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Spatial Analysis of Crime Incidence and Adolescent Physical Activity

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Abstract

Adolescents do not achieve recommended levels of physical activity. Crime is believed to be a barrier to physical activity among youth, but findings are inconsistent. This study compares the spatial distribution of crime incidences and moderate-to-vigorous physical activity (MVPA) among adolescents in Massachusetts between 2011 and 2012, and examines the correlation between crime and MVPA. Eighty adolescents provided objective physical activity (accelerometer) and location (Global Positioning Systems) data. Crime report data were obtained from the city police department. Data were mapped using geographic information systems, and crime and MVPA densities were calculated using kernel density estimations. Spearman's correlation tested for associations between crime and MVPA. Overall, 1,694 reported crimes and 16,702 minutes of MVPA were included in analyses. A strong positive correlation was present between crime and adolescent MVPA ($\rho=0.72$, $p<0.0001$). Crime remained positively associated with MVPA in locations falling within the lowest quartile ($\rho=0.43$, $p<0.0001$) and highest quartile ($\rho=0.32$, $p<0.0001$) of crime density. This study found a strong positive association between crime and adolescent MVPA, despite research suggesting the opposite relationship. This counterintuitive finding may be explained by the logic of a common destination: neighborhood spaces which are desirable destinations and promote physical activity may likewise attract crime.

Keywords

Crime; Youth; Adolescents; Physical activity; GIS

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Introduction

Adolescents do not achieve recommended levels of physical activity, despite known health benefits. Research has shown that health-enhancing physical activity behaviors may be influenced by certain aspects of the neighborhood environment, including availability of parks and green space, walkability, and crime and safety (Handy, et al, 2002, Oreskovic, et al, 2015).

Although neighborhood crime is believed to be a barrier to physical activity, research in both adult and pediatric populations has produced mixed findings. While several studies have found that higher crime rates and lower reported safety are associated with lower levels of physical activity (Gomez, et al, 2004,Gordon-Larsen, et al, 2000), other studies have found null associations (Prince, et al, 2011). One recent study in adults found that an increase in objectively measured crime was associated with increased walking frequency (Foster, et al, 2014). Furthermore, some evidence suggests that the relationship between crime and physical activity may vary depending on crime severity (Kerr, et al, 2015). Together these findings suggest that the relationship between crime and safety and physical activity is more complex than previously believed.

Prior mixed findings may be explained by inconsistencies as well as limitations in the measurement of both crime and physical activity. Past research has often focused on perceptions of crime and safety, a measure that may not reflect actual crime patterns (Carver, et al, 2008). Similarly, physical activity is frequently measured using self-report and questionnaire data, despite advances in more objective methods for quantifying physical activity, such as accelerometry. Reviews of the physical activity literature have highlighted the shortcomings of self-reported physical activity (Biddle, et al, 2011). Furthermore, studies that do use objectively measured crime and physical data are limited by the operationalization of the neighborhood environment or daily activity space, focusing on geographic proxies such as the area immediately surrounding the home (Janssen, 2014) or census units (O'Connor, et al, 2014). However, research has consistently shown that such geographic proxies do not necessarily represent the spaces that individuals are exposed to, let alone those in which individuals engage in physical activity (Robinson and Oreskovic, 2013). This study sought to compare the spatial relationship between local crime and objectively measured adolescent moderate-to-vigorous physical activity (MVPA), and to examine the statistical correlation between crime density and physical activity density.

Methods

Participants and Setting

We recruited 80 adolescents aged 11–14 years living in the greater Boston, Massachusetts area. Subjects were recruited from a local community health center and a community recreation center. Participants reported age (date of birth), sex, race/ethnicity, and highest level of parent education. We collected home and school addresses from each subject. This study was approved by the Partners HealthCare Institutional Review Board.

Measures

Physical Activity Data—Physical activity data were collected as part of a larger study assessing adolescent use of the built environment for physical activity (Oreskovic, et al, 2015). Each subject wore an elastic belt around the hip equipped with a GPS receiving unit (QStarz BT-Q1000XT) to record location and an accelerometer (GT3X; ActiGraph LLC) to record physical activity. Adolescents were instructed to wear the belt at all times except during water activities (e.g. bathing, swimming, etc.) and sleep hours, and to charge the GPS unit overnight. We asked subjects to wear the belt for two separate weeks between May 2011–2012, during both a warm and cold season.

GPS and accelerometer data were reviewed upon return to ensure each subject provided adequate data for analysis. The two files were joined and location and physical activity data were matched based on date and time. Joined datasets were validated and cleaned using a multistep approach previously described (Robinson and Oreskovic, 2013). Activity intensity was calculated for accelerometer data with MVPA defined as activity at or above a threshold of 2296 counts per minute, in accordance with age appropriate guidelines (Evenson, et al, 2008). As this study was primarily interested in the locations of health-enhancing physical activity (i.e. MVPA), all non-MVPA activity data were removed from the final dataset prior to analysis.

Crime Data—One year of contemporaneous crime report data was collected from the local city police department. Crime data were collected approximately one year after the study conclusion to allow for sufficient time for reported crimes to be entered in the police database. Crime data included crime type (e.g. robbery, assault, etc.), date and time of the reported crime, and address at which the crime occurred. The crime dataset was cleaned to remove crimes that were reported in duplicate. Crimes were then further categorized as serious crimes (aggravated assault, arson & bombing, burglary (B&E), forcible rape, homicide, kidnapping/abduction, robbery) and minor crimes (disorderly conduct, destruction/damage/vandalism, drugs/narcotics violations, drunkenness, liquor law violation, stolen property offenses, weapon laws violation, intimidation).

Spatial Analysis—All GIS analyses were conducted using ArcGIS version 10.1 (ESRI, Redlands, California). Crime and adolescent physical activity locations were geocoded and mapped. Additionally, subjects' home and school addresses were geocoded and mapped. Physical activity data were then categorized as taking place in one of the following built environment categories: home, school, parks, playgrounds, streets/sidewalks, and other. Details of the GIS methodology used to make these classifications is described elsewhere (Oreskovic, et al, 2015). In this study, physical activity data points that fell outside of the study area (city boundaries) were removed from analysis, as we did not have corresponding crime data. After mapping the physical activity and crime locations, we measured the densities of adolescent physical activity and crime incidences using kernel density estimation. Kernel density is a method of estimating the density of an event across a geographic area by creating a continuous density surface (Thornton, et al, 2011). Unlike simple density measurements which account only for data or events that occur immediately within a geographic area, kernel density provides a more practical density measure by accounting for events that occur not only within, but also around, an area. While events that occur in closer proximity are weighted more heavily, events within a specified radius are also incorporated into the density measurement (Smiley, et al, 2010).

We conducted kernel density analysis using several different parameters, in order to select those most appropriate for our dataset. The study area was divided into 50m (option 1) and 100m (option 2) grid cells. We then ran kernel density estimations for crime and physical activity using 400m (option 1a and 2a), 800m (1b and 2b), and 1600m (1c and 2c) bandwidths. We selected 50m grid cells and 400m bandwidth, as these parameters best captured variation in our dataset without over- or under-smoothing. Kernel densities for both crime and physical activity were then transformed to a 0–1 scale. We removed crime and MVPA kernel density data for grid cells that covered land use areas deemed unusable/ inaccessible, such as bodies of water (including lakes and wetlands) and waste disposal sites, identified using the MassGIS land use layer (Massachusetts Office of Geographic Information). These areas are unlikely to contain incidences of either physical activity or crime, and retaining these spaces in the analyses would have produced zero values for the grid cells contained within those spaces, potentially biasing the results. We then adjusted for population density by averaging kernel density values for both crime and physical activity to a census block group level, the smallest census unit available in US population data.

Crime Severity Analysis: Given some existing evidence that severity of crimes may differentially influence physical activity behaviors, we conducted additional kernel density estimations for crimes categorized as serious and minor, respectively. Crime severity subanalyses were conducted using 50m cells and 400m bandwidth.

Built Environment Analysis: The presence of crime, as well as other neighborhood characteristics, may influence a child or family's decision to engage certain built environments differently than others. Specifically, there are certain built environments that children and/or families generally make an active choice to engage (or avoid), such playgrounds and sidewalks. Other built environments in which children and adolescents spend time, namely home and school, are not actively chosen. Adolescents are typically not free to choose which school they attend or control where their home is located. For this reason, it is possible that neighborhood characteristics may play a partial role in an adolescent's decision to spend time in these spaces or be active in these spaces. To account for potential differences in these built environments, we dichotomized physical activity locations into "non-optional" built environments (home and school) and "optional" built environments (parks, playgrounds, streets/sidewalks, and other). Built environment subanalyses were conducted using 50m cells and 400m bandwidth.

Statistical Analysis

Descriptive statistics were calculated for the study sample, MVPA, and crime. Non-parametric Spearman correlation analyses were used to test for associations between overall crime densities and MVPA densities. We also ran Spearman correlation analyses on locations falling within the lowest crime density quartile and highest crime density quartile. Regression analyses tested for associations between overall crime and health-enhancing physical activity, controlling for population density. In subanalyses, Spearman correlations tested the association between MVPA densities and serious crime and minor crime densities Spearman correlation also tested the associations between crime densities and MVPA densities in non-optional built environments and optional built environments.

Results

Study Participants and Setting

The study city is located about eight kilometers northeast of Boston, Massachusetts and has three subway stations which are part of the Boston public transportation system. During the study period, the city had a population of approximately 52,000 people and was 62.4% non-Hispanic white, 4.3% non-Hispanic black, 5.6% Asian and 24.4 % Hispanic or Latino. The city is home to a significant immigrant population, with 30.5% of residents born outside the United States and 42.8% speaking a language other than English at home. The median household income was $51,863 with 15.4% of residents living below the poverty level (United States Census Bureau). The health care center from which participants were recruited was located approximately 1.5 kilometers from the city center and the community recreation center was located approximately 1 kilometer from the city center.

Participants in the study were 44% male, 40% white, 23% black, and 36% Hispanic or Latino. Mean age was 12.6 years. Eighty percent of adolescents lived with at least one parent who completed high school or greater (Oreskovic, et al, 2015).

On average, subjects provided 12.1 days of combined GPS-accelerometer data. Adolescents spent approximately 277 minutes per day at home, 296 minutes at school, 45 minutes on streets and sidewalks, 25 minutes at playgrounds, 17 minutes at parks, and 99 minutes in all other locations (Oreskovic, et al, 2015). Overall, subjects had a mean daily MVPA of 21.7 minutes (SD 15.8), with a median daily MVPA of 17.4 minutes (IQR: 12.6–27.5 minutes). Similar amounts of daily MVPA took place in indoor and outdoor built environments, although adolescents spent more overall time indoors. Adolescents achieved more MVPA at school than at home (median daily mean MVPA= 8 minutes vs. 4 minutes, $p < 0.001$). Additionally, adolescents spent more time in MVPA on streets and sidewalks than in playgrounds or parks (median daily mean MVPA = 5 minutes [streets/sidewalks] vs. 3 minutes [playgrounds] vs. 2 minutes [parks], $p=0.02$) (Oreskovic, et al, 2015).

Within the study city, census block groups in the highest quartile for adolescent MVPA density had a mean median household income of $49,385 with 22.4% of households living below the poverty level. Census block groups in the lowest quartile for adolescent MVPA density had a mean median household income of $66,009 with 6.3% of households living below the poverty level (American Fact Finder, United States Census Bureau).

Our final crime dataset contained 1,694 reported crimes, the majority of which were destructions/vandalisms, burglaries, or aggravated assaults. A total of 934 of reported crimes were categorized as serious crimes and 762 categorized as minor crimes.

Eighty seven percent of subjects' overall MVPA data points fell within city boundaries and were therefore included in analyses, totaling 16,702 minutes of geocoded MVPA. Overall, a strong positive correlation was present between crime and adolescent MVPA (ρ=0.72, p<0.0001) using a 50m cell and 400m bandwidth. Kernel density analysis revealed spatial overlap between crime and MVPA "hot spots" (regions of relatively high density) and "cold spots" (regions of relatively low density) (Figure).

The association was also strongly positive using 800m and 1600m bandwidths, as well as 100m grid cells (Table). Crime remained positively associated with MVPA in locations falling within the lowest (ρ =0.43, p<0.0001) and highest (ρ=0.32, p<0.0001) quartiles of crime density. After controlling for population density, crime remained a positive predictor of adolescent health-enhancing physical activity (beta=0.8, SE=0.2, p=0.001).

Crime Severity

After separating crimes by severity (serious vs. minor), we found a significant positive correlation between serious crimes and adolescent MVPA (ρ=0.73, p<0.0001). Similarly, we found a significant positive association between minor crimes and adolescent MVPA (ρ=0.66 p<0.0001).

Built Environment

Of the 16,702 minutes of MVPA, 6,682 minutes fell within home or school built environments ("non-optional built environments") and 10,020 minutes fell within parks, playgrounds, streets/sidewalks, or other built environments ("optional built environments"). We found a significant positive correlation between crime and adolescent MVPA occurring in non-optional built environments (ρ=0.62, p<0.0001) as well as crime and adolescent MVPA occurring in optional built environments (ρ=0.72 p<0.0001).

Discussion

This study found a strong positive correlation between crime incidence and adolescent MVPA, indicating that crime was more prevalent in locations where adolescents engaged in greater amounts of health-enhancing physical activity. This positive correlation remained significant regardless of crime severity or built environment functionality. Prior studies assessing the relationship between neighborhood crime or safety and physical activity have produced inconsistent findings, likely the result of variability in research methodology and measurements (Foster and Giles-Corti, 2008). Like Foster (2014) and colleagues, we found that crime was positively associated with physical activity. Though counterintuitive, these results may be explained by the logic of a common destination. That is, accessible and usable spaces that encourage physical activity may also attract crime. It is possible that a higher crime rate may be a byproduct of a more health-promoting neighborhood environment (Foster, et al, 2014).

Similar to past studies, we weighted all crimes equally in our primary analysis, as there is no existing gold-standard method for weighting crimes quantitatively by severity or perceived threat. However, given the possibility that the association between crime and MVPA may vary by crime type, we chose to additionally dichotomize crime types into serious and minor crimes. Despite some evidence that more severe crimes may be a stronger deterrent to neighborhood physical activity (Kerr, et al, 2015), we found a similar positive association for both serious crimes and minor crimes.

We classified physical activity as occurring in either optional built environments – those that an adolescent may actively choose to spend time in, or non-optional built environments – those that an adolescent has limited control over. We found significant positive associations between crime and MVPA in both optional and non-optional built environments, with the association being somewhat stronger in optional built environments.

Although this study found a positive relationship between crime and physical activity, these findings are not meant to suggest that crime and safety have no bearing on where youth spend time or where parents allow their children to play. Rather, this positive correlation supports the conclusion that crime does not deter or prevent physical activity entirely. It is possible that communities may overcome or negate the unfavorable effects of crime on active living, perhaps through a supportive built and social environment. In neighborhoods or spaces where crime may normally deter youth from engaging in physical activity, the presence of health-promoting infrastructures, such as accessible parks or functional sidewalks, may instead encourage health-enhancing behaviors. However, given the correlational relationship found in this study, we are cautious to speculate on the directionality of this relationship.

The strengths of this study include the use of objective, location-specific measures of physical activity and crime. Unlike past studies which have relied on self-report data or neighborhood estimations, the data collection and analysis methods in this study allow for a more objective and granular representation of both crime and MVPA occurrence with greater specificity. Furthermore, the use of kernel density estimation allows for a more flexible and realistic density measure.

This study has several limitations. We included crime and physical activity data from a single city in Massachusetts, limiting the generalizability of our findings. Crime data were collected from the local city police department and may not capture crimes that were not reported. This study did not look at potential mechanisms for the relationship between crime and MVPA. Although we were able to adjust for population density, other social or personal attributes may mediate this association. Specifically, we did not assess perceptions of crime and safety, which may independently influence physical activity behaviors. Additionally, unlike Foster (2014) and colleagues this study did not assess neighborhood and built environment characteristics, such as parks and green space or neighborhood walkability. Future research should aim to understand whether individual-level and neighborhood-level characteristics mediate the relationship between crime and adolescent physical activity.

Conclusion

Adolescent physical activity and crime occur in similar locations. A better understanding of the relationship between crime and adolescent physical activity, as well as the factors underlying this relationship, can aid in the development of health-promoting neighborhoods.

Supplementary Material

Refer to Web version on PubMed Central for supplementary material.

Acknowledgments

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Abbreviations

MVPA	Moderate-to-vigorous physical activity
GPS	Global Positioning System
GIS	Geographic Information System

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Highlights

- Studies assessing the relationship between crime and activity show mixed results.
- Prior studies largely use self-reported physical activity and location estimations.
- This study uses objective measures for location and physical activity.
- We test the association between objectively measured crime and physical activity.
- A strong positive association exists between crime and adolescent physical activity.

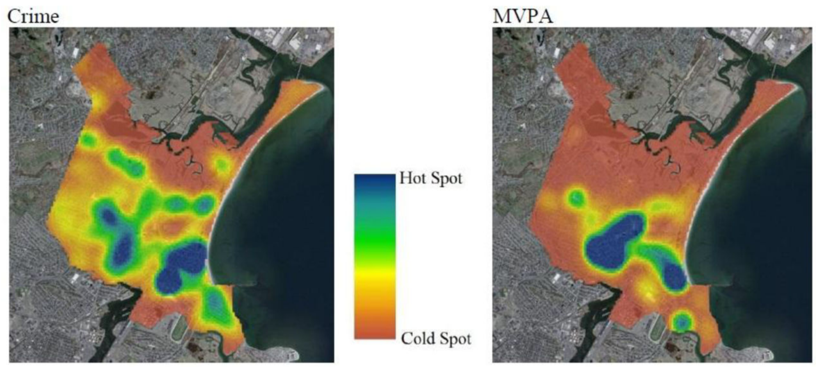

Figure.
Maps of crime and MVPA hot spots and cold spots; Massachusetts, 2011–2012.

Table

Association between crime and MVPA densities; Massachusetts, 2011–2012.

Density Parameters	ρ	***p*-value**
50m cells		
400m	0.72	<0.0001
800m	0.88	<0.0001
1600m	0.96	<0.0001
100m cells		
400m	0.74	<0.0001
800m	0.89	<0.0001
1600m	0.96	<0.0001