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Neighborhood Walkability and Active Travel (Walking and Cycling) in New York City

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ABSTRACT *Urban planners have suggested that built environment characteristics can support active travel (walking and cycling) and reduce sedentary behavior. This study assessed whether engagement in active travel is associated with neighborhood walkability measured for zip codes in New York City. Data were analyzed on engagement in active travel and the frequency of walking or biking ten blocks or more in the past month, from 8,064 respondents to the New York City 2003 Community Health Survey (CHS). A neighborhood walkability scale that measures: residential, intersection, and subway stop density; land use mix; and the ratio of retail building floor area to retail land area was calculated for each zip code. Data were analyzed using zero-inflated negative binomial regression incorporating survey sample weights and adjusting for respondents' sociodemographic characteristics. Overall, 44 % of respondents reported no episodes of active travel and among those who reported any episode, the mean number was 43.2 episodes per month. Comparing the 75th to the 25th percentile of zip code walkability, the odds ratio for reporting zero episodes of active travel was 0.71 (95 % CI 0.61, 0.83) and the exponentiated beta coefficient for the count of episodes of active travel was 1.13 (95 % CI 1.06, 1.21). Associations between lower walkability and reporting zero episodes of active travel were significantly stronger for non-Hispanic Whites as compared to non-Hispanic Blacks and to Hispanics and for those living in higher income zip codes. The results suggest that neighborhood walkability is associated with higher engagement in active travel.*

KEYWORDS *Active travel, Neighborhood walkability, Urban health, Walking*

Abbreviations: CHS – Community Health Survey; DOHMH – Department of Health and Mental Hygiene; NYC – New York City

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INTRODUCTION

Active travel, defined here as walking or cycling, holds promise for increasing physical activity and has consistently been found to be associated with lower obesity.[1,2] Walking as little as 2 h a week has been shown to be associated with positive health outcomes.[3] Cycling, another form of active travel, can be an efficient means of commuting and commuting by bicycle is associated with a lower likelihood of overweight and obesity.[4,5] In recent years, urban planners and public health researchers have suggested that urban design and modifications to the built environment can be used to promote active travel modes and address the rise in sedentary lifestyles.[6]

Research on built environments and active travel is for the most part consistent in demonstrating that active travel correlates with "the D's"—density, diversity, design, destination accessibility, and distance to transit.[7–11] Density refers to attributes of interest per geographic area, diversity refers to the mix of land uses, design pertains to the layout of the street grid, destination accessibility is the availability of destinations to travel to such as stores, and distance to transit is the physical distance to public transportation. The literature on built environment and urban design effects on biking is far less developed than that on pedestrian activity.[12] However, it suggests that bike lanes and infrastructure protecting cyclists from automobiles promotes biking[12,13] and two studies have suggested that the urban design factors of density, diversity, and street design predict biking behavior.[14,15] Several studies have noted that the relationship between the built environment and active travel vary across strata of race and socioeconomic status.[16] Both Frank et al.[17] and Reed et al.[18] found that variation in built environment conditions is related to walking and physical activity for Caucasians only. In New York City (NYC), higher neighborhood walkability is associated with lower body mass index among Caucasians and among those with higher socioeconomic status.[19] This finding suggests that for disadvantaged populations, active travel may not be strongly related to built environment factors.

In sum, the literature on active travel and the built environment is coalescing around a consensus that the built environment matters. Less clear, however, is the extent to which this relationship holds across all segments of the population, including whether associations between built environment characteristics and active travel previously observed in lower density urban areas hold for those living in very dense urban spaces at the high end of neighborhood walkability and in particular, for disadvantaged populations living in such urban settings. This report examines associations between neighborhood walkability and engagement in active travel and tests whether associations vary across subsets of the population.

MATERIALS AND METHODS

Data

Data for this study comes from the NYC Community Health Survey (CHS), a random-digit dial telephone survey conducted annually by NYC's Department of Health and Mental Hygiene (DOHMH).[20–22] The CHS is designed to be representative of non-institutionalized adults aged 18 and older who live in a household with a landline telephone in NYC and is modeled after the National Behavioral Risk Factor Surveillance System as a surveillance tool for health behaviors and conditions. The CHS sampling frame is based on United Hospital Fund (N=34) neighborhoods, administrative units used for health surveillance and medical resource planning and comprised of two to eight contiguous zip codes. Using the respondent's self-reported residential zip code, the 2002 to 2006 CHS data were linked to geospatial data on zip code level sociodemographic and built environment characteristics. Several 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, for a final sample of 164 zip codes. In instances where there were several neighboring zip codes to which a small zip code might be merged, zip codes with the most similar sociodemographic characteristics were chosen as the merge partner. Zip code level sample weights for the combined 2002–2006 data were estimated by DOHMH using constrained raking to race/ethnicity and age and sex totals from the 2000 Census.

In 2003, CHS respondents (N=9,802) were asked how frequently they walked or cycled a distance of ten blocks or more. In NYC, this distance is typically about half a mile, and a focus on active travel of this length or more is consistent with public health recommendations that physical activity be accumulated in bouts of 10 min or more of activity. The reported data were converted to the number of episodes of walking or biking ten blocks or more per month, a measure we conceptualize as reflecting episodes of sustained active travel. Zip code level sample weights were estimated for the 2003, by adjusting the 2002–2006 sample weights by the age, gender, race-adjusted inverse probability of the subject being included in the 2003 wave of data collection.

For each zip code, a measure of neighborhood walkability was calculated using a previously developed scale[23] which is an extension of a measure developed by Frank et al.[24] The walkability scale includes five components, each receiving equal weight: (1) residential density; (2) intersection density; (3) land use mix for five types of land use—residential, office, retail, education, and entertainment; (4) subway stop density; and (5) the ratio of retail building floor area to retail land area. Data on residential density were derived from the 2000 Census, data on land use were derived from the Primary Land Use Tax Lot Output data, produced by the NYC Department of City Planning[25] and data on the location of subway stops were derived from the NYC Metropolitan Transit Authority. Each scale component was calculated for each zip code, Z score transformed and the components were summed for each zip code. Several of the built environment characteristics used in the walkability scale have also been shown to be predictors of cycling.[14,15] In addition, it is not uncommon for residents of NYC to use multi-mode, bike-to-transit, commutes. Thus, while much of the research focus on these built environment characteristics has been predicated on pedestrian activity, it is hypothesized that these neighborhood level measures will be associated with both pedestrian and cycling activity.

Analytical Strategy

Cross-sectional associations between the zip code walkability and the number of episodes of sustained active travel were assessed, adjusting for individual-level sociodemographic characteristics, self-rated health and engagement in recreational physical activity. Since many respondents (44 %) reported zero episodes, zero-inflated negative binomial regression analyses were used to analyze the data. This approach simultaneously models: (1) the probability of the respondent reporting zero episodes; and (2) the count of episodes among those who report more than zero episodes. Among those reporting any episodes, the range was very wide and based on an inspection of the distribution, the decision was made to truncate the upper end of the data at 600 episodes per month (109 respondents reported more than 600 episodes). Although this threshold is somewhat arbitrary, it seems implausible that many people would walk or bike ten blocks more than 600 times a month. As a sensitivity check, data were reanalyzed for subjects who reported between 0 and 120 episodes per month. Among those who reported any episodes, the mean number of episodes of sustained active travel was 43.2 episodes per month. The analyses used robust standard error calculations to account for the non-independence of individuals living within the same zip code and used the survey sampling weights. Analyses were repeated using Tobit analyses to assess variability in the results across analytical strategies. Analyses were performed in Stata version 11.

Individual-level covariates in our models included variables based on self-reports for demographic characteristics, socioeconomic status, and health characteristics. Race/ethnicity was measured as non-Hispanic White, non-Hispanic Black, Hispanic, Asian, and other. Age was categorized as 18–24, 25–44, 45–64, and 65 years and above. Educational attainment was categorized into four categories: college degree, some college, high school graduate, and less than high school education. Respondent's income in relation to the poverty level was characterized as below the poverty threshold, 100–199 % of the poverty line, 200–399 % of the poverty line, 400–599 % of the poverty line, and above 600 % of the poverty line. Dichotomous variables were used to indicate gender, foreign versus US birth, married versus non-married status, any engagement in exercise in the past 30 days, excellent or very good self-rated health versus less than very good health, and employed versus unemployed status. The models also included the zip code level poverty rate based on 2000 Census data.

Analyses were also conducted to assess interactions between zip code level walkability and individual-level sociodemographic characteristics and zip code level poverty rate. A series of five separate zero-inflated negative binomial models were fit with interaction terms for neighborhood walkability and the sociodemographic characteristic of interest, which include: model 1, education (stratified as ≤high school education versus more than high school); model 2, income in relation to the poverty line (stratified as below 200 % of income to poverty line versus above 200 % of income to poverty line); model 3, race (non-Hispanic White versus non-Hispanic Black); model 4, ethnicity (non-Hispanic White versus Hispanic); and model 5, neighborhood poverty (stratified as living in a zip code in the top quartile of the distribution of zip code percent poverty versus living in a zip code in the bottom quartile). For each of the five analyses, results are presented for the association between zip code walkability and episodes of sustained active travel in each of the listed sociodemographic strata, along with the p value for the interaction term from the respective model.

RESULTS

Residential zip code data and full covariate data were available from 8,064 subjects of whom 43.7 % reported no episodes of sustained active travel. Across the 164 zip codes included in this analysis, the median walkability index score was −0.25 and with a range of −7.87 to 11.74 and an inter-quartile range of −1.92 to 1.25. Table 1 provides descriptive statistics for the individual-level sociodemographic and zip code level variables included in the analyses and reports results from the zero-inflated

TABLE 1 Associations between sociodemographic variables, zip code level walk ability and episodes of sustained active travel

	Sample characteristics $N=8{,}064$	Odds ratio[a] for reporting no episodes of active travel (95 % CI)	Exponentiated beta[b] for number of episodes of active travel (95 % CI)
Gender			
Male	44 %	Ref	Ref
Female	56 %	1.03 (0.89–1.20)	0.97 (0.84–1.12)
Race/ethnicity			
White	41 %	Ref	Ref
African–American	25 %	1.72*** (1.38–2.15)	1.00 (0.85–1.16)
Hispanic	25 %	1.29* (1.05–1.59)	0.82* (0.70–0.98)
Asian	7 %	1.67** (1.23–2.25)	0.84 (0.67–1.05)
Other	2 %	1.00 (0.56–1.76)	0.96 (0.67–1.36)
Age			
18–24	9 %	Ref	Ref
25–44	45 %	1.26 (0.94–1.68)	0.98 (0.78–1.23)
45–64	31 %	1.26 (0.94–1.71)	0.93 (0.74–1.17)
65 or more	15 %	1.60** (1.12–2.27)	1.07 (0.81–1.42)
Education			
Less than HS	14 %	Ref	Ref
High school	26 %	0.90 (0.71–1.15)	1.22 (0.98–1.52)
Some college	23 %	0.91 (0.71–1.15)	1.33* (1.03–1.72)
College graduate	37 %	0.71* (0.54–0.92)	0.93 (0.72–1.18)
Poverty			
Below poverty	15 %	Ref	Ref
100–199 % of poverty	20 %	0.94 (0.71–1.23)	0.93 (0.74–1.17)
200–399 % of poverty	28 %	1.01 (0.77–1.32)	1.01 (0.82–1.23)
400–599 % of poverty	15 %	1.10 (0.80–1.51)	1.00 (0.78–1.29)
600 % of poverty	22 %	1.00 (0.72–1.37)	1.05 (0.83–1.32)
Self-reported health status			
Less than very good health	50 %	Ref	Ref
Excellent/very good health	50 %	0.74*** (0.64–0.85)	0.94 (0.83–1.08)
Physical activity			
None in past month	34 %	Ref	Ref
Any in past month	66 %	0.23*** (0.20–0.27)	1.12 (0.98–1.28)
Marital status			
Not married	62 %	Ref	Ref
Married	38 %	1.12 (0.95–1.32)	1.06 (0.93–1.22)
Nativity status			
US Born	65 %	Ref	Ref
Foreign born	35 %	1.06 (0.91–1.25)	0.96 (0.82–1.12)
Employment status			
Unemployed	36 %	Ref	Ref
Employed	64 %	0.89 (0.74–1.07)	1.16 (0.99–1.37)
Percent of poverty in zip code	21.3 %	1.00 (0.40–2.54)	0.99 (0.55–1.77)
Walkability index score (per unit change)	Mean=0.05	0.90*** (0.87–0.94)	1.04*** (1.02–1.06)

*** $p<0.001$, ** $p<0.01$, * $p<0.05$

[a]Odds ratio estimated from zero-inflated negative binomial regression model. All odds ratio in the table are mutually adjusted for all the variables in the table

[b]Exponentiated beta coefficients estimated from zero-inflated negative binomial regression model. All exponentiated beta coefficients in the table are mutually adjusted for all the variables in the table

negative binomial models. Results for the zip code level walkability variable show that for a unit increase in the walkability scale, the odds of reporting zero episodes of sustained activity significantly decrease by 10 %. Comparing the 75th percentile to the 25th percentile of zip code walkability the odds ratio for reporting zero episodes of active travel was 0.71 (95 % CI 0.61, 0.83). Among those who reported greater than zero episodes of active travel, increasing neighborhood walkability was significantly associated with a higher number of episodes of active travel. Comparing the 75th percentile of walkability to the 25th percentile, the exponentiated beta coefficient was 1.13 (95 % CI 1.06, 1.21) for the number of episodes of active travel. In addition, the analyses show that relative to their respective reference groups, non-Hispanic Blacks, Hispanics, Asians, and the elderly were more likely to report engaging in zero episodes of sustained active travel. When compared to their respective reference groups, those with college degrees, with very good health and those who participated in any physical activity were less likely to report engaging in zero episodes of sustained active travel. Compared to their respective reference groups, Hispanics reported lower, and those with some college education reported higher, counts of episodes of sustained active travel.

Table 2 shows results from the zero-inflated negative binomial models with odds ratios and exponentiated beta coefficients reported by strata of the sociodemographic variables of interest and the p values reported for the interaction term of the walkability scale and the stratification variable. Whereas the relationships between the reported counts of episodes of sustained active travel and neighborhood walkability do not significantly vary by strata of sociodemographic variable, the association between walkability and reporting zero episodes does. The inverse association between neighborhood walkability and reporting zero episodes of sustained active travel is significantly stronger among non-Hispanic White than non-Hispanic Black (model 3) or Hispanic (model 4) subjects. Additionally, the association between neighborhood walkability and reporting zero episodes of active travel is stronger in low- as opposed to high-poverty zip codes (model 5).

Analyses of associations between zip code level walkability and episodes of sustained active travel were replicated excluding subjects who reported more than 120 episodes and using Tobit models which assume that reports of zero episodes reflect a left-truncated data distribution. Both sets of analyses produced results that did not materially differ from those presented here.

DISCUSSION

Our results show that neighborhood walkability measured at the zip code level in NYC is associated with higher engagement in active travel. However, the inverse association between walkability and reporting no episodes of active travel appears to be more pronounced among non-Hispanic Whites as compared to non-Hispanic Blacks and to Hispanics and for those living in higher income zip codes. However, among those who engaged in active travel, the association between walkability and the number of episodes of active travel did not appear to vary across sociodemographic strata. The results for no engagement in active travel are consistent with past research suggesting that associations between built environments and active travel vary by strata of race and socioeconomic status.[16–18]

While NYC may be considered as one of the most walkable cities in the USA, zip code level variation in walkability within the city is associated with differences in the extent of active travel. Considering previous work showing similar effects of

TABLE 2 Associations between zip code walkability and active travel, by strata of individual and area-based characteristics

	Walkability index and reporting no episodes of active travel			Walkability index and the number of episodes of active travel		
	Odds ratio[a]	95 % CI	*p* value for interaction	Exponentiated beta[b]	95 % CI	*p* value for interaction
Model 1, analyses of zip code walkability and active travel stratified by educational attainment						
High school or less $N=3{,}168$	0.92	0.86, 0.98		1.00	0.96, 1.05	
More than high school $N=4{,}896$	0.88	0.83, 0.94	0.25	1.04	1.02, 1.07	0.14
Model 2, analyses of zip code walkability and active travel stratified by income in relation to the poverty line						
Below 200 % of poverty line $N=2{,}881$	0.91	0.86, 0.96		1.04	1.01, 1.08	
Above 200 % of poverty line $N=5{,}183$	0.89	0.84, 0.94	0.48	1.04	1.02, 1.06	0.99
Model 3, analyses of zip code walkability and active travel stratified by race						
African–American $N=2{,}008$	0.93	0.86, 1.00		1.08	1.02, 1.14	
Non-Hispanic White $N=3{,}279$	0.81	0.76, 0.88	0.01	1.03	1.01, 1.06	0.17
Model 4, analyses of zip code walkability and active travel stratified by ethnicity						
Hispanic $N=2{,}010$	0.97	0.89, 1.04		1.02	0.97, 1.07	
Non-Hispanic White $N=3{,}279$	0.82	0.76, 0.88	0.002	1.04	1.01, 1.06	0.47
Model 5, analyses of zip code walkability and active travel stratified by zip code level poverty rate						
Top quartile of neighborhood poverty $N=1{,}845$	1.09	0.97, 1.22		1.04	0.96, 1.14	
Bottom quartile of neighborhood poverty $N=1{,}955$	0.85	0.78, 0.93	0.001	1.05	1.03, 1.08	0.87

[a]Odds ratio for reporting no episodes of sustained active travel per 1 unit difference in the walkability index. Analyses adjust for covariates reported in Table 1

[b]Exponentiated Beta for number of episodes of sustained active travel per 1 unit difference in walkability index. Analyses adjust for covariates reported in Table 1

neighborhood walkability in areas considered less walkable than NYC, our results suggest that a dose response between neighborhood walkability and active travel spans the range of urban landscapes present in the USA. Our results also add specificity to our understanding of which groups' active travel behavior are most sensitive to differences in the built environment. For Hispanics and non-Hispanic Blacks and those living in poorer neighborhoods, active travel behavior appears to be less influenced by differences in the built environment. These findings suggest that interventions to improve the walkability of neighborhoods, at least around the urban design dimensions of walkability measured here, may be less effective among less advantaged groups. Prior work has suggested that disadvantaged neighborhoods that appear quite walkable based solely on urban design considerations can have social and aesthetic qualities that may inhibit pedestrian activity.[23] Interventions to improve walkability in poorer neighborhoods may need to focus on issues such as crime, safety, and aesthetic qualities as well as urban design characteristics.

Neighborhood walkability was measured using a modified version of the walkability scale developed by Frank et al.[24,26] The primary modification to the scale was the inclusion of access to subway stops, reflecting the importance of public transit in the lives of NYC residents and the contributions transit can make to active transport. Analyses of the 2001 National Household Travel Survey show that users of transit spend a median of 19 min walking to and from transit stops and that 29 % of users meet health recommendations for physical activity solely by walking to and from transit stops.[27] Other studies have shown that public transit users engage in more walking and physical activity than non-users.[28,29] Our past work on walkability used measures a series of urban design characteristics related to walkability: population density, land use mix, intersection density, and subway and bus stop density, which tend to be highly correlated and are difficult to analyze simultaneously in a single statistical model.[30] The walkability scale captures the effects of these urban design dimensions in a single measure and provides a more comprehensive measure of the construct of neighborhood walkability. The built environment domains included in the walkability scale are hypothesized to influence both pedestrian and cycling activity. Prior work using Frank's original walkability scale and other studies that measured components of the scale (e.g., population density, land use mix or intersection density) have observed associations between these measures of the built environment and walking and physical activity.[17,24,26,31,32] In addition, a study found a higher odds of using bicycles for transport associated with a neighborhood walkability scale that incorporated measures of dwelling density, street connectivity, land use mix, and net retail area ratio.[15] In NYC, it is not unusual for residents to commute via a bike-to-subway multi-mode trip, either leaving their bike at racks near a subway stop or taking their bike on the subway cars. These prior findings and observations regarding pedestrian and cycling behavior corroborate our finding that neighborhood walkability as measured in this study is associated with active travel measured as either walking or biking.

Our results suggest that neighborhood walkability interacts with race/ethnicity to predict zero episodes of sustained active travel but not the count of episodes of sustained active travel. It is possible that there is more measurement error in respondent's estimation of the number of episodes than in the reporting of zero episodes. Greater random measurement error in the estimation of the number of episodes as compared to correctly recalling no episodes would cause larger reductions in statistical power to observe interactions in predicting the count of episodes of active travel than in power to observe interactions for predicting zero episodes.

The cross-sectional nature of this study limits causal inference from these results. It is possible that those predisposed to active travel select to live in walkable areas and that the neighborhood walkability index is merely an indicator of the actualization of such preferences.[31] However, neighborhood residential preferences in NYC are constrained by socioeconomic factors and influenced by patterns of residence along racial/ethnic lines. In an effort to control for neighborhood selection, we controlled for the socioeconomic and racial/ethnic characteristics of the respondents. Nonetheless, the possibility of unmeasured confounding related to neighborhood selection exists, and may be stronger among affluent individuals whose residential choices are less constrained.

The work presented here also has several limitations associated with secondary analyses of health surveillance data. Our measure of active travel is relatively crude as compared to those that would be used in a transportation study or physical activity study. The survey question asks the respondent to only report episodes of walking or biking that covered a distance of ten blocks or more. This approach is appropriate for a population wide health surveillance survey: current recommendations for physical activity are that activity be accrued in blocks of 10 min or more, roughly the time required to walk ten blocks. Furthermore, measures of total pedestrian activity and total biking would be more useful for planners and public health professionals interested in estimating the costs and benefits of built environment interventions. However, the aggregation of walking and cycling behavior into a single active transport measure is common in public health and physical activity research.[2,33–35] Lastly, to preserve anonymity the survey did not collect data on exact addresses, only zip codes, limiting our ability to define neighborhoods in ways that are consistent with theoretical considerations.[36] However, our past work in NYC has shown that associations between measures of neighborhood walkability and body mass index are consistent across neighborhood definitions commonly used in the literature, including Census tracts, zip codes, and half-mile street network buffers around subject's home addresses.[37–39] Despite these data limitations, the analyses presented here provide further evidence that active travel is influenced by built environment conditions.

In conclusion, higher neighborhood walkability measured at the zip code level predicts higher levels of active travel, suggesting that urban design can be used to promote transportation- related physical activity even in highly dense, walkable environments. Such activity can be sufficient to meet health recommendations for physical activity and can have positive impacts on health conditions, particularly obesity. However, associations between engagement in any active travel and neighborhood walkability appear to be confined to non-Hispanic White subjects and those living in higher income neighborhoods. Interventions to promote active travel for other groups may need to incorporate changes to the social and aesthetic characteristics of neighborhoods as well as to the urban design characteristics.

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