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Factors Influencing Whether Children Walk to School

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Abstract

Few studies have evaluated multiple levels of influence simultaneously on whether children walk to school. A large cohort of 4,338 subjects from ten communities was used to identify the determinants of walking through (1) a one-level logistic regression model for individual-level variables and (2) a two-level mixed regression model for individual and school-level variables. Walking rates were positively associated with home-to-school proximity, greater age, and living in neighborhoods characterized by lower traffic density. Greater land use mix around the home was, however, associated with lower rates of walking. Rates of walking to school were also higher amongst recipients of the Free and Reduced Price Meals Program and attendees of schools with higher percentage of English language learners. Designing schools in the same neighborhood as residential districts should be an essential urban planning strategy to reduce walking distance to school. Policy interventions are needed to encourage children from higher socioeconomic status families to participate in active travel to school and to develop walking infrastructures and other measures that protect disadvantaged children.

Keywords

walking to school; Children's Health Study; multilevel analysis; landscape metrics; Los Angeles

Introduction

Overweight and obesity during childhood increase the risk for a number of adverse health conditions including type 2 diabetes (Al Mamun et al., 2009), high cholesterol levels, cardiovascular complications (Thompson et al., 2007, Siervo et al., 2012), cancer (Bracci, 2012) and unfavorable musculoskeletal conditions (Haukka et al., 2012). In 2009-2010, 17% (or 12.5 million) of U.S. children and adolescents aged 2-19 years were obese (CDC, 2010, Ogden, 2012). Childhood obesity is largely thought to result from an imbalance between energy intake (i.e., dietary patterns) and expenditure (i.e., physical activity) (Goran et al., 1998). Energy expenditure has received much attention in recent years, as evidence is accumulating for the role of physical inactivity and sedentary behavior in the onset and progression of overweight and obesity among children and adolescents (Ogden, 2012, Sothorn, 2004). Physical inactivity is itself a leading cause of disease and disability (WHO, 2004, Jarrett et al., 2012, Lee et al., 2012).

Active transportation to school, including walking, incorporates physical activity into daily routines, reduces risk of childhood obesity (Giles-Corti et al., 2003), and alleviates automobile congestion and traffic-related air and noise pollution (Cavill and Davis, 2007). Walking and biking provide a reliable and affordable form of transport for most segments of the population (Lumsdon and Tolley, 2001). Kjartan (2004) estimated that the benefits (e.g., improved health, reduced noise and air pollution) of investments in infrastructure for walking and biking are 4-5 times larger than the associated costs and concluded that such investments are more beneficial to society than automobile-related transport investments.

Panter et al. (2008) provided a framework on the decision making process around travel choices for school for children and adolescents. The framework contains four main domains of influence on active travel behavior: individual factors, those associated with the physical environment, external factors such as planning and government policies, and main moderators including age, gender and distance.

Whether children engage in active transportation to school is consistently associated with child and parent perceptions of the neighborhoods through which children walk to school or other destinations (Carver et al., 2005). Concerns about traffic volume and risks (Carlin et al., 1997), air pollution (Binns et al., 2009), harassment (Larkin, 1994), street crossings and lack of traffic lights (Timperio et al., 2004) are frequently identified as factors that negatively affect perceptions about walking to school.

Walking to school and other forms of active transportation are also associated with urban form and land-use planning (Pucher et al., 2010, Frank et al., 2007, Voorhees et al., 2010). Because of the prevalence of low density suburban development (Schlossberg et al., 2005) and associated auto-dependency, the percent of children using active transportation to school (including walking and bicycling) dropped from 42% in 1969 to about 16% in 2001 (US CDC, 2008). Policy makers and scientists suggest a variety of land use planning strategies to encourage walking, including building new sidewalks; adding more road intersections (a measure of street network connectivity) and increasing traffic signals (Boarnet et al., 2005a, Boarnet et al., 2005b); promoting more land use mix; and placing schools in areas of high

population density. Braza et al. (2004), for example, found positive correlations between higher population density, greater school size, higher number of intersections, and increased rates of walking or biking to school. Additionally, demographic factors have been identified as having an influence on walking. Cooper et al. (2003) suggested that gender played an important role in the likelihood that youth would walk to school, with boys being more likely to walk to school and also engage in physical activity after school. Evenson et al. (2003) also explored the prevalence and correlates of walking to school and found rates of walking were generally higher for older boys (in high school) who were non-white, had a lower body mass index, and had parents that were infrequently home after school. Previous studies also found that parents having inadequate income or who were in lower paid occupational categories were more likely to walk to school (Pabayo et al., 2011).

Neighborhood landscape measures used in past studies manifest basic land use mix (such as percentage residential or commercial land use) (Frank et al., 2005) but they do not employ detailed metrics that characterize various dimensions of land use configuration such as shape and diversity. We conjecture these land use configurations such as convoluted roadways might indicate disorganized built environment and could thus impact whether a child walks to school.

While these and other studies have identified several factors impacting rates at which children walk to school, little analysis has integrated the analysis of such individual-level factors, land use metrics, school-level variables, and other neighborhood characteristics simultaneously. The advantage of integrating all these factors into a single study is that when investigating the effect of one factor, other variables can control for confounding.

Our study incorporated an extensive list of factors, including novel land use configuration metrics, to develop multi-level models to identify factors that promote or inhibit walking to school in a large cohort of children.

Materials and methods

Study population

Study participants were children recruited from 13 southern California Children's Health Study (CHS) communities during the 2002-03 school year. The present study is limited to 10 of these communities that had standardized land use data available in the Los Angeles Metropolitan area. Students in participating schools were enrolled in kindergarten or first grade (5–7 years of age). Informed consent was obtained from a parent or guardian who completed a questionnaire. The study was approved by the University of Southern California Institutional Review Board. Questionnaires were completed and returned from 65% eligible children, leaving 4,338 participants in the 10 communities for analysis. More information on the study design and the spatial distribution of the communities are available from McConnell et al. (2006). The questionnaires and derived variables used for this analysis included individual, school and town-level data. Measures included baseline CHS respondent data, child physical activity, socioeconomic status, land use and built environment characteristics.

Food access around schools

We assumed access to food around the school environments might change children's or accompanying parents' behavior for walking to school (e.g., encouraging walking for buying groceries after school). We included the number of grocery stores, fast food stores and no food stores within a 500 m network buffer around schools in the analysis. The food data were acquired from the InfoUSA (Omaha, NE) dataset and the detailed description of these variables can be obtained from Jerrett et al. (2010).

Traffic density and air pollution exposure estimates

Traffic density variables were based on the California Department of Transportation Functional Class (FC) data for year 2000. Because the FC data are linked to a road network with lower positional accuracy, the annual average daily traffic (AADT) volumes were conflated to the Teleatlas road network. The link-based traffic volume data are available for freeways, highways, arterials, and some major collectors. We explored point estimates of traffic density (i.e., AADT) around each child's home using the 150 and 300 m distance buffers details of which can be found from McConnell et al. (2006) and Jerrett et al. (2010).

Exposure to air pollution was assigned using the CALifornia LINE source dispersion model (CALINE4). This model used Gaussian plume dispersion parameters with traffic data, emissions factors, and local meteorology to estimate exposure to the mixture of near-roadway pollutants at the homes of the children. It is based on a model for the incremental increase in nitrogen oxides (NO_x) above regional background levels, as previously described (Shankardass et al., 2011). We assigned exposures for freeway and non-freeway sources to the baseline address of the children.

Urban form of land use represented by landscape metrics

We adapted ecological analysis tools, used to characterize natural landscapes, for use in characterizing land use patterns. Specifically, we utilized Fragstats (McGarigal et al., 2002), a widely-used set of habitat fragmentation metrics, to characterize buffer areas surrounding children's homes and schools. In landscape ecology, these metrics delineate the spatial organization of habitat (or vegetation) patches of various types, revealing the complexities of the landscape. Individual Fragstats metrics can be calculated at different spatial scales and provide many ways for describing both land use composition and configuration. For our purposes, we looked at "habitat patches," which are areas of uniform urban land use of a particular type (e.g., residential, commercial, institutional, industrial, etc).

The Fragstats program computes a large number of metrics. We considered the following Fragstats landscape metrics in our characterization of land use configurations around children's homes and schools: land shape index (LSI); percentage of landscape in a particular use (PLAND); fractal dimension (FRAC); contiguity (CONTIG); Simpson's diversity index (SIDI), and contagion and interspersion (CONTAG).

A brief explanation of each metric is described as follows: LSI (≥ 1) measures perimeter to area ratio, or "clumpiness," of a land use. As values approach 1, the shape of land use becomes more compact (like a square). Thus, higher values indicate more convoluted

boundaries and appear less as a symmetric shape, and imply potentially less opportunity for physical activity. PLAND (≥ 0 and ≤ 100) measures landscape composition by computing the percentage of each land use “patch” in a specified buffer including percent residential, agricultural/open, governmental and institutional land uses. Values closer to 100 indicate more homogeneous land use, i.e., land use is dominated by one particular type, thus less land use diversity and mix. FRAC (≥ 1 and ≤ 2) estimates shape complexity (fragmentation) and landscape configuration. FRAC approaches 1 for shapes with very simple perimeters such as squares, and approaches 2 for shapes with highly convoluted, plane-filling perimeters. Similar to LSI, a higher value may indicate lower walkability. CONTIG (≥ 0 and ≤ 1) measures land use patch configuration in relation to the city landscape. Rather than calculating a basic least-cost distance across a landscape (which fails to account for on-the-ground barriers), contiguity describes the connectedness of individual land use patches of particular types. SIDI (≥ 0 and ≤ 1) represents the probability that any 2 pixels selected at random would be different patch types. Higher value indicates greater land use diversity and mix and, in urban design, this typically leads to better walkability. Lastly, CONTAG (≥ 0 and ≤ 100) indicates measures of contagion and interspersion. CONTAG approaches 0 when land use patches of different types are maximally disaggregated and interspersed (equal proportions of all pairwise adjacencies or the greatest land use mix). CONTAG = 100 when all land use patch types are maximally aggregated; i.e., when the landscape consists of single land use patch of one type. Lower values would be expected to predict greater walkability.

Data on land use for the 10 CHS communities were derived from land use data from the Southern California Association of Governments for 2005, including residential, agricultural and open, commercial and industrial, governmental and institutional, and transportation and communication (freeways, major roadways and railways).

Greater land use mix enables a range of land uses to be co-located in an integrated way that supports sustainable forms of transport such as public transport, walking and biking, and increases neighborhood amenity. However, for children's walking to school, we presume that the main goal is to get to school quickly and safely. We hypothesized greater land use mix represented by higher SIDI and lower CONTAG would discourage children's walking to school because those two measures indicate children have to traverse commercial, industrial and other land uses to get to school. Local streets, walking and biking routes, and services that are linked or connected enhance access within a neighborhood. By contrast, freeways, major roadways and railroads will impede walking within a neighborhood. Thus we hypothesize higher contiguity between students' home and school from the second set of roadways, which were the land use types defined in the transportation and communication category, would make active travel to school more difficult for children (i.e., less walkable).

Statistical analysis

Our research used individual-level data as the outcome measure, i.e., a binary indicator of whether a child walked to and from school. Other individual-level variables included age, sex, race-ethnicity, distance from home to school, asthma status, and parent education. These individual measures also included Fragstats landscape metrics characterizing a 500 m

buffer and traffic density in a 300 m buffer around each child's home. We used a buffer distance of 500 m because typical kindergarten and first grade children will travel up to 10-15 minutes walking distance from home (Dill, 2004, Wolch et al., 2005, Sister et al., 2009). Traffic density buffers of 300 m were based on findings from previous research that suggested that this buffer had the largest impact on obesity formation (Jerrett et al., 2010).

We also compiled school-level variables for the Fragstats landscape metrics (500 m buffer). We deviated the individual-level landscape metrics (i.e., subtracted) from corresponding school-level statistics to isolate the impact of school-proximate land use configuration, as primary schools are typically close to where students live. This was required to assess the separate effects of the environment around the school versus that of the individual.

Other school variables tested included Title I school status and the percent of children who were English learners or on the Free and Reduced Price Meals Program (referred as free lunch program hereafter) (<http://www.cde.ca.gov/ds/sh/cw/filesafdc.asp>). Title I schools were identified by the federal government under the No Child Left Behind Act of 2001 to improve the academic achievement of disadvantaged populations (Shankardass et al., 2011). The purpose of this title is to ensure that all children have a fair, equal, and significant opportunity to obtain a high-quality education and reach, at a minimum, proficiency on challenging state academic achievement standards and state academic assessments. Two types of funding are available to support academic improvement: schools with >40% of students living in poverty are eligible to combine funding from Title I with other federal, state and local funds to implement school-wide programs aiming to improve conditions for all students, while schools with lower levels of poverty can apply for funding to support specific students of concern. Therefore, this measure may represent both low academic performance and deprivation at schools.

Before modeling children's walking to school, we normalized all the ranking and continuous variables using interquartile range increments for each variable. The variables normalized included age, parental education, distance to school, traffic density, landscape metrics and school-level socioeconomic position (SEP). Interquartile range normalization makes prediction coefficients in a model comparable. We then investigated Pearson partial correlations of various groups of continuous measures and conducted chi-square tests on categorical variables to identify directions of association and collinearity, including individual-level Fragstats measures and school-level variables such as percent enrolled in the free lunch program.

Since the outcome of interest is binary, a multi-level logistic regression approach was used to model this hierarchical structure. First, we modeled whether a child walked to school, using individual-level variables of interest (one-level model). In this one-level model, we used town identifier (c) as a fixed effect and the model structure is shown in eq. (1).

$$\log it(Y_{ci}=1)=A_c+\beta_I W_{ci} \quad (1)$$

A_c is the intercept of town c and W_{ci} are the individual-level predictors in town c , such as age, sex, race-ethnicity, distance from home to school, asthma, family SEP, landscape metrics and traffic density. W_{ci} makes all the W variables have a within-town c effect.

Then we extended the one-level model to include school-level predictors as a two-level mixed model. To account for possible non-independence in risk factors for children attending the same school, we included school identifiers (s) as a random effect. Again, we used town identifier (c) as a fixed effect. The model is shown in eq. (2).

$$\text{logit}(Y_{csi}=1)=A_c+\beta_1 W_{csi}+\beta_2 W_{cs}+e_s \quad (2)$$

W_{cs} are the school-level predictors, and like individual-level predictors W_{csi} , both of them have a within-town c effect. W_{cs} includes Fragstats land use metrics, distance to grocery and fast food stores, and percent children enrolled in the free lunch program. e_s is the school-level error term. Other variables have the same definition as in eq. (1).

To identify significant predictors of whether children walked to school, we first used bivariate analysis to identify factors with a significance level of 0.15 (Hosmer et al., 2008). We then proceeded with an individual-level automatic logistic regression model to identify the individual factors associated with walking to school. Only individual-level factors significant at the 0.15 level from bivariate analysis were selected for inclusion in the automatic stepwise logistic regression model. Variables significant at the 0.05 level in the multiple regression were included in the final model. Race-ethnicity, age, gender and town fixed effect were included in every model. Similar to the individual-level model, the two-level model used only variables significant at the 0.15 level and the variables maintained in the model were required to be significant at the 0.05 level in the final models. However, the variables in the two-level model were manually selected by adding one at a time in a manual forward selection that began with the most significant variable. Research also suggests potential modifiers of relationship with school transport (Wong et al., 2011). To understand how individual and environmental correlates interact with each other, we investigated interactions between race-ethnicity and other individual and school level variables and, between education and the same variables used for interaction with race-ethnicity. We also conducted a sensitivity analysis, treating town identifiers as a random effect and compared coefficients with models using town identifiers as a fixed effect. The models were developed using SAS 9.2 TS Level 2M0 (SAS Institute Inc., Cary, NC) on a Windows XP Professional platform (Microsoft, Redmond, WA).

Results

Descriptive statistics

Descriptive statistics for individual and school-level variables are listed in Table 1. For the children surveyed in the 10 communities, 20.2% walked to school. Participants were on average 6.6 years of age, with more than 90% of the students between 6 and 7. Over half (52.2%) of the participants were Hispanic, 30.3% were non-Hispanic white, and Asian and

African-American constituted 3.5% and 4.5% of the study sample, respectively. Mean home-to-school distance was 1.7 miles and the median distance was 0.9 miles.

At the school level, there were 0.5 grocery stores and 1.5 fast food stores within 500 m of a school on average, but about half (50.8 %) of all the schools did not have food stores within the 500 m buffer. Schools tended to be located in residential areas with 73.2% land in school buffers classified to residential uses. About 41.5 % of schools were Title I schools and 48.6 % of students in the study were enrolled in the free lunch program.

Partial correlations controlling for town of residence between individual-level Fragstats metrics showed moderate associations, with Pearson's correlation coefficients typically less than 0.40. There were, however, two exceptions: percent agricultural/open land use ($R=-0.51$, $p<0.01$) and Simpson's diversity index ($R=-0.77$, $p<0.01$) had higher correlations with percent residential land use. Partial correlations between school-level factors revealed that the share of children eligible for the free lunch program was highly correlated with percent English learners ($R=0.65$, $p<0.01$) and whether a school was a Title I school ($R=0.72$, $p<0.01$). Chi-square tests identifying a relationship between race-ethnicity and walking to school indicated that both Hispanic and Other race category children (race-ethnicity other than White, Asian, African American and Hispanic) were significantly associated with walking to school; while African American and Asian children were not significantly related to walking to school.

Individual-level logistic regression modeling

In the individual level model, we included all the race-ethnic variables other than non-Hispanic Whites in a single model. Table 2 lists those individual-level variables significant (except for race-ethnicity category) in predicting whether a child walked to school. Results indicated that gender was not a significant factor but age was important: with one interquartile range increase, the odds of walking increase of by 1.3 times. Children with more educated parents were, in contrast, less likely to walk ($OR = 0.68$; 95% $CI = 0.56-0.82$), as were children with asthma ($OR = 0.72$; 95% $CI = 0.55-0.94$). Children living further away from their school were less likely to walk: with one interquartile range increase of a distance category, there was a large decrease in walking ($OR = 0.17$; 95% $CI = 0.15-0.20$). Greater traffic density was negatively associated with walking to school (for buffer distance 300m IQR exposure increment; $OR = 0.94$; 95% $CI = 0.89-0.99$). Based on Fragstats landscape metrics, higher contiguity (i.e., connectivity) scores were also associated with lower odds of walking to school ($OR = 0.81$; 95% $CI = 0.71-0.92$). Children living in areas characterized by residential land use ($OR = 1.24$; 95% $CI = 1.09-1.40$), and government or institutional land use ($OR = 1.38$, 95% $CI = 1.27-1.49$), were more likely to walk to school. Decreased land use mix, represented by greater contagion index, was positively associated with walking to school ($OR = 1.31$; 95% $CI = 1.17-1.46$).

The model parameters and statistics are displayed in Table 3 for the individual-level model selected from the variables identified in Table 2 as likely predictors. Based on the prediction model, the age, gender and race-ethnicity variables had similar relationships as shown in bivariate analysis (Table 2). Children whose parents had more education were less likely to walk to school ($OR = 0.88$; 95% $CI = 0.79-0.99$). In terms of environmental variables,

children who lived closer to school (OR = 0.11; 95% CI = 0.09-0.14), in areas of lower traffic density (OR = 0.93; 95% CI = 0.87-0.99), and in neighborhoods with lower land use contagion (i.e., with less mixed land use) (OR = 1.33; 95% CI = 1.14-1.55), lower contiguity (i.e., less influence from highways, major roadways or railroads) (OR = 0.82; 95% CI = 0.68-0.98), and more government/institutional land uses (OR = 1.16; 95% CI = 1.03-1.29), were more likely to walk.

We tested whether the age effect was different across genders by including age, gender and their interaction in the individual-level model. The p-value for the age by gender interaction was 0.77, demonstrating that the age effect was not modified by gender. We also tested the individual-level model by removing socioeconomic variables (e.g., parental education) and found that all the variables remained significant and signs of association were not changed. This demonstrates that socioeconomic positions did not confound other individual-level variables, such as race, that were maintained in the model.

Two-level mixed regression model

Similar to the bivariate analysis described at the individual level, the bivariate analysis was also conducted for the school-level variables before the two-level mixed model was tested (Table 2). We found that greater ethnic diversity (OR = 0.50; 95% CI = 0.32-0.78) was negatively associated with the likelihood that children would walk to school. In contrast, higher percentages of English learners (OR = 2.18; 95% CI = 1.23-3.87) and students enrolled in free lunch program (OR = 3.66; 95% CI = 1.64-8.21) were positively associated with walking to school. By contrast, the presence or absence of food stores around the schools and school level landscape metrics did not have significant impacts on children's walking to school.

Similar to the individual-level logistic model, in the two-level model individual-level race-ethnicity, age and gender variables were forced into the model but other variables were required to have a significance level of 0.05. The final parameters and statistics of the two-level mixed model are displayed in Table 4.

Like the one-level logistic model, children who were older (OR = 1.38; 95% CI = 1.17-1.64) or lived a shorter distance (OR = 0.17; 95% CI = 0.09-0.15) from school were more apt to walk, as were children living in neighborhoods with lower traffic density (OR = 0.91; 95% CI = 0.85-0.97) and greater proportions of government and institutional land uses (OR = 1.24; 95% CI = 1.09-1.40). Asian children were still less likely to walk to school and rates for non-Hispanic African American and Hispanic children were statistically indistinguishable from non-Hispanic Whites ($p > 0.2$); additionally, the Other race-ethnicity was also not significant ($p > 0.1$). Lower land use mix (represented by greater contagion index) was positively associated with walking to school (OR = 1.20; 95% CI = 1.04-1.39). In addition, we found that children in schools with higher shares of students enrolled in the free lunch program were significantly more likely to walk to school: with one interquartile range increase of percent students in free lunch programs, there was more than a two-fold increase in propensity of walking. For all the significant predictors other than race-ethnicity, distance had the greatest impact on walkability, followed by schools with higher free lunch ratios and age of students.

The p-values for race-ethnicity in interaction with education, traffic density, urban land use metrics, and % English language learners in a school were not significant for all ($p>0.05$), demonstrating that the race-ethnicity effect was not modified by other individual and school level factors. By contrast, the p-values for interaction between parental education and % English language learners in a school, land use contagion index and % government and institutional land use were significant ($p<0.05$). In the models without interaction terms, children of higher parental education were associated with being less likely to walk to school. Schools with greater percentages of English language learners were associated with greater likelihood of children walking to school. The interaction of parental education with % English language learners had a significant but negative impact on walking to school, demonstrating parental education had relatively larger impact on walking to school. Parental education also showed a greater effect compared to % government and institutional land use in their interaction model. In the main effects model alone, lower land use mix (represented by high contagion index) was associated with greater potential for walking to school. The interaction of parental education with the contagion index had a significant positive impact on walking to school, demonstrating urban forms with lower land use mix had a relatively larger impact compared to parental education on walking to school.

Discussion

In this study, we modeled the factors that influence whether children walk to school for a cohort of 4338 children aged 5-7 years from the southern California's Children Health Study. Urban landscape metrics derived from Fragstats, such as contiguity, contagion and diversity indices, were used to reflect the influence of the neighborhood land use configuration on children's propensity to walk to school. By adding levels of analysis and including additional variables of interest, this study provides the first analysis of children's active transportation – in this case, walking to school – with multilevel control for confounding.

Not surprisingly, and consistent with other research, we found that as distance from home to school increased, the likelihood of walking to school decreased (Wen et al., 2008). Martin and Carlson (2005) also demonstrated that distance to school was the most important barrier for walking to school: the same research conclusion was supported in our one and two level models. Our research, which included an objective measure of traffic density, confirmed that students in neighborhoods of greater traffic density were associated with lower probability of walking to school (Cole et al., 2007, Giles-Corti et al., 2011). For example Giles-Corti et al. (2011), who used road category as proxy for traffic volume, found walking to school was more frequent among children attending schools in neighborhoods of low traffic volume.

Previous studies found boys were more active and more likely to walk to school than girls (Marten and Olds, 2004, Johnson et al., 2010). In our study, though the association was positive for boys, it was not significant ($p>0.2$). We also found there was no gender specific age effect, and the age effect was not modified by gender. This may be because the majority of the children in our study were quite young (>90% were between 6-7 years old). Gender differences at this age may not yet be large enough to be significant in influencing children's walking to school rates. Carlin et al. (1997) also found little evidence in overall walking

levels between boys and girls in their study of 6 and 9 year old children. Our research did, however, demonstrate that older children had a greater propensity to walk to school, consistent with other research findings that as children get older, the likelihood of using active transportation to school increases (Pabayo et al., 2011).

Some research indicated higher street connectivity (measured in our study by the landscape contiguity index) was associated with greater rates of children walking to school (Giles-Corti et al., 2011). Though it is true that connected street networks provide more direct routes to school, these direct routes are only effective for promoting walking if they are local streets, walking or biking routes. If the connectivity was mainly based on highways, major roadways or railroads, which is the case in our study, higher connectivity would impede walking to school. Timperio et al. (2006) also found that street connectivity was negatively associated with active commuting to school, and this may be because connected street networks had the potential for more traffic, higher speeds, and more street crossings (Sirard and Slater, 2008). Each of these factors increases the risk of pedestrian injury. This is consistent with findings from Martin and Carlson (2005), who found perceived traffic-related danger was the second greatest barrier for walking to school.

Our one-level logistic regression model also found that greater residential land uses and higher governmental and institutional compositions were associated with a greater probability of walking. Residential areas with some government and/or institutional land uses (for example, police and fire stations, other schools, recreation centers, etc.) might be associated with greater perceived safety and more developed pedestrian infrastructure, such as sidewalks and street crossings, which promote walking to school.

Urban form relates to travel patterns primarily by impacting proximity between origins and destinations and among destinations, and directness of travel (i.e., connectivity). Smart growth planning approaches emphasize higher density urban development with a high level of land use mix (Sallis et al., 2004, Frank and Engelke, 2001). High density urban design reduces travel distances, making active transport more convenient. Although our analysis linked shorter distance to school and higher population density with higher propensity to walk to school, we also found that greater land use mix, represented by greater landscape diversity and lower contagion/interspersion, was negatively associated with children's walking to school. This may be because walking to school is the only goal for these young children, and more complex landscape diversity may be a barrier for direct walking. For example, greater landscape diversity could reflect more people on the streets or a more disorganized built environment, leading parents to steer their children away from walking to school. Increasing land use mix could thus form barriers that impede children's active transport to school. The non-significant association of food stores also suggests that accompanying parents were not impacted by the food stores on the routes. In contrast, for adults whose destinations include work, grocery shopping, visiting friends or other activities, greater land use mix could mean that daily activities are within convenient distances for walking.

When the analysis was extended to two levels with school-level variables factored in, we found schools with greater percentage of enrollees in the Free and Reduced Price Meals

Program had greater probability of children walking to school. In California, children from a family of four with an annual income less than 185% (i.e., \$42,643) of the federal poverty levels qualify for reduced price meals and those with an annual income less than 130% federal poverty level (i.e., \$29,965) qualify for free lunch programs (USDA, 2012). This is consistent with our finding that lower parental socioeconomic status was linked to higher walking rates. Pabayo et al. (2011) also found that students whose parents had inadequate income or were in lower paid occupational categories were more likely to walk to school.

Some research found no difference from children in overall physical activity for active and non-active commuting to school (Ford et al., 2007, Metcalf et al., 2004, Sleaf and Warburton, 1993). However, there is also new evidence of increased overall physical activity with active travel to school (Cooper et al., 2012, Murtagh and Murphy, 2011, Roth et al., 2012, Sahlqvist et al., 2012, van Sluijs et al., 2009). Like most walk to school studies, we do not have the physical activity data to assess this directly; however, based on the new evidence, increasing participation in active travel to school or improving environment for such activity might be a useful strategy to increase overall physical activity.

Although the study area is confined to the Los Angeles Metropolitan region, as we have documented elsewhere (Wolch et al., 2011), the study communities vary considerably in size, social characteristics, urban form, and environmental characteristics. Substantial variations are also evident in racial composition, household income, crime, poverty, and unemployment rates. The communities range from low-density suburbs to high density, older cities. In terms of climate, the inland areas tend to experience extreme heat, while those near the coast have a more temperate Mediterranean climate. While the focus on Los Angeles limits generalizability, the types of communities represent the broad range observed in many places, and the racial-ethnic variation is also observed in many other American cities, particularly in California.

Conclusion

Understanding the factors that influence active transportation may support interventions that increase rates of walking to school, and in turn might promote children's physical activity. Among the large cohort of students who participated in our research, 20.2% walked to school, a number higher than reported in most studies.

Distance to school is a significant barrier to walking, as is landscape diversity. The interaction of education with land use mix showed that land use mix had even greater effect modification than parental education on children's walking to school. Thus the availability of neighborhood schools located in residential districts and balanced land use mix may be an essential urban planning strategy if the goal is to promote active travel to school and subsequent possible increase of overall physical activity among children. More research is needed to understand precisely what type of land use diversity is a barrier to walking to school, as this could facilitate the development of strategies for dealing with this issue. We also found that socioeconomic status matters: children from higher income families were less likely to walk to school. The interaction models also showed parental education had a larger effect modification than school student composition with respect to English language

learners and also by presence of governmental and institutional land use. Schools and communities may therefore choose to develop active travel strategies designed to increase rates of walking to school among children in higher socioeconomic status families.

Although children from low-income communities faced greater environmental and safety concerns yet were more apt to walk to school. Among the 10 communities we surveyed, with schools having less than 20% of students enrolled in the free lunch program, the walking rate was 13.3%; however, in schools with more than 80% of students enrolled in the free lunch program, the walking rate was 54.9%. Since the less advantaged communities had higher rates of children walking to school, attention to safety is particularly important so those children are not injured on their way to school. These safety measures include arranging for road crossing guards, designing under- or over-passes at high traffic intersections, constructing pedestrian routes such as redesigned back alley networks, creating or widening sidewalks and narrowing streets, and introducing traffic calming infrastructure. Overall, placing schools in residential areas and developing safe routes and social marketing strategies will shorten distances traveled and reduce safety concerns, and in the end encourage children from both high and low income families to be active in walking to school.

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Table 1
Descriptive statistics of individual and school-level variables for walking to school analysis

Variable Name	Percent	Mean	Std Dev
Individual Level [§]			
Rate of walking to school (%)	20.2		
Male (1=male, 0=other)	51.8		
Age		6.6	0.7
Asthma status (1= asthma, 0=other)	15.1		
Parent education (category) [†]	Category 1-5		
Distance to school (mile)		1.7	3.3
Distance to school (mile)		1.7	3.3
Total population within 200 m buffer		289	266
Total population within 500 m buffer		1728	1485
Total population within 1000 m buffer		6452	5339
NO _x freeway and non-freeway (ppb)		22.9	20.4
NO _x freeway (ppb)		15.2	17.4
NO _x non-freeway (ppb)		7.7	6.5
Traffic density in 150 m buffer (AADT)		48.5	108.5
Traffic density in 300 m buffer (AADT)		56.7	105.4
# days of sports in a week		4.2	2.3
# days of team sports in a week		0.6	0.9
Contagion index (500 m buffer)		58.9	15.4
Contiguity index (500 m buffer)		0.2	0.08
Fractal dimension index (500 m buffer)		1.2	0.07
Land shape index (500 m buffer)		2.2	0.9
Percent residential (500 m buffer)	68.0		18.0
Percent agriculture & open (500 m buffer)	12.9		15.5
Percent government & institutional (500 m buffer)	4.5		5.6
Percent other land use (500 m buffer)	14.5		14.3
Simpson's diversity index (500 m buffer)		0.4	0.2
School Level			
# grocery stores around school (500 m buffer)		0.5	0.9
# fast food stores around school (500 m buffer)		1.5	2.0
No food stores around school (%) (500m buffer)	50.8		50.0
Contagion index (500 m buffer)		64.7	7.4
Contiguity index (500 m buffer)		0.2	0.07
Fractal dimension index (500 m buffer)		1.2	0.03
Land shape index (500 m buffer)		2.1	0.7
Percent residential (500 m buffer)	73.2		15.3

Variable Name	Percent	Mean	Std Dev
Percent agriculture & open (500 m buffer)	8.5		10.8
Percent government & institutional (500 m buffer)	8.7		5.1
Percent other land use (500 m buffer)	9.7		10.6
Simpson's diversity index (500 m buffer)		0.4	0.2
Title one school (1=title one, 2=not title one)	41.5		49.3
Percent English learners	21.6		21.4
Percent Free and Reduced Price Meals Program	48.6		29.9
Ethnicity diversity index		36.1	12.7

^ζFor minority composition, this study includes 52.2% Hispanic, 4.5% Black, 3.5% Asian and others other than non-Hispanic White 9.5%.

[†]For parent education, 1=less than 12th grade with 21.9% of the study subjects; 2=12th grade with 20.3%; 3=some college with 37.9%; 4=4-yr college with 10.9%; 5=post-grade school with 8.9%.

Table 2
Variables significant at the 0.15 level in encouraging (+) or discouraging (-) children walking to school from bivariate analysis[†]

Parameter	Odds Ratio	95% Confidence Interval	Sig.
Parent education	0.68	0.56	0.82 <.01
Asthma status	0.72	0.55	0.94 0.02
Age	1.30	1.14	1.49 <.01
Gender (male = 1)	1.04	0.88	1.23 0.65
Asian	0.47	0.28	0.80 <.01
Black	0.80	0.52	1.22 0.29
Hispanic	1.06	0.85	1.33 0.59
Other	1.52	1.06	2.19 0.02
Distance to school (category) [‡]	0.17	0.15	0.20 <.01
Traffic density (150m buffer) (AADT)	0.96	0.92	1.00 0.06
Traffic density (300m buffer) (AADT)	0.94	0.89	0.99 0.02
Contagion index [‡]	1.31	1.17	1.46 <.01
Contiguity index [‡]	0.81	0.71	0.92 <.01
Percent residential land use [‡]	1.24	1.09	1.40 <.01
Percent agriculture & open [‡]	0.75	0.68	0.83 <.01
Percent government & institutional [‡]	1.38	1.27	1.49 <.01
Simpson's diversity index [‡]	0.91	0.80	1.03 0.14
Contiguity index [‡]	1.44	0.91	2.27 0.13
Percent English learners	2.18	1.23	3.87 0.01
Percent Free and Reduced Price Meals Program	3.66	1.64	8.21 <.01
Ethnicity diversity index	0.50	0.32	0.79 0.01

[†] Asian, African American, Hispanic and Other race-ethnicity (not including non-Hispanic Whites) variables were included in one model to assess the race-ethnicity effect on children's potential for walking to school. Town ID was used as a fixed effect. All the variables other than race-ethnicity, gender and asthma status were normalized using corresponding interquartile range.

[‡] The continuous distance to school variable was first classified into 5 distance categories before normalization. Distance categories: 1: <= 0.25 mi; 2: (0.25 – 0.50); 3: (0.50 – 1.00); 4: (1.00 – 3.00); 5: > 3 mi.

[‡] The landscape metrics had a buffer distance of 500 m and when at individual level, they were deviated from corresponding school level statistics.

Table 3
Multiple logistic regression modeling results of whether children walk to school using individual-level variables from Table 2[†]

Parameter	Odds Ratio	95% Confidence Interval	Sig.
Constant	1.08	0.33 3.58	0.90
Asian	0.46	0.24 0.90	0.02
Black	0.96	0.54 1.72	0.90
Hispanic	0.97	0.73 1.29	0.85
Others	1.41	0.87 2.27	0.17
Male	1.18	0.95 1.47	0.14
Age	1.34	1.13 1.60	<0.01
Parent education	0.88	0.79 0.99	0.03
Distance to school (category)	0.11	0.09 0.14	<0.01
Traffic density (300m buffer) (AADT)	0.93	0.87 0.99	0.03
Contagion index [‡]	1.33	1.14 1.55	<0.01
Contiguity index [‡]	0.82	0.68 0.98	0.03
Percent government & institutional [‡]	1.16	1.03 1.29	0.01

[†]The model used town indicator as a fixed effect, and the age, gender and race variables were always included; however, other variables were required to have a significance level of 0.05 for inclusion. All the variables other than race-ethnicity and gender were normalized using corresponding interquartile range.

[‡]Variable had a buffer distance of 500 m and was deviated from corresponding school level statistics.

Table 4

Two-level mixed multiple regression model on whether children walk to school*.

Parameter	Odds Ratio	95% Confidence Interval		Sig.
Constant	0.79	0.17	3.68	0.77
Asian	0.43	0.22	0.83	0.01
Black	0.75	0.43	1.32	0.32
Hispanic	0.94	0.71	1.24	0.64
Others	1.44	0.91	2.27	0.12
Male	1.13	0.91	1.39	0.27
Age	1.38	1.17	1.64	<0.01
Distance to school (category)	0.12	0.09	0.15	<0.01
Traffic density (300m buffer) (AADT)	0.91	0.85	0.97	<0.01
Contagion index (500m buffer) ^ζ	1.20	1.04	1.39	0.02
Percent government & institutional (500m buffer) ^ζ	1.24	1.09	1.40	<.01
Percent Free and Reduced Price Meals Program [‡]	2.06	1.06	4.03	0.05

* School identifier was used as a random effect while town identifier was used as a fixed effect. Individual-level age, gender and race variables were maintained in the model but other variables were required to have a significance level of 0.05 for inclusion. All the variables other than race-ethnicity and gender were normalized using corresponding interquartile range.

^ζ Individual-level variable with values deviated from school-level statistics.

[‡] School-level variable.