Walkability and Safety Around Elementary Schools
Economic and Ethnic Disparities

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Background: Children's physical inactivity and obesity are growing public health problems in the U.S., especially among low-income, minority populations. Walking to school may help address these problems.

Methods: This cross-sectional study examined disparities in the environmental support for walking around 73 public elementary schools in Austin TX. GIS was used to measure the neighborhood-level walkability and safety. Field audits were conducted to assess the street-level walkability. Analyses of variance and regressions were performed to analyze economic and ethnic disparities.

Results: For the top-quartile schools with higher poverty or Hispanic student percentages, the surroundings showed higher neighborhood-level walkability with shorter distances to school and more sidewalks compared with the bottom quartile. These areas, however, also had higher crash and crime rates and lower street-level walkability captured by visual quality, physical amenities, maintenance, and perceived safety. In predictions of environmental conditions using poverty and Hispanic student percentages, poverty was associated with many adverse conditions on the street level and with only two favorable situations, shorter distances to school and lower traffic volumes, on the neighborhood level. The Hispanic student percentage did not correlate with most street-level variables, but predicted both increased dangers from traffic and crime and higher neighborhood-level walkability with more sidewalks, greater density, and mixed land uses.

Conclusions: Economic and ethnic disparities exist in the environmental support for walking, suggesting the need for tailored interventions in promoting active living. Low-income, Hispanic children are more likely to live in unsafe areas with poor street environments but with some favorable neighborhood-level conditions.

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Introduction

Walking to school is an affordable and environmentally clean mode of transportation that may increase physical activity and reduce obesity.[1–3] Unfortunately, recent decades have witnessed a steep decline in walking to school among school-aged children.[4] In addition to individual and social factors, physical environmental barriers such as long travel distances,[4–11] poor or missing pedestrian facilities,[5–7,12,13] and dangers from traffic and crime[4,9–11,13,14] have contributed to this decline. Other physical environmental features such as density, land-use mix, street connectivity, and physical amenities (such as street lighting and trees) appeared to encourage walking to school in some studies[9,13,15,16] yet resulted in inconsistent findings in others.[5–7,14,15] Currently, programs are being implemented at the national, state, and local levels to improve the environmental support for walking to school. However, assessment methods and empirical evidence are still limited in terms of the specific walkability and safety issues related to children's walking-to-school behaviors.

Meanwhile, economic and ethnic disparities have emerged as new themes related to the environmental support for walking to school. Several studies found that low-income or minority children walked more often during school travels than did affluent or non-Hispanic white children.[6,15,17] However, other studies reported ethnicity and family income to be insignificant factors.[9,10,18] Further, walkability and safety of the built environment may differ by the neighborhoods' SES or ethnic composition. For example, a California study found that low-income or minority children were exposed to disproportionately high volumes of traffic.[19] In such a case, the potential health benefits of walking as physical activity may be undermined by the threats to personal safety and respiratory health. These low-income, minority children may have no alternative means of transportation and are thereby called "captive walkers" in

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transportation literature.[20] They also may have limited access to physical activity facilities[21] and healthy diet options,[22] and therefore have a high risk of developing obesity.[23,24]

Despite these recent studies, low-income and minority neighborhoods have been underrepresented in the walkability literature.[25] Very few studies have examined the relationships among walkability factors at different spatial scales[26–28] or between walkability and safety.[13,29] This study examines different aspects of environmental support for walking around elementary schools, including neighborhood-level walkability, street-level walkability, and neighborhood-level safety related to traffic and crime. It also explores disparities based on the students' economic status and ethnicity.

Methods

The study site consisted of the attendance areas of 73 public elementary schools in the Austin Independent School District within the city of Austin TX; the unit of analysis was the school's attendance area. This district covers 230 square miles (59,560 hectares) and features a unique mix of sociodemographic and physical environmental characteristics. Its high percentage of Hispanic students (54.7% during the 2004–2005 school year)[30] represents an important trend in the Texas population (35.9% Hispanic in 2006).[31] Meanwhile, non-Hispanic white students and other ethnic groups accounted for 29.0% and 16.3% of the total students in the district, respectively.[30] A school's "poverty rate" was defined as the percentage of students eligible for free or reduced-price lunch based on household income and size, and ranged among schools from 2.0% to 98.9%.[30] Geographically, low-income Hispanic students were concentrated in the eastern district, while affluent, non-Hispanic white students lived primarily in the western area (Figure 1). GIS was used to measure the neighborhood-level walkability, traffic dangers, and crime rates; field audits were conducted to assess the street-level walkability. Study variables were identified based on the literature review.

GIS Measures

ArcGIS 9.0 was used for all GIS measures, utilizing the secondary data collected from the city of Austin,[32] the Capital Area Metropolitan Planning Organization, the Texas Department of Transportation, and the U.S. Census Bureau.[33] Because the size and shape of the attendance areas varied across schools, all variables were captured by normalized measurements (density or percentage) (Table 1). Measures for the neighborhood-level walkability included the estimate of potential walkers (based on the percentage of students living within a half mile from school); pedestrian facilities (sidewalk completeness and traffic-signal density); residential density; street connectivity (street density and intersection density); and land-use mix. Neighborhood-level safety was captured by crime rates and traffic dangers such as traffic volumes, percentages of high-speed streets, and crash rates.

The land-use mix measure was adopted from the Strategies for Metropolitan Atlanta's Regional Transportation and Air Quality study.[34] It had a value range from 0 to 1. Higher values indicated more even distributions of residential, commercial, and office land uses, which were assumed to be more supportive of walking. The crash rate was measured using geo-coded point data for all crashes between 2002 and 2006, including automobile–automobile, automobile–bike, and automobile–pedestrian crashes. The crime rate was based on geo-coded Part-I crime data (2005–2006) consisting of eight major index crimes, including criminal homicide, forcible rape, robbery, aggravated assault, burglary, larceny–theft, motor-vehicle theft, and arson.

Field Audits

Field audits were conducted to assess the street-level walkability. Due to resource limitations, only one 200-meter street segment was sampled from each attendance area. The initial exploratory observation of the street-level features showed little variation within the same attendance area, while presenting clear differences across schools. Therefore, this approach allowed the capture of a fairly representative street condition of the attendance area. The street segment was sampled using the following criteria: (1) proximity to the geographic center of the attendance area; (2) posted speed limit of 30 miles per hour;

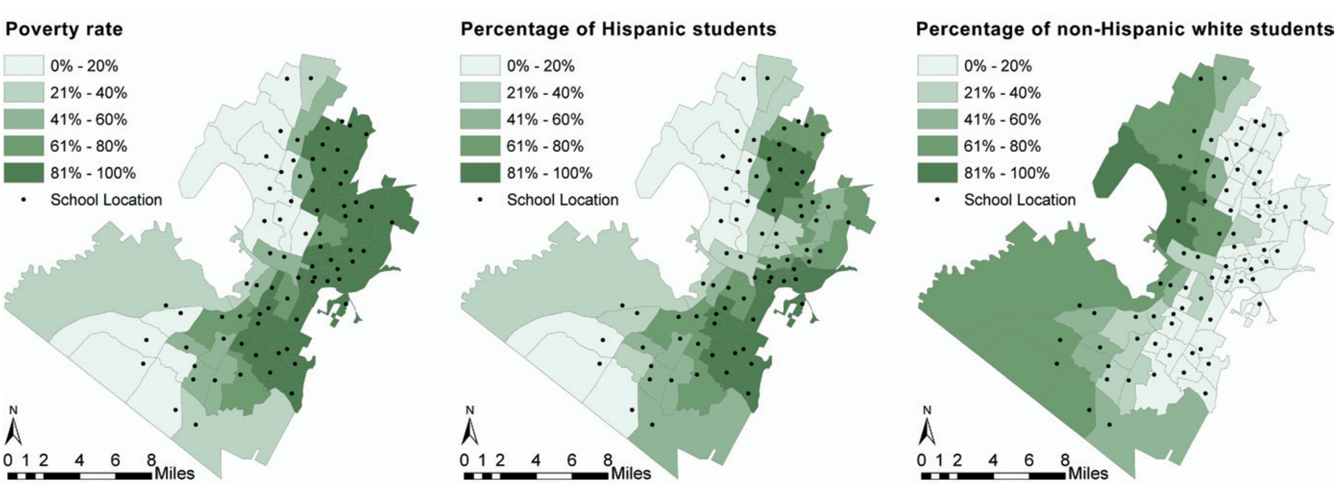

Figure 1. Spatial patterns of selected sociodemographic characteristics in the Austin Independent School District, Austin TX, by attendance area.

Table 1. Definitions, equations, and descriptive statistics of the neighborhood-level walkability and safety variables[a]

Variable	Definition	Equation	M	SD
Neighborhood-level walkability				
Estimate of potential walkers	Percentage of students living near school	Number of students living within half a mile from school/total number of students within school	0.240	0.156
Pedestrian facilities	Sidewalk completeness	Total miles of sidewalks/(total miles of streets×2)	0.267	0.137
	Traffic-signal density	Number of traffic signals/total miles of streets	0.266	0.198
Residential density	Gross population density	Total population/total acres of the area	6.815	3.717
Street connectivity	Street density	Total footage of streets/total acres of the area	136.067	48.678
	Street-intersection density	Number of street intersections (≥3-way)/total acres of the area	0.197	0.113
Land-use mix[b]	Evenness of distribution based on square footage of R, C, and O	See equation below[c]	0.450	0.241
Neighborhood-level safety				
Traffic danger	Average traffic volume	Average daily traffic count of sampled locations	8552.384	3872.626
	Percentage of high-speed streets	Total footage of streets with speed limit>30 miles per hour/total footage of all streets	0.208	0.078
	Yearly crash rate	(Number of crashes between year 2002 and 2006)/(total miles of streets×5)	4.673	2.733
Crime	Yearly crime rate	(Number of Part-I crimes[d] in year 2005 and 2006×100)/(total acres of the area×2)	52.102	38.705

[a]All neighborhood-level variables were measured using ArcGIS. The unit of analysis was the school's attendance area.
[b]The land-use mix measure was adopted from the Strategies for Metropolitan Atlanta's Regional Transportation and Air Quality study.[34]
[c](−1)×[(area of R/total area of R, C, and O)×ln (area of R/total area of R, C, and O)+(area of C/total area of R, C, and O)×ln (area of C/total area of R, C, and O)+(area of O/total area of R, C, and O)×ln (area of O/total area of R, C, and O)]/ln (number of land uses present).
[d]Part-I crimes consist of eight major index crimes, including criminal homicide, forcible rape, robbery, aggravated assault, burglary, larceny-theft, motor-vehicle theft, and arson.
C, commercial land use; O, office land use; R, residential land use.

(3) a majority (>80%) of roadside parcels being residential developments; (4) sidewalks on at least one side of the street; and (5) not a dead-end street. These criteria ensured consistency among sample segments in terms of the overall characteristics of the street networks such as street connectivity, pedestrian facilities, and adjacent land uses, which were already captured as part of the neighborhood-level walkability. By these means, the audit was restricted to street-level walkability, focusing on the urban design and architectural qualities. The speed limit of 30 miles per hour was used as a sampling criterion, because it was the most frequently encountered speed limit in the study area, accounting for 75% of total streets excluding highways and freeways. High-resolution aerial photographs and GIS datasets including street centerlines, land uses, and sidewalks were utilized for sampling.

The audit instrument was adopted from the previously validated Pedestrian Environment Data Scan Tool,[35] and was revised to account for this particular study's design and setting and to incorporate additional findings from the recent literature. Audit measures included various attributes of sidewalks, roads, and roadside buildings, as well as perceptions of the overall walking environment (Table 2). All subjective variables were measured on a 5-point Likert-type scale, covering the maintenance, visual quality, physical amenities, safety, and other aspects. Objective variables were captured by either absolute values (e.g., width, distance, or count) or dichotomous measures (e.g., presence or absence).

The audit was conducted independently but simultaneously by two researchers in May and June 2006. The interrater reliability was tested by the average measure intraclass correlation coefficients (ICCs). Except for a few items, including the degree of enclosure and surveillance along sidewalks, air quality, and quietness, all variables showed moderate-to-high reliability (ICCs ranging from 0.698 to 0.871) (Table 2). The final analysis used the average value of the two auditors' ratings.

Data Analysis

Series of GIS maps were developed to visually examine spatial disparities of environmental variables. Moran's I and Gini coefficients were also calculated for continuous variables to measure their spatial autocorrelations and disparities, respectively. Spatial autocorrelation describes the spatial dependency (influence of spatial proximity) of measurements for a single variable at different locations. The expected value of Moran's I is $E(I) = -(n-1)^{-1}$ under a randomization hypothesis.[36] Generally, its value ranges from −1 to 1.[36] More departure from $E(I)$ in either direction suggests stronger spatial dependency. Significant, positive I values imply the existence of spatial clustering, meaning similarities of nearby measurements, while negative values reflect dissimilarities. ArcGIS was used to calculate the Moran's I.

Gini coefficient is a measure of disparities widely used in the field of economics for variables such as income. It evaluates how close a variable's actual distribution is to an ideal distribution with perfect equity.[37] It has a value range from 0 (perfect equity) to 1 (perfect disparity), and higher values indicate greater disparities. This study used the Gini coefficient as an exploratory measure to evaluate the spatial distribution of walkable environmental features or safety

Table 2. Intraclass correlation coefficients (ICCs) and descriptive statistics for the street-level walkability variables[a]

Street-level walkability variables	ICC	M or %	SD
SUBJECTIVE VARIABLES MEASURED ON A 5-POINT LIKERT-TYPE SCALE			
Maintenance			
Sidewalk maintenance	0.764	2.676	0.728
Road maintenance	0.717	3.179	0.581
Building maintenance	0.870	2.556	0.777
Overall maintenance	0.839	2.487	0.783
Visual quality			
Visual quality of buildings	0.851	2.460	0.742
Overall visual quality	0.794	2.621	0.695
Physical amenities			
Degree of tree shade along sidewalks	0.810	2.684	0.813
Degree of enclosure along sidewalks	0.487	2.705	0.599
Overall physical amenities	0.769	2.461	0.718
Safety			
Degree of surveillance from windows along sidewalks	0.577	2.775	0.533
Overall perceived safety	0.698	2.916	0.635
Others			
Air quality	0.294	3.397	0.499
Quietness	0.547	3.020	0.767
Overall convenience of walking	0.731	2.921	0.680
OBJECTIVE VARIABLES MEASURED WITH ABSOLUTE VALUES			
Sidewalk distance from the curb (unit: feet)	—	2.726	1.850
Sidewalk width (unit: feet)	—	4.137	0.502
Building setback from the road (unit: feet)	0.871	32.185	12.101
OBJECTIVE VARIABLES MEASURED WITH BINARY VALUES (0=NO; 1=YES)			
Presence of discernable slopes while walking	—	58% yes	—
Presence of sidewalk obstructions	—	45% yes	—
Presence of buffers between sidewalks and roads	—	74% yes	—
Presence of on-street parking	—	95% yes	—
Presence of power lines along streets	—	40% yes	—

[a]All street-level variables were measured by field audits, and the unit of analysis was a 200-meter street segment sampled from each school's attendance area. Several additional variables were measured, yet revealed no variation among the sampled segments. These variables were sidewalk material (concrete); presence of pedestrian-oriented lighting (no); presence of off-street parking lots (no); the need to walk through parking lots in order to access buildings (no); number of lanes (2); and presence of street furniture (no). However, since this field audit focused on only one type of street segment, it is highly possible that these measures do vary across different types of street segments in the study area.

concerns as compared with the distribution with perfect equity (i.e., each attendance area having the same value). Calculations were made with the Free Statistics Software.[38]

Regression analyses and ANOVAs were conducted to examine economic and ethnic disparities in walkability and safety. First, ANOVAs were used to compare the top-quartile schools (poverty rate ≥92.3%, or percentage of Hispanic students ≥82.1%) with the bottom quartile (poverty rate <45.1%, or percentage of Hispanic students <37.6%) based on economic status or ethnic composition. Next, three sets of regression models were estimated to predict each environmental variable, using (1) only the poverty rate, (2) only the percentage of Hispanic students, and (3) both variables. Because of non-normal distributions, the poverty and Hispanic student rate variables were transformed into five ordinal categories based on percentiles and were treated as continuous variables in the regression analyses. Linear and binary logistic regression analyses were used for continuous and dichotomous outcome variables, respectively.

Results

According to GIS maps (see Figure 2 for examples), schools with higher poverty or Hispanic student rates had greater neighborhood-level walkability in their attendance areas: more students living near school, more completed sidewalk networks, and greater residential density and land-use mix. However, they also had increased dangers from traffic and crime and lower street-level walkability such as poor visual quality, lack of physical amenities, and poor maintenance.

Based on Moran's *I*, most sociodemographic (Table 3) and environmental variables (Table 4) showed small yet significant effects of spatial clustering. The exceptions were two traffic safety variables (traffic volume and percentage of high-speed streets) and a few street-level variables, including sidewalk width and distance from the curb, and the degrees of tree shade, enclosure, and surveillance along sidewalks.

Gini coefficients are new measures to be used in walkability studies, and therefore there is no recommended threshold for determining high versus low levels of disparities. However, it is useful to compare the values across the study variables. For sociodemographic factors (Table 3), the distribution of non-Hispanic white students showed a greater disparity (Gini coeffi-

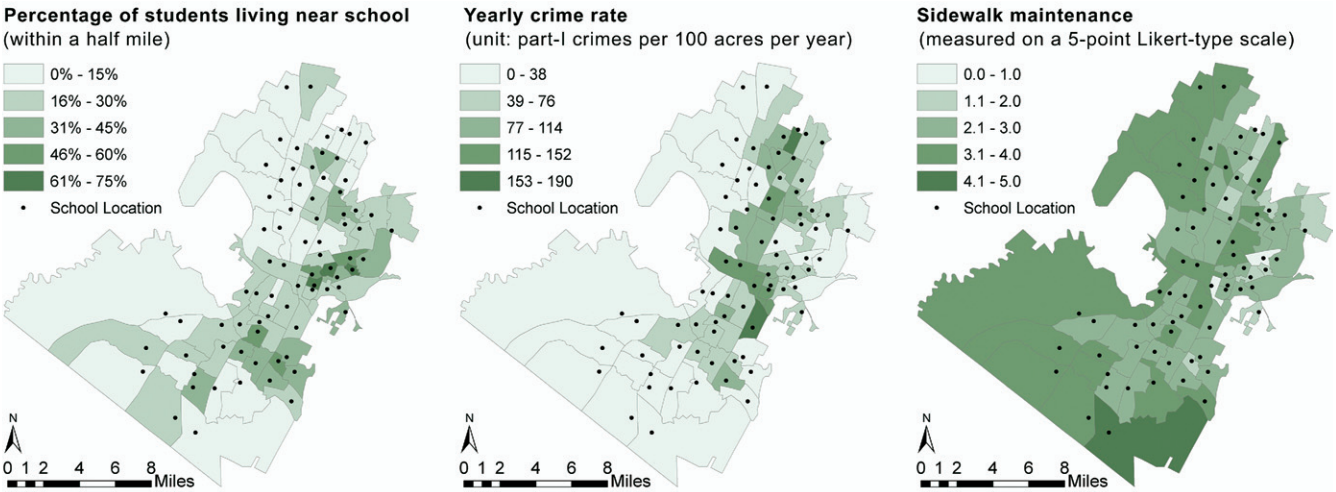

Figure 2. Spatial patterns of selected walkability and safety variables in the Austin Independent School District, Austin TX, by attendance area.

cient=0.597) than did the poverty rate and the percentage of Hispanic students. This implies that white students were more likely to be segregated from other ethnic groups in their residential locations and school attendance. For continuous environmental variables (Table 4), crime rate showed the most serious disparity (Gini coefficient=0.401), followed by traffic-signal density (0.361), sidewalk distance from the curb (0.361), percentage of students living near school (0.343), crash rate (0.317), residential density (0.305), and land-use mix (0.305).

The results from ANOVAs are listed in Table 4. Based on economic status, the top-quartile, high-poverty (≥92.3%) schools showed higher neighborhood-level walkability than did the bottom quartile. This was demonstrated by three conditions: 20.9% more students living within a half mile from school, 13.2% higher sidewalk completeness, and a higher density with about three more people per acre. Meanwhile, the top-quartile schools were less safe, having about 2.5 more crashes per mile of street per year (M=4.7) and about 44.7 more Part-I crimes per 100 acres per year (M=52.1) in their attendance areas. They also showed poor street-level walkability with lower ratings for maintenance, visual quality, physical amenities, perceived safety, air quality, quietness, and convenience of walking, as well as greater likelihood to have sidewalk obstructions and on-street parking in their surroundings.

From another set of ANOVAs based on the percentage of Hispanic students, very similar patterns were observed between the top-quartile (≥82.1%) and the bottom-quartile (<37.6%) schools (Table 4). Meanwhile, a few additional variables became significant: the top quartile showed greater land-use mix on the neighborhood level and less enclosure along sidewalks, shorter distances between buildings and roads, and fewer slopes on the street level. In contrast, road maintenance and the presence of sidewalk obstructions became insignificant.

The results from the three sets of regression models are presented in Table 5. The first set used only the poverty rate to predict each environmental variable. For the neighborhood-level walkability, poverty showed favorable positive associations with the percentage of students living near school, sidewalk completeness, and population density. For safety, however, higher poverty rates were correlated with higher crash and crime rates. For the street-level walkability, higher poverty rates predicted poorer maintenance and visual quality, fewer physical amenities, and lower perceived safety, as well as more sidewalk obstructions and power lines along sidewalks.

In the second set of regression analyses, only the percentage of Hispanic students was used to predict the environmental condition, and the overall results were similar to those for poverty. However, several additional

Table 3. Descriptive statistics, Moran's *I* indices, and Gini coefficients of schools' sociodemographic characteristics

Variable	M	SD	Moran's *I*	Gini coefficient
Poverty rate (percentage of students eligible for free or reduced-price lunch)	0.679	0.326	0.145*	0.248
Percentage of Hispanic students	0.591	0.267	0.114*	0.252
Percentage of non-Hispanic white students	0.240	0.277	0.138*	0.597

*$p<0.001$.

Table 4. Moran's *I* indices, Gini coefficients, and estimated mean differences (EMD) between the top-quartile and the bottom-quartile schools

Outcome variable	Moran's *I*	Gini coefficient	EMD based on poverty rate	EMD based on Hispanic student rate
NEIGHBORHOOD-LEVEL WALKABILITY				
Students living near school (unit: %)	0.113***	0.343	0.209**	0.196***
Sidewalk completeness (unit: %)	0.050***	0.286	0.132**	0.150***
Traffic-signal density (unit: signals per mile street)	0.052***	0.361	0.044	0.035
Gross population density (unit: persons per acre)	0.077***	0.305	2.992**	4.268***
Street density (unit: feet per acre)	0.122***	0.195	27.358	30.213
Street-intersection density (unit: intersections per acre)	0.138***	0.287	0.040	0.047
Land-use mix (range: 0–1)	0.084***	0.305	0.130	0.165*
NEIGHBORHOOD-LEVEL SAFETY				
Average traffic volume (unit: cars per day)	0.018	0.250	−1302.208	−90.310
Percentage of high-speed streets	−0.011	0.211	−0.003	−0.005
Crash rate (units: crashes per mile street per year)	0.109***	0.317	2.453**	3.648***
Crime rate (unit: Part-I crimes per 100 acres per year)	0.114***	0.401	44.680***	45.478***
STREET-LEVEL WALKABILITY				
Subjective variables measured on a 5-point Likert-type scale				
Maintenance				
Sidewalk maintenance	0.045***	0.152	−0.991***	−0.879***
Road maintenance	0.024*	0.101	−0.380*	−0.366
Building maintenance	0.096***	0.170	−1.196***	−1.206***
Overall maintenance	0.086***	0.176	−1.248***	−1.127***
Visual quality				
Visual quality of buildings	0.084***	0.163	−1.151***	−1.156***
Overall visual quality	0.072***	0.146	−1.077***	−1.035***
Physical amenities				
Degree of tree shade along sidewalks	0.014	0.158	−0.507	−0.436
Degree of enclosure along sidewalks	0.013	0.115	−0.361	−0.425*
Overall physical amenities	0.081***	0.162	−1.163***	−1.137***
Safety				
Degree of surveillance along sidewalks	0.006	0.107	−0.016	0.101
Overall perceived safety	0.069***	0.123	−1.012***	−0.866***
Others				
Air quality	0.053***	0.078	−0.552***	−0.408*
Quietness	0.019*	0.140	−0.540*	−0.590*
Overall convenience of walking	0.064***	0.130	−0.733***	−0.518*
Objective variables measured with absolute values				
Sidewalk distance from the curb (unit: feet)	−0.003	0.361	−0.094	0.436
Sidewalk width (unit: feet)	−0.035	0.056	−0.209	−0.171
Building setback from the road (unit: feet)	0.076***	0.170	−6.725	−10.374**
Objective binary variables (0=no, 1=yes)				
Presence of discernable slopes while walking	—	—	−0.181	−0.462**
Presence of sidewalk obstructions	—	—	0.345*	0.246
Presence of buffers between sidewalks and roads	—	—	−0.020	0.181
Presence of on-street parking	—	—	0.211**	0.167*
Presence of power lines along streets	—	—	0.289	0.304

*$p<0.05$; **$p<0.01$; ***$p<0.001$.

variables became significant, including street density (positive), land-use mix (positive), and presence of slopes (negative). Road maintenance, degree of tree shade and enclosure along sidewalks, and the presence of sidewalk obstructions and power lines became insignificant.

Finally, the poverty rate and the percentage of Hispanic students were used together to predict each environmental variable. The multicollinearity was not a serious problem (variance inflation factor=2.080) despite the predictors' strong bivariate correlations (coefficient=0.721, $p<0.01$). Interesting patterns of associations emerged from the findings, revealing the contrasting relationships between the neighborhood-level and the street-level walkability and between the neighborhood-level walkability and safety. After controlling for the percentage of Hispanic students, poverty was associated with many adverse conditions on the street level (negative for maintenance, visual quality, physical amenities, perceived safety, and convenience of walking) but with only two favorable situations on the neighborhood level, including more students living near school and lower traffic volumes. In contrast, after adjusting for poverty, the percentage of Hispanic students was no longer associated with the

Table 5. Beta coefficients from three sets of regression models predicting walkability and safety[a]

Outcome variable	Regressions including poverty rate only	Regressions including Hispanic student rate only	Regressions including both poverty and Hispanic student rates: Poverty rate	Regressions including both poverty and Hispanic student rates: Hispanic student rate
NEIGHBORHOOD-LEVEL WALKABILITY				
Percentage of students living near school	0.515**	0.417***	0.446**	0.096
Sidewalk completeness	0.344**	0.422***	0.084	0.361*
Traffic-signal density	0.023	0.165	−0.200	0.309
Gross population density	0.328**	0.452***	0.005	0.448**
Street density	0.199	0.243*	0.050	0.207
Street-intersection density	0.143	0.163	0.054	0.124
Land-use mix	0.160	0.328**	−0.160	0.444**
NEIGHBORHOOD-LEVEL SAFETY				
Average traffic volume	−0.178	0.109	−0.533**	0.493**
Percentage of high-speed streets	0.028	0.058	−0.029	0.079
Yearly crash rate	0.364**	0.577***	−0.107	0.654***
Yearly crime rate	0.375**	0.527***	−0.010	0.535***
STREET-LEVEL WALKABILITY				
Subjective variables measured on a 5-point Likert-type scale				
Maintenance				
Sidewalk maintenance	−0.477***	−0.375**	−0.431**	−0.064
Road maintenance	−0.260*	−0.189	−0.258	−0.003
Building maintenance	−0.575***	−0.522***	−0.414**	−0.224
Overall maintenance	−0.554***	−0.510***	−0.388**	−0.230
Visual quality				
Visual quality of buildings	−0.571***	−0.520***	−0.407**	−0.227
Overall visual quality	−0.565***	−0.501***	−0.424**	−0.195
Physical amenities				
Degree of tree shade along sidewalks	−0.290*	−0.168	−0.351*	0.085
Degree of enclosure along sidewalks	−0.279*	−0.205	−0.274	−0.008
Overall physical amenities	−0.601***	−0.516***	−0.475**	−0.174
Safety				
Degree of surveillance along sidewalks	−0.008	0.051	−0.094	0.119
Overall perceived safety	−0.567***	−0.476***	−0.466**	−0.140
Others				
Air quality	−0.357**	−0.311**	−0.278	−0.111
Quietness	−0.277*	−0.311**	−0.110	−0.232
Overall convenience of walking	−0.406***	−0.239*	−0.468**	0.111
Objective variables measured with absolute values				
Sidewalk distance from the curb	−0.029	0.051	−0.136	0.149
Sidewalk width	−0.125	−0.084	−0.135	0.013
Building setback from the road	−0.241*	−0.281*	−0.081	−0.222
Objective binary variables (0=no, 1=yes)				
Presence of discernable slopes while walking	−0.253	−0.658**	0.462	−0.997**
Presence of sidewalk obstructions	0.368*	0.290	0.321	0.066
Presence of buffers between sidewalks and roads	0.000	0.131	−0.192	0.274
Presence of on-street parking	1.709	1.725	0.804	0.914
Presence of power lines along streets	0.351*	0.299	0.274	0.111

[a]The originally continuous poverty and Hispanic student rate variables were transformed into five ordinal categories based on percentiles, and were treated as continuous variables. Linear and binary logistic regressions were used for continuous and dichotomous outcome variables, respectively. For linear regressions, standardized beta coefficients are reported in this table.
*$p<0.05$; **$p<0.01$; ***$p<0.001$

street-level variables except the presence of slopes (negative). In other words, the street-level walkability was predicted primarily by poverty instead of by the percentage of Hispanic students. Meanwhile, at the neighborhood level, higher Hispanic student rates were associated with increased crimes, traffic volumes, and crashes from the safety perspective, and with greater sidewalk completeness, population density, and land-use mix from the walkability aspect.

Discussion and Conclusion

Several limitations of this study should be noted. First, GIS data were collected at different times from 2000 to

2007, and had different levels of accuracy from precise points to census blocks. However, the utility of GIS data for this type of research seems promising, because of their increasing availability, precision, and coverage. Second, different units of analyses were used for the neighborhood-level and the street-level measures. In the assessment of street-level conditions, only one street segment was sampled for each attendance area. Although more-extensive assessments could have strengthened this study, this was considered a reasonable approach because of (1) the homogeneity in the street environments within the individual attendance area, (2) resource limitations, and (3) the simultaneous consideration of the neighborhood-level walkability. The explicit consideration of the neighborhood-level and street-level walkability was important, as demonstrated by their potentially different roles across the neighborhoods. Third, while the field audits by researchers ensured higher internal validity, their assessment of the built environment may be different from the residents' assessment, especially for perceptual variables. This potential difference requires further attention in future research. Further, this study examined only the urban and suburban settings. Rural environments will likely present different issues to be addressed for enhancing walkability and safety. Finally, walkability of the built environment was inferred by researchers based on the previous literature instead of testing through the empirical data on walking behaviors. A follow-up study is under way that will examine the actual school travel modes and residents' environmental perceptions.

Despite these limitations, this study has added to the walkability literature and has several implications for research, practice, and policy. First, new aspects of economic and ethnic disparities were explored in terms of walkability and safety around public elementary schools in Austin TX. Schools with higher poverty rates were located closer to their students' homes but showed much worse street environments. Schools with higher percentages of Hispanic students were exposed to more dangers from traffic and crime, although their neighborhood conditions were considered more walkable based on the aggregated measures. Unsafe neighborhoods and poor street conditions may influence not only children's school travels but also their play activities and the overall physical activities of all residents. These disparities became aggravated when considering the limited access by low-income and minority populations to private automobiles and formal or paid physical activity facilities, such as parks and gyms.

By examining the relationships among different aspects of walkability and safety, this study has supplemented existing literature. Neighborhood-level and street-level walkability showed contrasting variations across the neighborhoods, and had reversed associations with the students' ethnic and economic conditions. Similarly, neighborhood-level safety and walkability appeared to have contrasting variations and thereby different impacts on walking behaviors. Street-level field audits and traffic and crime measures were important in quantifying the environmental support for walking. Future research should consider walkability and safety at multiple spatial scales, to further the understanding of their relationships and their interactive roles in promoting walking.

Finally, the findings offered some insights into the design and policy interventions that target walking-to-school behaviors. From the measurement perspective, timely support is provided for the comprehensive assessment of the environmental support for walking. Tailored strategies are warranted to account for different physical settings and populations, because fine-grained differences exist in multilevel walkability factors and traffic and crime safety. Although the provision of new, high-quality pedestrian infrastructure is important whenever possible, the improvement of dilapidated and unsafe existing facilities seems crucial for low-income, minority neighborhoods. This analysis also suggests that low-income or Hispanic children may have greater potential and needs for walking to school, because they tend to live closer to school, have more sidewalks in their neighborhoods, and may have no means to get to school other than walking. However, such potential and needs may be undermined by serious safety threats and poor street conditions, which may also compromise the health benefits of walking as physical activity.

In conclusion, economic and ethnic disparities exist in the environmental support for walking around public elementary schools in Austin TX. A high priority is warranted for future efforts to enhance the environmental support for walking in low-income, minority neighborhoods in the light of equity, mobility, and health.

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