ann. behav. med. (2013) 45 (Suppl 1):S76–S85
DOI 10.1007/s12160-012-9416-z

ORIGINAL ARTICLE

Aesthetic Amenities and Safety Hazards Associated with Walking and Bicycling for Transportation in New York City

Gina S. Lovasi, PhD, MPH · Ofira Schwartz-Soicher, MBA · Kathryn M. Neckerman, PhD · Kevin Konty, MS · Bonnie Kerker, PhD · James Quinn, MA · Andrew Rundle, DrPH

Published online: 26 September 2012

Abstract

Background One strategy to address health problems related to insufficient physical activity is to examine modifiable neighborhood characteristics associated with active transportation.

Purpose The aim of this study is to evaluate whether neighborhoods with more aesthetic amenities (sidewalk cafés, street trees, and clean sidewalks) and fewer safety hazards (pedestrian-auto fatalities and homicides) are associated with active transportation.

Methods The 2003 Community Health Survey in New York City, which asked about active transportation (walking or bicycling >10 blocks) in the past 30 days, was linked to ZIP-code population census and built environment characteristics. Adjusted associations were estimated for dichotomous (any active transportation versus none) and continuous (trip frequency) active transportation outcomes.

Results Among 8,034 adults, those living near sidewalk cafés were 10 % more likely to report active transportation (p=0.01). Homicide rate was associated with less frequent active transportation among those reporting any active transportation (p=0.002).

Conclusions Investments in aesthetic amenities or homicide prevention may help to promote active transportation.

Keywords Geographic information systems · Neighborhood built environment · Aesthetic amenities · Safety hazards · Physical activity

G. S. Lovasi (✉) · J. Quinn · A. Rundle
Department of Epidemiology, Columbia University Mailman School of Public Health,
New York, NY, USA
e-mail: gl2225@columbia.edu

O. Schwartz-Soicher
Columbia University School of Social Work,
New York, NY, USA

K. M. Neckerman
Columbia University Institute for Social and Economic Research and Policy,
New York, NY, USA

K. Konty · B. Kerker
New York City Department of Health and Mental Hygiene,
New York, NY, USA

Introduction

Insufficient physical activity is a persistent public health problem, with less than 5 % of adults in the US population meeting public health recommendations in a national study with objectively monitored physical activity data [1]. Health benefits are well documented for even short periods of moderate physical activity, such as 10 min of brisk walking [2–5]. Current US recommendations for adults emphasize the benefits of accumulating at least 10 min at a time of moderate-intensity aerobic activities such as brisk walking or bicycle riding, for a total of 150 min or more throughout the week [6]. Walking is the most common and accessible adult physical activity [7]. Since the most common setting for walking is along neighborhood streets [7], the features of the neighborhood built environment may plausibly be associated with walking or active transportation more generally [8, 9].

Several recent reviews [9–12] and a meta-analysis [13] have assembled the evidence linking infrastructure for active transportation to physical activity or associated metabolic risk factors. Research in this area has included measures of urban form, which can be defined as the spatial imprint of a transportation system and surrounding physical infrastructures [14]. Indicators of walkable urban form such as residential density, land use mix, and connectivity have been among the most commonly studied features of the built environment in this literature [13, 15–18]. Yet neighborhoods with highly walkable urban form may have important aesthetic and safety problems, such as physical disorder or threatening traffic patterns, that make active transportation unattractive, uncomfortable, or even perilous [19–21]. Conversely, positive natural or community amenities, such as shade trees or sidewalk cafés, may provide pedestrian comfort and interest that encourages active transportation [22, 23]. Many of the same neighborhood built environment attributes that facilitate walking may encourage bicycling [24–27], though studies linking the built environment to bicycling are not as common as those on predictors of walking [13].

We used data from the Community Health Survey in New York City (NYC) to evaluate the associations of aesthetic and safety characteristics with active transportation by walking or bicycling, while adjusting for potential confounding by neighborhood walkability, neighborhood composition, and individual sociodemographic characteristics. We hypothesized that traffic and crime safety hazards would be associated with less active transportation, while aesthetic amenities (sidewalk cafés, street trees, and clean sidewalks) would be associated with more active transportation. In addition, we examined whether these associations were modified by participant gender or neighborhood poverty. The effect modification analyses were exploratory, but were informed by prior recommendations to evaluate such interactions [10, 28, 29] as well as work suggesting that neighborhood–health associations may be different by gender [30–33] or socioeconomic context [34–37].

Methods

Subjects and Setting

We used data from the 2003 NYC Community Health Survey (CHS), a random digit dial telephone survey conducted annually by the NYC Department of Health and Mental Hygiene [38, 39]. The CHS study design is based upon the national Behavioral Risk Factor Surveillance System, conducted by the Centers for Disease Control and Prevention. Each year, the CHS samples approximately 10,000 non-institutionalized adults aged 18 and older. In 2003, all respondents lived in a household with a landline telephone in NYC. The CHS sampling frame is based on United Hospital Fund (N=42) neighborhoods, which are administrative units comprised of two to eight contiguous ZIP codes and are used for health surveillance and medical resource planning. A computer-assisted telephone interviewing system was used to collect survey data including information on physical activity, sociodemographic characteristics, and residential ZIP code. In 2003, 9,799 adults participated, with a cooperation rate (number of participants/ number of individuals who were contacted and identified as eligible) of 63.3 % and a response rate of 44.2 % [40].

Survey Questions to Assess Outcome (Walking and Bicycling Frequency) and Covariates

All respondents in 2003 were asked "Over the past 30 days, have you walked or bicycled more than 10 blocks as part of getting to and from work, or school, or to do errands?" Active transportation trips of this length may signal accumulation of at least 10 min of physical activity at a time, as recommended for health benefits [2, 41]. The contribution of cycling to the active transportation measure is expected to be low: for example, only 0.6 % of all New York workers commute to work by bicycle, as compared with 10.4 % commuting on foot [42]. Data on individual age, sex, race, ethnicity, nativity, marital status, household composition, health status, education, and household income were also reported.

Assessment of Neighborhood Socioeconomic and Built Environment Characteristics

The residential ZIP code reported during the interview (n=188) was used to characterize the local environment through linkage to Geographic Information Systems (GIS) data from national and local sources. ZIP codes with low residential populations, and thus few CHS respondents, were merged with larger neighboring ZIP codes to preserve the anonymity of the data. In instances where there were several neighboring ZIP codes to which a small ZIP code could have been merged, the ZIP code with the most similar sociodemographic characteristics was chosen as the merge partner. The modified set of ZIP codes (n=164) were then intersected with geographic data on residential composition and the built environment from using a spatial overlay [43]. For all geographic data, we sought the closest available temporal match to the 2003 data collection, and all geographic data were from within the period of 2000 to 2007.

Safety hazard indicators included pedestrian-auto fatality rate and homicide rate. Pedestrian-auto fatality locations in 2003 were based on the intersection closest to the collision site, as provided by the local non-profit organization Transportation Alternatives. The pedestrian-auto fatality rate was used as the primary indicator of traffic hazards to limit the potential bias from selective under-reporting of less serious injuries. As previously described, homicide locations for the year 2003 were obtained from the NY Times website (http://projects.nytimes.com/crime/homicides/map/) [19]. Homicide rate was selected as the primary indicator of crime safety because of its spatial precision (in contrast to less severe violent crime rates available at the precinct level), and because of expectations that homicide rate would be both salient in shaping safety perceptions and correlated with less severe criminal infractions. Denominators for these rates were based on population count using US Census data for the year 2000, summary file 3 [44], for the corresponding ZIP code tabulation area (ZCTA), or for the merged set of ZCTAs most closely corresponding to the modified postal ZIP codes described above.

Aesthetic characteristics were selected from those found previously in NYC to distinguish walkable areas with at least 20 % poverty from similarly walkable but lower-poverty areas [21] and to be associated with adult body mass index [34]: sidewalk cafés, street trees, and acceptably clean streets. Locations of legally operating sidewalk cafés were obtained from the NYC Department of Consumer Affairs in 2006 and used to create an indicator of whether each modified ZIP code had one or more sidewalk cafés. The density of street trees per square kilometer was estimated based on data from a 2005 to 2006 street tree census by the NYC Department of Parks & Recreation. The proportion of streets rated as acceptably clean was estimated within 234 NYC Sanitation Sections during the period from 2002 to 2006, available from Project Scorecard [45] which was conducted by the Mayor's Office of Operations; the threshold used to define "acceptable" cleanliness was informed by the Department of Sanitation's standards and public surveys.

Neighborhood socioeconomic context and walkable urban form indicators previously linked to adult body mass index in NYC [46, 47] were included as potential confounders. Neighborhood poverty (percentage living below the federal poverty line) and residential density (residents per square kilometer) variables were constructed using US Census data for the year 2000, summary file 3 at the ZCTA level. Land use mix was constructed using building area designated for residential and commercial uses in the 2004–2005 Primary Land Use Tax Lot Output data, a parcel-level dataset available from the Department of City Planning. The numbers of bus and subway stops per square kilometer were from the 2004 and 2007 New York City Metropolitan Transit Authority data, respectively (more recent data were used for subway stops because of improved spatial alignment and because subway-stop locations are relatively stable over time).

ArcGIS, version 9.3, was used for all geospatial analysis (ESRI, Redlands, CA, USA).

Statistical Analysis

Participants who responded to the question on walking or bicycling for transportation by saying that they were unable to do these activities (N=102) were excluded. Follow-up questions asked the frequency per day, per week, or per month. Participants with missing data on walking or bicycling frequency (N=275), income (N=1,219), or other model covariates (N=169) (i.e., age, education, employment status, self-reported health status, marital status, number of children, and US nativity) were also excluded from our analytic dataset, resulting in an analytic sample of 8,034 individuals. Simple descriptive statistics were generated for all individual and neighborhood characteristics that were considered to be exposures of interest (safety or aesthetic characteristics) or potential confounders. Excluded participants were more likely to be female, to be younger than 24 or older than 65, and to have lower educational attainment, lower household income, and lower self-reported health.

The continuous data on engagement in active transport was initially dichotomized to reflect reporting any active transport of more than 10 blocks in the past 30 days versus none. Multi-level regression models for individuals clustered within ZIP codes were created using a log link and Poisson variance structure to estimate prevalence ratios associated with variation in the aesthetic and safety characteristics. Negative binomial models were also examined to investigate associations with frequency of active transportation (number of active transportation trips during the past 30 days) among those who reported any active transportation trips.

For our regression analyses, each of the continuous predictors of interest was rescaled to have an interquartile range of 1 in order to facilitate comparisons. Thus, exponentiated coefficients presented in the tables indicate the relative increase in probability or frequency of active transportation for exposure at the 75th percentile compared with the 25th percentile.

Regression models were estimated using HLM version 6.08 (Scientific Software International, Lincolnwood, IL, USA) or Stata 11.0 (Stata Corp., College Station, TX, USA). Potential confounders at the individual or neighborhood levels were selected for inclusion based on previous experience and the published literature [9, 28, 46], and remained in the models regardless of statistical significance. Level 1 variables included individual sex, age, race, ethnicity, education, income, employment status, birth within the USA, marital status, children in the household, and health status. Level 2 variables included neighborhood percent poverty and indicators of walkable urban form (population density, land use mix, and bus and subway stop density). Models were run for the entire population and stratified by gender or neighborhood poverty (based on a median split). To assess the statistical significance of effect modification for each stratifying variable and each exposure of interest, a single interaction term was added to the model for the entire population. ZIP-code-level sample weights for the combined 2002–2006 data were estimated by NYC Department of Health and Mental Hygiene using constrained raking to race/ethnicity and age and sex totals from the 2000 Census, and these weights were modified for the year 2003. Robust standard errors were used to account for clustering within ZIP code.

Results

Adults were more likely to report active transportation if they were young, male, non-Hispanic white, born within the USA, unmarried, in very good or excellent health, college-educated, employed, or in high-income households (all $p<0.05$ based on t test or chi-squared test, Table 1). Descriptive statistics also suggest that participants reporting active transportation were more likely to live in dense, mixed use, and transit accessible neighborhoods with more aesthetic amenities and lower homicide rates (Table 1).

In multivariable adjusted models, sidewalk cafés were significantly associated with the probability of any walking or bicycling for more than 10 blocks (Table 2). The probability of reporting active transportation was 10 % higher in neighborhoods with any sidewalk cafés present (prevalence ratio, 1.10; 95 % confidence interval, 1.02 to 1.17), compared to those without sidewalk cafés, after adjustment for individual and neighborhood characteristics including safety hazards and other aesthetic amenities. Safety characteristics were not significantly associated with whether or not a participant reported any active transportation (all $p>0.05$, Table 2). Of the walkable urban form indicators considered as potential confounders, all associations were in the hypothesized direction but only population density remained a statistically significant predictor ($p=0.02$) in multivariable adjusted models of active transportation.

We examined the combined model results stratified by sex or neighborhood poverty (Table 2). The interaction for neighborhood poverty and street tree density was marginally significant ($p=0.059$); increased street tree density was more strongly associated with active transportation within low-poverty ZIP codes. We did not observe any significant associations for sidewalk cafés, street trees, or clean sidewalks with probability of active transportation within high-poverty neighborhoods (all $p>0.05$, Table 2).

Table 3 presents rate ratios for associations between aesthetic characteristics and safety characteristics and the frequency of active transportation trips. In the full sample, none of the aesthetic characteristics were significantly associated with the frequency of episodes of active transport; however, safety conditions as represented by pedestrian-auto fatality and homicide rates were associated with frequency of active transport trips. The association for pedestrian-auto fatality rate and frequency of active transportation was in the opposite of the hypothesized direction with a rate ratio of 1.10, which is interpretable as meaning that residents of neighborhoods at the 75th percentile of pedestrian-auto fatalities engaged in 10 % *more* active transportation trips than those living in neighborhoods at the 25th percentile. Homicide rate, on the other hand, was associated with fewer active transportation trips: residents living in neighborhoods at the 75th homicide rate percentile engaged in 20 % fewer active transportation trips compared with those at the 25th percentile. For example, if participants residing in neighborhoods at the 25th percentile of homicide rate engage in active transportation daily (30 trips per month on average), we would expect that otherwise similar participants residing in neighborhoods with the higher 75th percentile homicide rate would engage in only 24 active transportation trips per month (30 trips per month $\times$ 0.80). There were marginally significant interactions for sidewalk cafés with both gender and neighborhood poverty, suggesting an unanticipated trend for sidewalk cafés to be associated with *less* frequent active transportation among men or among residents of high poverty neighborhoods.

Discussion

In our examination of selected aesthetic and safety characteristics, sidewalk cafés were positively associated with reporting any active transportation as hypothesized. In addition, neighborhood homicide rate was associated with a lower frequency of active transportation as hypothesized. In contrast, pedestrian-auto fatality rate had an unanticipated positive association with more frequent active transportation, possibly because higher rates of active transportation place more pedestrians at risk. The observed associations were generally small in magnitude, but potentially important determinants of active transportation at a population level. When effect modification by sex or neighborhood poverty was considered, none of the interactions reached traditional levels of statistical significance but a few were marginally significant ($0.10>p\geq0.05$).

Our work adds to previous literature investigating safety and aesthetic characteristics that has largely relied on self-report for measurement of neighborhood context. While indicators of walkable urban form can be readily assessed for the current built environment using GIS data from national, state, or local sources [48], such sources have not been as consistently available for safety and aesthetic characteristics. Our study uses point-level homicide and pedestrian-auto fatality data to indicate safety hazards from crime and traffic, as well as locations of sidewalk cafés, street trees, and clean sidewalks. These data may not capture the full range of safety and aesthetic characteristics with relevance to active transportation. However, these GIS sources have the advantage of being assessed independently of physical activity; this avoids potential bias from correlated errors if the same person over-reports both their physical activity and the safety or aesthetic quality of their neighborhood environment. Neighborhood

Table 1 Participant and neighborhood characteristics in the 2003 Community Health Survey, New York City, NY

	All participants (*N*=8,034)	No walking or bicycling >10 blocks (*N*=3,516)	Any walking or bicycling >10 blocks (*N*=4,518)
Individual and household characteristics:			
Age			
18–24	8.6 %	7.5 %	9.5 %
25–44	45.5 %	43.6 %	47.0 %
45–64	31.2 %	31.9 %	30.6 %
65 or more	14.7 %	17.0 %	12.9 %
Female	55.9 %	59.1 %	53.5 %
Race/ethnicity			
White	40.7 %	33.8 %	45.9 %
African-American	24.9 %	28.6 %	22.1 %
Hispanic	24.9 %	27.6 %	22.8 %
Asian	7.0 %	7.7 %	6.6 %
Other	2.5 %	2.3 %	2.6 %
Born within the USA	64.8 %	60.9 %	67.8 %
Married	37.9 %	39.2 %	36.9 %
Number of children in household, mean (SD)	1.7 (1.1)	1.8 (1.1)	1.7 (1.1)
Excellent/very good health status reported	49.6 %	41.4 %	55.9 %
Education			
Less than high school	13.6 %	17.4 %	10.6 %
High school	25.7 %	27.7 %	24.1 %
Some college	23.3 %	24.3 %	22.6 %
College graduate	37.4 %	30.6 %	42.7 %
Employed	64.1 %	60.1 %	67.3 %
Household income relative to federal poverty line			
Below poverty	16.1 %	18.6 %	14.0 %
100–199 % of poverty	19.6 %	21.8 %	18.0 %
200–399 % of poverty	27.7 %	28.8 %	27.0 %
400–599 % of Poverty	15.0 %	13.7 %	15.9 %
600 % of Poverty	21.6 %	17.1 %	25.1 %
Neighborhood characteristics:			
Proportion below poverty line, mean (SD)[a]	0.21 (0.11)	0.22 (0.11)	0.21 (0.11)
Walkable urban form indicators, mean (SD)[a]			
Population density (10,000s of residents/km^2)	1.7 (1.1)	1.6 (1.0)	1.9 (1.2)
Land use mix	0.47 (0.24)	0.45 (0.22)	0.49 (0.25)
Bus stops/km^2	27.8 (12.1)	25.8 (11.1)	29.3 (12.7)
Subway stops/km^2	1.2 (1.4)	1.0 (1.2)	1.4 (1.6)
Aesthetic amenities, percent or mean (SD)[a]			
Sidewalk café present	44.8 %	35.9 %	51.8 %
Street tree density (trees/km^2)	917 (376)	878 (352)	947 (391)
Percent of sidewalks acceptably clean	90.2 (8.3)	89.8 (8.5)	90.6 (8.1)
Safety hazards, mean (SD)[a]			
Pedestrian-auto fatalities (count/10,000 residents)	0.19 (0.22)	0.18 (0.22)	0.19 (0.22)
Homicide rate (count/10,000 residents)	0.72 (0.68)	0.76 (0.70)	0.68 (0.66)

Values shown are percent or mean (SD); walking and bicycling >10 blocks is dichotomized based on responses to the following question: "Over the past 30 days, have you walked or bicycled more than 10 blocks as part of getting to and from work, or school, or to do errands?"

[a] Neighborhood characteristics were assessed for modified residential ZIP codes using a spatial overlay

Table 2 Stratified analyses of associations of safety and aesthetic characteristics with walking or bicycling for more than 10 blocks in the 2003 Community Health Survey, New York City, NY

	Relative risk (95 % confidence interval) for association with active transportation						
	All (N=8043)	Women (N=4497)	Men (N=3546)	Interaction p value	High-poverty neighborhood[a] (N=3,933)	Low-poverty neighborhood[a] (N=4,110)	Interaction p value
Aesthetic amenities							
Sidewalk cafés	**1.10 (1.02 to 1.17)**	**1.11 (1.02 to 1.20)**	1.08 (0.98 to 1.20)	0.927	1.02 (0.92 to 1.12)	**1.14 (1.03 to 1.26)**	0.151
Street trees	1.03 (0.97 to 1.08)	1.03 (0.96 to 1.10)	1.02 (0.95 to 1.10)	0.539	0.95 (0.85 to 1.06)	**1.10 (1.04 to 1.16)**	0.059
Clean sidewalks	1.03 (0.99 to 1.06)	1.04 (0.98 to 1.10)	1.02 (0.98 to 1.06)	0.751	1.02 (0.98 to 1.06)	0.99 (0.90 to 1.08)	0.341
Safety hazards							
Pedestrian-auto fatalities	0.97 (0.94 to 1.00)	0.97 (0.93 to 1.01)	0.97 (0.93 to 1.02)	0.968	0.99 (0.94 to 1.05)	**0.95 (0.92 to 0.99)**	0.263
Homicides	1.02 (0.96 to 1.09)	1.04 (0.95 to 1.13)	1.01 (0.91 to 1.11)	0.324	0.96 (0.87 to 1.05)	1.06 (0.98 to 1.16)	0.418

Values shown are relative risks and 95 % confidence intervals for the probability of reporting any active transportation associated with a 1 unit increase in exposure from multilevel relative risk regression models; continuous predictors have been rescaled to have an interquartile range of 1 to ensure that a 1 unit increase in exposure is meaningful within the range of the observed data; boldface is used to indicate statistical significance (p<0.05) based on a comparison with the null value of 1.0; all models adjusted for individual sex, age, race, ethnicity, education, income, employment status, birth within the USA, marital status, children in the household, and health status as well as neighborhood percent poverty and neighborhood indicators of walkable urban form (population density, land use mix, and bus and subway stop density)

[a] The high-poverty and low-poverty strata were defined based on a median split of neighborhood percent poverty.

Table 3 Associations of safety and aesthetic characteristics with frequency of walking or bicycling for more than 10 blocks among those reporting any active transportation in the 2003 Community Health Survey, New York City, NY

	Negative binomial estimate of association with log-transformed frequency of active transportation						
	All (N=4,518)	Women (N=2,415)	Men (N=2,103)	Interaction p value	High-poverty neighborhood[a] (N=2,175)	Low-poverty neighborhood[a] (N=2,343)	Interaction p value
Aesthetic amenities							
Sidewalk cafés	0.97 (0.83 to 1.15)	1.13 (0.90 to 1.41)	0.84 (0.68 to 1.04)	0.070	**0.76 (0.60 to 0.97)**	1.12 (0.90 to 1.40)	0.050
Street trees	1.07 (0.94 to 1.21)	1.11 (0.96 to 1.29)	1.03 (0.85 to 1.23)	0.365	0.93 (0.72 to 1.20)	1.10 (0.96 to 1.25)	0.206
Clean sidewalks	0.97 (0.91 to 1.04)	0.94 (0.85 to 1.04)	0.98 (0.91 to 1.06)	0.895	0.95 (0.86 to 1.05)	0.93 (0.77 to 1.12)	0.590
Safety hazards							
Pedestrian-auto fatalities	**1.10 (1.03 to 1.18)**	1.08 (1.00 to 1.18)	**1.12 (1.02 to 1.22)**	0.729	1.02 (0.91 to 1.13)	**1.15 (1.06 to 1.24)**	0.125
Homicides	**0.80 (0.69 to 0.92)**	0.86 (0.73 to 1.01)	**0.76 (0.62 to 0.93)**	0.319	**0.70 (0.56 to 0.87)**	0.87 (0.73 to 1.03)	0.575

Values shown are exponentiated coefficients and 95 % confidence intervals from negative binomial models, which can be interpreted as the relative increase in active transportation frequency for a 1 unit increase in exposure (e.g., a value of 1.10 would indicate that each 1 unit higher exposure was associated with a 10 % higher frequency); continuous predictors have been rescaled to have an interquartile range of 1 to ensure that a 1 unit increase in exposure is meaningful within the range of the observed data; boldface is used to indicate statistical significance (p<0.05) based on a comparison with the null value of 1.0; all models adjusted for individual sex, age, race, ethnicity, education, income, employment status, birth within the USA, marital status, children in the household, and health status as well as neighborhood percent poverty and neighborhood indicators of walkable urban form (population density, land use mix, and bus and subway stop density)

[a] The high-poverty and low-poverty strata were defined based on a median split of neighborhood percent poverty

characteristics related to aesthetics and safety have been previously measured using self-report [49], reports of other area residents [50], through in-person [51] or virtual [52] neighborhood audits, and occasionally GIS [34, 53]. Discordance among these methods is substantial [51, 54], systematically different across population subgroups [55, 56], and deserving of further direct investigation [57].

We examined the consistency of associations in high- and low-poverty areas to assess potential effect modification. Previous studies have found that walkable urban form indicators such as population density are less closely linked to physical activity and obesity within disadvantaged populations or high-poverty neighborhoods [35, 36, 58]. One explanation for this pattern is that other safety or aesthetic problems [59, 60] are more prevalent and salient in high-poverty settings [21]. We were not able to detect any significant associations in the hypothesized direction among high-poverty neighborhoods except for an association of homicide rate with lower active transport frequency; however, the interactions with neighborhood poverty were not statistically significant. This could reflect that we have not yet identified the most relevant aesthetic characteristics to facilitate active transportation within high-poverty neighborhoods. Alternatively, the physical activity patterns in high-poverty areas may be "over-determined" such that any single neighborhood characteristic is unlikely to predict behavior. On one hand, there may be residents who rely on active modes of transportation regardless of how convenient, safe, or pleasant walking and bicycling are in the neighborhood context. Or, there may be individuals whose sedentary lifestyle is reinforced by an array of accumulated health impairments, time commitments, social interactions, and habits. Even if neighborhood characteristics played a role earlier in the life course [10, 61, 62], there may be no detectable influence of the current neighborhood environment on physical activity in the presence of these other barriers. Finally, there is almost certainly a bidirectional association between neighborhood selection and health-relevant behaviors [63]. If preferences or some other common prior cause influences both residential location and active transportation patterns, the cross-sectional associations reported may be biased. However, our adjustment for demographic, socioeconomic, and family structure variables closely tied to residential selection was designed to attenuate such bias. Nonetheless, unmeasured confounding remains plausible and may be particularly strong among affluent individuals whose residential choices are less constrained.

This analysis examined both the likelihood and the frequency of active transportation, and found a different pattern of associations for these two outcomes (similar results were obtained when using a zero-inflated negative binomial model to examine both simultaneously). Sidewalk cafés, an indicator of neighborhood aesthetics, had the hypothesized positive association with the likelihood of active transportation, particularly in low-poverty neighborhoods. This echoes a previous finding that sidewalk cafés were associated with lower body mass index among adults living in low-poverty, but not high-poverty, neighborhoods [34]. The two safety measures were associated with frequency of active transportation, but pedestrian-auto fatality rate was surprisingly associated with more frequent active transportation. These findings highlight the need for further development of conceptual frameworks linking neighborhood attributes and travel behavior.

Strengths and Limitations

Key strengths of the CHS data used for this analysis include the large sample reflecting the demographic diversity of New York City residents. In addition, we analyzed geographic data on aesthetic amenities and safety hazard indicators while controlling for walkable urban form indicators. Our outcome assessment focused on walking and bicycling for transportation, which may be more sensitive to the influence of the local environment compared with recreational or total physical activity [9, 64]. Finally, we were able to exclude individuals who were unable to walk or bicycle for transportation, making the findings more directly relevant to the population for whom the built environment may plausibly encourage walking and bicycling and limits the likelihood of confounding by physical disability.

However, important limitations should be noted. First, this cross-sectional and observational study was conducted several years ago among NYC residents who were willing and able to participate in a landline telephone survey, and findings may not be generalizable to the full NYC population or to other settings. Although the built environment is continually changing in New York City and elsewhere, these data likely remain relevant to understanding the associations between the contemporary built environment and active transportation. Reliance on self-reported physical activity makes the observed associations vulnerable to measurement error and may also bias our findings if over-reporting is systematically higher in some neighborhoods. The questions administered to this study population did not support separate analyses of walking and bicycling behavior, and future work is needed to clarify whether these active transportation modes are equally supported by neighborhood aesthetic amenities and safety, or are better facilitated by mode-specific infrastructure investments such as bicycle lanes. We were not able to distinguish active transportation that was discretionary or by necessity, and discretionary active transportation may be more sensitive to the aesthetic and safety-related features of the local environment. Future research efforts might benefit from assessing the availability of alternatives to active transportation, such as access to a private vehicle and affordable parking. In addition, the neighborhood definition used in this study was based on modified postal ZIP codes, an administrative unit that does not correspond with the perceptions of residents or the areas they access throughout the day [28]. Yet previous work in adult residents of New York City [65] and other populations [66] supports the robustness of health associations to the range of common neighborhood definitions. Finally, although we made efforts to maximize the temporal agreement and validity of our geographic data sources, these data were drawn from a range of several years during which the environment characteristics changed and from a variety of secondary sources, resulting in potential misclassification. In particular, the relative severity of homicides and pedestrian-auto collisions considered in this study may not capture the full range of safety characteristics relevant to active transportation.

Conclusions

Active transportation promotes health and may also have local pedestrian safety [67] and environmental [68, 69] benefits. Yet municipal officials in a position to support pedestrians and bicyclists face funding limitations and competing priorities [70]. This analysis, along with future studies with attention to aesthetic and safety characteristics and to effect modification, can help inform efforts to make urban environments more supportive of physical activity. If the observed results are borne out by longitudinal and causally informative analyses, investments in neighborhood aesthetic amenities or homicide prevention may be warranted in order to promote active transportation. In addition to using study designs that allow causal inference, future research should consider interactions among neighborhood characteristics in order to inform tailored interventions to address health disparities resulting from multiple barriers to physical activity.

Acknowledgment This work was supported by grants from the National Institutes of Health (grant numbers 5R01DK079885, P60-MD0005, and K01HD067390).

Conflict of interest The authors have no conflict of interest to disclose.

References

1. Troiano RP, Berrigan D, Dodd KW, et al. Physical activity in the United States measured by accelerometer. *Med Sci Sports Exerc*. 2008; 40: 181-188.
2. Haskell WL, Lee IM, Pate RR, et al. Physical activity and public health. Updated recommendation for adults from the American College of Sports Medicine and the American Heart Association. *Med Sci Sports Exerc*. 2008; 39: 1423-1434.
3. Blair SN, Church TS. The fitness, obesity, and health equation: is physical activity the common denominator? *JAMA*. 2004; 292: 1232-1234.
4. Thompson PD, Buchner D, Pina IL, et al. Exercise and physical activity in the prevention and treatment of atherosclerotic cardiovascular disease: a statement from the Council on Clinical Cardiology (Subcommittee on Exercise, Rehabilitation, and Prevention) and the Council on Nutrition, Physical Activity, and Metabolism (Subcommittee on Physical Activity). *Circulation*. 2003; 107: 3109-3116.
5. Poirier P, Giles TD, Bray GA, et al. Obesity and cardiovascular disease: pathophysiology, evaluation, and effect of weight loss: an update of the 1997 American Heart Association Scientific Statement on Obesity and Heart Disease from the Obesity Committee of the Council on Nutrition, Physical Activity, and Metabolism. *Circulation*. 2006; 113: 898-918.
6. *2008 physical activity guidelines for Americans*: US Department of Health and Human Services, 2008.
7. Eyler AA, Brownson RC, Bacak SJ, Housemann RA. The epidemiology of walking for physical activity in the United States. *Med Sci Sports Exerc*. 2003; 35: 1529-1536.
8. Sallis JF, Cervero RB, Ascher W, et al. An ecological approach to creating active living communities. *Annu Rev Publ Health*. 2006; 27: 297-322.
9. Saelens BE, Handy SL. Built environment correlates of walking: a review. *Med Sci Sports Exerc*. 2008; 40: S550-S566.
10. Davison KK, Lawson CT. Do attributes in the physical environment influence children's physical activity? A review of the literature. *Int J Behav Nutr Phys Act*. 2006; 3: 19.
11. Durand CP, Andalib M, Dunton GF, Wolch J, Pentz MA. A systematic review of built environment factors related to physical activity and obesity risk: implications for smart growth urban planning. *Obes Rev*. 2011; 12: e173-e182.
12. Leal C, Chaix B. The influence of geographic life environments on cardiometabolic risk factors: a systematic review, a methodological assessment and a research agenda. *Obes Rev*. 2011; 12: 217-230.
13. Ewing R, Cervero R. Travel and the built environment. *J Am Plan Assoc*. 2010; 76: 265-294.
14. Rodrique J, Comtois C, Slack B. *The Geography of Transport Systems*. New York: Routledge; 2009.
15. Jacobs J. *The Death and Life of Great American Cities*. New York: Vintage; 1961.
16. Boarnet MGS. Sharon: can land-use policy really affect travel behaviour? A study of the link between non-work travel and land-use characteristics. *Urban Stud*. 1998; 35: 1155-1169.
17. Cervero R, Kockelman K. Travel demand and the 3Ds: density, diversity, and design. *Transpn Res-D*. 1997; 2: 199-219.
18. Sallis JF. Measuring physical activity environments: a brief history. *Am J Prev Med*. 2009; 36: S86-S92.
19. Weiss CC, Purciel M, Bader M, et al. Reconsidering access: park facilities and neighborhood disamenities in New York City. *J Urban Health*. 2011; 88: 297-310.
20. Cutts BB, Darby KJ, Boone CG, Brewis A. City structure, obesity, and environmental justice: an integrated analysis of physical and social barriers to walkable streets and park access. *Soc Sci Med*. 2009; 69: 1314-1322.
21. Neckerman KM, Lovasi GS, Davies S, et al. Disparities in urban neighborhood conditions: evidence from GIS measures and field observation in New York City. *J Publ Health Pol*. 2009; 30(Suppl 1): S264-S285.
22. Lovasi GS, Bader M, Quinn J, et al. Neighborhood safety, aesthetics and body mass index in New York City. *Obesity*. 2008; 16: S249.
23. Alfonzo MA. To walk or not to walk? The hierarchy of walking needs. *Environ Behav*. 2005; 37: 808.
24. Owen N, De De Bourdeaudhuij I, Sugiyama T, et al. Bicycle use for transport in an Australian and a Belgian city: associations with built-environment attributes. *J Urban Health*. 2010; 87: 189-198.

25. Huang L, Stinchcomb DG, Pickle LW, Dill J, Berrigan D. Identifying clusters of active transportation using spatial scan statistics. *Am J Prev Med*. 2009; 37: 157-166.
26. Berrigan D, Pickle LW, Dill J. Associations between street connectivity and active transportation. *Int J Health Geogr*. 2010; 9: 20.
27. Pucher J, Dill J, Handy S. Infrastructure, programs, and policies to increase bicycling: an international review. *Prev Med*. 2010; 50 (Suppl 1): S106-S125.
28. Lovasi GS, Grady S, Rundle A. Steps forward: review and recommendations for research on walkability, physical activity and cardiovascular health. *Publ Health Rev.* 2011; *33*. Epub ahead of print.
29. Trasande L, Cronk C, Durkin M, et al. Environment and obesity in the National Children's Study. *Environ Health Perspect*. 2009; 117: 159-166.
30. Dunn JR, Walker JD, Graham J, Weiss CB. Gender differences in the relationship between housing, socioeconomic status, and self-reported health status. *Rev Environ Health*. 2004; 19: 177-195.
31. Stafford M, Cummins S, Macintyre S, Ellaway A, Marmot M. Gender differences in the associations between health and neighbourhood environment. *Soc Sci Med*. 2005; 60: 1681-1692.
32. Borrell LN, Diez Roux AV, Rose K, Catellier D, Clark BL. Neighbourhood characteristics and mortality in the Atherosclerosis Risk in Communities Study. *Int J Epidemiol*. 2004; 33: 398-407.
33. Lisabeth LD, Diez Roux AV, Escobar JD, Smith MA, Morgenstern LB. Neighborhood environment and risk of ischemic stroke: the brain attack surveillance in Corpus Christi (BASIC) Project. *Am J Epidemiol*. 2007; 165: 279-287.
34. Lovasi GS, Bader M, Weiss C, Neckerman KM, Rundle A. Are neighborhood aesthetic amenities and safety hazards associated with body mass index in New York City? *Am J Prev Med.* 2012; Epub ahead of print.
35. Lovasi GS, Neckerman KM, Quinn JW, Weiss CC, Rundle A. Effect of individual or neighborhood disadvantage on the association between neighborhood walkability and body mass index. *Am J Public Health*. 2009; 99: 279-284.
36. Lovasi GS, Hutson MA, Guerra M, Neckerman KM. Built environments and obesity in disadvantaged populations. *Epidemiol Rev*. 2009; 31: 7-20.
37. Ford PB, Dzewaltowski DA. Disparities in obesity prevalence due to variation in the retail food environment: three testable hypotheses. *Nutr Rev*. 2008; 66: 216-228.
38. Black JL, Macinko J. The changing distribution and determinants of obesity in the neighborhoods of New York City, 2003–2007. *Am J Epidemiol*. 2010; 171: 765-775.
39. Black JL, Macinko J, Dixon LB, Fryer GE Jr. Neighborhoods and obesity in New York City. *Health Place*. 2010; 16: 489-499.
40. http://www.nyc.gov/html/doh/html/survey/chs-methods.shtml. Retrieved July 3, 2012.
41. Manson JE, Greenland P, LaCroix AZ, et al. Walking compared with vigorous exercise for the prevention of cardiovascular events in women. *N Engl J Med*. 2002; 347: 716-725.
42. NYDCP: NYC Bicycling Demand. New York, NY: http://www.nyc.gov/html/dcp/pdf/transportation/bike_share_part5.pdf, 2009.
43. Vine MF, Degnan D, Hanchette C. Geographic information systems: their use in environmental epidemiologic research. *Environ Health Perspect*. 1997; 105: 598-605.
44. http://www.census.gov/census2000/sumfile3.html. Retrieved July 3, 2012, from www.census.gov/Press-Release/www/2002/sumfile3.html.
45. http://www.usmayors.org/USCM/best_practices/litter/NewYork.html. Retrieved July 3, 2012.
46. Rundle A, Field S, Park Y, et al. Personal and neighborhood socioeconomic status and indices of neighborhood walk-ability predict body mass index in New York City. *Soc Sci Med*. 2008; 67: 1951-1958.
47. Rundle A, Roux AV, Freeman L, et al. The urban built environment and obesity in New York City: a multilevel analysis. *Am J Health Promot*. 2007; 21: 326-334.
48. Porter DE, Kirtland KA, Neet MJ, Williams JE, Ainsworth BE. Considerations for using a geographic information system to assess environmental supports for physical activity. *Prev Chronic Dis*. 2004; 1: A20.
49. Brownson RC, Chang JJ, Eyler AA, et al. Measuring the environment for friendliness toward physical activity: a comparison of the reliability of 3 questionnaires. *Am J Public Health*. 2004; 94: 473-483.
50. Mujahid MS, Diez Roux AV, Morenoff JD, Raghunathan T. Assessing the measurement properties of neighborhood scales: from psychometrics to ecometrics. *Am J Epidemiol*. 2007; 165: 858-867.
51. Boehmer TK, Hoehner CM, Deshpande AD, Brennan Ramirez LK, Brownson RC. Perceived and observed neighborhood indicators of obesity among urban adults. *Int J Obes (Lond)*. 2007; 31: 968-977.
52. Rundle AG, Bader MD, Richards CA, Neckerman KM, Teitler JO. Using Google Street View to audit neighborhood environments. *Am J Prev Med*. 2011; 40: 94-100.
53. Carver A, Timperio A, Hesketh K, Crawford D. Are safety-related features of the road environment associated with smaller declines in physical activity among youth? *J Urban Health*. 2010; 87: 29-43.
54. Kirtland KA, Porter DE, Addy CL, et al. Environmental measures of physical activity supports: perception versus reality. *Am J Prev Med*. 2003; 24: 323-331.
55. Gebel K, Bauman A, Owen N. Correlates of non-concordance between perceived and objective measures of walkability. *Ann Behav Med*. 2009; 37: 228-238.
56. Adams MA, Ryan S, Kerr J, et al. Validation of the Neighborhood Environment Walkability Scale (NEWS) items using geographic information systems. *J Phys Act Health*. 2009; 6(Suppl 1): S113-S123.
57. Blacksher E, Lovasi GS. Place-focused physical activity research, human agency, and social justice in public health: taking agency seriously in studies of the built environment. *Health Place*. 2012; 18: 172-179.
58. Casagrande SS, Gittelsohn J, Zonderman AB, Evans MK, Gary-Webb TL. Association of walkability with obesity in Baltimore City, Maryland. *Am J Public Health*. 2011; 101(Suppl 1): S318-S324.
59. Roman CG, Chalfin A. Fear of walking outdoors. A multilevel ecologic analysis of crime and disorder. *Am J Prev Med*. 2008; 34: 306-312.
60. Sampson R, Raudenbush S. Seeing disorder: neighborhood stigma and the social construction of "broken windows". *Soc Psychol Q*. 2004; 67: 319.
61. Lovasi GS, Jacobson JS, Quinn JW, et al. Is the environment near home and school associated with physical activity and adiposity of urban preschool children? *J Urban Health*. 2011; 88: 1143-1157.
62. Spruijt-Metz D. Etiology, treatment and prevention of obesity in childhood and adolescence: a decade in review. *J Res Adolesc*. 2011; 21: 129-152.
63. Plantinga AJ, Bernell S. The association between urban sprawl and obesity: is it a two-way street? *J Reg Sci*. 2007; 47: 857-879.
64. Lee C, Moudon AV. Correlates of walking for transportation or recreation purposes. *J Phys Act Heal*. 2006; 3: S77-S98.
65. Lovasi GS, Quinn JW, Neckerman KM, et al. Walkability and obesity in New York City: an examination of differences by scale and subpopulation. *Walk21 Conference*. New York, NY, 2009

66. Lovasi GS, Moudon AV, Smith NL, et al. Evaluating options for measurement of neighborhood socioeconomic context: evidence from a myocardial infarction case–control study. *Health Place*. 2008; 14: 453-467.
67. Jacobsen PL. Safety in numbers: more walkers and bicyclists, safer walking and bicycling. *Inj Prev*. 2003; 9: 205-209.
68. Frank LD, Greenwald MJ, Winkelman S, Chapman J, Kavage S. Carbonless footprints: promoting health and climate stabilization through active transportation. *Prev Med*. 2010; 50(Suppl 1): S99-S105.
69. Frank L, Sallis JF, Conway JM, et al. Many pathways from land use to health: associations between neighborhood walkability and active transportation, body mass index, and air quality. *JAPA*. 2006; 72: 75-87.
70. Evenson KR, Aytur SA, Satinsky SB, Rodriguez DA. Barriers to municipal planning for pedestrians and bicyclists in North Carolina. *N C Med J*. 2011; 72: 89-97.