Estimating the Proportion of Children Who Can Walk to School

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Background: Walking to school can be an important contributor to the daily physical activity of children. However, little is known about the percentage of children who could reasonably be expected to walk to school. The purpose of this study was to estimate the percentage of children in Georgia who live within a safe and reasonable walking distance from school and to identify demographic, school, and neighborhood connectivity characteristics associated with the potential to walk to school.

Methods: Geographic information systems techniques were used to estimate the number of school-age children living 1 mile and 0.5 mile from public schools in Georgia. Potential walkers were estimated by dividing the number of children living in the specified distances from school in the 2000 U.S. Census by the number of children enrolled at the school in the 1999–2000 school year. Safety parameters were based on posted speed limits.

Results: The percentage of potential walkers ranged from 1% to 51% depending on grade group and parameters of distance and safety. Using preferred parameters of distance and safety we estimated that 6% of elementary school students (K–5), 11% of middle school students (6 to 8), and 6% of high school students could walk to school. High population density, small enrollment size, and high street connectivity were associated with higher percentages of potential walkers.

Conclusions: While few children could reasonably be expected to walk, this does not reduce the value of walking to school. Increasing the percentage of students who walk will require both educational efforts and changes to the built environment.

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Introduction

Designing and constructing neighborhoods where residents can easily engage in active transportation has a broad range of benefits for the entire population. The potential benefits of children walking to school have received special attention. Most,[1–5] but not all,[6] studies comparing children who walk to school with children who are driven report that the walkers are more fit or physically active. Other research suggests that children walking rather than being driven to school reduces traffic and air pollution,[7] and encourages social interaction and communication.[8–10] The Institute of Medicine's report on childhood obesity recommends that communities provide safe pedestrian routes to school and encourage children and youth to use them.[11] *Healthy People 2010* recommends that more children and youth walk to school more frequently and sets an objective of 50% of trips for children living within a mile of school.[12]

Despite these benefits and recommendations, relatively few children and youth in the United States walk to school. National estimates generally range around 14% to 19%,[13–16] state and local estimates from 4% to 20%.[17–20] These current percentages stand in contrast with 35 years ago when an estimated 42% of all children walked or bicycled to school.[21] Both parental concerns and neighborhood walkability influence the proportion of children who walk to school.[22] The most commonly reported reason why children in the U.S. do not walk to school is the distance to school, reported by 62% of parents, followed by traffic-related danger (30%), weather (19%), crime (12%), school policy (6%), and other (15%).[14]

National programs such as the U.S. Department of Transportation's Safe Routes to School Program and the Center for Disease Control and Prevention's Nutrition and Physical Activity Program to Prevent Obesity and Other Chronic Diseases are devoted in full or in

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part to increasing the percentage of children who walk to school. Early evidence suggests that walking promotion programs and environmental modifications can increase the proportion of children who walk to school.[20,23] Presently, in Georgia, as in other states, the Georgia Department of Transportation, Georgia Department of Human Resources, and other state and local organizations are taking steps to encourage and facilitate walking and biking to school.

Unknown, however, is the percentage of children who live within a safe and reasonable walking distance from school. That percentage needs to be known in order to develop and implement the most sensible programs and evaluations, to set appropriate objectives, and to place estimates of the percentage of children who walk to school into proper context. The following study was performed to provide such an estimate.

Methods

Overview

The purpose of the study was to estimate the proportion of Georgia children in early elementary school (grades K–2), late elementary school (grades 3 to 5), middle school (grades 6 to 8), and high school (grade 9 only) who lived within a reasonable and safe walking distance from their neighborhood public school. Grade-specific enrollment of public schools in the 1999–2000 school year provided by the Georgia Department of Education was used to estimate the denominator. The numerator was estimated by using demographic information collected in the 2000 U.S. Census. Information about the type and location of schools came from the Georgia Department of Education.

School Location

The Georgia Department of Education provided addresses and contact information for all 1887 public schools. Using ArcGIS, version 9 (Earth Systems Research Institute, Redlands CA, 2006) and the Georgia TIGER/Line® 2004 file, 1170 (62%) schools were address matched. The location of the remaining 717 (38%) schools was verified by telephone calls to schools, Internet-based mapping sites, and aerial photo interpretation. During the manual verification of the positional accuracy of all 1887 schools, 257 (22%) of the 1170 originally matched schools were relocated because the original mapping was found to be >500 feet from the actual school location. After verification, the location of each school was set at the point of the school's main entrance, usually where school buses enter and exit the premises.

Inclusion Criteria for Schools

The focus of the project was on schools that were primarily neighborhood schools. Therefore, 128 schools whose names suggested that the school was not a neighborhood school such as special education, night, magnet, and vocational were excluded. An additional 13 schools with less than seven students per grade in the pertinent grades and six schools with unusual grade groupings, such as kindergarten only and grades 2 and 3 only, were excluded as well. The final analysis included 1060 schools with early elementary grades (K–2), 1052 schools with late elementary grades (3 to 5), 413 middle schools, and 284 high schools. Most elementary schools were included in assessments for both early elementary grades and late elementary grades because they included at least two grades in each grouping.

Walkable Areas or Pedestrian Catchment Areas

Eight pedestrian catchment areas were drawn for each school using standard geographic information system (GIS) techniques. Two pedestrian catchment areas (PCAs) were circles with a 1-mile and a 0.5-mile radius from the school's main entrance (radial PCAs). Two PCAs were irregular polygons representing the land areas from which students could reach school traveling along the existing street network for no more than 1-mile or 0.5-half mile (street network PCAs). Two PCAs were irregular polygons representing the land areas from which students could reach school using only streets with speed limits ≤35 mph and traveling no more than 1 mile or 0.5 mile (35-mph PCAs). The final two PCAs were irregular polygons including only streets with speed limits ≤25 mph and students traveling no more than 1 mile or 0.5 mile (25-mph PCAs). Posted speed limits were used as a proxy for safety because of the correlation between lower posted speed limits and reduced pedestrian fatality and injury rates.[24]

Potential Walkers

The estimated number of potential walkers for each school, grade group, and PCA were developed using single-age population estimates from 2000 census-block data. Population estimates for block groups not fully contained within the PCA were calculated using area-weighted proportionate analysis. The fraction of the census block within the PCA was calculated and the population, assumed to be evenly distributed throughout the census block, was multiplied by that fraction. The population estimates from these partially contained census blocks were added to the population of the fully contained census blocks to obtain the population counts within each PCA.

Students in a specific grade are not all the same calendar age. To estimate the total number of children in a given PCA who would be in early elementary grades, the estimated number of children aged 5 to 7 was summed together. Similarly, to estimate the number of children in late elementary grades and middle school, the number of children aged 8 to 10 and 11 to 13 was summed together, respectively. The percentage of high school students who could walk to and from school was estimated using enrollment data for 9th grade only because only about 60% of Georgia ninth-grade students graduate from high school.[25] The number of potential walkers in the ninth grade was estimated by summing the number of children aged 13 to 15 years in the PCA and dividing by 3.

Grade Enrollment

School- and grade-specific enrollment data for the 1999–2000 school year were provided by the Georgia Department of Education. If a school included only two of the three pertinent grades (e.g., only grades 6 and 7), the number of potential walkers was adjusted accordingly (i.e., multiplied by two thirds).

Calculations

For a given PCA and grade group, the estimated fraction of children who could walk to school was the number of children in a given age group (e.g., ages 5 to 7) living within the PCA divided by the number of children enrolled in the corresponding grades for that school (e.g., grades K through 2). For some PCA and school-grade groups, the number of potential walkers exceeded the number of enrollees. Most of these schools were elementary schools in such close proximity to another elementary school that they shared portions of their PCAs. When this occurred, the number of potential walkers was set to equal the enrollment for the corresponding grade group, making the estimated percentage of potential walkers 100% for that grade group at that school.

Potential walker estimates were made at the student and school levels. For students the overall percentage of potential walkers for each type of PCA was calculated by summing the potential walkers of a given age group and dividing by the sum of enrollees in the corresponding grade group for all schools in the analysis. In the school-level analysis, schools were categorized into those with ≥30% estimated potential walkers and those with <30%.

Regression Analysis

To identify characteristics of schools with high percentages of potential walkers, a multivariate linear regression analysis was performed for each grade group. Independent variables in the analysis included school enrollment, demographic information, and measures of neighborhood connectivity. For school enrollment, enrollment for the grade group was used. Population density (total population per square mile), median household income, percentage of non-white residents (total population), percentage of housing built before 1950, and urbanization classification for each school developed by the National Center for Education Statistics (urban, suburban, town, and rural)[26] were used for demographic variables. For each PCA, the area-weighting proportionate analysis technique was used for all variables except median household income and urbanization classification. The median household income was calculated by averaging the median household income of all block groups within or partially within the PCA. Street density (street length/PCA area in square miles), intersection density (three- to five-way intersections/street length in miles), ratio of three- to five-way intersections to three- to five-way intersections plus cul-de-sacs, and ratio of street network PCA area to radial PCA area were used for connectivity variables. The ratio of street network PCA area to radial PCA area represents the land area from which students could reach school traveling 1 mile along the existing street network divided by the area with a 1-mile radius (Figure 1). Neighborhoods with a high ratio of street network to radial PCA area tend to have more gridded street patterns and fewer cul-de-sacs.

To better meet the assumptions of linear regression, all variables were log transformed except for metropolitan statistical area (MSA) classification, intersection density, and ratio of three- to five-way intersections to three- to five-way intersections plus cul-de-sacs. Independent variables were first tested in bivariate analysis to determine if they were associated with the dependent variable. Variables significantly associated with the dependent variable ($p<0.05$) were entered into the multivariate linear regression model. Backward stepwise regression was used to identify variables significantly associated with the dependent variable. Exploratory data analysis and regression modeling were performed using SAS, version 9.1 (SAS Institute Inc., Cary NC, 2006).

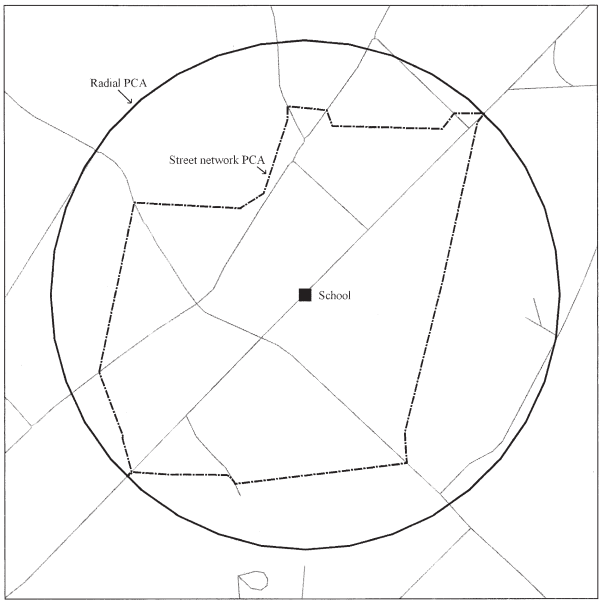

Figure 1. 1-mile radial and 1-mile street network pedestrian catchment areas for an elementary school in Georgia.

Assumed Preferences

For this article, the assumed PCA preferences for students in grades K-5 require them to walk no farther than 0.5 mile along streets with speed limits ≤25 mph. For students in grades 6 to 9, the preferred PCA requires them to walk no farther than 1 mile along streets with speed limits ≤35 mph.

Results

Student Estimates

The estimated percentage of students in Georgia who, in 2000, could walk to school varied substantially by grade and type of pedestrian catchment area (PCA) ranging from 51% for early and late elementary school students using a PCA with a 1-mile radius and no other restrictions to 1% for high school students using a PCA with a 0.5-mile distance along streets with speed limits ≤25 mph (Table 1). Using the preferred PCA definitions of 0.5 mile along streets with speed limits ≤25 mph for elementary school students and 1 mile along streets with speed limits ≤35 mph for middle and high school students, the estimated percentage of students who could walk to school were 6% for early and late elementary school students, 11% for middle school students, and 6% for high school students.

School Estimates

The estimated proportion of schools to which ≥30% of enrolled students could walk also varied substantially by

Table 1. Percent of children in public schools who are potential walkers by grade and definition of potential walker, Georgia, 2000

	Grade			
Definition of potential walker	**Grades K–2 (n=329,921)**	**Grades 3–5 (n=330,791)**	**Grades 6–8 (n=304,870)**	**Grade 9[a] (n=108,390)**
≤1 mile				
Radius from school	51	51	23	13
Via street network	30	31	12	7
Via street network using only streets with speed limit ≤35 mph	29	29	11[b]	6[b]
Via street network using only streets with speed limit ≤25 mph	19	19	7	4
≤½ mile				
Radius from school	19	19	7	4
Via street network	9	9	3	2
Via street network using only streets with speed limit ≤35 mph	8	9	3	2
Via street network using only streets with speed limit ≤25 mph	6[b]	6[b]	2	1

[a]Analysis restricted to 9th-grade students due to the large number of dropouts from grades 10 through 12.
[b]Preferred safety and distance parameters for grade group.

grade and type of PCA, ranging from 63% for early and late elementary school students using a PCA with a 1-mile radius and no other restrictions to 0% for high school students using all half-mile PCAs (Table 2). Using the preferred PCA definitions for safety and distance, ≥30% of enrolled students could walk to school at only 5% of schools with early elementary grades, 6% of schools with late elementary grades, 13% of middle schools, and 2% of high schools.

Regression Analysis

Schools with a higher proportion of walkers were characterized by high population density, low school enrollment, and high ratio of street network PCA to radial PCA area (Table 3). All ten demographic, school, and connectivity measures were associated with higher proportion of potential walkers for one or more grade groupings. However, the contribution of population density, school enrollment, and ratio of street network to radial PCA area as measured by partial R^2 values was ≥10-fold larger than the contribution of the other variables to the elementary and middle school models. For high schools, school enrollment was not associated with higher proportion of potential walkers, and the contribution of population density and ratio of street network to radial PCA were three-fold or greater than the contribution of other variables in the model.

Table 2. Percent of public schools where ≥30% of students are potential walkers by school level and definition of potential walker, Georgia, 2000

	School level			
Definition of potential walker	**Early elementary (n=1060)[a]**	**Late elementary (n=1052)[a]**	**Middle school (n=413)[a]**	**High school (n=284)[a]**
≤1 mile				
Radius from school	63	63	29	10
Via street network	43	43	14	2
Via street network using only streets with speed limit ≤35 mph	41	41	13[b]	2[b]
Via street network using only streets with speed limit ≤25 mph	27	28	7	<1
≤½ mile				
Radius from school	25	26	5	0
Via street network	8	10	2	0
Via street network using only streets with speed limit ≤35 mph	8	9	2	0
Via street network using only streets with speed limit ≤25 mph	5[b]	6[b]	1	0

[a]Number of schools in the analysis.
[b]Preferred safety and distance parameters for grade group.

Table 3. Characteristics of neighborhoods associated with higher percentages of potential walkers within 1-mile street network pedestrian catchment area by grade group, Georgia, 2000

	Grades K–2		Grades 3–5		Grades 6–8		Grade 9[a]	
Characteristic	**Beta**	**Partial R^2**	**Beta**	**Partial R^2**	**Beta**	**Partial R^2**	**Beta**	**Partial R^2**
VARIABLES MAKING LARGER CONTRIBUTIONS TO MODEL[b]								
Population density	1.005	0.166	0.981	0.129	0.909	0.468	0.652	0.099
School enrollment	−0.887	0.094	−0.775	0.066	−0.856	0.189	—	
Ratio of street network to radial PCA area	0.972	0.044	0.890	0.034	1.083	0.066	1.272	0.067
VARIABLES MAKING SMALLER CONTRIBUTIONS TO MODEL								
Percentage of non-whites	0.056	0.002	0.056	0.002	0.072	0.003	0.115	0.007
Percentage of housing built before 1950	−0.035	<0.001	−0.073	0.003	−0.051	0.002	—	
Street density	−0.152	<0.001	−0.179	0.001	—		—	
Median household income	−0.119	<0.001	−0.088	<0.001	—		—	
Ratio of intersections to intersections plus cul-de-sacs	−0.176	<0.001	—		—		—	
Intersection density	—		—		—		0.076	0.020
Urbanization								
Rural schools	reference		reference		reference		reference	
Town schools	—		—		—		−0.099	0.004
Suburban schools	—		−0.025	<0.001	—		−0.183	0.011
Urban schools	−0.028	<0.001	−0.031	<0.001	—		−0.236	0.011
Adjusted R^2		0.933		0.941		0.940		0.795

Note: Characteristics are significantly associated ($p<0.05$) with percentage of potential walkers if values for beta and partial R^2 are provided.
[a]Analysis restricted to 9th-grade students due to large number of dropouts from grades 10 to 12.
[b]Contribution of variables was three-fold or greater than the contribution of other variables as measured by partial R^2 values.

Discussion

The proportion of children who appear to live within a reasonable and safe walking distance from school in Georgia is small. For all but the 1-mile radius for early and late elementary school students, the proportion of potential walkers is well below 50%. The regression analysis suggests that characteristics of the population (higher population density within the PCA), school (lower school enrollment), and neighborhood connectivity (higher ratio of street network to radial PCA area) all contribute importantly to having larger percentages of children who can walk to school. Higher population density increases the likelihood that more children will live within walking distance of the school. This effect was observed after adjusting for urbanization. Lower school enrollment increases the likelihood that a higher proportion of students can live within walking distance of the school; larger schools tend to draw from larger geographic areas. The higher ratio of street network to radial PCA indicates a larger land area from which students can reach school using local streets without exceeding a specific walking distance (e.g., 1 mile). Neighborhoods with high connectivity are more likely to have gridded street layouts, high street densities, high intersection densities, and relatively fewer cul-de-sacs. These measures of connectivity are automobile oriented. Measures of connectivity that are pedestrian oriented, such as sidewalk or pedestrian pathway density, are not currently available.

Assumptions

Several of the analytic decisions made are likely to have influenced the accuracy of the estimates. First, although great care was taken to ensure that schools were correctly located on the map, only one entry into the school grounds was mapped for each school. Many schools have more than a single entry point, and this decision likely lowered the estimated proportion of students who could walk. The second assumption was that children must use local streets to get to school. Pedestrian-only pathways may enable some students who live outside of the calculated PCAs to walk to school without exceeding the 1-mile or 0.5-mile limit. The third assumption was that the student population was evenly distributed throughout the census blocks that were only partly included in the walkable network. This may cause an over-estimation of potential walkers for some schools and an under-estimate for others; this issue was assumed to have little effect on the overall statewide estimates. Fourth, posted speed limits were the only limiting hazard for streets along which students would be required to walk. Other types of hazards may be present, such as absent sidewalks or crossing high-volume streets, that may even make streets with acceptable speed limits hazardous and make the estimates too high. Fifth, schools that appeared not to be neighborhood schools were excluded from the analysis. Few students can walk a reasonable distance to these schools because their

catchment areas extend beyond the immediate neighborhood. This would cause the statewide estimates to be too high. Sixth, students who attend private, parochial, or home schools—approximately 8% of school-aged children in Georgia[27]—and who live within the PCA of a public school would be counted as potential walkers. This, too, would cause the estimates to be too high. Seventh, students who attend a magnet or special focus public school or who choose to attend a public school in another neighborhood for race-ethnicity or school quality reasons would be counted as potential walkers, also causing the estimates to be too high. Eighth, for some schools (most often urban or suburban elementary schools) the estimate of potential walkers exceeded the number of enrolled students. Most instances of this impossible result occurred because of overlapping PCAs. For all such schools the number of potential walkers was reduced to the level of enrollees, thereby setting the percentage of potential walkers for that school and grade group at 100%. Few schools would be expected to have 100% potential walkers; this maneuver would have led to an over-estimate of the percentage of potential walkers. The ninth assumption was all students are physically capable of walking to school. This, too, probably caused a small over-estimate in the proportion of potential walkers. Of these potential biases, only the first two would cause the estimated percentages of potential walkers to be too low; the next one is expected to have negligible impact on the estimates; the remaining six would cause the estimated percentages to be too high. Finally, arbitrary preferences were set for distances and safety conditions for the preferred networks. Other options are available and these estimates have been provided.

Generalizability

The methods used in this study should be widely applicable. However, the variability in demographic, educational, and housing characteristics suggest that the percentages of potential walkers may vary among geographic areas. Georgia's population growth since 1950, a time during which automobile-oriented suburban development has been popular, has been relatively rapid.[28] States that are more densely populated or have grown less rapidly over the past half-century may have larger percentages of potential walkers.

Conclusion

The surprisingly small percentages of children in Georgia who appear to live within a safe and reasonable walking distance from school do not reduce the value of walking to school for those students who can do so and for the neighborhoods in which they live. The findings do, however, suggest a framework for enabling more children and youth to walk to school. First, at schools where a large proportion of students live within a safe and reasonable distance from school, advocacy efforts for improved safety measures such as adult guards at high-volume crossings and quality sidewalks should continue. Second, enabling substantially more children to live within a safe and reasonable walking distance from school will require policy and environmental changes. Smaller schools located in population-dense areas should be encouraged. Such schools would not only enable students to walk to school, but would reduce air pollution and improve neighborhood social capital as well. Third, improved surveys and surveillance systems to measure and monitor the number of children who can and who do walk to school need to be developed and implemented. Finally, more information about the benefits and risks of walking to school and the effectiveness of different types of interventions is needed.

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