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Walking to Work: The Roles of Neighborhood Walkability and Socioeconomic Deprivation

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Background: There are few studies that aimed to find a relationship between transportation-related physical activity and neighborhood socioeconomic condition using a composite deprivation index. The purpose of this study is to assess the relationship of neighborhood walkability and socioeconomic deprivation with percentage of adults walking to work. ***Methods***: A walkability index and a socioeconomic deprivation index were created at block group-level. The outcome variable, percentage of adults who walk to work was dichotomized as < 5% of the block group walking to work low and ≥ 5% of the block group walking to work as high and applied logistic regression to examine the association of walkability and socioeconomic deprivation with walking to work. ***Results***: Individuals in the most walkable neighborhoods are almost 5 times more likely to walk to work than individuals in the least walkable neighborhoods (OR = 4.90, 95% CI = 2.80–8.59). After adjusting for neighborhood socioeconomic deprivation, individuals in the most walkable neighborhoods are almost 3 times more likely to walk to work than individuals in the least walkable neighborhoods (OR = 2.98, 95% CI = 1.62–5.49). ***Conclusions***: Walkability (as measured by the walkability index) is a very strong indicator of walking to work even after controlling for neighborhood socioeconomic disadvantage.

Keywords: health disparities, physical activity, community design

While the Centers for Disease Control and Prevention (CDC) recommends that all adults get at least 150 minutes of moderate-intensity activity a week, physical inactivity remains a major public health problem in the United States.[1] By adding moderate-intensity physical activity into daily routines, the risk of several chronic diseases (eg, diabetes) is reduced.[2] Finding ways to increase adult physical activity is a public health imperative.

One way for Americans to reach the recommended minutes of moderate to vigorous physical activity (MVPA) each day is through transportation-related physical activity. Walking and cycling are of particular interest to researchers because of their overwhelming prevalence as a leisure-time activity, low cost to society and an easy addition to a daily routine.[3] Several studies have identified street infrastructure, sidewalk connectivity, mixed land use, residential density, facility provisions, aesthetics, and safety as independently associated variables affecting transport physical activity levels in area residents.[3–9] In addition, the actual and perceived distance to and from local shops and transit also influences a person's choice to travel by foot or bike.[7]

A walkable neighborhood consistently sees higher levels of physical activity, particularly for transport physical activity.[9–14] According to one recent review of the literature, transport physical activity is positively associated with connectivity, land use mix and density. Therefore, walkability has been defined as neighborhood supports for physical activity, including residential density, street connectivity and land use mix.[15] Adams et al found evidence suggesting residents living in more walkable neighborhoods with diverse land uses have an average of 13 more minutes of MVPA than residents in less walkable and recreationally sparse neighborhoods.[12] Additionally, residents walked for transportation 60 minutes more on average than their low walkability neighborhood counterparts. Frank and colleagues[15] found that regardless of neighborhood income, residents of highly walkable neighborhoods were significantly more likely to walk to work than less walkable neighborhoods.[3,10,15] It has also been suggested that individuals living near public transit tend to walk more frequently than car commuters.[16,17]

Residents of less-walkable and low-income neighborhoods are at a disadvantage in their ability to achieve the recommended minutes of physical activity. A 2009 study found, despite income level, residents living in a highly walkable neighborhood met the 30-minute physical activity recommendation 1 extra day per week on average compared with residents in less walkable neighborhoods.[10] Additionally, the only significant interaction between income and walkability was a strong, positive association between walking for transport and high socioeconomic status.[10] Another study by Sallis, et al used the Neighborhood Environment Walkability Scales (NEWS) to assess perceived features of the built environment and found 10 of the 15 features to have a positive association with income; however, there was no significant interaction between income and walkability.[18] Better infrastructure, lighter traffic, safe walking environments and the absence of physical barriers influence neighborhood walkability and are often attributes of high socioeconomic areas.[4] Disadvantaged socioeconomic neighborhoods are frequently without these characteristics, and therefore, often have lower walkability. Further, Kelly, et al conducted an assessment of 210 block groups in St. Louis and found predominantly African-American block groups were more likely to have unfavorable characteristics (ie, unevenness in the sidewalks, obstructions in the sidewalks, more physical disorder) and block groups with the highest poverty rates were more likely to have physical disorder.[19]

Additional literature from the transportation field has found that individuals more likely to drive to work rather than walk or cycle tend to be older, have higher education, are married, and have a

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further distance to work.[20] Car ownership also predicts mode choice, with fewer cars owned in walkable neighborhoods and individuals owning cars more likely to chose to drive.[21–23]

While there are several studies that examine the relationship between built environment and transportation physical activity, and we know there are physical environment differences between socioeconomic classes, there are few studies that have aimed to find a relationship between transportation-related physical activity and neighborhood socioeconomic condition using a composite deprivation index rather than examining the relationship based on individual characteristics (eg, income, education, car ownership). The aim of this study is to assess the relationship of neighborhood walkability and an area-level socioeconomic deprivation index with the percent of adults walking to work at the census block group level in the St. Louis region. Walkability is defined as neighborhood supports for transportation walking, including residential density, street connectivity and land use mix.[15] While these neighborhood supports may influence recreational or leisure-time walking as well, the purpose of this study was to assess the relationship of neighborhood walkability with transportation walking only. Socioeconomic deprivation index is an area-level index using Census block group variables. In recent years, neighborhood socioeconomic deprivation index has become a common measure in assessing community socioeconomic conditions. It has been recognized that a composite index could capture broader socioeconomic concept than a single indicator alone, such as poverty rate.[24,25] Both walkability and socioeconomic deprivation indices were created using objective measures.

Methods

The study area includes 1124 block groups in St. Louis City and County, covering 590 square miles. Using GIS and local parcel data, we computed census block group-level walkability index scores by incorporating the net residential density, intersection density, and land-use mix based on Frank's approach.[3,10,15] Residential density is defined as the "the ratio of residential units to the land are devoted to residential use per block group"; intersection density is defined as "the connectivity of the street network, represented by the ratio between the number of true intersections (3 or more legs) to the land area of the block group in acres"; and land-use mix is defined as "the diversity of land use types present in a block group."[15] The index is the sum of the z-scores of 3 urban form measures [walkability = (2 × z-intersection density) + (z-net residential density) + (z-land use mix)][15] For more information on how to calculate this index, please review the work of Frank and colleagues.

This is an indexed value without a unit, and a higher value indicates higher walkability. The walkability index was categorized into quartiles (from least walkable neighborhood to most walkable block group). Least walkable block group was the referent group in all analyses.

Twenty-one census variables from 2000 U.S. Census in 6 domains were selected to build a composite Census block group-level socioeconomic deprivation index.[25] These domains and variables included education (% population with less than high school and % population with a college degree), occupation (% civilian labor force unemployed and % white collar), housing conditions (% rent households, % vacant households, % households with ≥ 1 person/room, median value of all owner-occupied households, % female headed households with dependent children, % households with public assistance income, % households without vehicle, % households with no kitchen, % households with no phone, and % occupied households with incomplete plumbing), income and poverty (median family income, % households with income ≥ 4 times of the US median household income and % population below federal poverty line), racial composition (% non-Hispanic African Americans and % population foreign born), and residential stability (% persons living in same house ≥ 5 years and % residents aged 65+ years). Common factor analysis with varimax rotation was applied to examine the data structure and the deprivation common factor from these Census variables. Variables with large factor loading on the deprivation factor were selected to build the socioeconomic deprivation index and Cronbach's alpha was used to evaluate the internal consistency of selected variables.

The outcome variable, percent of adults who walk to work, was gathered from the 2005–09 American Community Survey at the block group level and dichotomized to < 5% of the block group walking to work as 0 (low walking to work) and ≥ 5% of the block group walking to work as 1 (high walking to work).

Considering the potential specific role of a single neighborhood deprivation indicator, we also selected 5 other census variables, including housing density, percentage of households below poverty, percentage of households without vehicle, percentage of non-Hispanic African Americans, and percentage of population below poverty. All 5 census variables were categorized as quartiles based on their distributions.

Statistical Analysis

Statistical analyses were conducted in 2 steps. First, the Spearman correlation matrix was calculated between percentage of walking to work and 7 explanatory variables, including walkability index, socioeconomic deprivation index and 5 other Census variables to determine their intercorrelation. Second, all 7 explanatory variables were categorized into quartiles. A series of logistic regressions were performed to examine their associations with neighborhood walking to work.

Results

Using common factor analysis with varimax rotation, the first common factor was identified as the deprivation factor that explained about 44% of the total variance. Finally, the deprivation index was computed based on 9 Census variables, including % civilian labor force unemployed, % vacant households, % households with at least 1 person/room, % female headed households with dependent children, % households with public assistance income, % households with no vehicle, % households with no phone, % population below federal poverty line, and % non-Hispanic African Americans. They had a high internal consistency (Cronbach's $\alpha = .93$).

Block groups in St. Louis City and County were analyzed (n = 1124). Table 1 describes the characteristics of the block groups. Fifteen percent of this population was age 65 and older, while 15% was under the age of 18. Majority of this population was non-Hispanic white, with 35% African American and 2% Latino. Walkability in each neighborhood ranged from –10.2 to 19.0, mean of 3.6. Ninety-eight percent of the block groups had residents living there. Approximately 2% of residents in these block groups walked to work.

Table 2 shows the percentage of population walking to work was significantly correlated with block group walkability, percentage of households below poverty, and percentage of population below poverty. Block group walkability index was highly correlated with block group socioeconomic deprivation index and all other 5 neighborhood socioeconomic indicators (all Ps < 0.0001). This

Table 1 Block Group Descriptive Statistics in St. Louis, Missouri (n = 1124)

	N	Mean	Median	Range
% walk to work	1106	2.2%	0	0–57.23
Standardized walkability index	1124	3.6	–0.99	–10.0 to 19.0
Standardized SES deprivation index	1108	0.0	–0.41	–1.2 to 4.9
Housing density	1124	2766	2245	0–18,931
Households below poverty	1108	13.9%	9	0–78.6
Households without car	1108	14.6%	8.9	0–79.9
African Americans	1109	34.7%	14.6	0–100
% male	1109	47.1%	47.1%	0–63.8
Population below poverty	1109	14.9%	9.4	0–78.3

suggests it is necessary to consider neighborhood socioeconomic conditions as potential confounders.

The base model assessing the relationship between individuals walking to work and neighborhood walkability found individuals in the most walkable neighborhoods are 4.9 times more likely to walk to work than individuals in the least walkable neighborhoods [odds ratio (OR) = 4.90, 95% confidence interval (CI) = 2.80–8.59] (Table 3). In addition, individuals in the most socioeconomically deprived neighborhoods are 3.1 to 5.0 times more likely to walk to work (unadjusted OR = 5.02, 95% CI = 2.86–8.81; walkability-adjusted OR = 3.08, 95% CI = 1.66–5.70) compared with residents living in the least socioeconomically deprived neighborhoods.

Next, adjusting for socioeconomic deprivation index in each neighborhood, individuals in the most walkable neighborhoods are 3.0 times more likely to walk to work than individuals in the least walkable neighborhoods (OR = 2.98, 95% CI = 1.62–5.49).

Adjusting for housing density (housing units per square mile) in each neighborhood, individuals in the most walkable neighborhoods are 3.9 times more likely to walk to work than individuals in the least walkable neighborhoods (OR = 3.88, 95% CI = 2.18–6.91). Adjusting for percent of households below federal poverty level in each neighborhood, individuals in the most walkable neighborhoods are 2.8 times more likely to walk to work than individuals in the least walkable neighborhoods (OR = 2.82, 95% CI = 1.53–5.20). Adjusting for percent of households without a car in each neighborhood, individuals in the most walkable neighborhoods are 3.1 times more likely to walk to work than individuals in the least walkable neighborhoods (OR = 3.06, 95% CI = 1.65–5.70). Adjusting for percent of African Americans in each neighborhood, individuals in the most walkable neighborhoods are almost 4.5 times more likely to walk to work than individuals in the least walkable neighborhoods (OR = 4.45, 95% CI = 2.50–7.92). Adjusting for percent of persons below federal poverty level in each neighborhood, individuals in the most walkable neighborhoods are 2.5 times more likely to walk to work than individuals in the least walkable neighborhoods (OR = 2.52, 95% CI = 1.37–4.64).

Discussion

Despite the small percentage of adults that walk to work in our population, significant associations with walkability were found. Walkability (as measured by the walkability index) is a very strong indicator of walking to work even after controlling for other neighborhood-level factors. Individuals living in highly walkable neighborhoods are 2.8 to 4.5 times more likely to walk to work even after adjusting for several neighborhood factors, including socioeconomic deprivation, housing density, household poverty, percent of households without a car, percent of minorities, and percent of population living below poverty. This study builds on the literature by highlighting the relationship of area-level deprivation and walkability on transport physical activity (ie, walking to work). Previous research has found that individual wealth (higher income, higher education, car ownership) may affect mode choice[20–23] but we know little about how area-level deprivation affects mode choice. This study found that individuals in the most socioeconomically deprived neighborhoods are 3.1 to 5.0 times more likely to walk to work. However, even after controlling for area-level deprivation, individuals in the most walkable neighborhoods are more likely to walk to work. This suggests that while area-level deprivation and individual wealth contribute to mode choice, the walkability of a neighborhood is still an important determinant of walking to work.

These findings contribute to the literature that walkability of a neighborhood is important for meeting physical activity recommendations, even after controlling for several other correlates of physical activity. Public health strategies to increase physical activity should consider transportation-related physical activity as an opportunity in neighborhoods that could be classified as walkable. In neighborhoods without these supports, efforts should be made to provide connections that support all modes of transportation, particularly when redesigning streets or sidewalks for other reasons. Adopting and implementing Complete Streets policies is one mechanism for which communities can advocate that supports all modes of transit.

While the field continues to develop evidence in support of the built environment and physical activity, we must continue to recognize the limitations of these findings. While the findings support previous research linking the built environment and transport physical activity, we still do not know how the built environment contributes to total physical activity behavior. Similarly, we do not know why individuals moved to their neighborhood and if it was because they could walk to work or if they decided to walk for transportation after moving there. We cannot ascertain cause and effect from this cross-sectional study. However, significant associations, such as the ones in this study, provide evidence for neighborhoods and cities to ensure environments support physical activity (eg, mixed land use, street connectivity). Combined with health education, these environmental supports have the potential to reach a large number of individuals and would likely have an impact on health outcomes.

Table 2 Spearman Rho Correlation of Variables

	Walk to work	Walkability index	Socioeconomic deprivation index	Housing density	Households below poverty	Household without a car	Population African American	Population below poverty
Walk to work	1.00	0.13258	0.02791	0.04548	0.07535	0.04591	–0.03259	0.07788
		< .0001	0.3537	0.1307	0.0122	0.1271	0.2789	0.0096
Walkability index	0.13258	1.00	0.46957	0.27874	0.46871	0.49922	0.29051	0.46008
	< .0001		< .0001	< .0001	< .0001	< .0001	< .0001	< .0001
Socioeconomic deprivation index	0.02791	0.46957	1.00	0.52498	0.90397	0.86902	0.83512	0.91635
	0.3537	< .0001		< .0001	< .0001	<.0001	< .0001	< .0001
Housing density	0.04548	0.27874	0.52498	1.00	0.52064	0.53313	0.36129	0.5053
	0.1307	< .0001	< .0001		< .0001	< .0001	< .0001	< .0001
Households below poverty	0.07535	0.46871	0.90397	0.52064	1.00	0.81078	0.72631	0.96836
	0.0122	<.0001	< .0001	< .0001		< .0001	< .0001	< .0001
Household without a car	0.04591	0.49922	0.86902	0.53313	0.81078	1.00	0.65108	0.80684
	0.1271	< .0001	< .0001	< .0001	< .0001		< .0001	< .0001
Population African American	–0.03259	0.29051	0.83512	0.36129	0.72631	0.65108	1.00	0.73031
	0.2789	< .0001	< .0001	< .0001	< .0001	< .0001		< .0001
Population below poverty	0.07788	0.46008	0.91635	0.5053	0.96836	0.80684	0.73031	1.00
	0.0096	< .0001	< .0001	< .0001	< .0001	< .0001	< .0001	

Table 3 Association of Neighborhood (Block Group) Walkability Index With Walking to Work (n = 1124 Block Groups)[a]

	Odds ratio (95% confidence interval)						
	Model 1	Model 2	Model 3	Model 4	Model 5	Model 6	Model 7
Walkability index							
Lowest quartile	1.00	1.00	1.00	1.00	1.00	1.00	1.00
2nd lowest quartile	1.52 (0.80–2.87)	1.27 (0.66–2.42)	1.22 (0.64–2.35)	1.23 (0.64–2.36)	1.26 (0.66–2.42)	1.47 (0.78–2.79)	1.17 (0.61–2.24)
2nd highest quartile	2.44 (1.35–4.42)	1.68 (0.90–3.15)	1.91 (1.03–3.53)	1.63 (0.88–3.05)	1.71 (0.91–3.22)	2.29 (1.26–4.19)	1.49 (0.80–2.79)
Highest quartile	4.90 (2.80–8.59)	2.98 (1.62–5.49)	3.88 (2.18–6.91)	2.82 (1.53–5.20)	3.06 (1.65–5.70)	4.45 (2.50–7.92)	2.52 (1.37–4.64)

[a] Model 1 is a univariate model; Model 2 is adjusted for socioeconomic deprivation index; Model 3 is adjusted for household density; Model 4 is adjusted for household below poverty; Model 5 is adjusted for household with no car; Model 6 is adjusted for %AA; Model 7 is adjusted for % population below poverty.

This study has several strengths. First, an objective, composite walkability index was built to measure neighborhood walkability. The walkability index is better than single measures of walkability (eg, residential density alone) because it represents the overall walkability of a neighborhood, and it has been correlated with activity in previous research.[3,9,10,15] Second, socioeconomic deprivation also was comprehensively evaluated using an index, while performing a sensitivity analysis comparing socioeconomic deprivation index to single socioeconomic indicators. An index to represent socioeconomic variation captures a broader concept of deprivation than a single deprivation indicator (eg, housing density). A composite index is better because it can capture more aspects reflecting deprivation or walkability. Therefore, the use of indices has increased in research. The use of these 2 objective indices in 1 study is a unique contribution to the literature.

Limitations

A few limitations of this study should be noted. A neighborhood was classified as a block group. Individuals living in these block groups may travel outside these boundaries for their activity. We also do not know where the individuals work or how far their active transportation takes them. Where an individual works may have a stronger effect on their commute choice. In addition, it is possible, and likely, they pass through more than 1 block group during the journey to work each day. In this study, we can only account for the walkability of the block group in which they live and cannot account for the walkability in block groups they may encounter on their journey. Similarly, research shows that distance to work and access to public transit are factors in individual mode choice.[16,17] This study was not able to account for distance to work or access to public transit.

Based on recent findings from Hearst et al suggesting both area-level and individual-level SES played important role in walking, future research needs to comprehensively evaluate the role of neighborhood physical activity environment in walking behavior using a multilevel framework, including both neighborhood-level and individual-level factors.[26]

Although objective measures of the environment have been shown to be related to physical activity, an individual's perception of the environment likely influences their decision to walk for transportation. Therefore, future studies should assess the environment using both objective and perceived measures and capture the actual path a person walks to work. This would allow us to measure the relationship between walkability and activity based on the actual streets an individual chooses to walk, or conversely, chooses not to walk.

Last, the percentage of adults walking to work in our neighborhoods was low, limiting our variability. Future research should attempt to select neighborhoods with a higher percentage of adults walking to work. It is hypothesized that the results will be stronger when the percentage is increased.

Despite these limitations, this study highlights the relationship of neighborhood walkability and transportation-related activity. While we cannot ascertain cause and effect, this study provides further evidence of the need for mixed land use, residential density and streets that are connected. Further research is needed to understand if walkability of neighborhoods changes individual behaviors or if people choose to live in walkable neighborhoods because they are already active.

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