multi-dimension indicators (e.g., MVPA measured as minutes per day) for PA levels are considered as continuous variables. They are measured at the individual level.

<u>Independent variables (IVs)</u> are measured at multi-levels. The first level, which consists of individual level factors, includes measures of socio-demographic status and

commercial and recreation environments for each student. The second level is the neighborhood level, which refers to the measure of residential environment of the actual "city neighborhood." Students were nested within their residential neighborhood.

Analytical model: Given the multilevel nature of the data, the hierarchical linear model (HLM) analysis was employed. The HLM allows for the simultaneous estimation of the effects of neighborhood level and individual level factors, accounting for non-independence of observations within residential environment.

Multilevel models are divided into the random intercept model and the random coefficient model, based on how to treat an intercept and covariates. The random intercept model only considers the intercept as a random component, whereas the random coefficient model treats covariates as well as the intercept as random variables. By treating the intercept and covariates as random components, the variation and effects of clusters can be examined (Kreft & De Leeuw, 1998). Contrary to the multilevel models, the conventional linear regression model does not consider the plausibility of similarity among observations in a cluster, and simply postulates that all the error terms are not related to one another. In this study, the random intercept model was adopted and was presented with an example of one covariate in a two-level structure.

For the random intercept model, only the intercept is allowed to differ across clusters.

$$\mathbf{y_{ij} = (\alpha + \beta x_{ij}) + (\mu_j + e_{ij})} \qquad \textbf{(Equation 1)}$$

Where Y_{ij} is the dependent variable, body mass index for example, for observation *i* in cluster *j*, α is the intercept, β is the effect of the covariate X_{ij}, u_j is the random effect associated with jth cluster, and e_{ij} is the level-1 random effect (i.e., random error term for ith student in jth cluster). The random intercept model is considered to have two parts, fixed effects and random effects. In equation 1, ($\alpha + \beta X_{ij}$) does not change, regardless of observations and clusters. But ($u_j + e_{ij}$) could change according to clusters and observations. Because of these characteristics, the former and the latter can be called fixed effects and random effects, respectively (Kreft & De Leeuw, 1998).

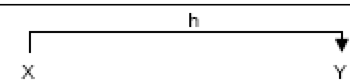
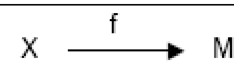
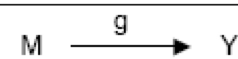
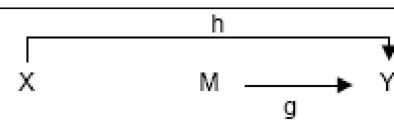
The random effects at the cluster level, u_j, are assumed to have the mean of 0 and the variance of σ_u^2. Also, the random effect in cluster j should not be correlated with either the random effects at the observational level, e_{ij}, or the random effect of other clusters. The assumptions related to e_{ij} are the same as those in the conventional linear regression model (Hox J., 2002).

Aim2: To estimate the effects of multi-dimension factors on BMI and assess how the relationships may be mediated by PA levels.

Dependent variable: BMI is considered as continuous variable.

Analytical model: The same HLM model with BMI and the same set of IVs was employed.

Analysis procedures: Similar procedures were conducted as in Aim 1 since Aim 2 has similar purpose. An additional interest of Aim 2, however, is the mediating effect of PA levels. The mediation analyses were based on the framework proposed by Baron and Kenny (Baron & Kenny, 1986). Baron and Kenny (1986) proposed a four step approach in which several regression analyses are conducted and significance of the coefficients is examined at each step.

	Analysis	Visual Depiction
Step 1	Conduct a simple regression analysis with X predicting Y to test for path h along, $Y=B_0+B_1X+e$	
Step 2	Conduct a simple regression analysis with X predicting M to test for path f, $M=B_0+B_1X+e$	
Step 3	Conduct a simple regression analysis with M predicting Y to test the significance of path g alone, $Y=B_0+B_1M+e$	
Step 4	Conduct a multiple regression analysis with X and M predicting Y, $Y= B_0+B_1X+B_2M+e$	

The purpose of Steps 1-3 is to establish that zero-order relationships among the variables exist. If one or more of these relationships are non-significant, researchers usually conclude that mediation is not possible or likely. Assuming there are significant relationships from Step1 through Step 3, one proceeds to Step 4. In the Step 4 model, some form of mediation is supported if the effect of M (path b) remains significant after controlling for X. if X is no longer significant (path c') when M is controlled, the finding supports full mediation. If X is still significant (i.e., both X and M significantly predict Y), the finding support partial mediation.

The mediated effect can be tested for significance with an estimate of its standard error. The most common used estimate of standard error ($\acute{\upsilon}_{\alpha\beta}$) is the approximate formula derived by Sobel (Sobel, 1982) using the multivariate delta method:

$$z' = \frac{\alpha\beta}{\sqrt{\alpha^2 s_\beta^2 + \beta^2 s_\alpha^2}}$$

The mediated effect divided by its standard error yields a z-score of the mediated effect. Typically, if the z-score is greater than 1.96 we conclude that the effect is larger than would be expected by chance and call the effect significant. The standard error can also be used to construct confidence intervals around the mediated effect. Ninety-five percent confidence intervals are calculated by adding and subtracting the product of 1.96 and the standard error from the mediated effect.

Intraclass correlation refers to correlation among observations within a cluster. The intraclass correlation coefficient (ICC) measures this degree of correlation. An ICC can be determined from an intercept-only model as follow:

$$\mathbf{y_{ij} = \alpha + u_j + e_{ij}}$$

The intercept-only model only separates the variances of the dependent variable into two parts; that is, the variance of clusters, σ_u^2, and the variances of observations at level 1, σ_s^2. The ICC, written as "ρ", can be computed on the basis of the two variance components.

$$\boldsymbol{\rho = \sigma_u^2 / (\sigma_u^2 + \sigma_s^2)}$$

The ICC ranges between -1.0 and 1.0. A value of zero indicates no association within clusters, meaning that respondents within clusters are no more alike than between clusters. In another words, all observations are independent of one another. A value of 1.0 indicates perfect positive association within clusters, meaning that all respondents within the cluster respond the same (Hox J., 2002). The interpretation of the ICC is the proportion of total variance (i.e., cluster plus individual variance) that is attributed to the cluster level. Therefore, as the relative variance of the clusters increases, the less likely you are to assume that the groups are similar. Another interpretation of the ICC is the anticipated correlation between two observations that are randomly chosen from the same cluster (e.g., correlation of students within the same neighborhood) (Hox J., 2002; Kreft & De Leeuw, 1998).

Statistical Analysis

The address geo-coding and spatial analyses were conducted with ArcGIS 9.2 (ESRI, Redlands, CA). All statistical analyses were conducted using SAS version 9.3 (Cary, NC), and all models were fit using PROC MIXED. The data can be considered to have a hierarchical structure, in which students (level 1) are nested within neighborhood (level 2). Therefore neighborhoods were treated as random effect in the mixed model. Intraclass correlations (ICCs) were calculated for models. The intraclass correlation (ICCs) ranged 0.035 to 0.038, which means roughly 3.5% to 3.8% of the total variance can be explained by cluster membership. Typically, ICCs for school based adolescent intervention, such as adolescent substance use, with school as the grouping factor, have ranged from just above zero to 0.07 (Dielman, 1994; D. M. Murray, et al., 1994;

Siddiqui, Hedeker, Flay, & Hu, 1996). Values as small as 0.0025 have been shown to be significantly different from 0 at the 0.05 level of statistical significance (D. Murray & Hannan, 1990). Despite such small magnitudes, these ICCs indicate substantial school clustering. The ICCs (ranged from 0.035 to 0.038) found in this study; indicated that a multilevel or hierarchical model would provide benefits over a standard fixed effects model for the analysis of these data. For the purposes of the study, only coefficients of fixed effects were interpreted and presented in this study. Individual sociodemographic variables (e.g., age, gender and race/ethnicity) were entered as covariates because of their known association with physical activity. Due to the (1) exploratory nature of the study, (2) high prevalence of sedentary activity observed among the subjects, and (3) levels of significance used in other physical activity studies with the multilevel analysis approaches (Kelly R. Evenson, Scott, Cohen, & Voorhees, 2007; B. A. Murray, Brahler, Baer, & Marotta, 2003; Vallance, Courneya, Plotnikoff, & Mackey, 2008), significance was set to p=0.10 (two-tailed). Care must be exercised in the interpretation of statistical significance. Collinearity was also checked among them. None of the variables were collinear, using the guide of obtaining a condition index value of 30 or greater (Belsley, Kuh, & Welsch, 1980). For all models presented, the normality assumption appeared valid based on examination of the R x P plots (i.e., plot of residuals vs. predicted values) at the individual level and the Q-Q plot of the residuals at all levels (i.e., individual and neighborhood).

3.7 Human Subjects Procedures

This Human Subjects Research falls under Exemption 4. The proposed research study is a secondary data analysis. The larger ALR study (i.e., BALTS) dataset is not publicly available. The PI (Yan) has obtained permission from the Principal Investigator (Voorhees) of the parent study to use a sub-set of this data. A sample of students in grades 9 to 12 was drawn from two urban magnet high schools in Baltimore City. We obtained written parental consent and child assent from all participants. Three hundred and fifty students participated in the study. Students were considered eligible unless they had a health problem that restricted them from engaging in physical activity. Those students who returned informed consent forms signed by a parent were invited to participate in the study. Participants will not be contacted for the proposed study. No data will be recorded on the human subjects involved in this study. The parent study (Voorhees) was approved by the University of Maryland Institutional Review Board. All the recruitment and consent procedures met the requirements of 45 CFR 46, Protection of Human Subjects, including the purpose of the study, guarantees of confidentiality and privacy, statement of possible risk, and resources for grievances. Protection was assured in accordance with the ethnical principle of (a) respect for persons, (b) beneficence, and (c) justice.

To ensure confidentiality, all the survey information was identified only by unique randomly generated ID numbers. No names were entered into the database. Access to the personal identifiable information (students' home addresses) is restricted to the student PI during the mapping process only. All data files that link addresses with master identification numbers are password protected. The PI ensured that study database files are password protected at all times. Data stored on computer were backed up weekly.

CHAPTER FOUR: RESULTS

4.1 Characteristics of participants and their body mass index and physical activity levels

The majority of the sample was African American (69.1%) and female (58.3%) with a fairly equal distribution across grades 9, 10 and 12 with the exception of fewer eleventh grade participants. The average age was 15.7 years old. More than half (55.5%) of students' fathers had a high school education level. Almost one third of students' mothers attended some college and 37% of them were college graduates or had an advanced degree (see Table 6).

Table 6. Social demographic characteristics of study participants

Characteristics	N (350)	%
Age group		
14	70	20
15	112	32
16	51	14.6
17	98	28
18	19	5.4
Gender		
Girls	204	58.3
Boys	146	41.7
Race/ethnicity		
Black	242	69.1
White, non-Hispanic	58	16.6
Other (Asian/Pacific Islander, American Indian, Hispanic, and others)	50	14.3
Grade in school		
9^{th}	114	32.6
10^{th}	82	23.4
11^{th}	46	13.1
12^{th}	108	30.9
Mother's education		
Some high school, high school grads and trade school grads	113	34.9
Some college	91	28.1
College graduates and advance degree	120	37
Father's education		
Some high school, high school grads and trade school grads	152	55.5
Some college	48	17.5
College graduates and advance degree	74	27

BMI Measures

Age and gender were obtained through the Web-based survey. Objectively measured weight and height were obtained to calculate body mass index (BMI). Weight was measured in kilograms to the nearest 0.1 kg using a medical weight scale (Tanita Digital Medical Scale), zeroed and calibrated before each weight. A stadiometer (Schorr Board), calibrated in 0.1-cm intervals, was used to determine height. The NCHS-CDC 2000 growth charts were used to calculate BMI and percentile for age and sex (Kuczmarski, et al., 2002). Objective weight status was based on participants' BMI percentile. Weight classifications were as follows: underweight (less than the 5^{th} percentile); normal weight (the 5^{th} percentile to less than the 85^{th} percentile); at-risk for overweight (the 85^{th} percentile to less than 95^{th} percentile); overweight ($\geq 95^{th}$ percentile). Among subjects, 350 had date of birth and gender information available, which were used to calculate age- and gender-specific body mass indexes. The data set containing date of birth and gender was matched to the data set containing weight and height information based on the unique ID for each subject. BMI were calculated for 334 (95%) matched participants.

Table 7: Body Mass Index (BMI) Descriptive

Weight status	Frequency	Percent
Normal weight	195	58.4
Underweight	4	1.2
Risk of overweight	66	19.8
Overweight	69	20.7

Among 334 students, 19.8% of the sample was at risk of overweight and 20.7% was overweight. When combining the at-risk of overweight and overweight categories, the total accounted for almost 40% of the sample. There was no significant difference by gender in categorical BMI or continuous measures (see Table 7). The average height was 166.9 cm and the average weight was 69.4 kg (see Table 8).

Table 8: Descriptive for the height and weight information.

	N	Minimum	Maximum	Mean	Std. Deviation
Height (cm)	334	146.5	189.3	166.9	8.60592
Weight (kg)	334	42.1	144.8	69.4	18.03152

Note. There is no statistical difference in height and weight between the two sets of data (350 versus 334 subjects).

<u>Physical Activity levels</u>

For the accelerometer-measured physical activity, students spent an average of 76.1% of the total valid accelerometer measurement time in sedentary activity, 16.2% in light physical activity, and 7.7% in moderate-to-vigorous physical activity (MVPA). Among all walking trips, 31.2% were school-related trips (transport to school from home and going back home from school). Neighborhood places and other destinations accounted for 33.1% and 31.9% of all walking trips, respectively. Work-related trips accounted for a small portion (3%) of all walking trips. Overall, students averaged 0.7 walking trips per day during weekdays, with the number of walking trips ranging between 0 and 5.2. Descriptive statistics for each type of physical activity level and walking are shown in Table 9 and Table 10. There was no difference between normal weight group and at risk of overweight and overweight groups on physical activity levels (Table 11).

Table 9: Summary of accelerometer measured physical activity

PA levels	Mean	Std. Dev	Min	Max
Weekday total MVPA (min)	212.5	104.8	20.5	591.5
Whole week mean moderate PA (min)	48.0	19.6	13.7	113.3
Whole week mean vigorous PA (min)	2.2	3.8	0	38.7
Weekday total sedentary PA (%)	76.1	7.1	49.7	93.9
Weekday total light PA (%)	16.2	4.9	4.3	35.2
Weekday total moderate PA (%)	7.4	3.2	1.7	18.0
Weekday total vigorous PA (%)	0.3	0.6	0	4.3
Weekday total MV (%)	7.7	3.5	1.8	19.5

Note. N=360, MVPA= moderate-to-vigorous physical activity

Table 10: Summary of weekday walking trips (self report travel diary)

	N	Means	Std dev	Minimum	Maximum
Female	165	0.68	0.89	0	5.2
Male	108	0.70	0.83	0	4.0
Overall	273	0.69	0.86	0	5.2

Table 11: Physical activity levels between normal weight and overweight groups.

PA levels	Normal weight (min)	At risk of overweight or overweight (min)	P value
Weekday total MV	215.76	212.20	0.7906
Whole week mean moderate PA	48.54	47.82	0.7517
Whole week mean vigorous PA	2.52	1.81	0.1711
Weekday average walking trips	0.67	0.76	0.4556

4.2 Residential psychosocial environments

Analyses for Hypotheses:

Null Hypothesis 1. Living in a neighborhood with increased psychosocial hazards is not associated with increased body mass index (BMI), independent of known social demographic risk factors.

Null Hypothesis 2. Living in a neighborhood with increased psychosocial hazards is not associated with decreased levels of physical activity (e.g., walking and moderate-vigorous physical activity), independent of known social demographic risk factors.

Null Hypothesis 3. The physical activity will not mediate the effects of neighborhood residential psychosocial hazard on BMI.

Residential Psychosocial Environments

Neighborhood boundaries were created by the Baltimore City Department of Planning based on community definitions of existing neighborhoods. A summary scale was created and examined in this study: the Neighborhood Psychosocial Hazards (NPH) scale (Glass, et al., 2006). Six indicators were used to measure psychosocial hazards, defined as stable and visible features of the neighborhood environment that give rise to a heightened state of vigilance, alarm, or fear in residents(Glass, et al., 2006). Six indicators were measured at the census block level in which where students reside. Each indicator was standardized (z-score) and the sum of all standardized scores was used to create the final Neighborhood Psychosocial Hazards Scale (NPH). For modeling, the

NPH was divided into quartiles (low, low-moderate, high-moderate, and high) to test across levels of neighborhood psychosocial hazards.

The descriptive information of each indicator and the NPH scale is presented in Table 12. Of all the students' residential environment, the average count of violent crime per 10,000 people was 0.02. There was an average of 47.37 abandoned/vacant housing units for students' neighborhood. The average per capita income is $17,207 for students' neighborhood. In addition, the average unemployment rate was 5% and an average of 17% of families in poverty in the students' neighborhood. Finally, the average number of 911 calls per resident per year was 0.08. The NPH score was the sum of the six standardized indicators and the average score was -0.05.

Table 12: Summary of the Neighborhood Hazards Scale Variables in the Baltimore Active Living Teens Study Cohorts

Variables	N	Mean	Std Dev	Minimum	Maximum
Un-standardized					
Violent crimes rate(count per 10,000)	321	0.02	0.04	0.00	0.63
Abandoned/vacant housing units	321	47.37	38.83	7.00	209.00
Per capita income ($)	321	17207.61	6663.63	5039.00	81303.00
Unemployment rate	321	0.05	0.05	0.00	0.21
Proportion of families in poverty	321	0.17	0.12	0.01	0.67
911 calls per resident per year	321	0.08	0.17	0.01	2.95
Neighborhood Psychosocial Hazard Score (NPH)	321	-0.05	3.46	-4.02	32.01

Differences in individual characteristics across quartiles of the Neighborhood Psychosocial Hazard Scale (NPH) were examined in Table 13. Bivariate associations were evaluated using chi-squared tests for pairs of ordinal variables, and one-way analysis of variance for pairs of continuous and discrete variables. The higher quartile corresponds with more psychosocial hazards in the neighborhood. Of all the variables, only the association between levels of NPH and race/ethnicity and walking were statistically significant. A strong association was observed between race/ethnicity and NPH ($p<.0001$); 28.1% residents in the highest quartile neighborhood were Black, which is more than four times higher than Whites. In the highest quartile neighborhood, 39% were members of other ethnic groups, which is more than six times higher than White. The same trend was observed in the high-moderate hazard neighborhood, with most residents being African American (28.6%) and fewer White (14.3%) or other (9.8%). Higher NPH scores were associated with more walking trips per day.

Table 13: Associations between the weight status and Neighborhood Hazards Scale (in quartiles) and Selected Covariates

Variables	Lowest quartile	Low-moderate	High-moderate	High quartile	Test for differences (P value)
	% or mean (SD)	% or mean (SD)	% or mean (SD)	% or mean (SD)	
All participants (n=311)	24.6%	25.9%	23.5%	25.9%	
Weight status					0.2617
Normal weight (n=174)	23.6%	28.2%	23.0%	25.3%	
At risk of obesity (n=59)	28.8%	28.8%	25.4%	16.9%	
Obese (n=60)	23.3%	16.7%	23.3%	36.7%	
Body mass index (mean)	24.8(0.70)	24.1(0.68)	25.4(0.72)	25.4(0.68)	0.611
Female sex (n=173)	22.5%	27.2%	24.9%	25.4%	0.7287
Race/ethnicity					**<.0001****
% African-American (n=203)	19.7%	23.6%	28.6%	28.1%	
% White (n=49)	40.8%	38.8%	14.3%	6.1%	
% Others [a] (n=41)	29.3%	21.9%	9.8%	39.0%	
MVPA (total min weekday)	221.4(12.38)	230.7(12.21)	210.7(12.65)	196.8(12.12)	0.145
Walking trips (per day/weekday)	0.68(0.11)	0.60(0.11)	0.73(0.12)	0.97(0.11)	**0.074***

Note. **P*<.10, ***P*<.05 ; [a] other racial/ethnicity group including American Indians, Asian Americans, and Latinos.

Random effects (multilevel) linear regression models were used to examine associations of neighborhood psychosocial hazards with obesity and physical activity, controlling for individual-level confounders. By fitting a random intercept for each neighborhood, the models took account of the correlation among persons within a neighborhood, yielding more accurate standard errors and unbiased maximum likelihood parameter estimates. The interpretation of parameters is analogous to the standard regression model.

Results of Analyses for $H_0$1

The first null hypothesis states: "Living in a neighborhood with increased psychosocial hazards is not associated with increased body mass index (BMI), independent of known social economic risk factors (age, gender, and race). The research question which led to this hypothesis seeks to determine if higher psychosocial hazard score is associated with increased BMI. A multilevel model with Baltimore city neighborhood (CSA) as a random effect was conducted with SAS PROC MIXED procedure. The multilevel mixed model was adopted because it was believed that individual students were nested within the CSA.

The multilevel mixed model was used to measure the association between the neighborhood residential psychosocial risk factors and body mass index (BMI). The dependent variable was the BMI. Each of the six indicators that composed the Neighborhood Psychosocial Hazards index (NPH) as well as the NPH served as independent variables for each model, respectively. The covariates are age, gender, race/ethnicity, and mother's education level. The covariates were added one at a time. For step 1, no covariate was controlled. For step 2, age was added as covariate. For step 3, age and gender were covariate. For step 4, age, gender, and race/ethnicity were controlled. For step 5, age, gender, race/ethnicity, and mother's education were controlled. No single indicator was associated with BMI. Furthermore, the NPH index was not associated with BMI.

Table 14: Associations of neighborhood psychosocial risk factors for BMI using mixed model

Parameter	Step 1		Step 2		Step 3		Step 4		Step 5	
	Coefficient	*p*	Coefficient	*p*	Coefficient	*p*	Coefficient	*p*	Coefficient	*p*
Violent crimes rate	0.38	0.2566	0.38	0.2559	0.38	0.2520	0.34	0.3142	0.93	0.3246
Abandoned/vacant housing units	0.15	0.6550	0.15	0.6534	0.15	0.6543	0.20	0.5686	0.99	0.8228
Per capita income ($)	0.06	0.8616	0.06	0.8601	0.06	0.8600	0.10	0.7848	1.05	0.9002
Unemployment rate	0.01	0.9800	0.01	0.9805	0.01	0.9807	-0.13	0.7181	0.02	0.9612
% families in poverty	0.34	0.3720	0.34	0.3715	0.34	0.3764	0.36	0.3593	0.48	0.2611
911 calls per resident per year	0.25	0.4539	0.25	0.4531	0.25	0.4452	0.22	0.4987	0.23	0.4991
NPH Index	0.12	0.2625	0.45	0.2597	0.13	0.2583	0.11	0.3116	0.10	0.3538

Note. Step 1: no covariates; Step 2: age as covariate; Step 3: age and gender as covariates; Step 4: age, gender and race as covariates. Step 5: age, gender, race, and mother's education as covariates.
For each model, the dependent variable is BMI, and each row represented an independent variable.

Results of Analyses for $H_0$2

The second null hypothesis states: "Living in a neighborhood with increased psychosocial hazards is not associated with decreased levels of physical activity (e.g., walking and moderate-to-vigorous physical activity), independent of known social demographic risk factors (age, gender, and race). The research question which led to this hypothesis seeks to determine if higher psychosocial hazard score is associated with decreased physical activity. A multilevel model with Baltimore city neighborhood (CSA) as a random effect was conducted with SAS PROC MIXED procedure. The multilevel mixed model was adopted because it was believed that individual students were nested within the CSA.

The multilevel mixed model was used to measure the association between individual and neighborhood residential risk factors and moderate-to-vigorous physical activity. The dependent variable was the total moderate-to-vigorous physical activity minutes during weekdays (Monday to Friday). Each of the six indicators that comprised the Neighborhood Psychosocial Hazards Scale (NPH) as well as the NPH served as independent variables for each model, respectively. The covariates are age, gender, race/ethnicity, and mother's education level. The covariates were added one at a time. For step 1, no covariate was controlled. For step 2, age was added as covariate. For step 3, age and gender were covariate. For step 4, age, gender, and race/ethnicity were controlled. For step 5, age, gender, race/ethnicity, and mother's education were controlled. Only unemployment rate and percent of families in poverty were associated with the total moderate-to-vigorous physical activity minutes during weekdays. In step 1, a one-unit increase in unemployment rate increased the total moderate-to-vigorous physical activity minutes during weekdays by 12.27 minutes ($p<0.05$); a one-unit increase in percent of families in poverty increased the total moderate-to-vigorous physical activity minutes during weekdays by 11.61 minutes ($p<0.10$). Similarly, when controlling for age in step 2, a significant increase in the total moderate-to-vigorous physical activity minutes during weekdays was observed as both unemployment rate ($p<0.05$) and percent of families in poverty increased ($p<0.10$). After controlling for gender and age, similar increases were observed; indicating the association between unemployment rate and percent of families in poverty and moderate-to-vigorous physical activity was consistent. The NPH index was not associated with total moderate-to-vigorous physical activity (out of school days during a week) (see Table 15).

Table 15: Associations of neighborhood psychosocial risk factors for MVPA using mixed model

Parameter	Step 1		Step 2		Step 3		Step 4		Step 5	
	Coefficient	*p*	Coefficient	*p*	Coefficient	*p*	Coefficient	*p*	Coefficient	*p*
Violent crimes rate	7.03	0.2249	5.85	0.3004	4.28	0.4345	1.97	0.7088	3.44	0.5148
Abandoned/vacant housing units	-0.42	0.9444	-2.60	0.6555	-2.60	0.6478	-4.68	0.3951	-5.75	0.3098
Per capita income ($)	-3.78	0.5388	-7.03	0.2384	-6.91	0.2330	-0.93	0.8730	1.29	0.8285
Unemployment rate	12.27	**0.0495****	13.64	**0.0235****	14.65	**0.0125****	7.26	0.2209	2.14	0.7243
% families in poverty	11.61	**0.0812***	10.50	**0.0982***	12.00	**0.0540***	7.75	0.2107	5.88	0.3531
911 calls per resident per year	3.53	0.5404	2.38	0.6728	0.422	0.9384	-0.94	0.8583	0.43	0.9348
NPH Index	2.98	0.1289	2.22	0.2418	2.06	0.2657	0.87	0.6308	0.49	0.7741

Note. Step 1: no covariates; Step 2: age as covariate; Step 3: age and gender as covariates; Step 4: age, gender and race/ethnicity as covariates; Step 5: age, gender, race/ethnicity, and mother's education as covariates.
*P<.10, **P<.05
For each model, the dependent variable is weekday total moderate-to-vigorous physical activity, and each row represented an independent variable.

The multilevel mixed model was used to measure the association between individual and neighborhood residential risk factors and moderate physical activity. The dependent variable was the average moderate physical activity minutes in a week (Monday to Sunday). Each of the six indicators that comprised the Neighborhood Psychosocial Hazards Scale (NPH) as well as the NPH served as independent variables for each model, respectively. The covariates are age, gender, race/ethnicity, and mother's education level. The covariates were added one at a time. For step 1, no covariate was controlled. For step 2, age was added as covariate. For step 3, age and gender were covariate. For step 4, age, gender, and race/ethnicity were controlled. For step 5, age, gender, race/ethnicity, and mother's education were controlled. Only percent of families in poverty was associated with the average moderate physical activity minutes. In step 1, a one-unit increase in percent of families in poverty increased the moderate physical activity minutes by 2.77 minutes ($p<0.05$). Similarly, after controlling for individual demographic variables, an increase in the average moderate physical activity minutes was observed as the percent families in poverty increased ($p<0.05$) and the coefficients were significant across all steps. The NPH index was not associated with moderate physical activity (see Table 16).

Table 16: Associations of neighborhood psychosocial risk factors for moderate PA using mixed model

	Step 1		Step 2		Step 3		Step 4		Step 5	
	Coefficient	*p*	Coefficient	*p*	Coefficient	*p*	Coefficient	*p*	Coefficient	*p*
Violent crimes rate	1.16	0.2859	0.92	0.3863	0.61	0.5607	0.28	0.7850	0.50	0.6223
Abandoned/vacant housing units	-0.42	0.7129	-0.85	0.4388	-0.81	0.4582	-1.02	0.3489	-1.28	0.2476
Per capita income ($)	-0.24	0.8356	-0.85	0.4512	-0.78	0.4869	-0.005	0.9962	0.06	0.9565
Unemployment rate	1.39	0.2393	1.691	0.1393	1.83	0.1059	0.90	0.4436	0.13	0.9095
% families in poverty	2.77	**0.0276****	2.52	**0.0361****	2.78	**0.0222****	2.32	**0.0621***	2.43	**0.0534***
911 calls per resident per year	0.72	0.5085	0.48	0.6486	0.11	0.9172	-0.10	0.9182	0.03	0.9736
NPH Index	0.52	0.1609	0.37	0.3016	0.34	0.3456	0.19	0.6012	0.12	0.7137

Note. Step 1: no covariates; Step 2: age as covariate; Step 3: age and gender as covariates; Step 4: age, gender and race as covariates; Step 5: age, gender, race/ethnicity, and mother's education as covariates; *$P<.10$, **$P<.05$
For each model, the dependent variable is the average minute for moderate physical activity, and each row represented an independent variable.

The multilevel mixed model was used to measure the association between individual and neighborhood residential risk factors and vigorous physical activity. The dependent variable was the average vigorous physical activity minutes in a week (Monday to Sunday). Each of the six indicators that comprised the Neighborhood Psychosocial Hazards Scale (NPH) as well as the NPH served as independent variables for each model, respectively. The covariates are age, gender, race/ethnicity, and mother's education level. The covariates were added one at a time. For step 1, no covariate was controlled. For step 2, age was added as covariate. For step 3, age and gender were covariate. For step 4, age, gender, and race/ethnicity were controlled. For step 5, age, gender, race/ethnicity, and mother's education were controlled. No single indicator was associated with vigorous physical activity. Furthermore, the NPH index was not associated with vigorous physical activity (see Table 17).

Table 17: Associations of neighborhood psychosocial risk factors for vigorous PA using mixed model

	Step 1		Step 2		Step 3		Step 4		Step 5	
	Coefficient	*p*	Coefficient	*p*	Coefficient	*p*	Coefficient	*p*	Coefficient	*p*
Violent crimes rate	-0.05	0.8263	-0.08	0.7113	-0.14	0.4953	-0.15	0.4748	-0.13	0.5420
Abandoned/vacant housing units	-0.19	0.4090	-0.25	0.2711	-0.26	0.2390	-0.23	0.2935	0.21	0.3907
Per capita income ($)	0.12	0.5972	0.074	0.7699	0.07	0.7608	0.05	0.8325	0.06	0.7924
Unemployment rate	-0.04	0.8674	-0.007	0.9750	0.02	0.9186	0.01	0.9600	-0.03	0.9023
% families in poverty	-0.19	0.4758	-0.22	0.3824	-0.16	0.5086	-0.14	0.5767	-0.06	0.8275
911 calls per resident per year	-0.01	0.9556	-0.04	0.8526	-0.11	0.5808	-0.12	0.5631	-0.10	0.6365
NPH Index	-0.03	0.6534	-0.05	0.4764	-0.06	0.3883	-0.06	0.3887	-0.05	0.4799

Note. Step 1: no covariates; Step 2: age as covariate; Step 3: age and gender as covariates; Step 4: age, gender and race as covariates; Step 5: age, gender, race/ethnicity, and mother's education as covariates; *P<.10, **P<.05
For each model, the dependent variable is the average minute for vigorous physical activity, and each row represented an independent variable.

The multilevel mixed model was used to measure the association between individual and neighborhood residential risk factors and walking. The dependent variable was the average number of walking trips per day. Each of the six indicators that composed the Neighborhood Psychosocial Hazards Scale (NPH) as well as the NPH served as independent variables for each model, respectively. The covariates are age, gender, and race/ethnicity and mother's education. The covariates were added one at a time. For step 1, no covariate was controlled. For step 2, age was added as covariate. For step 3, age and gender were covariate. For step 4, age, gender, and race/ethnicity were controlled. For step 5, age, gender, race/ethnicity, and mother's education were controlled. Three indicators were found to be associated with walking. They were per capita income, unemployment rate, and percent of families in poverty. A one-unit change in per capita income decreased the number of walking trips per day from 0.09 to 0.12. The strongest positive association was found between percent of families in poverty and average number of walking trips per day after controlling for individual demographic variables ($p<0.05$) and the coefficients were significant across all steps. Similarly, after controlling for individual demographic variables, an increase in the average number of walking trips was observed as unemployment rates increased ($p<0.10$). The NPH index was only associated with the average number of walking trips when no covariates were controlled for (see Table 18).

Table 18: Associations of neighborhood psychosocial risk factors for walking using mixed model

	Step 1		Step 2		Step 3		Step 4		Step 5	
	Coefficient	*p*	Coefficient	*p*	Coefficient	*p*	Coefficient	*p*	Coefficient	*p*
Violent crimes rate	0.04	0.3740	0.04	0.4512	0.04	0.4531	0.03	0.5473	0.04	0.4071
Abandoned/vacant housing units	0.08	0.1505	0.07	0.2116	0.07	0.2124	0.06	0.2622	0.06	0.2882
Per capita income ($)	-0.11	**0.0439***	-0.12	**0.0267****	-0.12	**0.0268****	-0.09	**0.0918***	-0.06	0.3050
Unemployment rate	0.09	**0.0959***	0.10	**0.0734***	0.10	**0.0729***	0.06	0.2994	0.05	0.3966
% families in poverty	0.17	**0.0041****	0.17	**0.0055****	0.17	**0.0052****	0.15	**0.0164****	0.13	**0.0513***
911 calls per resident per year	0.02	0.6888	0.01	0.7910	0.01	0.7937	0.01	0.8510	0.02	0.6595
NPH Index	0.03	0.0935*	0.03	0.1417	0.03	0.1422	0.02	0.2699	0.02	0.1330

Note. Step 1: no covariates; Step 2: age as covariate; Step 3: age and gender as covariates; Step 4: age, gender and race as covariates.
Step 5: age, gender, race/ethnicity, and mother's education as covariates; *P<.10, **P<.05
For each model, the dependent variable is the average walking trip, and each row represented an independent variable.

Results of Analyses for $H_0$3

In order to test whether there is a mediation effect of physical activity, I followed the Baron and Kenny (1986) four step procedure. In Step 1, I checked whether the neighborhood psychosocial hazard variable(s) was associated with body mass index outcome. The results were presented to address the null hypothesis one as well. The results indicated that none of the coefficients were significant. Therefore, the first mediation criterion of Baron and Kenny (1986) was not satisfied. In Step 2, when testing $H_0$2, a few testes were conducted with the conclusion to reject $H_0$2. In Step 3, when testing the association between physical activity (mediator) and BMI (outcome), walking was found to have positive relation with BMI and vigorous physical activity was found to have negative relation with BMI (**Table 19**). Both MVPA and moderate physical activity are not associated with BMI (**Table 19**). As a result, no further tests were conducted because not all three criteria were met. The hypothesis testing did not reject the null hypothesis. Therefore, the conclusion is that there is no mediation effect of physical activity in this sample.

Table 19: Associations of physical activity with BMI using mixed model

Parameter	Step 1		Step 2		Step 3		Step 4	
	Coefficient	*p*	Coefficient	*p*	Coefficient	*p*	Coefficient	*p*
Moderate-to-vigorous PA (MVPA)	-0.002	0.5854	-0.002	0.5707	-0.002	0.5918	-0.004	0.2606
Moderate PA	-0.017	0.3457	-0.018	0.3283	-0.018	0.3373	-0.027	0.1730
Vigorous PA	-0.158	**0.0837***	-0.161	**0.0804***	-0.172	**0.0759***	-0.187	**0.0524***
Walking trip	1.176	**0.0062****	1.205	**0.0053****	1.204	**0.0055****	1.152	**0.0086****

Note. Step 1: no covariates; Step 2: age as covariate; Step 3: age and gender as covariates; Step 4: age, gender and race as covariates.

Random effect =CSA

*P<.10, **P<.05

4.3 Commercial Environment

Analyses for Hypotheses:

Null Hypothesis 1. The density and proximity of a variety of destinations (e.g., grocery stores/supermarkets, restaurants) are not associated with body mass index (BMI).

Null Hypothesis 2. The density and proximity of a variety of destinations are not related to physical activity (e.g., walking for transportation and moderate–to–vigorous physical activity (MVPA)).

Null Hypothesis 3. The association between overweight and proximity and density of destinations is not mediated by physical activity levels (e.g., MVPA and walking for transportation).

Random effects (multilevel) linear regression models were used to examine associations between proximity and density of a variety of destinations and obesity or physical activity, controlling for individual-level confounders. By fitting a random intercept for each neighborhood, the models took into account the correlation among persons within a neighborhood, yielding more accurate standard errors and unbiased maximum likelihood parameter estimates. The interpretation of parameters is analogous to the standard regression model.

Density of six types of destinations were measured, including grocery stores, post offices, retail and shopping, schools and museums, fast food restaurants, and parks and recreation centers (Table 20). A calculated cumulative opportunity measure represented destination mix (Handy & Clifton, 2001). This measure of destination mix included a total count of different types of destinations within predefined buffer distances from the respondent's home. Within a 0.25 mile radius buffer, destinations that have the highest density were retail and shopping malls (mean=7.40), followed by schools and museums (mean=0.53) and grocery stores (0.51). The parks and recreation (mean=0.12) and post offices (mean=0.05) had the lowest density within the 0.25 mile buffer. Fast food restaurants had a density of 0.21. The densities of all destinations increased as the buffer sizes increased.

Table 20: The average density of destination variables within buffers

Destinations	Respondents with destination data (n)	Within 0.25 miles Mean (SD)	Within 0.5 miles Mean (SD)	Within 1-mile Mean (SD)	Within 1.5 mile Mean (SD)
1. Grocery stores	355	0.51(0.85)	2.14(2.60)	7.34(5.96)	16.08(11.64)
2. Post offices	355	0.05(0.23)	0.21(0.45)	0.84(0.80)	1.88(1.35)
3. Retail and shopping	355	7.40(15.91)	28.11(51.85)	95.39(130.56)	208.44(249.93)
4. Schools and museums	355	0.53(0.73)	2.09(1.88)	7.91(5.99)	17.26(11.37)
5. Fast food restaurant	355	0.21(0.56)	0.90(1.22)	3.29(2.93)	6.98(5.04)
6. Parks and recreation	355	0.12(0.35)	0.46(0.76)	1.47(1.79)	3.13(3.02)
7. Theaters and pools	355	0.04(0.22)	0.19(0.53)	0.77(1.43)	1.65(2.35)
8. All types recreational and utilitarian destinations	355	8.66(16.65)	33.21(55.15)	113.77(142.63)	248.44(274.48)

Note. 1 mile = 1609.344 meters

Proximity of six types of destinations to students' home were measured, including grocery stores, post offices, retail and shopping, schools and museums, fast food restaurants, and parks and recreation centers. Schools and museums are closest to students' home with an average distance of 542 meters, followed by retail and shopping with an average distance of 734 meters. Fast food restaurants (2382 meters) and parks and recreation (2134 meters) are farthest away from students' residence. The complete list of average distances of destinations from home is listed in Table 21.

Table 21: Descriptive information on the closest distance (proximity) to various destinations

Destinations	N	Mean (meters)	Std Dev	Minimum	Maximum
Grocery stores	355	876.13	619.33	68	3261
Parks and Recreation	355	2133.89	1452.65	134	6310
Post offices	355	1833.50	988.31	190	6314
Retail and shopping	355	733.67	466.94	28	3739
Schools and museums	355	541.65	377.38	6	2413
Fast food restaurants	355	2382.05	1326.95	126	8140
Theaters and pools	355	1241.24	786.98	55	3675

Results of Analyses for H_01

The first null hypothesis states: "the density and proximity of a variety of destinations are not associated with increased body mass index (BMI)." The research question which led to this hypothesis seeks to determine whether closer proximity and higher density of a variety of destinations are associated with increased BMI. A multilevel model with Baltimore city neighborhood (CSA) as a random effect was conducted with SAS PROC MIXED procedure. The multilevel mixed model was adopted because it was believed that individual students were nested within the CSA. The dependent variable was BMI. For tests examining the association of density and BMI, densities of each of the six destinations as well as the destination mix served as independent variables for each model, respectively. For tests examining the association of proximity and BMI, proximity of each of the six destinations served as independent variables for each model, respectively.

Results in Tables 22-25 demonstrate that the densities of destinations were not associated with BMI across four buffer sizes, with the exception that increased density of fast food restaurants in a 0.25 mile buffer (see Table 22) was associated with increased BMI. Table 26 tested the associations between BMI and the closest distance to destinations using a mixed model. Results in Table 26 indicate that proximities of all destinations were not associated with BMI. In summary, there is no effect of either density or proximity of destinations on BMI, except that the fast food restaurant within 0.25 mile associated with increase BMI.

Table 22: Associations between BMI and the destination densities using mixed model (0.25 mile buffer)

Destinations	Body Mass Index (BMI)	
Destinations	**Coefficient**	***p* value**
Grocery stores	-0.25	0.5457
Retail and shopping	-0.54	0.5838
Theaters and pools	-0.00	0.9988
Post offices	0.03	0.1612
Schools and museums	0.01	0.9810
Fast food restaurants	2.86	**0.0648***
Parks and recreation	0.34	0.5972
All types recreational and utilitarian destinations	0.03	0.2022

Note. $*P<.10$, $**P<.05$

Table 23: Associations between BMI and the destination densities using mixed model (0.5 mile buffer)

Destinations	Body Mass Index (BMI)	
Destinations	**Coefficient**	***p* value**
Grocery stores	-0.03	0.8338
Retail and shopping	-0.16	0.7634
Theaters and pools	-0.70	0.3928
Post offices	0.00	0.6795
Schools and museums	-0.21	0.2531
Fast food restaurants	0.63	0.3397
Parks and recreation	0.16	0.5764
All types recreational and utilitarian destinations	0.00	0.7497

Table 24: Associations between BMI and the destination densities using mixed model (1.00 miles buffer)

Destinations	Body Mass Index (BMI)	
Destinations	**Coefficient**	***p* value**
Grocery stores	0.04	0.4818
Retail and shopping	-0.05	0.8251
Theaters and pools	-0.31	0.4991
Post offices	-0.00	0.9400
Schools and museums	0.04	0.4809
Fast food restaurants	0.07	0.7592
Parks and recreation	-0.05	0.6537
All types recreational and utilitarian destinations	-0.00	0.9834

Table 25: Associations between BMI and the destination densities using mixed model (1.5 mile buffer)

Destinations	Body Mass Index (BMI)	
Destinations	**Coefficient**	***p* value**
Grocery stores	0.05	0.2936
Retail and shopping	0.01	0.9292
Theaters and pools	-0.09	0.7295
Post office s	0.00	0.3375
Schools and museums	0.03	0.2977
Fast food restaurants	0.04	0.7652
Parks and recreation	0.04	0.5797
All types recreational and utilitarian destinations	0.00	0.3235

Table 26: Associations between BMI and the closest distance of residence to destinations (proximity) using mixed model

Destinations	Body Mass Index (BMI)	
Destinations	**Coefficient**	**P value**
Grocery stores	-0.00	0.4414
Retail and shopping	0.00	0.6212
Theaters and pools	-0.00	0.9197
Post offices	-0.00	0.3882
Schools and museums	-0.00	0.5466
Fast food restaurants	0.00	0.5701
Parks and recreation	-0.00	0.4064

Results of Analyses for $H_0$2

The second null hypothesis states: “the density and proximity of a variety of destinations are not associated with physical activity (e.g., walking for transportation and moderate–to–vigorous physical activity (MVPA)).” The research question which led to this hypothesis seeks to determine whether higher density and closer proximity of a variety of destinations are associated with increased physical activity. A multilevel model with Baltimore city neighborhood (CSA) as a random effect was conducted with SAS PROC MIXED procedure. The multilevel mixed model was adopted because it was believed that individual students were nested within the CSA. The dependent variable was the physical activity as measured by MVPA and walking. For tests examining the association of density and physical activity, densities of each of the six destinations as well as the destination mix served as independent variables for each model, respectively. For tests examining the association of proximity and physical activity, proximity of each of the six destinations served as independent variables for each model, respectively.

Results in Table 27, Table 28, Table 29, and Table 30 demonstrate that the densities of destinations were associated with walking across four buffer sizes. For example, access to schools and museums within 0.25 mile, and grocery stores, retail and shopping, post offices and mix of destinations within 0.5 mile and beyond was positively associated with participation in walking. In addition, densities of fast food restaurants and parks and recreation within 1 mile and 1.5 mile were associated with increased walking. Closer proximity to schools and museums increased both student’s MVPA level and their walking trips. As for the correlates to vigorous physical activity, only the park and recreation density within 0.5 mile buffer was marginally significant. Closer proximity to school increased both student's MVPA level and their walking trips. In addition, closer to parks and recreation increase students' walking trips (Table 31).

Table 27: Associations between destination densities and physical activity using mixed model (0.25 mile buffer)

Dependent variable	MVPA		Moderate PA		Vigorous PA		Walking	
Destinations	**Coefficient**	***p* value**	**Coefficient**	***p* value**	**Coefficient**	***p* value**	**Coefficient**	***p* value**
Grocery stores	0.14	0.9845	-0.53	0.7015	-0.20	0.4750	0.058	0.3917
Parks and recreation	10.31	0.5445	1.84	0.5652	0.66	0.3062	0.13	0.4205
Post offices	23.14	0.4033	1.80	0.7287	-0.91	0.3849	0.09	0.7474
Retail and shopping	-0.05	0.8826	-0.00	0.9549	-0.01	0.4292	0.005	0.1284
Schools and museums	13.18	0.1271	0.92	0.5721	-0.14	0.6806	0.20	**0.0109****
Theaters and pools	-23.31	0.3872	-0.32	0.9488	0.34	0.7388	0.21	0.4312
Fast food restaurants	17.91	0.1120	3.30	0.1188	-0.02	0.9650	0.14	0.1756
All types recreational and utilitarian destinations	-0.02	0.9476	-0.00	0.9730	-0.01	0.4280	0.005	0.1007

Note. *P<.10, **P<.05

Table 28: Associations between destination densities and physical activity using mixed model (0. 5 mile buffer)

Dependent variable	MVPA		Moderate PA		Vigorous PA		Walking	
Destinations	**Coefficient**	***p* value**	**Coefficient**	***p* value**	**Coefficient**	***p* value**	**Coefficient**	***p* value**
Grocery stores	2.57	0.2814	0.35	0.4336	-0.06	0.5260	0.06	**0.0093****
Retail and shopping	-3.06	0.7201	-0.25	0.8749	-0.00	0.9859	0.13	**0.0862***
Theaters and pools	30.24	**0.0363****	4.96	**0.0673***	0.50	0.3626	0.14	0.2962
Post offices	0.14	0.2493	0.03	0.2562	0.00	0.8918	0.002	**0.0666***
Schools and museums	5.58	**0.0857***	0.39	0.5310	0.01	0.9264	0.04	0.1868
Fast food restaurants	0.56	0.9610	1.40	0.5196	0.03	0.8888	0.02	0.8785
Parks and recreation	7.59	0.1283	1.03	0.2741	0.74	**0.0927***	0.03	0.5297
All types recreational and utilitarian destinations	0.14	0.2277	0.02	0.2519	0.00	0.9002	0.0021	**0.0524***

Note. **P*<.10, ***P*<.05

Table 29: Associations between destination densities and physical activity using mixed model

(1 mile buffer)

Dependent variable	**MVPA**		**Moderate PA**		**Vigorous PA**		**Walking**	
Destinations	**Coefficient**	***p* value**	**Coefficient**	***p* value**	**Coefficient**	***p* value**	**Coefficient**	***p* value**
Grocery stores	0.04	0.9722	0.007	0.9729	-0.03	0.3937	0.02	**0.0145****
Retail and shopping	4.66	0.1842	0.42	0.5374	-0.08	0.5925	0.07	**0.0303****
Theaters and pools	-4.59	0.5649	-0.32	0.8318	0.13	0.6764	0.10	0.2124
Post offices	0.05	0.3093	0.009	0.3042	0.00	0.9574	0.009	**0.0362****
Schools and museums	1.02	0.3349	0.18	0.3546	-0.01	0.7448	0.03	**0.0018****
Fast food restaurants	2.25	0.6013	0.77	0.3416	0.08	0.6143	0.07	**0.0926***
Parks and recreation	0.13	0.9508	0.005	0.9891	-0.11	0.1756	0.05	**0.0051****
All types recreational and utilitarian destinations	0.04	0.3228	0.008	0.3195	7.116E-6	0.9967	0.0008	**0.0280****

Note. $^{*}P<.10$, $^{**}P<.05$

Table 30: Associations between destination densities and physical activity using mixed model (1.5 mile buffer)

Dependent variable	MVPA		Moderate PA		Vigorous PA		Walking	
Destinations	**Coefficient**	***p* value**	**Coefficient**	***p* value**	**Coefficient**	***p* value**	**Coefficient**	***p* value**
Grocery stores	0.17	0.76	0.04	0.6942	-0.02	0.2362	0.01	**0.0017****
Retail and shopping	0.83	0.70	0.05	0.8952	-0.07	0.4016	0.04	**0.0258****
Theaters and pools	8.58	**0.07***	1.19	0.1798	0.15	0.4041	0.07	**0.0942***
Post offices	0.03	0.28	0.004	0.3631	-0.00	0.7828	0.000525	**0.0211****
Schools and museums	0.69	0.21	0.11	0.3075	-0.01	0.6408	0.01450	**0.0041****
Fast food restaurants	3.46	0.19	0.68	0.1732	0.002	0.9848	0.04	**0.0934***
Parks and recreation	0.85	0.50	0.12	0.6166	-0.03	0.5623	0.03	**0.0109****
All types recreational and utilitarian destinations	0.02	0.29	0.004	0.3652	-0.00	0.7472	0.0004	**0.0165****

Note. *$P<.10$, **$P<.05$

Table 31: Associations of closest distance to destinations for physical activity using mixed model

Dependent variable	**MVPA**		**Moderate PA**		**Vigorous PA**		**Walking**	
Destinations	**Coefficient**	***p* value**	**Coefficient**	***p* value**	**Coefficient**	***p* value**	**Coefficient**	***p* value**
Grocery stores	0.01	0.2208	0.00	0.3997	0.00	0.1995	-0.00	0.3585
Retail and shopping	-0.00	0.6046	0.00	0.7324	-0.00	0.8659	-0.00	0.1822
Theaters and pools	0.00	0.9554	0.00	0.7913	0.00	0.7100	-0.00	0.7629
Post offices	0.00	0.9768	-0.00	0.8842	0.00	0.4132	-0.00	0.2472
Schools and museums	0.03	**0.0196****	-0.00	0.1831	-0.00	0.8947	0.00029	**0.0220****
Fast food restaurants	0.00	0.9563	-0.00	0.8067	0.00	0.3116	-0.00	0.1943
Parks and recreation	0.00	0.9647	-0.00	0.6566	0.00	0.1715	0.00017	**0.0221****

Note. *P<.10, **P<.05

Results of Analyses for $H_0$3

In order to test whether there is a mediation effect of physical activity, I followed the Baron and Kenny (1986) four-step procedure. In Step 1, I checked whether the proximity or density of destinations were associated with body mass index outcome. The results were presented to address the null hypothesis 1 as well. The results indicated that none of the coefficients were significant. Therefore, the first mediation criterion of Baron and Kenny (1986) was not satisfied. As a result, no further tests were conducted. The hypothesis testing did not reject the null hypothesis. Therefore, the conclusion is that there is no mediation effect of physical activity.

4.4 Recreation Environment

Analyses for Hypotheses:

Null Hypothesis 1. After controlling for residential density, neighborhood greenness or open space coverage is not associated with body mass index (BMI).

Null Hypothesis 2. After controlling for residential density, neighborhood greenness or open space coverage is not associated with physical activity levels (MVPA and walking).

Null Hypothesis 3. Physical activity levels do not mediate the effect of greenness or open space on BMI.

The primary independent variables are (1) the percentage of coverage of green space around students' homes, and (2) the percentage of open space coverage around students' homes and (3) the closest distance from students' homes to green space or open space. The descriptive statistics of primary independent variables is presented in Table 32. Continuous variables are summarized by mean, standard deviation, minimum and maximum values. Four predefined buffers were created around each student's home. For example, the percentage of green space coverage was calculated as the area of green space within the specific buffer size divided by the total area of that buffer. When looking at students' distribution by population and land-use density, it was found that most of the students were distributed in the medium-density (28%) or high-density (70%) residential areas (Table 33). **Figure 4** showed students' distribution and land use/ land cover map in Baltimore city.

Table 32: Descriptive data for land use variables (i.e., open space and greenness)

Variable	Mean	Std Dev	Minimum	Maximum
Green coverage at 0.25 mile buffer (%)	0.04	0.09	0	0.59
Green coverage at 0.50 mile buffer (%)	0.06	0.09	0	0.5
Green coverage at 1.0 mile buffer (%)	0.07	0.07	0	0.4
Green coverage at 1.5 mile buffer (%)	0.07	0.06	0	0.28
Open space coverage at 0.25 mile buffer (%)	0.04	0.08	0	0.52
Open space coverage at 0.50 mile buffer (%)	0.06	0.08	0	0.49
Open space coverage at 1.0 mile buffer (%)	0.06	0.06	0	0.28
Open space coverage at 1.5 mile buffer (%)	0.06	0.04	0	0.18

Note.
Open urban land – urban areas whose use does not require structures, or urban areas where non-conforming uses characterized by open land have become isolated. Included are golf courses, parks, recreation areas (except areas associated with schools or other institutions), cemeteries, and entrapped agricultural and undeveloped land within urban areas.
Green –Areas that cover deciduous forest, evergreen forest, mixed forest, and brush.

Table 33: Students distribution in residential areas with different population densities

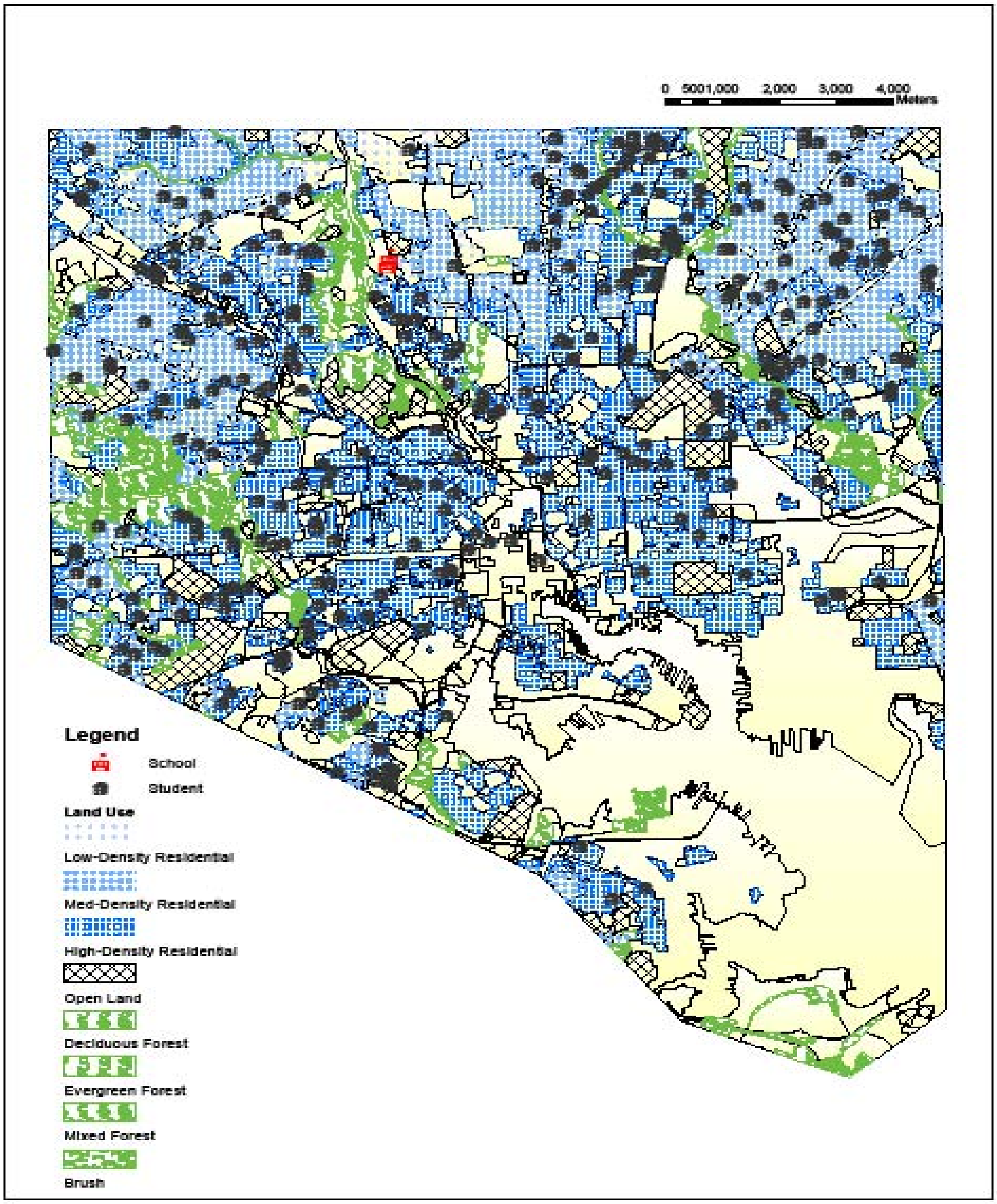
Residential Land use	Frequency	Percent
Low-density [a]	3	1.12
Medium-density [b]	75	28.09
High-density [c]	189	70.79

Note. [a] Low-density residential - Detached single-family/duplex dwelling units, yards and associated areas. Areas of more than 90 percent single-family/duplex dwelling units, with lot sizes of less than five acres but at least one-half acre (.2 dwelling units/acre to 2 dwelling units/acre).

[b] Medium-density residential - Detached single-family/duplex, attached single-unit row housing, yards, and associated areas. Areas of more than 90 percent single-family/duplex units and attached single-unit row housing, with lot sizes of less than one-half acre but at least one-eighth acre (2 dwelling units/acre to 8 dwelling units/acre).

[c] High-density residential - Attached single-unit row housing, garden apartments, high-rise apartments/condominiums, mobile home and trailer parks. Areas of more than 90 percent high-density residential units, with more than 8 dwelling units per acre.

Figure 4: Students distribution and land use/ land cover map in Baltimore city.



Results of Analyses for $H_0$1

The first null hypothesis states: "After controlling for residential density, neighborhood greenness or open space coverage is not associated with body mass index (BMI)." The research question which led to this hypothesis seeks to determine if greater coverage of green space or open space is associated with decreased BMI. A multilevel model with Baltimore city neighborhood (CSA) as a random effect was conducted with SAS PROC MIXED procedure. The dependent variable was BMI. Residential population density was controlled for. For tests examining the association of greenness and BMI, the independent variable was the percentage of green space coverage in the buffer area around students' homes. For tests examining the association of open space and BMI, the independent variable was the percentage of open space coverage in the buffer area around students' homes.

Results in Table 34 demonstrate that the percentage of green space coverage around homes was not associated with BMI, except for the 0.25 mile buffer. Results in Table 35 indicate that percentage of open space coverage around homes was not associated with BMI across four buffer sizes. In summary, there is no effect of open space coverage on BMI. For greenness, only coverage in the 0.25 mile buffer has an effect on BMI. Increased neighborhood green space coverage was associated with decreased body mass index in the 0.25 mile buffer.

Table 34: Associations between percentage of green space coverage around home and BMI using mixed model

Dependent variable	BMI	
Green space coverage (in %)	**Coefficient**	***p* value**
Green coverage in 0.25 mile buffer	-6.43	**0.0739***
Green coverage in 0.50 mile buffer	-3.39	0.3949
Green coverage in 1.0 mile buffer	-2.32	0.6393
Green coverage in 1.5 mile buffer	0.03	0.9964

Note. **P*<.10

Table 35: Associations between percentage of open space coverage around home and BMI using mixed model

Dependent variable	BMI	
Green space coverage (in %)	**Coefficient**	***p* value**
Green coverage at 0.25 mile buffer	1.08	0.8065
Green coverage at 0.50 mile buffer	-0.65	0.8864
Green coverage at 1.0 mile buffer	-1.91	0.7702
Green coverage at 1.5 mile buffer	5.92	0.5196

Results of Analyses for $H_0$2

The second null hypothesis states: "After controlling for residential density, neighborhood greenness or open space coverage is not associated with physical activity (e.g., walking for transportation and moderate–to–vigorous physical activity (MVPA))." The research question which led to this hypothesis seeks to determine if greater coverage of green space or open space is associated with increased physical activity. A multilevel model with Baltimore city neighborhood (CSA) as a random effect was conducted with SAS PROC MIXED procedure. The multilevel mixed model was adopted because it was believed that individual students were nested within the CSA. The dependent variable was the physical activity as measured by MVPA and walking. For tests examining the association of greenness and physical activity, the independent variable was the percentage of green space coverage in the buffer area around students' homes. For tests examining the association of open space and physical activity, the independent variable was the percentage of open space coverage in the buffer area around students' homes.

Results in Table 36 demonstrate that the percentages of green space coverage around homes were not associated with PA. Results in Table 37 indicated that the percentage of open space coverage around homes was not associated with BMI across four buffer sizes.

Table 36: Associations of percentage of green space coverage around home for physical activity using mixed model

Dependent variable	MVPA		Moderate PA		Vigorous PA		Walking	
Green space coverage (in %)	**Coefficient**	***p* value**	**Coefficient**	***p* value**	**Coefficient**	***p* value**	**Coefficient**	***p* value**
Green coverage in 0.25 mile buffer	-48.43	0.5043	10.60	0.4453	-2.49	0.3753	-0.15	0.8059
Green coverage in 0.50 mile buffer	-120.26	0.1135	-14.68	0.3130	-3.28	0.2794	-0.29	0.6484
Green coverage in 1.0 mile buffer	-165.53	0.1694	-27.44	0.1177	-3.27	0.3721	-0.11	0.8769
Green coverage in 1.5 mile buffer	-198.84	0.1759	-36.19	0.0972	-1.80	0.6919	0.15	0.8695

Note. Controlled for residential density.

Table 37: Associations of percentage of open space coverage around home for physical activity using mixed model

Dependent variable	MVPA		Moderate PA		Vigorous PA		Walking	
Open space coverage (in %)	**Coefficient**	**P value**	**Coefficient**	**P value**	**Coefficient**	**P value**	**Coefficient**	**P value**
Open space coverage in 0.25 mile buffer	-103.78	0.1761	-21.45	0.1378	-0.39	0.8945	0.47	0.5241
Open space coverage in 0.50 mile buffer	-43.75	0.5796	-5.67	0.7033	1.95	0.5219	0.47	0.5134
Open space coverage in 1.0 mile buffer	-16.39	0.8852	10.40	0.6220	0.28	0.9514	0.99	0.3305
Open space coverage in 1.5 mile buffer	-28.89	0.8528	7.74	0.7910	-2.01	0.7491	1.86	0.1704

Note. Controlled for residential density.

Results of Analyses for $H_0$3

In order to test whether there is a mediation effect of physical activity, I followed the Baron and Kenny (1986) four-step procedure. In Step 1, I checked whether the neighborhood greenness or open space coverage was associated with body mass index outcome. The results indicated that increased neighborhood green space coverage was associated with decreased body mass index in the 0.25 mile buffer only. The first mediation criterion of Baron and Kenny (1986) was satisfied. When testing the second criterion, whether neighborhood green space coverage was associated with physical activity in the same 0.25 mile buffer area, it was found that neither green space coverage nor open space coverage was associated with physical activity. As a result, no further tests were conducted. The hypothesis testing did not reject the null hypothesis. Therefore, the conclusion is that there is no mediation effect of physical activity.

CHAPETER FIVE: DISCUSSION

1. **Conclusions for analyses on residential psychosocial environments**

The study addressed the following research questions:

1. Is living in a neighborhood with increased psychosocial hazard associated with increased body mass index (BMI)?
2. Is living in a neighborhood with increased psychosocial hazard associated with decreased levels of physical activity (e.g., walking and moderate-vigorous physical activity), independent of known sociodemographic risk factors?
3. Can physical activity mediate the effects of the neighborhood psychosocial hazards on body mass index (BMI)?

Three null hypotheses were tested to address the research questions for this study. Random effect (multilevel) linear regression models were used to test the hypotheses. By fitting a random intercept for each neighborhood, the models took account of the correlation among persons within a neighborhood, yielding more accurate standard errors and unbiased maximum likelihood parameter estimates (Singer, 1998). The first null hypothesis ($H_0$1) was not rejected. It was concluded that neighborhood psychosocial hazards were not associated with BMI in our study subjects. The second null hypothesis ($H_0$2) was rejected. It was concluded that the neighborhood psychosocial hazards were associated with moderate-to-vigorous physical activity (MVPA) and walking for transportation. The third null hypothesis ($H_0$3) was not rejected and therefore there is not sufficient evidence that physical activity mediates neighborhood psychosocial environments on body mass index.

Although associations between individual-level socioeconomic status and obesity have been repeatedly observed, the relationship between neighborhood characteristics and physical activity and obesity is less clear. This study tried to answer the questions of whether neighborhood social and economic factors may be related to both physical activity and obesity. Unlike previous studies, this study systematically looked at how neighborhood environments influenced different types of physical activity, including moderate-vigorous physical activity, and walking for transportation in particular. The main finding is that after adjusting for individual-level sociodemographic factors, a significant association was found between NPH and physical activity in a predominately minority adolescent sample in a major U.S. urban area. The neighborhood NPH were found to be unrelated to overweight and obesity in minority adolescents in our study. This provides additional evidence that the risk of psychosocial environmental factors for overweight and obesity may differ in different age groups.

Neighborhood deprivation may operate through at least two pathways. First, deprivation may reduce walking (B. Giles-Corti & R. Donovan, 2002; Humpel, et al., 2002; Saelens, Sallis, Black, et al., 2003) and outdoor physical activity (Fisher, Li, Michael, & Cleveland, 2004) due, in part, to perceptions of safety and fear of crime (Ross, 1993). Second, the association may be purely economic (poor people can afford only cheap, calorie-dense foods that are more likely to lead to obesity) (Drewnowski & Specter, 2004).

The effect on health of the places in which people live—apart from individual, genetic, or lifestyle characteristics—is of increasing interest to researchers. A new wave of research is examining the health consequence of various aspects of residential neighborhoods. Moving beyond the study of individual risk factors to the study of neighborhoods maybe a key to understanding widening health disparities across racial/ethnic and sociodemographic groups (Mendes de Leon CF & Glass, 2004). Some data suggest that residents of socioeconomically deprived neighborhoods are more likely to engage in high-risk health behaviors, including inactivity (Fisher, et al., 2004; Humpel, Owen, Iverson, Leslie, & Bauman, 2004) and poor diet (Morland, Wing, & Diez-Roux, 2002). Psychosocial hazards in the neighborhood may be an important link between neighborhood socioeconomic disadvantage and adverse health outcomes (T. D. Hill, Ross, & Angel, 2005). Psychosocial hazards are visible characteristics of neighborhoods – such as violent crime, abandoned housing, and signs of incivility – that give rise to a heightened state of vigilance, alarm, or threat (Ross & Mirowsky, 2001).

This study found that NPH and neighborhood psychosocial hazard indicators were not associated with overweight or obesity. The findings are different from Glass and colleagues who found that living in more hazardous neighborhoods was associated with a graded increase in the odds of obesity in a sample of community-dwelling men and women aged 50-70 years in Baltimore city (Glass, et al., 2006). There are three possible reasons to explain the difference. First of all, the sample in two studies is different. Our subjects are predominately minority adolescents 15-18 years of age. Although 40.5% of the sample is overweight or at the risk of overweight, no significant differences were found in physical activity levels between normal weight and overweight students. Second, BMI is influenced by many factors including dietary behaviors. In this study, no dietary intake data was available, so we were not able to control for the dietary behavior. Lastly, the students in this study may not have exposed to psychosocial hazards environment long enough to lead to chronic activation of, and dysregulation of, the hypothalamic – pituitary – adrenal (HPA) axis response (Chrousos, 2000). The different findings of this study and Glass et al. in regard to the association of BMI and NPH are supported by the theory that prolonged exposure to environments that evoke vigilance, threat, and alarm, may be an important and modifiable contributor to the epidemic of obesity.

In our study, higher physical activity levels were observed in students living in neighborhoods with more hazards. Neighborhood factors such as perceived safety have received increasing attention as barriers to physical activity. Perceptions of neighborhood safety maybe particularly salient among those residents in lower-income urban settings who are from racial or ethnic minority groups. Most of the previous studies looked at the perception of safety alone without looking at the other neighborhood environmental indicators, especially those with objective measures. Indeed, the perception of being in an unsafe neighborhood were the results of many visible characteristics– such as violent crime, abandoned housing, and signs of incivility – that give rise to a heightened state of vigilance, alarm, or threat (Ross & Mirowsky, 2001). While many have hypothesized an inverse association between the perception of unsafe surroundings and physical activity, empirical support for the association has been inconsistent (Humpel, et al., 2002). A number of studies, for example, have found support for an inverse relation between perceived neighborhood safety and physical activity in children (K. Evenson, Birnbaum, Bedino-Rung, Sallis, & Voorhees, 2006; Gomez, Johnson, Selva, & Sallis, 2004; Romero, 2005). Romero et al. report that the perception of more neighborhood hazards (crime, gangs, drugs, traffic, and noise) was associated with more physical activity, not less activity (Romero, et al., 2001). Our finding, consistent with their findings, can provide empirical support to this inverse relation with objective measures of a broader array of neighborhood hazard indicators.

Studies on violence and physical activity are inconsistent. Perception of neighborhood crime was associated with less adult physical activity (Ross C. Brownson, Baker, Housemann, Brennan, & Bacak, 2001), but objectively measured crime was associated with more adolescent physical activity (Gordon-Larsen P, McMurray RG, & Popkin BM., 2000). In this study, objectively measured violence and physical activity is not related. The neighborhood environment may influence adults and adolescents differently, possibly because environments outside the neighborhood are less accessible to adolescents.

It is not clear why objective violent crime rates predicted adolescent physical activity in this study. Perceived crime was expected to predict physical activity better than objective crime because perceived crime reflects direct exposure to specific types of crime (J. Kuo, Voorhees, Haythornthwaite, & Young, 2007). Because community statistical areas are large, students may not know about crimes that happened within their community statistical area if those crimes occurred too far from home. The objective crime measurement was made on the basis of reported crimes, which may have underestimated the actual number of crimes that were committed. The overall inactivity of the study population may explain why differences by crime were not detected.

The association between NPH and BMI was not substantially mediated through physical activity in this study. Body weight was influenced by many factors other than physical activity. Without taking television time and dietary intake into consideration, it is possible that the mediation effect was not detected. When controlling for dietary intake, Glass and colleagues found a slight but not significant mediation effect of physical activity on BMI in their study. The association between NPH and obesity was reduced slightly when self-reported physical activity was added, indicating that this association may be mediated, at least in part, by the impact of neighborhoods on physical activity. This suggests that pathways may exist if more physical activity related factors are controlled in future studies. It is worth noting the relationship between local neighborhood and physical activity, namely walking and cycling, is a complex issue. For example, living in an urban environment was associated with a greater number of sidewalks, which were a predictor of walking for exercise or transportation, but were also in a high crime area, which is a deterrent for walking (Rutt & Coleman, 2005).

2. Conclusions for analyses on commercial environment

The study addressed the following research questions:

1. Is living in a neighborhood with closer proximity and higher density of a variety of destinations associated with body mass index (BMI)?
2. Is living in a neighborhood with closer proximity and higher density of a variety of destinations associated increased levels of physical activity (e.g., walking and moderate-vigorous physical activity)?
3. Can physical activity mediate the destination effects on body mass index (BMI)?

Three null hypotheses were tested to address the research questions for this study. Random effect (multilevel) linear regression models were used to test the hypotheses. By fitting a random intercept for each neighborhood, the models took account of the correlation among persons within a neighborhood, yielding more accurate standard errors and unbiased maximum likelihood parameter estimates (Singer, 1998). The first null hypothesis ($H_0 1$) was not rejected. It was concluded that there is no effect of either density or proximity of destinations on BMI. The second null hypothesis ($H_0 2$) was rejected. It was concluded that densities of destinations were associated with walking across four buffer sizes. Access to school and museums within 0.25 mile, and grocery stores, retail and shopping, post offices and mix of destinations within 0.5 mile and beyond was positively associated with participation in walking. In addition, densities of fast food restaurants and parks and recreation within 1 mile and 1.5 mile were associated with increased walking. As for the correlates to vigorous physical activity, only the park and recreation density within 0.5 mile buffer was marginal significant. Closer proximity to schools and museums increased both student's MVPA level and their walking trips. The third null hypothesis ($H_0 3$) was not rejected and therefore there is not sufficient evidence to support that physical activity mediates the effects of density and proximity of destinations on body mass index.

Consistent with the literature, the findings in this study have found associations between proximity of destinations and physical activity. Literature from public health and health have shown positive associations between accessibility of destinations such as shops, stores and interesting places within walking distance (Santos, Silva, Santos, Ribeiro, & Mota, 2008) and moderate physical activity level. Recently, studies found a significant association between access to destinations and walking for transport (Cerin, Leslie, Toit, Owen, & Frank, 2007; McCormack, et al., 2008). In addition, perceptions of certain neighborhood features (e.g., well-lit streets, having biking or walking trails and more places to go, pedestrian safety, traffic volume and speed, and crime) (K. R. Evenson, et al., 2006; K.R. Evenson, Scott, Cohen, & Voorhees, In Press; Kelly R. Evenson, et al., 2007; Mota, Almeida, Santos, & Ribeiro, 2005; Moudon, et al., 2007; J. Sallis & Kerr, 2006) are associated with physical activity. Evidence from transportation and urban planning has suggested that residents from communities with higher population density, greater connectivity, and more land-use mix (e.g., shops within walking distance of homes) report higher rates of walking/cycling for utilitarian purposes (Ross C. Brownson, et al., 2004; Saelens, Sallis, & Frank, 2003).

The uniqueness of this study is that it examined the association between destination proximity and densities and physical activity in different buffer sizes, that is, in different “walkable” distances. Generally, walkable distance have ranged from 90 m to 1 km (Cervero, 1996; L. D. Frank, Andresen, & Schmid, 2004) or a 10- to 15-minute walk from home (Saelens, Sallis, & Frank, 2003). Aultman-Hall et al. (Aultman-Hall, Roorda, & Baetz, 1997) suggest that 400 m (0.25 mile) is considered the greatest distance a transit walker is likely to walk to a transit station in Australia.

The findings of this study suggest that the proximity and mix of some types of destinations within 0.5 mile (~800 meters) and 1 mile (~1600 meters) of people’s homes may be more influential than others for supporting different types of physical activity (i.e., behavior specific). Transportation-related walking appeared to be more influenced by the presence and mix of destinations than MVPA or vigorous physical activity. Of all the walking distances, the 0.5 mile (~800 meters) distance seems to be the optimal distance to encourage both MVPA and walking for transportation. Positive association between both the proximity of destinations and land-use mix and transport-related walking have been found elsewhere (Handy & Clifton, 2001; Hoehner, Brennan Ramirez, Elliott, Handy, & Brownson, 2005b). In the current study, the presence of grocery stores, retail and shopping, post offices, and destination mix were significant correlates of transportation-related walking irrespective of the network buffer size examined. Nevertheless, a preliminary conclusion drawn from the results is that built environment policy and practice should pay additional attention to the creation of proximal destinations within walking distance in order to encourage physical activity.

In our study, densities of fast food restaurant within 0.25 mile buffer were associated with increased BMI. Previous studies regarding adults suggest that closer proximity to fast-food restaurants and convenience stores raises risk of overweight, while closer proximity to supermarkets may be expected to protect against overweight (Cheadle, Psaty, & curry, 1991; Zenk, Schulz, & Hollis-Neely, 2005). In the context of the few studies on the relationships between diet, the food environments, or body mass index among adolescents, the results remain mixed and the relationships are poorly understood (Burdette & Whitaker, 2004). The reality is that American adults and children are consuming greater quantities of food, food retail portion sizes have increased substantially (L. R. Young & Nestle, 2002), and palatable, inexpensive energy-dense foods are readily accessible. Interestingly, urban residents pay 3% to 37% more for groceries in their local community than suburban residents who purchased similar groceries at large supermarket (Obtaining food: Shopping Constraints of the Poor, 1987). Moreover, supermarkets have sharply declined in low-income inner city areas. Further research is needed to examine access, types and costs of different foods actually served at establishments, and valid measures of dietary intake in adolescents, especially in inner cities.

Our findings showed that of all destinations, only the presence of parks and recreation within 0.5 mile distance was related to vigorous physical activity. Cohen and colleagues suggested that girls who live near more parks engaged in more nonschool vigorous physical activity than those with fewer parks (D. A. Cohen, et al., 2006). In their study, the association between physical activity and park proximity was strongest up to 0.5 miles and diminished significantly for parks that were farther away. Both findings are consistent with the 2001 national Household Transportation Survey finding that the average walking trip is 0.5 miles (National Household Transportation Survey, 2001).

Future studies could be more comprehensive, examining features such as aesthetics, facilities, and the presence of organized activities in the parks.

Findings in this study underscore the importance of walkable communities with destinations and recreation facilities. In adults, it was reported (Kockelman, 1997) that a positive association between land-use mix and increased walking for transportation would be related to increased energy expenditure and theoretically to lower BMI . In this study, the destination was not related to BMI, probably due to the cross-sectional nature of the study.

3. Conclusions for analyses on recreation environment

The study addressed the following research questions:

1. Is living in a neighborhood with greater greenness or open space coverage associated with body mass index (BMI)?
2. Is living in a neighborhood with greater greenness or open space coverage associated with increased levels of physical activity (e.g., walking and moderate-vigorous physical activity)?
3. Can physical activity mediate the effects of greenness or open space coverage on body mass index (BMI)?

Three null hypotheses were tested to address the research questions for this study. Random effect (multilevel) linear regression models were used to test the hypotheses. By fitting a random intercept for each neighborhood, the models took account of the correlation among persons within a neighborhood, yielding more accurate standard errors and unbiased maximum likelihood parameter estimates (Singer, 1998). The first null hypothesis ($H_0$1) was not rejected with the exception of the 0.25 mile buffer distance. It was concluded that increased neighborhood green space coverage was associated with decreased BMI in the 0.25 mile distance only. The percentage of open space coverage around homes was not associated with BMI across four buffer sizes. The second null hypothesis ($H_0$2) was not rejected. It was concluded that percentages of both green space and open space coverage around homes were not associated with physical activity. The third null hypothesis ($H_0$3) was not rejected and therefore there is not sufficient evidence to support that physical activity mediates the effects of greenness and open space coverage on BMI.

This study presents the results of an exploratory analysis of the relationship of adolescents' body weights to objective measures of "greenness" n in an urban setting. It was found that the green space coverage within 0.25 mile distance was associated with decreased BMI. Previous studies on the interaction between human health and the physical environment suggest that exposure to green landscapes has a positive influence on variety of psychological and physiological processes. An often cited example is the work of Ulrich, who found that postsurgical hospital patients with window views of green landscapes had significantly shorter recovery periods and reduced need for pain medication compared to patients with views of urban setting (Ulrich, 1984). This study's findings are consistent with previous research linking exposure to green landscapes with health improvements. Among children and youth, the positive health effects of green landscapes include improved cognitive functioning (Wells & Evans, 2006) and reduced attention deficit hyperactivity disorder symptoms (F. E. Kuo & Faber Taylor, 2004).

Our findings indicated that greenness may be an important factor to consider in addition to accessibility in active living research. Even though this study did not show a relationship between objective measures of greenness and MVPA or walking, it was found that BMI was lower in areas that had high objective greenness measures than in areas with low greenness. This result also is supported by a previous study (Tilt, Unfried, & Roca, 2007). In a longitudinal study, Bell and colleagues found children and youth in greener settings were less likely to increase their BMI z-scores over 2 years compared to their counterparts in less-green neighborhoods (Bell, Wilson, & Liu, 2008). After controlling for residential density, our finding indicated that the effect of greenness on weight status is independent of residential density.

4. Limitations

This study had limitations that merit noting. First, we cannot assess a causal relationship due to the cross-sectional nature of the data. Longitudinal data that capture clinical data for subjects residing in the same place before and after changes such as the development of a park or construction of a supermarket are needed to assess unknowns stemming from individual preference for certain neighborhoods (e.g., self-selection). Second, it is worth notice that when examining behavior-specific destinations, the physical activity did not necessarily occur at these destinations. Generally, mixed use neighborhoods have higher population densities and greater connectivity (L. Frank, Engelke, & Schmid, 2003). This study has adjusted for population density, which in turn may produce unbiased results. Furthermore, several destinations that may be important for transport-related and vigorous physical activity were not included. Third, data collection has always been a challenge for travel behavior research, even more so for youth. The potential drawbacks of travel surveys (e.g., non-response), as another limitation of this study, are well known. In order to address this limitation, we call for the use of alternative approaches for data collection, such as GPS or PDA, in future studies. Fourth, the racial distribution of this population limits generalization of findings. This study consisted of large numbers of Blacks who have been shown to be at higher risk for obesity related morbidity and mortality in studies of adolescents. In addition, the sample is drawn from 9th through 12th graders in two magnet schools and therefore the results may not be reflective of the nation as a whole. The general hypothesis for this study is that environmental factors such as psychosocial hazards or greenness affect health-related behaviors (such as providing opportunities for or barriers against physical activity) and that these behaviors in turn affect the accumulation of body mass. It is important to keep in mind, however, that these behaviors are only a few of the factors determining a person's weight status.

5. Implementations and recommendations for future studies

Individuals generally report "lack of time" and "motivation" as barriers to participating in physical activity (Dishman & Sallis, 1994). Reducing to barriers to transport-related walking trips or MVPA might be one strategy to encourage people engage in the recommended levels of physical activity into daily activities (L. Frank, et al., 2003). The creation of supportive physical environments, including the development of destinations within walkable distance to homes may encourage more walking trips or MVPA and help people achieve recommended physical activity.

Some of the weaker or non-significant association may be attributed to characteristics of the environmental features studies, measurement errors, or a limited direct effect of the environmental characteristics on generating physical activity. It is important to add the subjective measures of the environment, in supplement to the objective measures as studies indicated that the perceptions of the environment may be more influential to individual's PA decision making (Ries, et al., 2008). Future studies should examine both objective and individual perception of the environment. Furthermore, to test whether individual perceptions modify the influence of objective indicators on physical activity is an area that needed more attentions in the future.

APPENDICES

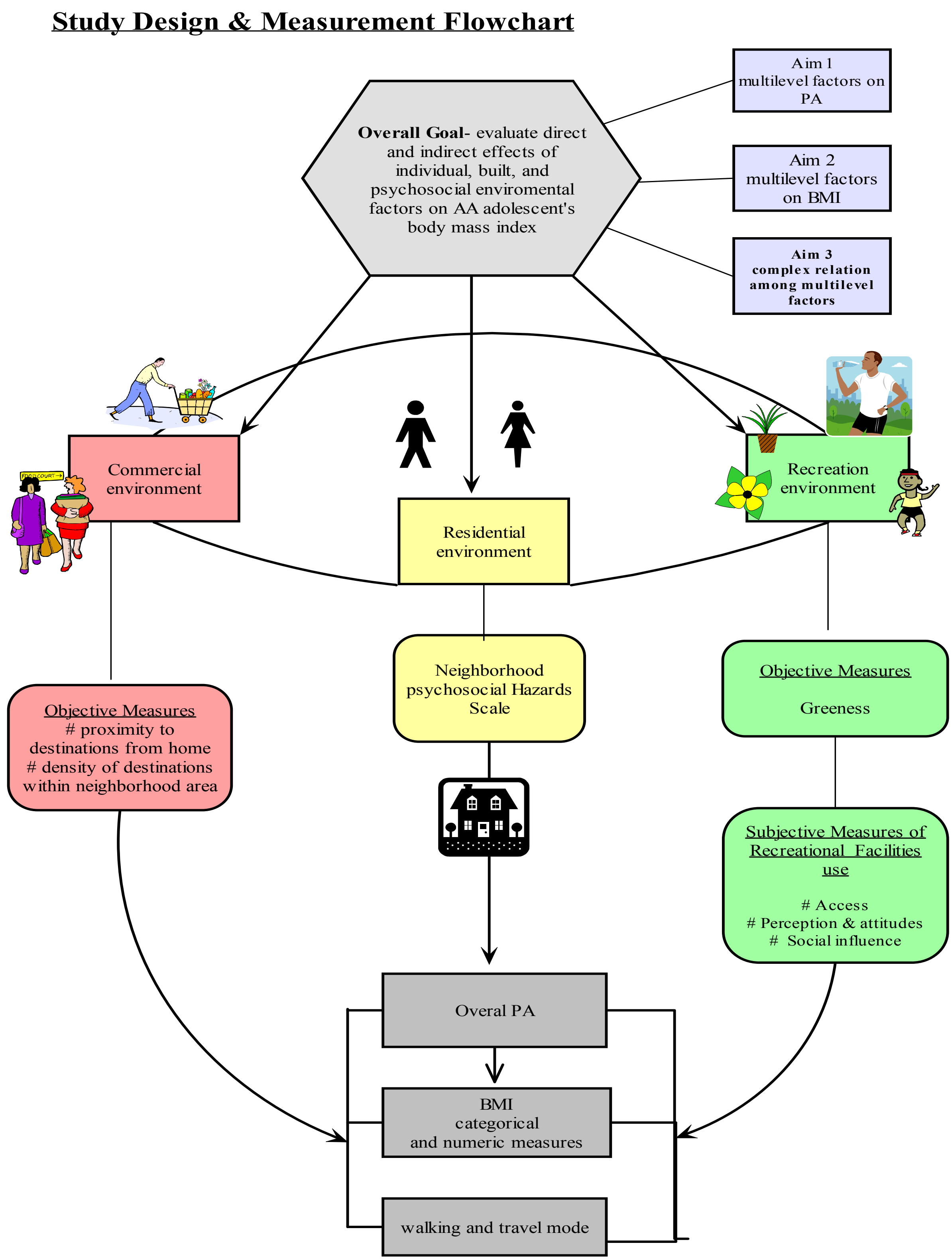
Appendix A: Dimension of the Variables and Corresponding Indicators/Measures

Table 1 Dimension of the Variables and Corresponding Indicators/Measures

Dimensions	Indicators/Measures	Sources
Latent variables measuring three environments		
Residential Psychosocial Environment	1) Violent crimes 2) Abandoned/vacant housing units 3) Per capita income 4) Unemployment rate 5) % families in poverty 6) 911 calls per resident per year Each variable is standardized (z-score) The sum of all standardized scores represents the Neighborhood psychosocial Hazards scale (NPH)	• Baltimore city crime data • Census data, U.S. Census Bureau • Census data, U.S. Census Bureau • Census data, U.S. Census Bureau • Census data, U.S. Census Bureau • 911 calls data, Baltimore City Police Department
Commercial Environment	• Number of destinations within 0.25-mile, 0.5-mile and 1-mile, and 1.5-mile radius distance as measured by GIS Network Analysis. Seven destinations will be measured: Fast food restaurant, grocery stores, post offices, schools and museums, theaters and swimming pools, retail and shopping malls and parks and recreations. • Street networks	• MdProperty View 2000, ADS database from Maryland State Geospatial data Archive • Census data, U.S. Census Bureau
Recreation Environment	1) Calculate the area of interests (e.g., green space) within 0.25-mile, 0.5-mile, 1-mile, and 1.5-mile radius distance from each student's home. 2) Proximity to parks, playgrounds, and recreation facilities 3) Density of park & recreation facilities	• Land use land cover data (2002) archived at the University of Maryland's Global Landcover Data Facility • GIS data survey • GIS data survey
Latent variables measuring individual demographic and socioeconomic status		
Demographic	• Sex	• Voorhees

information	• Age • Race & Ethnicity	
Outcome variables ***-Measures of Physical Activity and Body Mass Index*** **[Data were measured and collected through a bigger ALR study (PI: Voorhees)]**		
Physical Activity	• **Walking measures** -walking for recreation -walking for transportation • **Overall physical activity measures** -minutes spend in moderate or vigorous PA (MVPA) per week -Frequency (bouts) of specified activities per week by MET value • **Walking trip measure** -number of trips made by foot per week	• Self-report PA checklist for the consecutive six-day Measured as frequency (unit=30 min) per day and per week • Both objective and subjective measures -MTI Actigraph uniaxial accelerometer - Self-report PA checklist • Travel diary
Body Mass Index	• **Body Mass Index (BMI)** Continuous measure and binary measure (e.g. at risk of overweight & overweight Versus normal weight)	• Weight, height measures • Body mass index [BMI = weight (kg)/height^2 (m)] • Body weight status was classified on the basis of the age- and sex- specific BMI percentiles provided in the 2000 growth charts of the Centers for Disease Control and Prevention • Overweight = BMI ≥ 95th percentile, at risk of overweight = BMI ≥ 85th percentile

Appendix B: Study design and measurement flowchart



Appendix C: Measurement instruments

Intensity Scale for Certain Activity (with activity # as examples):

• **Light - Slow breathing, little or no movement.**

#9

#14

#5

#1

•**Moderate - Normal breathing and some movement**.

#23

#21

29

#27

• **Hard - Increased breathing and moderate movement**.

#43

#40

#46

#68

• **Very Hard - Hard breathing and quick movement.**

#58

#30

#53

#61

Appendix C.1: Instrument 1: Physical activity checklist (recall)

Day: ______________

Put an "X" to rate the intensity of each

Write numbers for "where" and

Write 'Activity' numbers in this

	Activity Number	Light	Moderate	Hard	Very Hard	Where	With Whom
6:00-6:30							
6:30-7:00							
7:00-7:30							
7:30-8:00							
8:00-8:30							
8:30-9:00							
9:00-9:30							
9:30-10:00							
10:00-10:30							
10:30-11:00							
11:00-11:30							
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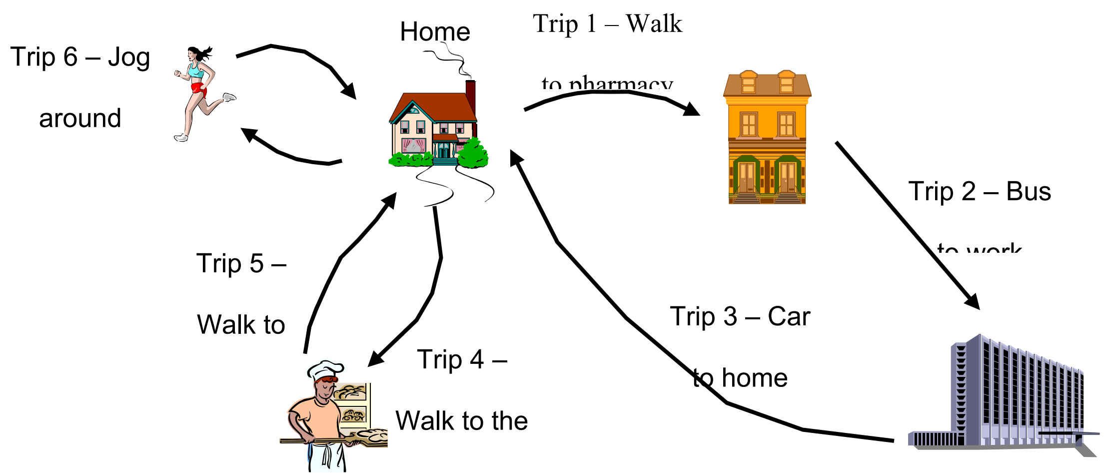
7:30-8:00								
8:00-8:30								
8:30-9:00								
9:00-9:30								
9:30-10:00								
10:00-10:30								
10:30-11:00								
11:00-11:30								
11:30-12:00								

<u>**Appendix C.2: Instrument 2: Travel Diary (recall)**</u>

EXAMPLES OF TRIPS AS DESCRIBED IN EXAMPLES 1-3 BELOW



EXAMPLE 1: I woke up at home in the morning, and departed at 8:12 am. I walked to my neighborhood pharmacy, which is at the stop where I catch the bus to work. I arrived at the pharmacy at 8:22 am. The bus departed at 8:35 am. The bus dropped me off in front of my office at 8:55 am and I walked <u>less</u> than 300 ft to my workplace. I arrived at work at 8:57 am. My entries would look like this:

#	**WHEN** did you leave?	**WHERE** did you go? Mark only one		**HOW** did you travel? *Mark only one*			**WHEN** did you arrive?
1	8:12 am	☐ Home ☐ Work/School ☐ Other	✖ Home Neighborhood ☐ Work/School Neighborhood	☐ Auto ✖ Walk/Run	☐ Rail ☐ Cycle	☐ Bus ☐ Other	8:22 am

2	8:35 am	☐ Home ☐ Home Neighborhood ☐ Auto ☐ Rail ✖ Bus ✖ Work/School ☐ Work/School Neighborhood ☐ Walk/Run ☐ Cycle ☐ Other ☐ Other	8:57 am

EXAMPLE 2: That afternoon, I caught a ride home from work with a friend; we left the office at 4:30 and drove home. My carpool dropped me off at home at 4:43. Once at home I immediately set out on foot for the bakery to pick up some bread. By the time I got to the bakery it was 4:51, and there was a long line. I didn't leave until 5:15, and then walked home, arriving at 5:23.

#	**WHEN** did you leave?	**WHERE** did you go? Mark only one	**HOW** did you travel? *Mark only one*	**WHEN** did you arrive?

1	4:30 pm	✖ Home ☐ Home Neighborhood ✖ Auto ☐ Rail ☐ Bus ☐ Work/School ☐ Work/School Neighborhood ☐ Walk/Run ☐ Cycle ☐ Other ☐ Other	4:43 pm
2	4:43 pm	☐ Home ✖ Home Neighborhood ☐ Auto ☐ Rail ☐ Bus ☐ Work/School ☐ Work/School Neighborhood ✖ Walk/Run ☐ Cycle ☐ Other ☐ Other	4:51 pm
3	5:15 pm	✖ Home ☐ Home Neighborhood ☐ Auto ☐ Rail ☐ Bus ☐ Work/School ☐ Work/School Neighborhood ✖ Walk/Run ☐ Cycle ☐ Other ☐ Other	5:23 pm

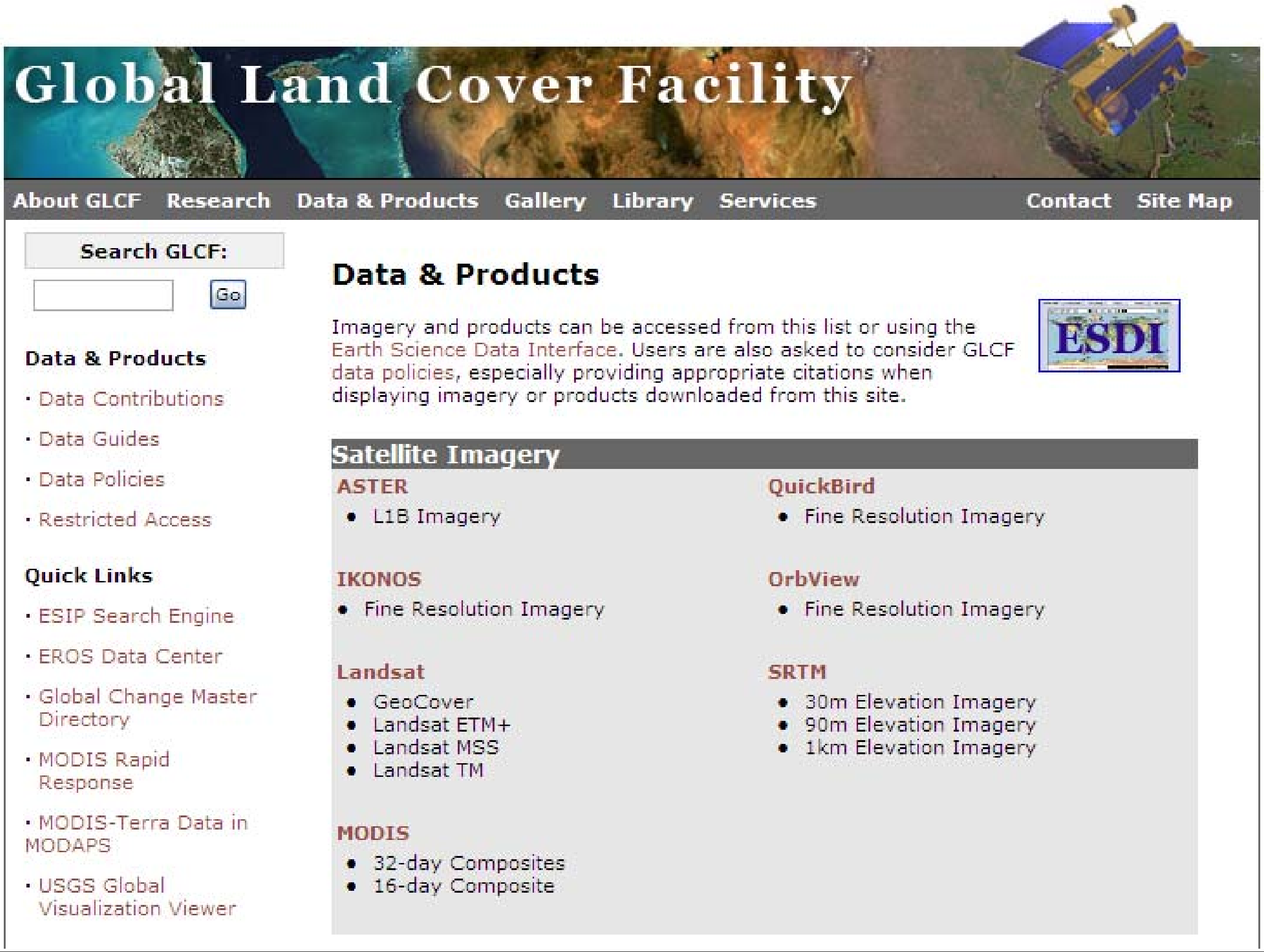
Appendix D: GIS facility in the University of Maryland

Research supporting Centers at University of Maryland

- The Regional Earth Science Applications Center (RESAC) at the University of Maryland, College Park facilitates interactions between researchers and a broad base of end-users working on resource management issues in the mid-Atlantic region using geospatial data and technologies (Goetz et al. 2001). The RESAC has developed new land cover and land use maps using remotely sensed data and new mapping technologies for the Chesapeake Bay watershed and the intersecting counties.

- The Global Land Cover Facility at the University of Maryland, College Park is a research center focusing on the investigation of land cover dynamics and the development and distribution of products that explain aspects of land cover and land cover change. Interests in the Carbon Cycle and Global Climate Change have involved GLCF in developing forest change products. Past research efforts were directed at boreal forests in Canada and Russia, and tropical rainforests in the non-Brazilian Amazon and Central Africa. (http://glcf.umiacs.umd.edu/aboutUs/)

Data & Products provided


Global Land Cover Facility
About GLCF
Research
Data & Products
Gallery
Library
Services
Contact
Site Map
Search GLCF:
Go
Data & Products
Data & Products
· Data Contributions
· Data Guides
· Data Policies
· Restricted Access
Quick Links
· ESIP Search Engine
· EROS Data Center
· Global Change Master Directory
· MODIS Rapid Response
· MODIS-Terra Data in MODAPS
· USGS Global Visualization Viewer
Imagery and products can be accessed from this list or using the Earth Science Data Interface. Users are also asked to consider GLCF data policies, especially providing appropriate citations when displaying imagery or products downloaded from this site.
ESDI
Satellite Imagery
ASTER
• L1B Imagery
QuickBird
• Fine Resolution Imagery
IKONOS
• Fine Resolution Imagery
OrbView
• Fine Resolution Imagery
Landsat
• GeoCover
• Landsat ETM+
• Landsat MSS
• Landsat TM
SRTM
• 30m Elevation Imagery
• 90m Elevation Imagery
• 1km Elevation Imagery
MODIS
• 32-day Composites
• 16-day Composite

Products Derived from Satellite Imagery

AVHRR

- GIMMS
- GloPEM
- Land Cover Classification
- Tree Cover Continuous Fields
- Burned Areas in Russia

Landsat

- Forest Change Products
  - Amazon Basin
  - Central Africa
  - Paraguay
- Landsat Mosaics
- Landsat Subsets
- Coastal Marsh Health Index

GOES

- Radiative Fluxes

MODIS

- Vegetative Cover Conversion (VCC)
- Vegetation Continuous Fields (VCF)
- Vegetation Index (NDVI)

Special Collections

- Hurricane Katrina
- Hurricane Rita
- 2004 Tsunami

The land cover map

The land cover classification is modified from Anderson Level II (Anderson et al., 1976). A decision-tree machine leaning algorithm is used for classification that produces an explicit, hierarchical tree that can be used to classify additional data that have similar properties to those for which it was constructed. The methodology developed by the RESAC is described in Varlyguin et al. (2001).

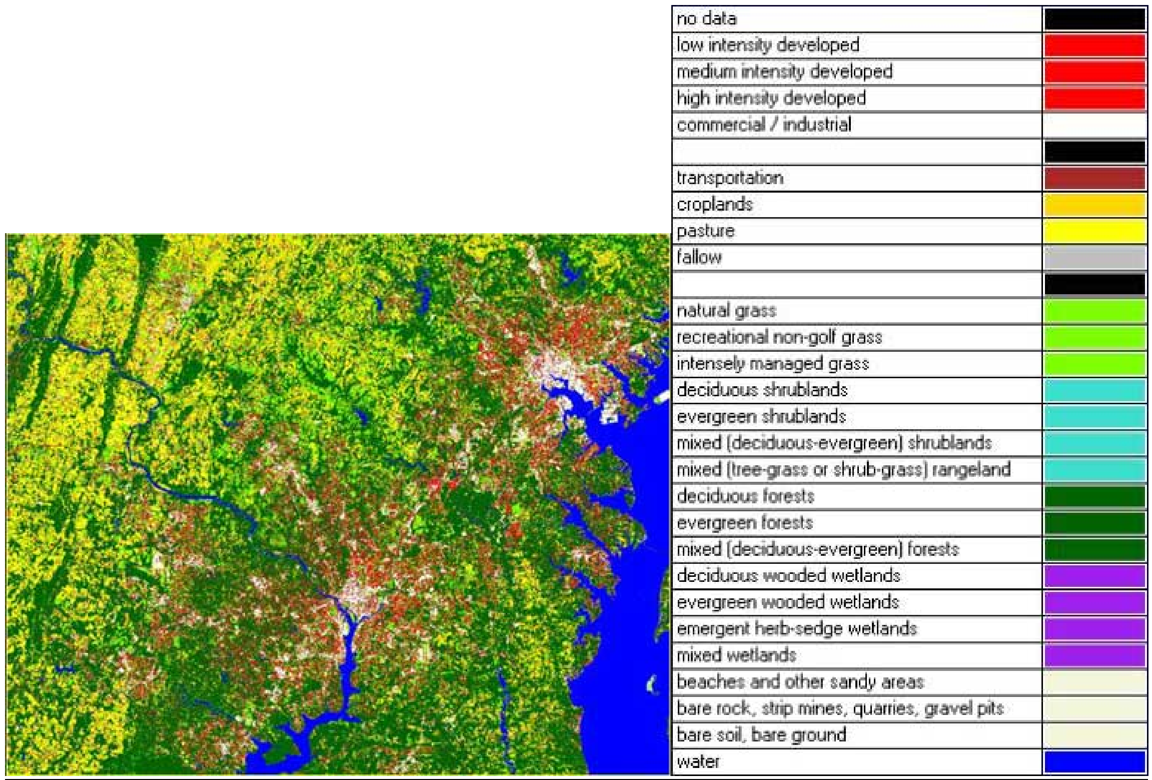
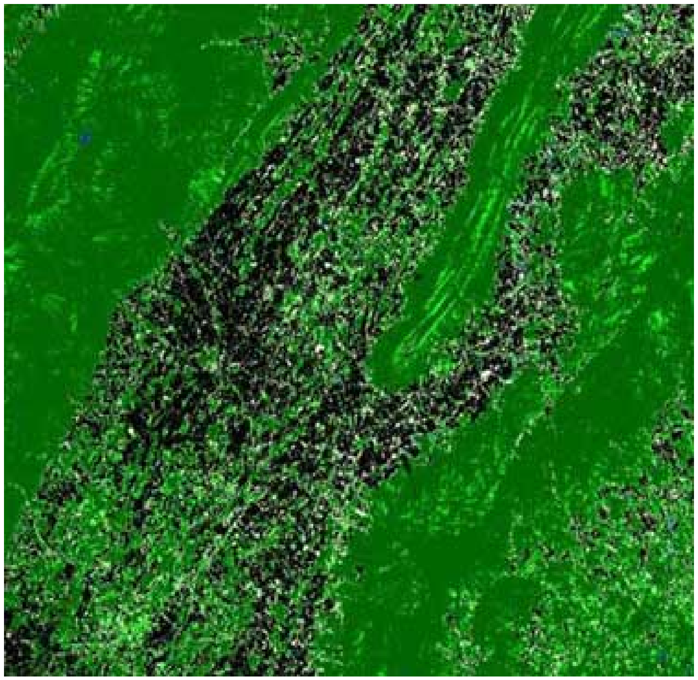


Figure 1. RESAC land cover map of an enlarged segment over Washington, D.C showing the classes mapped.

The tree cover density map

The RESAC team has developed a new technique for mapping tree density using information gathered by the Landsat 7 satellite. The tree cover map shares some characteristics with the impervious surface map in that measurements are taken directly from the sensor and processed through a regression tree algorithm to produce estimates of tree density on a scale from 0-100%. The map is sensitive to features that are overlooked in traditional land cover maps, in which some forested land cover classes are placed in non-forest classes and are therefore not incorporated into estimates of forest cover. This ability to discriminate small patches of trees and partially tree-covered pixels greatly improves the discrimination of forests. The new maps have been used in applications related to connectivity of resource lands, and in preliminary assessments of standing above-ground biomass for carbon accounting.

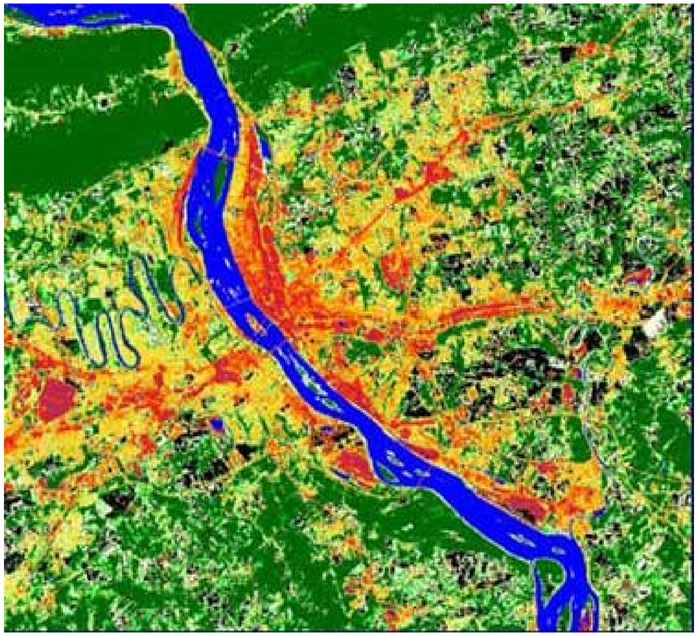
(a)



(b)

Figure 2 (a) Map of tree cover in the Chesapeake Bay Watershed and intersecting counties. (b) An enlargement of the Shenandoah Valley and

Harrisonburg showing agricultural and urban areas in black and tree cover in shades of green.



(a) (b)

Figure 3. Harrisburg PA. The impervious surface and the tree cover density maps can be combined (a) to characterize the complex cover types created by variation in density of development (imperviousness) and tree cover. The tree cover map alone (b) shows how land cover classes in and around complex, fragmented environments may, nevertheless, form continuous corridors of forest cover.

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