Preventive Medicine 95 (2017) S28–S36

Contents lists available at ScienceDirect

Preventive Medicine

journal homepage: www.elsevier.com/locate/ypmed

From sedentary to active school commute: Multi-level factors associated with travel mode shifts

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ARTICLE INFO

Article history:
Received 3 May 2016
Received in revised form 18 October 2016
Accepted 19 October 2016
Available online 24 October 2016

Keywords:
Active commuting to school
Walking to school
Children
Active transportation
Neighborhood environment

ABSTRACT

Previous research has examined personal, social, and environmental correlates of active commuting to school, but most were cross-sectional and mode choice studies. This exploratory case study utilized a retrospective natural experiment opportunity, where a group of students transferred to a new school, and therefore experienced changes in their home-to-school travel environments. It examined whether such changes led to mode shifts from sedentary (car or school bus) to active (walking and bicycling) and what factors were associated with those shifts.

Retrospective parental survey data ($n = 165$, response rate = 46%) were collected in 2011 from a new elementary school that opened in 2010 in Austin, Texas. The survey asked about the child's school travel mode and parental perceptions of home-to-school travel environments before and after the transfer, as well as personal and social factors. Multivariate logistic regressions were used to predict the odds of shifting from sedentary to active modes, using personal, social, and physical environmental variables.

Sixty-eight (41.2%) respondents reported a sedentary-to-active mode shift for school commuting. Such shifts were associated with changes in school travel environments (e.g., shorter travel distance, improved safety, and decreased availability of bike lanes/paths) and relevant programs/services (e.g., increase in walking-promotion programs, and decrease in school bus service due to shortened distances).

Targeting the current sedentary mode users is important to bring health benefits through increased physical activity and environmental benefits from reduced automobile use. Sedentary-to-active mode shifts may be encouraged by providing walking-promotion programs and by reducing travel distances and safety threats en route to school.

1. Introduction

Walking and bicycling to school have attracted increasing attention as healthful physical activities that double as environment-friendly travel modes. However, the rate of active school commuting has continued to decrease since the 1960s (McDonald et al., 2011a). Various policy and program interventions have been implemented to promote active transportation to school, such as the federal Safe Routes to School (SRTS) programs, pedestrian safety trainings at local schools, Walking School Bus (WSB) programs (a group of students walking to school together led by an adult supervisor), and walking-to-school day events. In research, a growing number of studies have identified personal, social, and physical environmental correlates of active commuting to school. Results have shown the impact of walking-friendly environmental features such as shorter distances, sidewalks, crosswalks, slow traffic, and street lighting on promoting active school commute (Deka, 2013; Kerr et al., 2006; McMillan, 2007; Oluyomi et al., 2014; Su et al., 2013). Personal and social factors such as school bus service; children's age, race, gender, and attitudes; parents' education, income, and attitudes; and peer influence have also been correlated with active school commute (McDonald et al., 2010; Rodríguez and Vogt, 2009; Rothman et al., 2014; Yu and Zhu, 2016; Zhu et al., 2008).

However, most existing studies were cross-sectional and focused on travel mode choice (Panter et al., 2008; Pont et al., 2009; Saelens and Handy, 2008). Interventions based on such studies may not lead to mode shifts toward active school commuting among those who currently use a sedentary mode. A few studies have used a randomized controlled design or a quasi-experimental trial to investigate the effects of program or policy interventions such as education programs, WSB programs, and SRTS projects on commuting mode shifts (Boarnet et al., 2005; McKee et al., 2007; Mendoza et al., 2011; Sirard et al., 2008). While those studies reported significant impacts of the interventions on mode shifts, they target either non-environmental interventions (e.g., WSB) or overall programs/projects (e.g., SRTS) without separating

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http://dx.doi.org/10.1016/j.ypmed.2016.10.018
0091-7435/

out the specific roles of individual environmental components (McDonald, 2015; Stewart et al., 2014). To our knowledge, only a few studies have examined the effects of environmental changes on mode shifts. One pre-post study in California assessed the aggregated effect of multiple SRTS projects such as the installation of sidewalks, crossing signals, and traffic control facilities. It found that students who passed the SRTS project were significantly more likely to switch to active school commute, compared to the control students who did not pass the project (Boarnet et al., 2005). Another pre-post study involving 801 schools from three U.S. States and the District of Columbia reported engineering improvements (e.g., sidewalks, crosswalks) to cause significant increases in walking and bicycling to school. A smaller study of 14 schools in Eugene, Oregon found that only the non-environmental programs (e.g., education, encouragement) were linked to significant increases in walking to/from school (McDonald et al., 2013).

More studies are needed to better understand the causal relationships between environmental improvements and mode shifts (Handy et al., 2006). Targeting the currently sedentary mode users who live within a walkable distance to school is especially important to bring about the health benefits (Janssen and LeBlanc, 2010; Larouche et al., 2014) that may last throughout the life span (Reiner et al., 2013; Saunders et al., 2013). Additional environmental benefits are also expected from replacing motorized trips with the environmentally clean non-motorized trips (Mueller et al., 2015).

2. Methods

2.1. Study design

This case study utilized a retrospective natural experiment opportunity, where students transferred from schools outside their neighborhood to a newly opened school within their neighborhood. As a result, they experienced changes in their school travel distance and environments. This study examined whether such changes led to mode shifts from sedentary (private car or school bus) to active (walking and bicycling), and if yes, what factors contributed to those shifts.

2.2. Study setting and population

The study school was located in a new, affluent neighborhood in the southwest corner of Austin, Texas (Fig. 1) (Zhu and Lee, 2008). This area has experienced a rapid growth in new residential developments, which prompted the opening of this new public school in August 2010. Before its opening, students had to travel long distances outside their neighborhood to attend other existing schools (Fig. 1). Therefore, for most students, transferring to this new school meant shorter travel distance, making the school commute to occur primarily within the neighborhood and to be perceived safer. Most (92.1%) students transferred from another school (a total of 13 other schools) within Austin, and all but six used a motorized mode (car or school bus) for school commuting prior to the transfer. Most (79.4%) of the respondents reported the same home locations before and after the school transfer, and no statistically significant difference was found between home relocation and travel mode change (Chi-Square $= 2.441$, $p = 0.118$). The new school had a total enrollment of 506 students (pre-K to the fifth grade) in the 2010–2011 academic year. It had a higher percentage of White, non-Hispanic students (66.0%) and a lower percentage eligible for free or reduced-price lunch (14.4%), compared to district-wide statistics (24.3% White, non-Hispanic and 64.0% eligible for special lunch) (Texas Education Agency, 2010-2011).

2.3. Data collection

Data used in this study were collected from a larger project funded by the Robert Wood Johnson Foundation's Active Living Research program, which aimed to assess active school commute behaviors and the roles of the built environment among diverse groups of students attending elementary schools in the Austin Independent School District (AISD), Texas (Lee et al., 2013). The survey was carried out in a retrospective manner in the new school in early May of 2011, 8.5 months after its opening in late August 2010. The administration of and recruitment for the survey were assisted by the City of Austin's Child Safety Program and AISD. A hard copy survey instrument and an introductory cover letter were distributed through school teachers to 387 parents/guardians of the first through the fifth grade students (excluding pre-K and K) by inserting those to the student's weekly portfolio. A total of 178 (response rate: 46%) surveys were returned to the students' teachers, which were later collected by our research staff. The study protocols were approved by the researchers' University Institutional Review Board.

2.4. Survey instrument and study variables

A bilingual (English and Spanish) paper survey questionnaire was developed by adopting items from the National Center for Safe Route To School (SRTS) survey (McDonald et al., 2011b; National Center for Safe Route to School) and other previously developed/validated instruments (Forman et al., 2008; McMillan, 2003; Varni et al., 2001; Zhu and Lee, 2009; Zhu et al., 2011). The Spanish version was developed using a forward and backward translation process. However, all survey respondents included in this study completed the English version. The internal consistency of the survey instrument was tested to be acceptable with Cronbach's alpha of 0.789 (Hair et al., 2006).

2.4.1. Mode shift outcome variables

The sedentary-to-active mode shift outcome variable was a binary variable (coded as one if shifted and zero if not). It was calculated based on the answers from the two questions asked twice for before and after the school transfer: "On a normal day, how did/does your child travel from home to school?" and "On a normal day, how did/does your child travel from school to home?" The response options included walk, bike, school bus, and private car including carpool. If the response answered walk or bike in either traveling to or from school, the respondent is coded as an active mode user.

2.4.2. Physical environmental variables

Physical environmental changes en route to school were captured in three sub-domains: (a) distance, (b) safety, and (c) walkability (Table 1). The **distance** sub-domain included two questions that asked about the home-to-school distance for before and after the transfer, respectively. These two questions used the same set of multiple choices: <1/4 miles (coded as 1), 1/4–1/2 miles (2), 1/2–1 mile (3), 1–2 miles (4), and >2 miles (5). The distance variable used in the analysis was calculated as the after value minus the before value, which then was categorized as: shorter (coded as −1), same (0) and longer (1). The **safety** sub-domain questions directly asked about the before-after *change* of each item to be "more," "about the same," or "less." The question was worded as "Compared to the previous school, how concerned are you about the following safety issues related to walking to [name of the study school]," and the eight specific safety issues asked are listed in Table 1. The **walkability** sub-domain included variables capturing land uses and overall walking environments en route to school (Table 1). The variables in this sub-domain were derived from two types of survey questions. The first type involved asking about the presence or absence (coded as 1 or 0) of a feature (e.g., land uses, highway) en route to school before and after the transfer, separately. The differences were calculated as the after value minus the before value, which resulted in positive values when new features were found en route to school after the transfer, negative values indicating the opposite conditions, and zero indicating no changes. The second type involved directly asking about the changes after the transfer using three ordinal categories of "better," "about the same," and "worse."

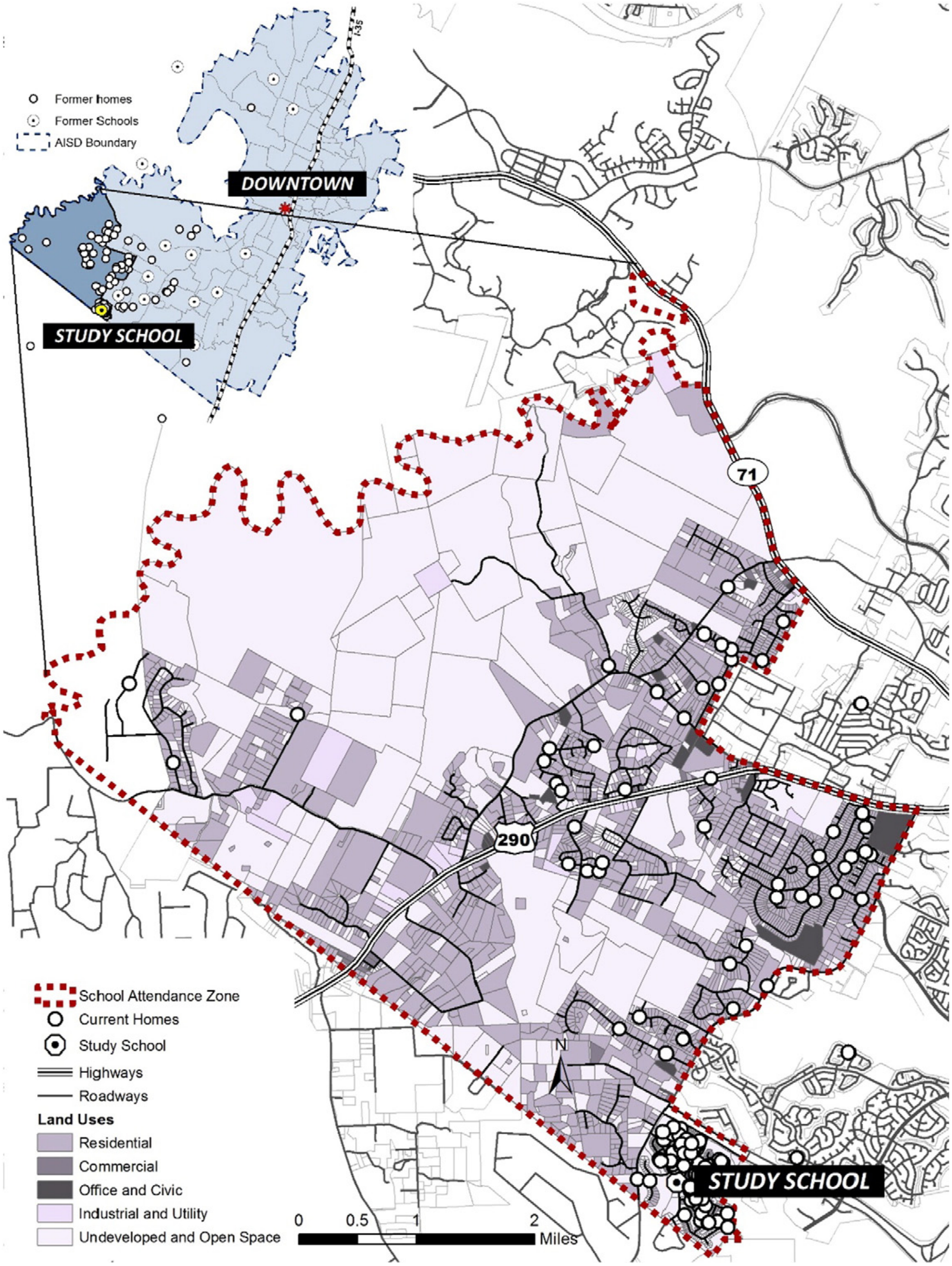


Fig. 1. Locations of participants' former homes and schools (upper left), and current homes and school, and land use patterns in the attendance area of the study school (main figure), Austin, Texas, 2011.
(Source: City of Austin).

The types of questions and response options were determined based on the pilot test results, and selected to facilitate easy and reliable responses to these questions requiring recalls. Due to the significant correlations found among variables in the safety and walkability subdomains, principal component analysis (PCA) with the Varimax orthogonal rotation method was used to extract latent factors. These factor variables were used in all statistical analyses (Table 1).

2.4.3. Personal and social variables

Two domains covering personal and social factors related to school travel mode choice were considered in this study. Unlike the physical environmental variables, these variables are captured just once as their current status/condition. Personal factors included socio-demographics of the children, parents, and households; attitudinal and behavioral factors; and social factors (Table 2). Attitudinal and

Table 1
A list of original physical environmental variables captured from survey, and converted variables for analysis.

Domains	Variables	Original measures from survey	Converted variables for analysis[a]	Items adopted/modified from
Distance	How far did/does your child live from school	Categorized distances, asked twice for before and after transfer (rated as <1/4, 1/4–1/2, 1/2–1, 1–2, and 2 + miles)	Increase in distance to school[a]	McMillan (2003), National Canter for Safe Route to School
Safety	My child may get lost My child may be taken or hurt by a stranger My child may get bullied, teased, or harassed My child may be attacked by stray dogs My child may be hit by a car Exhaust fumes may harm my child's health No one will be able to see and help my child in case of danger My child may get injured by falling (due to drainage ditch, uneven walking surface, etc.)	Level of concerns changed after transfer (rated as more, less, or about the same)	Factor: Increase in safety problems en route to school[a]	Zhu and Lee (2009), Zhu et al. (2011)
Walkability: land uses	Bakery/cafe/restaurant Small retail/business Large parking lot/garage Gas station Convenience store Bus stop Bike lane Walking path/trail Vacant lot Playground/park	Presence en route to school (1 if present, 0 if absent), asked twice for before and after transfer	Factor: Increase in utilitarian destinations[a] Factor: Increase in auto-oriented land uses[a] Factor: Increase in bike lanes/paths[a] Factor: Increase in vacant lots and decrease in parks[a]	Zhu and Lee (2009), Zhu et al. (2011)
Walkability: overall walking environment	Highway or freeway road with busy traffic intersection without a crossing guard intersection without a painted crosswalk or stop sign/signal	Presence en route to school (1 if present, 0 if absent), asked twice for before and after transfer	Factor: Increase in unsafe roads[a]	Zhu and Lee (2009), Zhu et al. (2011)
	Sidewalk availability and completeness better worse about the same Sidewalk maintenance and cleanliness (without trash, holes, cracks) Sidewalk width (wide enough for two persons walking together) Sidewalk buffer/protection (sidewalks are separated from traffic by grass or trees) Sidewalk free of obstructions (without trash cans, power poles, parked cars blocking)	Level of concerns changed after transfer (rated as more, less, or about the same)	Factor: Improvement in sidewalk condition[a]	Zhu et al. (2011)
	Route directness (without a lot of detours) Street maintenance and cleanliness School zones/enforcement of traffic control near school	Level of concerns changed after transfer (rated as more, less, or about the same)	Factor: Improvement in overall walking environment[a]	Zhu et al. (2011)

Factor: latent factor variable generated from the principal component analysis.
[a] Generated based on the after-transfer value minus the before-transfer value.

behavioral variables further included (a) attitudes toward active school commuting (i.e., factors affecting parental decisions to allow active school commuting); (b) attitudes toward walking and walking habits; (c) residential self-selection in relation to school and neighborhood quality; and (d) the number of outdoor locations used for child's play. Social factors included the availability of school bus service, relevant school and neighborhood programs/events (i.e., programs promoting active school commute or safety in schools or neighborhoods), and crash and crime incidences in schools or neighborhoods.

2.5. Data processing and analysis

Among the total of 178 survey respondents, seven were excluded because they did not report one or more key study questions in the survey and six were further excluded as they used an active school travel mode prior to the school transfer. The 165 remaining responses still included some missing values ranging from 0.0% to 8.5%. Most missing responses were imputed with a method similar to expectation maximization, assigning a value based on the information from other relevant variables. This approach has been shown to introduce no/minimal bias (Catellier et al., 2005). For example, a missing value in the distance to school was imputed with the best matching value derived from each respondent's responses to time to school, perceived proximity to school, and travel mode variables. Several variables lacking reference variables/responses were imputed with the median or random value, which can introduce biases but likely minimal in our study due to the small number (e.g., ≤3) of imputations. Potential biases from the imputation were further tested by estimating the model using a listwise deletion method which excluded respondents with any missing values, and the results were generally consistent with the model with imputed variables in terms of the p-values and the coefficients.

Binomial logistic regression models were used to estimate the odds of sedentary-to-active mode shift. The three-step modeling process involved: (a) bivariate tests by adding one variable at a time to the binomial regression model to select candidates for the multivariate modeling; (b) base multivariate model estimation with significant personal demographic variables; and (c) final model estimation by adding significant variables from the other domains to the base multivariate

Table 2
Participants' Personal and Social Variables: Descriptive statistics and bivariate tests using logistic regressions predicting sedentary-to-active mode shift (Austin, Texas, 2011).

Domain and variable	Descriptive statistics N (%) of "yes" or "1", Mean ± SD, or min.–max.			Bivariate tests	
	Sub-sample *without* mode shifts ($n = 97$)	Sub-sample *with* mode shifts ($n = 68$)	Total sample ($n = 165$)	Odds ratio	*p*-Value
Personal — sociodemographics					
Child characteristics					
Gender (girl = 1; boy = 0]	47 (48.5%)	36 (52.9%)	83 (50.3%)	1.19	0.571
Grade (first - fifth)	2.47 ± 1.362	2.29 ± 1.235	2.40 ± 1.310	0.90	0.384
First grade	31 (32.0%)	24 (35.3%)	55 (33.3%)		
Second grade	24 (24.7%)	17 (25.0%)	41 (24.8%)		
Third grade	18 (18.6%)	13 (19.1%)	31 (18.8%)		
Fourth grade	13 (13.4%)	11 (16.2%)	24 (14.5%)		
Fifth grade	11 (11.3%)	3 (4.4%)	14 (8.5%)		
Obese or overweight	22 (22.7%)	13 (19.1%)	35 (21.2%)	0.88	0.300
Race: non-Hispanic White	72 (74.2%)	50 (74.6%)	122 (74.4%)	1.04	0.911
Qualification for free or reduced-price lunch	20 (20.6%)	4 (5.9%)	24 (14.5%)	0.24	0.013
Parent characteristics					
Race: non-Hispanic White	74 (76.3%)	53 (77.9%)	127 (77.0%)	1.10	0.804
Born in the U.S.	83 (85.6%)	53 (77.9%)	136 (82.4%)	0.60	0.208
Barrier: no one to walk with child	41 (42.3%)	2 (2.9%)	43 (26.1%)	0.04	<0.001
Household characteristics					
Highest education level in household [college graduate/Bachelor's degree] (ref: [high school/some college])	40 (41.2%)	30 (44.1%)	70 (42.4%)	5.75	0.008
Highest education level in household [graduate/professional degree] (ref: [high school/some college])	34 (35.1%)	35 (51.5%)	69 (41.8%)	7.89	0.002
Number of cars in household	2.22 ± 0.77	2.05 ± 0.35	2.15 ± 0.63	0.64	0.105
Annual household income [$100,000 or more] (ref: [prefer not to answer/not sure])	38 (39.2%)	36 (52.9%)	74 (44.8%)	1.20	0.077
Personal — attitudes and behaviors					
Factors considered for school commute mode decision					
Increased attention to safety barriers (crime, traffic, etc.), after transfer[a]	0.30 ± 0.58	−0.43 ± 1.28	−3.12–1.98	0.44	<0.001
Increased attention to route safety (crossings, sidewalk) and travel time, after transfer[a]	−0.29 ± 0.47	0.41 ± 1.35	−3.37–3.49	2.42	<0.001
Increased attention to crime safety and reduced attention to distance/weather, after transfer[a]	−0.08 ± 0.8	0.12 ± 1.2	−4.40–4.63	1.22	0.218
Grade level at which parents would allow child to walk or bike without an adult to school	2.05 ± 2.50	2.96 ± 2.01	2.43 ± 2.35	1.18	0.015
Attitudes toward walking					
Enjoyment of walking to school and daily walking of parents/neighbors[b]	−0.28 ± 1.10	0.40 ± 0.67	−3.30–1.82	2.58	<0.001
Barrier to walking to school[b]	0.37 ± 0.9	−0.53 ± 0.8	−2.35–2.10	0.32	<0.001
Residential self-selections					
School and neighborhood quality and proximity[c]	−0.29 ± 0.94	0.42 ± 0.93	−2.02–1.65	2.22	<0.001
Proximity to work and neighborhood walkability[c]	−0.20 ± 0.94	0.28 ± 1.02	−1.04–3.37	1.65	0.004
Child's play behavior					
Increase in the number of outdoor locations used for child's play [more] (ref: [less/same])[d]	13 (13.4%)	26 (38.2%)	39 (23.6%)	4.00	<0.001
Social factors:					
More or same bus service (ref: [less])[d]	77 (79.4%)	20 (29.4%)	97 (58.8%)	0.108	<0.001
Increase in programs to promote walking to school[c]	−0.24 ± 0.95	0.34 ± 0.98	−2.39–2.13	1.83	<0.001
Increase in crash/crime incidents in school or neighborhood[c]	−0.03 ± 0.98	0.05 ± 1.04	−3.40–2.09	1.08	0.614

Note: for latent factor variables, min.–max. range is reported for total sample instead of Mean ± SD, because they have a fixed mean of 0 and SD of 1.
[a] Latent factor variable created from multiple observed variables measured with binary scale: "1" affecting and "0" not affecting mode choice decision.
[b] Latent factor variable created from multiple observed variables measured with 5-point scale: "1" strongly disagree to "5" strongly agree.
[c] Latent factor variable created from multiple observed variables measured with binary scale: "1" yes and "0" no.
[d] Binary variable created from after minus before transfer values.

model. All statistical analyses were performed in SPSS 19.0. As an exploratory case study, an alpha level of up to $p < 0.1$ was considered when discussing significant results in the following sections.

3. Results

3.1. Participant characteristics

Children's mean grade level was 2.4; 50.3% were female; 74.4% were White, non-Hispanic; 21.1% were obese or overweight (≥85th percentile); and 14.5% were eligible for free or reduced-price lunch programs (Table 2). Compared to all students attending the study school, the survey participants represented a higher percentage of White, non-Hispanic students (74.4% vs. 66.0% school-wide), but other characteristics were similar in general. For the parental respondents, over 80% were born in the U.S.; 84.2% had education attainment higher than college graduate; their households had 2.15 cars on average; and 44.8% earned $100,000 or more annually. Of the 165 children included in this study, 103 (62.4%) used a private car and 62 (37.6%) used the school bus before the transfer. Sixty-eight of them (41.2%) changed to an active mode (walking or bicycling) after the transfer, while the remaining 97 students (58.8%) continued using a sedentary travel mode. About half (84 out of 165, 50.9%) of the respondents reported that their school travel distance became shorter after the transfer, 63 (75%) of whom switched to an active mode.

3.2. Factors associated with school commute modes shifts from the bivariate analyses with logistic regression models (results from modeling process step a)

3.2.1. Personal and social variables

Personal factors included socio-demographics and attitudinal and behavioral factors. Six socio-demographic variables were significant in the bivariate tests using binomial logistic regressions (Table 2). Among the attitudinal and behavioral factors, positive correlates included increased attention to route safety (crossings, sidewalk) and sensitivity to travel time after transfer; enjoyment of walking and peers' frequent walking behaviors; residential self-selection related to school and neighborhood quality, proximity to work and neighborhood walkability; and increases in the number of outdoor locations used for child's play (Table 2). Negative correlates included increased attention to safety barriers (crime, traffic, etc.), and increased barrier to active school commuting. From the social factors, those who perceived increases in walking-to-school promotion programs and decreases in school bus service were more likely to change to an active mode (Table 2).

3.2.2. Physical environmental variables

Physical environmental changes in home-to-school routes were captured in terms of distance, safety, and walkability. Based on the bivariate tests (Table 3), the sedentary-to-active mode shift was less likely to occur when parents perceived increased distance, more safety problems, more auto-oriented land uses, more vacant lots and fewer parks, and more unsafe roads en route to school. In contrast, the mode shift was more likely to happen when parents perceived improvements in sidewalk conditions or overall walking environments.

3.3. Factors associated with school commute modes shifts from multivariate analyses with logistic regression models (results from modeling process step c)

The final multivariate model contained only those variables maintaining the statistical significance at the 0.1 level, which included: socio-demographics (1 variable), attitudes and behaviors (3), social factors (2), and physical environmental factors (3).

3.3.1. Personal and social variables

As shown in Table 4, the sedentary-to-active mode shift was more likely to occur among parents who reported enjoyment of walking and frequent walking behaviors of themselves or neighbors (OR = 1.991, $p = 0.090$), increased attention to route safety and travel time after transfer (OR = 2.738, $p = 0.015$), increased number of outdoor locations used for child's play (OR = 6.537, $p = 0.021$), and increased availability of programs promoting active school commuting (OR = 1.925, $p = 0.041$) (Table 4). In contrast, the shift was less likely to take place among parents who were born in the U.S. (OR = 0.213, $p = 0.072$), and who reported more or the same level of school bus service compared to the availability prior to the transfer (OR = 0.302, $p = 0.091$).

3.3.2. Physical environmental variables

After controlling for all significant personal and social factors, the sedentary-to-active mode shift was less likely to occur when parents perceived increased distance (OR = 0.436, $p < 0.001$), increased availability of bike lanes/paths (OR = 0.418, $p = 0.006$), and more safety problems (OR = 0.257, $p = 0.001$) en route to school (Table 4).

4. Discussions

Results from the final model suggest that the sedentary-to-active mode shift can be facilitated by addressing several modifiable conditions: shortening the home-to-school distance, reducing safety problems en route to school, increasing programs promoting active school

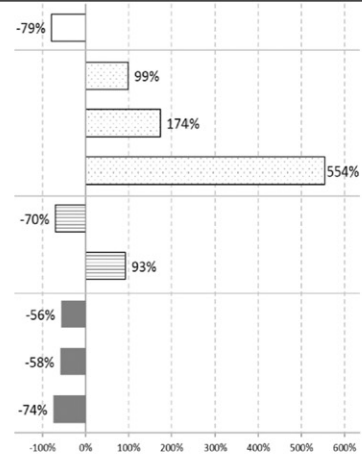
Table 3
Physical Environmental Variables: Descriptive statistics and bivariate tests using logistic regressions predicting sedentary-to-active mode shift (Austin, Texas, 2011).

Domain and variable	Descriptive statistics Mean ± SD or min.–max.			Bivariate tests	
	Sub-sample *without* mode shift ($n = 97$)	Sub-sample *with* mode shift ($n = 68$)	Total sample ($n = 165$)	Odds ratio	*p*-value
Distance					
Increase in distance to school[a]	−0.20 ± 1.27	−3.01 ± 1.41	−4.00–4.00	0.30	<0.001
Safety[b]					
Increase in safety problems en route to school	0.44 ± 0.91	−0.63 ± 0.76	−1.44–2.61	0.25	<0.001
Walkability					
Land uses en route to school[c]					
Increase in utilitarian destinations	0.03 ± 0.93	−0.05 ± 1.10	−2.95–2.03	0.92	0.597
Increase in auto-oriented land uses	0.49 ± 0.88	−0.69 ± 0.72	−2.00–2.21	0.16	<0.001
Increase in bike lanes/paths	0.08 ± 0.80	−0.12 ± 1.22	−2.46–2.82	0.82	0.210
Increase in vacant lots and decrease in parks	0.14 ± 0.79	−0.19 ± 1.22	−2.48–3.73	0.71	0.040
Increase in unsafe roads	0.40 ± 0.82	−0.57 ± 0.96	−1.55–2.89	0.32	<0.001
Walking environments en route to school[d]					
Improvement in sidewalk condition	−0.14 ± 1.03	0.21 ± 0.928	−2.70–1.23	1.43	0.028
Improvement in overall walking environment	−0.25 ± 1.02	0.35 ± 0.87	−3.16–1.30	1.90	<0.001

Note: for latent factor variables, min.–max. Range is reported for total sample instead of Mean ± SD, because they have a fixed mean of 0 and SD of 1.
[a] Ordinal variable calculated as the after-transfer value minus the before-transfer value; both values originally captured using a 5-category distance variable: "1" < ¼, "2" ¼-½, "3" ½-1, "4" 1–2 and "5" 2+ miles.
[b] Latent factor variable created from multiple variables measured with 3-point scale: "1" less concerned, "2" about the same, and "3" more concerned, compared to pre-transfer.
[c] Latent factor variable created from multiple variables measured with binary scale: "0" absence and "1" presence.
[d] Latent factor variable created from multiple variables measured with 3-point scale: "1" worse, "2" about the same, and "3" better, compared to pre-transfer.

Table 4
Variables Predicting Odds of Sedentary-to-active Mode Shift: Results from multivariate binomial logistic regression models (Austin, Texas, 2011).

Domain	Variable	Odds Ratio	p-value	90% CI Lower	90% CI Upper
Personal – Sociodemographics	Parent born in the U.S.	.213	.072	.052	.877
Personal – Attitudes and Behaviors	Enjoyment of walking to school and daily walking of parents/neighbors[a]	1.991	.090	1.021	3.880
	Increased attention to route safety (crossings, sidewalk) and travel time, after transfer[b]	2.738	.015	1.386	5.409
	Increase in outdoor locations used for child's play [More] (ref: [Less/Same])[c]	6.537	.021	1.708	25.021
Social	More or same bus service (ref: [Less])[c]	.302	.091	.094	.970
	Increase in programs to promote walking to school[b]	1.925	.041	1.136	3.261
Physical Environmental	Increase in distance to school[d]	.436	<.001	.307	.621
	Increase in bike lanes/paths en route to school[b]	.418	.006	.249	.703
	Increase in safety problems en route to school[e]	.257	.001	.129	.513



[a]Latent factor variable created from multiple variables measured with 5-point scale: "1" strongly disagree to "5" strongly agree.
[b]Latent factor variable created from multiple variables measured with binary scale: "1" yes/present and "0" no/absent.
[c]Binary variable created from after minus before transfer values.
[d]Ordinal variable calculated as the after-transfer value minus the before-transfer value; both values originally captured using a 5-category distance variable: "1" <¼, "2" ¼-½, "3" ½-1, "4" 1-2 and "5" 2+ miles.
[e]Latent factor variable created from multiple variables measured with 3-point scale: "1" less concerned, "2" about the same, and "3" more concerned, compared to pre-transfer.

commute, and limiting school bus services. Attitudinal and behavioral variables were also shown to be important in predicting the mode shift (for students living within a reasonable walking distance). The following discusses key findings from the final model (Table 4) based on the study domains.

4.1. Personal variables

Some of the previously reported correlates of walking to school such as age, gender and race of the child, and socio-economic status of the family were not significant in this study, once social and physical environmental variables were controlled. This may be due to the relatively homogeneous characteristics of our study population but their insignificant roles in predicting active commuting to school, once built environmental variables are controlled, have also been reported previously (Oreskovic et al., 2014). The only socio-demographic variable remained significant in the final model was the parental birth place. U.S.-born parents were less likely to have mode shifts in this study, which appears consistent with previous studies reporting higher rates of active school travels among foreign-born children (Martinez et al., 2008) and among children with lower levels of acculturation (Mendoza et al., 2010). The positive association between the use of more outdoor play locations (which included school, park/playground, yards at home, friend's house, and neighborhood streets in this study) and the mode shift indicates that active commuting can further contribute to increasing healthy outdoor physical activities among children. This finding is somewhat inconsistent with a recent study which reported park space en route to school to be negatively associated with active commuting to school (Oreskovic et al., 2014), and a literature review reporting inconsistent or non-significant relationships between parks and children's physical activity (Kaczynski and Henderson, 2007). While the significant roles of parks and neighborhood streets in promoting overall physical activity and walking have been documented (Frank et al., 2007; Kerr et al., 2006; Sallis et al., 2002), findings related to their roles in promoting active school commuting have not been confirmatory.

4.2. Social variables

Increased availability of school bus was negatively, while increased availability of programs to promote walking to school (e.g., walking to school month/day event, pedestrian safety education program) was positively associated with the sedentary-to-active mode shift. Social and policy strategies such as school bus policies and walking-to-school promotional campaigns appear promising as relevant intervention strategies. Although not significant in the final model, the non-shift group was much more likely to report 'not having someone to walk the child' as a barrier to walking to school, compared to the mode shift group (42.3% vs. 2.9%). Programs like WSB may be helpful in reducing such social barriers (Kong et al., 2009).

4.3. Physical environmental variables

Increases in (a) distance to school, (b) availability of bike lane/path, and (c) perceived safety problems (e.g., risks from stranger, injury, traffic, and dog) were negatively associated with the odds of changing to an active travel mode. This study further confirmed the critical role of travel distance in influencing school travel modes (Martin and Carlson, 2005; Salmon et al., 2007). For the current school, 53.3% of the parents felt the distance was close enough for their children to walk, compared to only 3.8% for previous schools. From another survey question asking about the home-to-school distance with a five-item ordinal categorical scale, 44.8% respondents answered that they lived further than two miles from the current school, while 77.8% lived further than two miles from previous schools before the transfer. Shortened distances after the transfer were the strongest predictor of mode shift. Results also demonstrated that the shortened distance led to the decline in the school bus service availability, which might also have encouraged using active modes. Although shortening the school travel distance is not easy, active school commuting cannot be promoted without reducing the distance barrier. Relevant strategies may include locating schools centrally within the residential neighborhoods and revisiting attendance zone policies to increase the number of students living within a walkable commute distance. A pre-post study by Sirard et al. (2015), however, found that a new policy restricting school choice to one near home did not lead to changes in active commuting rates. This finding can be in part due to the fact that the actual changes in the distance-to-school resulted from the policy intervention, although statistically significant, was small (1.83 to 1.74 miles) and the percentage of students living within a walkable distance, e.g., 0.5 miles, did not increase significantly (Sirard et al., 2015).

The negative role of bike lanes/paths is somewhat counter-intuitive, but it is likely that those who changed the travel mode from sedentary to active are more likely to be aware of the problematic conditions of non-motorized transportation facilities, such as lack of bike lanes/paths. It might also be due to the fact that most (85.3%) of the active commuters were walkers, and the possibility that parents who drove their children or let their children take the school bus might not care about such deficiency related to active mode users. For practice and policy strategies related to addressing the safety problems, increased police or community surveillance, street maintenance, management of traffic speed and volume, and control of stray/unattended dogs may need to be considered.

4.4. Limitations

The use of a single retrospective survey administered after the transfer instead of having two rounds of surveys at both before and after the transfer might have introduced measurement errors related to recall biases/difficulties. In addition, we conducted this study on a single case school with a relatively small sample size and affluent populations, and therefore the findings are not generalizable to other schools/populations. The limited significance of the socio-demographic variables may be due to the relatively homogeneous population of this study. Future studies should explore opportunities to conduct more rigorous experimental studies with larger samples and with more diverse study settings and populations. Further, this study did not include objective physical environmental measures. Further studies with objective environmental measures can offer additional insights with more specific and detailed physical environmental features that may contribute to promoting sedentary-to-active mode shifts among school-aged children.

5. Conclusion

Results from this exploratory case study suggest that the sedentary-to-active mode shift decisions are associated with perceived environmental changes, such as shorter travel distance, improved safety conditions en route to school, and increased availability of programs supporting walking to school. After controlling the distance and other personal factors, perceived safety problems (e.g., risks from strangers, injuries, traffic, and stray dogs) still played a significant role in predicting the likelihood of mode shift. A comprehensive approach encompassing various walkability and safety improvement measures targeting the popular home-to-school travel routes, and school/neighborhood based programs focusing on social supports for walking appear important. This exploratory study offered some initial insights on the additional factors other than the evident distance factor, associated with the mode shift. The fact that many significant variables in the final model are modifiable (e.g., attitudinal, social and physical environmental factors) is encouraging. Collecting longitudinal pre-post transfer data with control groups will help further the understanding of factors contributing to school travel mode changes. More efforts are needed to target the currently sedentary mode users living within a walkable distance to school, to bring about the health and environmental benefits expected from replacing motorized trips with non-motorized trips.

Conflict of interest

The authors have no conflict of interest to disclose.

Acknowledgments

This study was funded by two grants from the Robert Wood Johnson Foundation's Active Living Research program (Grant IDs: 65539 and 65695).

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