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Findings from Research on Active Transportation to School and Implications for Safe Routes to School Programs

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Abstract

This literature review identified common factors associated with active transportation to school (ATS). It used a conceptual framework of a child's commute mode to school to classify 480 variables from forty-two studies that were tested for association with ATS. Four factors most frequently influenced ATS: distance, income, traffic and crime fears, and parental attitudes and schedules. Regular ATS results in more physical activity but research is lacking on other outcomes. Safe Routes to School, a program designed to increase rates and safety of ATS, can use an understanding of these influences and outcomes to more effectively allocate its limited resources.

Keywords

active transportation to school, safe routes to school, walking, biking, children

Introduction

This literature review identified factors that were commonly associated with walking, biking, and other forms of active transportation to school (ATS). It summarized findings from research that examined correlates of walking and biking to school. Findings were reviewed within a conceptual framework of a child's commute mode to school to understand hypothesized paths of influence. The results provide a broad understanding of the factors that influence and result from ATS.

ATS is believed to be a convenient way for children to obtain regular physical activity, explore their local environments, and reduce their environmental impact. Regular physical activity helps prevent chronic diseases of inactivity, such as obesity and diabetes (CDC 2008b). Interaction with the outdoor environment is believed to contribute to social skills, independence, and self-sufficiency as children develop (National Safe Routes to School Task Force 2008). And to the extent that walk and bike trips replace automobile trips to school, ATS mitigates air, noise, and other forms of pollution (Environmental Protection Agency [EPA] 2003). Despite these potential personal and societal benefits, rates of ATS in the United States have declined—from 40.7 percent in 1969 to 12.9 percent in 2001—as rates of students being driven to school in the family car have increased (McDonald 2007a). It was recently estimated that 20 to 30 percent of local morning traffic during the school year is a result of parents driving their children to school (Hubsmith 2006).

Safe Routes to School (SRTS) programs aim to reverse these trends. The primary objectives of SRTS is to increase the rate and safety of ATS through both infrastructure improvements and non-infrastructure activities. The national SRTS program has received an overwhelming response since it began in 2005. State Department of Transportations (DOTs) that administer the program have received more than 8,000 applications for projects totaling more than $1.3 billion. The program has only been able to fund about a third of these (NCSRTS 2009). Because demand far outstrips available SRTS funding, methods are necessary for allocating limited resources to projects that most efficiently address barriers to safe walking and biking to school.

The first step toward addressing barriers to ATS is to identify the barriers themselves. This review article is intended to help identify common barriers to ATS, which can help inform the design of SRTS projects, the selection of SRTS applications with the greatest potential for success, the evaluation of SRTS projects, and additional planning activities or policies that support ATS. An understanding of ATS outcomes can contribute to an accurate estimate of the benefits of the SRTS program.

Previous review articles have summarized literature on children's active transport to school (Davison, Werder, and Lawson 2008; Sirard and Slater 2008), children's active transport to school and health outcomes (Faulkner et al. 2009), and children's active transport to any destination (Pont et al. 2009). This article contributes to the literature by framing the findings

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from research on active transport to school in terms of implications for SRTS and planning practitioners.

SRTS Background

Originally developed in Denmark during the 1970s in response to unsafe pedestrian and bicyclist environments for children, SRTS programs soon spread internationally. The first U.S. programs appeared in 1997 in Florida and New York. After numerous grassroots, state-funded, and pilot SRTS programs, the 2005 federal transportation bill, Safe Accountable Flexible Efficient Transportation Equity Act: A Legacy for Users (SAFETEA-LU), established a national SRTS program within the Federal Highway Administration (FHWA). The FHWA allocates money to State DOTs, which in turn award grant money to local agencies for SRTS projects (NCSRTS 2006). SAFETEA-LU also established a National Center for Safe Routes to School (NCSRTS) to act as a clearinghouse for SRTS program resources.

SRTS programs support children walking or biking safely to and from school through some combination of the five Es: Engineering (e.g., pedestrian and bicycle infrastructure improvements); Education (e.g., pedestrian and bicyclist safety courses); Enforcement (e.g., increased police patrols near schools); Encouragement (e.g., special events or media campaigns); and Evaluation (e.g., data collection and analysis). SAFETEA-LU stipulates that each state spend 70 to 90 percent of its federal SRTS funding on infrastructure development and the remainder on non-infrastructure activities (NCSRTS 2006).

SAFETEA-LU allocated $612 million to the federal SRTS program and, as of December 31, 2009, State DOTs have announced $427 million in awards for SRTS projects. Demand for these projects has outpaced funding. The awarded $427 million represents less than a third of the $1.3 billion in SRTS funding requested through grant applications (NCSRTS 2009). Some states and regional agencies provide additional funding for their SRTS programs and SRTS stakeholders are lobbying to expand the program with the passage of the next transportation bill (Safe Routes to School National Partnership 2009).

SRTS Evaluations

Evaluations of SRTS programs are limited. This may be in part to the newness of the program and the few completed projects due to the lag time required for money to flow from the FHWA to grant recipients. Additionally, SAFETEA-LU did not mandate data collection nor evaluations of the SRTS program (National Safe Routes to School Task Force 2008). The NCSRTS does act as a data clearinghouse for programs that choose to collect data and is developing a national program evaluation plan. To date the published body of SRTS evaluations consists of legacy SRTS programs—those that were established before the FHWA SRTS program.

Rates of ATS. Three evaluations of SRTS projects in California examined pre- and post-project rates of walking and biking to school (Boarnet et al. 2005; Orenstein et al. 2007; Staunton, Hubsmith, and Kallins 2003). In a convenience sample of ten elementary schools that implemented a SRTS project, rates of walking and bicycling reported through a parent survey declined after SRTS projects were implemented; however, rates increased for students who passed a sidewalk or traffic signal improvement on the way to or from school (Boarnet et al. 2005). In an evaluation of 125 SRTS schools, only a small number of schools reported pre- and post-project rates of walking and biking. Rates varied greatly from school to school and depending on the data collection method. Direct observations yielded increases from 20 to 200 percent while increases reported through parent surveys were in the range of 10 percent (Orenstein et al. 2007). In Marin County, public schools that took part in a SRTS program were surveyed during the 2000–2001 and 2001–2002 school years. Six schools were surveyed in 2000–2001 and seven in 2001–2002. From fall 2000 to spring 2002, researchers observed a 64 percent increase in the number of children walking, a 114 percent increase in the number of students biking, a 91 percent increase in the number of students carpooling, and a 39 percent decrease in the number of children arriving by private car carrying only one student (Staunton, Hubsmith, and Kallins 2003). The validity of these figures is questionable because only two schools participated in surveys in both school years. In all three evaluations, none of the changes in rates of ATS could be directly attributed to the effects of SRTS programs because they were not compared to changes in rates at control schools. Evaluations using more rigorous experimental designs are necessary to assess the effect of SRTS programs on ATS.

The walking school bus (WSB)—sometimes a component of SRTS programs—consists of an adult chaperone that walks with children along a specified route to or from school, picking up or dropping off children along the way. The adult monitors children, providing regular encouragement of proper pedestrian skills (Johnston et al. 2006). In Seattle, a WSB program resulted in a 25 percent increase in children walking to school (Johnston 2008). in Auckland, New Zealand, children who participated in a WSB program walked to or from school an average of 6.7 trips per week, resulting in an estimated 19.5 fewer cars outside the school at the start or end of each school day (Kearns, Collins, and Neuwelt 2003). In Hertfordshire, England, 22 schools with a total of 26 WSBs reported an average of ten children per route, 62 percent of whom previously traveled to or from school by car (Mackett et al. 2005).

Safety. In a California SRTS evaluation, the overall annual rate of collisions that resulted in injury or death of child pedestrians or bicyclists within a quarter mile of SRTS schools declined by 13 percent from pre-project to post-project periods (Orenstein et al. 2007). Control areas also experienced a similar decline in pedestrian and bicyclist collisions. These findings show that SRTS programs are at least benign in terms of crash involvement—they do not result in increased collisions. A similar conclusion was reached in a study that examined rates of child pedestrian and bicycle collision in three states (Blomberg et al. 2008). The authors of the California evaluation went on to conclude that SRTS areas would have seen a net increase in exposure-based pedestrian and bicyclist safety based on limited evidence that the number of children walking and biking to school increased at SRTS schools (Orenstein et al. 2007). They estimated that safety benefits ranged from no net change to a 49 percent decrease in the collision rate among child pedestrians and a 100 percent decrease for child bicyclists. They calculated that the cost for each collision prevented by a SRTS project ranged from $40,397 to $282,779, depending on the assumed increase in ATS. These costs were greater than other road safety improvement programs, but did not account for other potential benefits of the SRTS program, such as decreased traffic congestion and air quality near schools, increased safety for adult pedestrians in the vicinity, and increases in physical activity among students.

Dumbaugh and Frank (2007) reviewed the results of empirical safety evaluations of ten pedestrian countermeasures commonly included in SRTS projects. They found that active police enforcement and physical traffic calming features, such as speed humps, slow motorists to a degree that would reduce the frequency of pedestrian–vehicle collisions. Sidewalks and raised medians reduced the actual frequency of pedestrian–vehicle collisions by effectively separating vehicular from pedestrian traffic. The effectiveness of other common SRTS program elements was largely assumed. Signalized crossings were found to result in safer pedestrian–auto interactions, but unsignalized crosswalks were found to result in more collisions. This corresponded with research done at SRTS projects in California, where sidewalk and traffic signal improvements were associated with improved safety behaviors while crosswalk installation, crosswalk signal improvements, and bicycle path improvements were not (Boarnet et al. 2005). Dumbaugh and Frank (2007) found that school zone flashing lights were found to reduce speeds only by about 5 mph, with average travel speeds remaining above speed zone limits. The safety effects of bicycle lanes were disputed. Motorist education programs resulted in little or no behavior change. Child pedestrian education programs were only shown to increase safety knowledge in pencil-and-paper tests. But a Miami-Dade County, Florida elementary school-based pedestrian safety program was found to increase pedestrian safety knowledge in paper-and-pencil tests *and* positive pedestrian crossing behaviors, even three months after the program (Hotz et al. 2004). Finally, no studies were found on the safety effects of crossing guards. Research examined in Dumbaugh and Frank's (2007) evaluation, however, did not specifically measure the potential combined influence of these measures or the effect of these measures on children. Due to developmental limitations, children up to age nine are at "considerable risk" of traffic danger (Ampofo-Boateng and Thomson 1991) and the maximum vehicular confrontation speed for children aged six and younger is estimated at 10 mph (Vahl and Giskes 1990). For these reasons, considerable safety measures may be necessary to ensure the safety of young children walking and biking to school.

Qualitative outcomes. Agencies involved in California SRTS projects generally felt that the program had succeeded in improving safety for schoolchildren and for other neighborhood residents (Orenstein et al. 2007). The majority of parents at SRTS schools noticed the construction project, thought it would increase safety, and thought it was important (Boarnet et al. 2005). The inner-city Seattle WSB program was attributed with helping to forge a functioning parent–teacher association at a school that had been divided across multiple ethnic, cultural, and linguistic lines (Johnston 2008). This suggests that walking to school with neighbor children can promote a sense of community and trust among families. Parents involved in the Auckland WSB programs cited personal benefits in the amount of time saved, the removal of the hassle of driving and finding a parking space, and knowing that children were safe. Parents saw their children benefiting from the healthy aspects of exercise, mixing with other children, and the independence of walking (Kearns, Collins, and Neuwelt 2003). WSBs do not always result in positive outcomes. Some parental participants reported time loss and negative social outcomes (Mackett et al. 2005). WSBs have also been criticized as a form of social control, since they are dependent upon parental surveillance and are subject to adult-imposed rules (Kearns, Collins, and Neuwelt 2003). However, interviews with WSB participants in Christchurch, New Zealand, indicated that in addition to many social benefits, the program encouraged children's independent mobility (Kingham and Ussher 2007). Unfortunately, WSBs are difficult to maintain due to lack of volunteers, coordination difficulties, persistent fears of traffic safety, and insufficient ongoing support from schools (Kingham and Ussher 2005; Mackett et al. 2005).

Method

A literature review was conducted in the summer of 2008. The majority of articles identified in this review were cited in a recently published review of children's ATS (Davison, Werder, and Lawson 2008). Additional literature was identified through searches of PubMed, ScienceDirect, the National Transportation Library, and Active Living Research databases using relevant keywords. Included in this review were articles and reports published after 2000 that presented findings from correlational research on children's ATS. Children were defined as aged eighteen and younger. Additional SRTS resources were obtained through the NCSRTS and the Safe Routes to School National Partnership, an organization of SRTS stakeholder groups.

In the literature reviewed, factors influencing the choice of ATS came in the form of variables that were tested for a significant association with ATS. To assemble the evidence, each variable was recorded along with three possible statistical associations with ATS: a positive significant association ($p \leq .05$), a negative significant association ($p \leq .05$), or no significant ($p > .05$) association. The measurement technique used was also recorded for each variable. Any single article could contribute to the evidence with multiple variables and only variables with a reported association with the ATS were included.

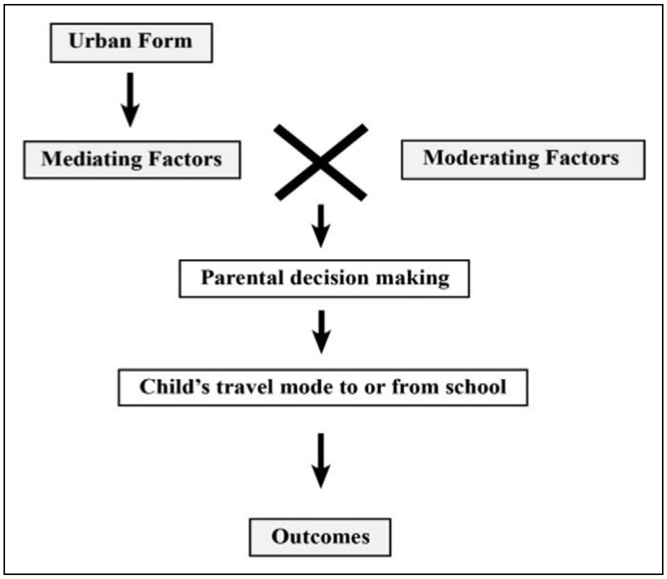

Figure 1. Conceptual framework of a child's commute mode to/from school. Arrows indicate hypothesized direction of relationships. X indicates interaction between mediating and moderating factors. Adapted from McMillan (2005).

Variables were first grouped into a conceptual framework of a child's commute mode to school based on McMillan's (2005) "Conceptual Framework of an Elementary-Aged Child's Travel Behavior." The conceptual framework included five levels filtering the decision to select a specific mode of travel and its outcome (figure 1). First were the characteristics of the urban form at the home and the school locations, and between the two. Second were mediating and moderating factors influencing the decision. Third and fourth were the parent's decision and the resulting mode of travel used by the child. And fifth were the health and other outcomes of the travel mode choice. McMillan's conceptual framework suggested that urban form characteristics, such as sidewalks, crosswalks, or other features of the built environment, had an *indirect* effect on a child's mode of transportation to or from school. Instead, given certain urban from characteristics, *a parent developed opinions about the ability of the built environment* to support different modes of travel for their child. These opinions were called mediating factors because they acted as intervening causal variables, or mediators, on a child's travel behavior. Mediating factors included other factors that were hypothesized to have a *direct* effect on a child's transportation options, such as the availability of a car or bike. These mediating factors were moderated—either intensified or diminished—by cultural norms, attitudes, and other factors external to the immediate environment and the trip to school. These were called moderating factors. The interaction of mediating and moderating factors shaped the parent's decision of how a child travels to or from school.

Hypothesized outcomes of children walking or biking to or from school included physical health improvements, air quality improvements, and traffic congestion relief near schools during peak commute times (National Safe Routes to School Task Force 2008). This conceptual framework served as an outline for examining the results of all the variables that had been tested for correlation with ATS.

The conceptual framework was originally developed for elementary-aged students. As such, it might be less accurate for younger children, who likely had fewer transportation options due to developmental limitations, and older children, who might have more to say about their mode of travel. Some research suggested that a child's travel mode on the trip to school was more of the result of a negotiation between child and parent than that of a purely parental decision (Valentine 1997). McMillan (2005) contended that the ultimate decision was likely to be made by the parent.

The framework identified paths of influence. Paths were helpful for understanding possible relationships between different variables and ATS. However, since the vast majority of research on the subject was cross sectional—only two studies tested change in body mass index (BMI) over time (Heelan et al. 2005; Rosenberg et al. 2006)—paths of influence could not be confirmed. Finally, this framework did not include paths of feedback. It was suggested that travel mode to school, parental concerns of traffic danger, and concerns about the risks of criminal danger were interrelated (Carver, Timperio, and Crawford 2008). Parents who drove their children to school might be attempting to protect them from traffic danger, to which they in turn were contributing. Increased traffic danger might lead to fewer people cycling, walking, or generally out and about in a neighborhood. This might then lead to less familiarity with neighbors and increased fear of danger from strangers. As a result, other parents might fear that their child would become a victim of crime and feel it was necessary to drive them to school, thus further increasing traffic volume and, once again, contributing to traffic safety fears. The conceptual framework did not capture such complex interrelationships.

The variables associated with ATS were grouped in four of the conceptual framework categories: urban form, mediating and moderating factors, and outcomes. The noted limitations of the conceptual framework were addressed by in-depth discussions of the variables grouped within each category. For discussion, variables with similar characteristics were further grouped into subcategories.

Findings and the Implications for SRTS Programs

The literature review identified forty-two articles and government reports that presented findings from correlational research on ATS (table 1).

A direct comparison of results was prohibited due to various measurements and methodologies. Most studies used children as the unit of analysis, although one used schools (Sirard, Ainsworth et al. 2005). Geographic scope ranged from nationwide to school-specific. Data were obtained from a variety of sources including parent and child surveys, transportation diaries, physical activity recall questionnaires, census and other government-supplied data, geographic information system (GIS)

Table 1. Articles Identified in Literature Review. "Reference Code" Links Each Article to its Reported Variables in Tables 2–5

Reference Code	Reference	Population	Location	*n*	Year of Data
1	(Alexander et al. 2005)	Children aged 13–14	Edinburgh, United Kingdom	92	2004
2	(Black, Collins, and Snell 2001)	Children aged 5–7	Urban England	4,180	1996
3	(Bricker et al. 2002)	Children aged 5–15	GA	1,656	2000
4	(Bringolf-Isler et al. 2008)	Children aged 6/7, 9/10, 13/14	Switzerland	1,031	2004–2005
5	(Cooper et al. 2003)	Children aged 10	Bristol, England	114	2002
6	(Cooper et al. 2005)	Children aged 9/10	Odense, Denmark	323	1997–1998
7	(Cooper et al. 2006)	Children aged 9–15	Odense, Denmark	919	1998–1999
8	(diGuiseppi et al. 1998)	Children Aged 6/7, 9/10	London	2,086	Not reported
9	(Evenson et al. 2003)	Children grades 9–12	NC	2,297	2001
10	(Evenson et al. 2006)	Girls grades 6/8	Cities in AZ, MD, MN, LA, CA, SC	480	2002
11	(Ewing, Schroeer, and Greene 2004)	Children grades K–12	Gainesville, FL	709	2000–2001
12	(Kweon et al. 2007)	Children grades 5–8	College Station, TX	186	Not reported
13	(Fulton et al. 2005)	Children grades 4–12	United States	1,395	1996
14	(Heelan et al. 2005)	Children aged 10	Rural NE	320	Not reported
15	(Kerr et al. 2006)	Children aged 5–18	King County, WA	259	Not reported
16	(Loucaides and Jago 2008)	Children aged 10–11	Cyprus	247	2007
17	(Martin and Carlson 2005)	Children aged 5–18	United States	1,588	2004
18	(Martin, Lee, and Lowry 2007)	Children aged 9–15	United States	2,649	2004
19	(McDonald 2007a)	Children aged 5–18	United States	14,553	2001
20	(McDonald 2007b)	Children aged 5–18	Alameda County, CA	614	2000
21	(McDonald 2008a)	Children aged 5–13	United States	6508	2001
22	(McDonald 2008b)	Children aged 5–18	United States	14,553	2001
23	(McMillan 2006)	Children grades 3–5	10 CA communities	1,244	Not reported
24	(McMillan 2007)	Children grades 3–5	CA	1,128	Not reported
25	(Merom et al. 2006)	Children aged 5–12	NSW, Australia	812	2002
26	(Metcalf et al. 2004)	Children aged 5	Urban England	275	Not reported
27	(Mota et al. 2007)	Children aged 5	Urban England	275	Not reported
28	(Nelson et al. 2008)	Children aged 15–17	Ireland	4,013	2003–2005
29	(Pabayo and Gauvin 2008)	Children aged 9, 13, 16	Quebec, Canada	3,613	1999
30	(Rosenberg et al. 2006)	Children grades 4–5	Southern CA	924	1990
31	(Saksvig et al. 2007)	Girls grade 6	Cities in AZ, MD, MN, LA, CA, SC	1,596	Not reported
32	(Schlossberg et al. 2006)	Children grades 6–8	Oregon	287	2004
33	(Schofield, Schofield, and Mummery 2005)	Children grades 8, 11	Queensland, Australia	1,033	Not reported
34	(Sirard, Ainsworth et al. 2005)	Elementary schools	Columbia, SC	8	2002
35	(Sirard, Riner et al. 2005)	Children grade 5	Columbia, SC	219	Not reported
36	(Timperio et al. 2006)	Children aged 5, 6, 10–12	Melbourne, Australia	885	2001
37	(Tudor-Locke et al. 2002)	Children aged 7–13	Russia	1,094	1998
38	(Tudor-Locke et al. 2003)	Children aged 14–16	Philippines	691	1998-99
39	(Yang et al. 2008)	Children in elementary school	Lane County, OR	1,197	2007
40	(Yarlagadda and Srinivasan 2008)	Children aged <18	San Francisco Bay Area, CA	4,352	2000
41	(Yeung, Wearing, and Hills 2008)	Children aged 4–12	Brisbane, Australia	318	Not reported
42	(Ziviani, Scott, and Wadley 2004)	Children grades 1–7	Brisbane, Australia	164	Not reported

data, accelerometer data, and direct observations. Many studies used random sampling techniques or a convenience sample; others used purposeful sampling techniques to compare, for example, students in urban and suburban areas (Sirard, Ainsworth et al. 2005; Schlossberg et al. 2006).

The majority of studies included all children that attended a school or a set of schools or all trips to school from a set of travel diaries. A few limited their analyses to children that could readily use ATS because they lived either within a school walk zone (Kweon et al. 2007), a distance considered walkable (Martin, Lee, and Lowry 2007), or an empirically defined maximum walking and biking distance (Yarlagadda and Srinivasan 2008).

ATS was defined in various ways. Some research simply used the child's usual mode of transportation (Bricker et al. 2002), while other studies defined ATS as walking or biking to school at least once a week (Evenson et al. 2006). Martin, Lee, and Lowry (2007) found that in a nationally representative sample of children aged nine to fifteen who lived within a mile of school, almost three-quarters of children who walked or biked to school at least once in a week did so all five school days. The variables they found to be significantly associated with ATS changed very little when they changed their definition of ATS from walking or biking at least one day a week to all five days.

From the 42 articles, 480 variables tested for correlation with ATS were identified. Variables were classified into all four categories of the conceptual framework; 38 subcategories of variables that measured similar characteristics were identified.

Urban Form Factors

Urban form factors were features of the physical environment in which a child's commute to school occurred. The conceptual framework suggested that urban form indirectly affected a child's school commute mode by shaping parents' opinions about the ability of the built environment to support various transportation options.

Measures of urban form variables were both objective (GIS data or direct observations) and subjective (parent or child surveys). For discussion, urban form variables have been classified into the following eight subcategories: distance to school, non-motorized infrastructure, route barriers, network connectivity, land use mix, density, walkability, and urbanization (table 2).

Distance from a child's home to school was the clearest correlate of ATS. Of the twenty-two times distance to school was examined, the only time a significant negative relationship was not found was when children living between one half and one mile to school were compared with children living within 1–2 miles from school (McDonald 2008b).

The strong influence of distance on ATS illustrates the conceptual model. Distance from a child's home to school is a feature of the built environment directly related to travel time to school—a mediating factor that directly influences mode choice. In a nationwide U.S. study, a 1-minute increase in the time it takes to walk to school led to a 0.2 percent decrease in the likelihood of a child walking to school (McDonald 2008a). The relationship between distance to school and the probability of ATS was linear for trips less than a mile but dropped to a constant low rate for trips greater than 1 mile (McDonald 2008a). These thresholds differed slightly from those found in Ireland, where a 1-mile increase in a child's distance from school was found to decrease the probability of active commuting by 71 percent and the majority of walkers lived within 1½ miles of school and the majority of cyclists lived within 2½ miles (Nelson et al. 2008).

In a study using San Francisco Bay Area travel diaries, six miles was found to be the maximum distance a child would walk or bike to or from school (Yarlagadda and Srinivasan 2008). In the same study, distance was found to have a greater impact on travel to school than travel from school, which suggested that pressure to arrive at school on time might result in greater sensitivity to distance.

Distance was a strong correlate of, but not a sufficient factor determining, ATS. In the United States, only 47 percent of the decline in the rate of ATS between 1969 and 2001 was explained by greater distances from homes to school (McDonald 2007a). And nationally, of children who lived within a mile of school, only 47.9 percent walked or biked to school (Martin, Lee, and Lowry 2007).

The presence of various non-motorized transportation infrastructure features—mostly sidewalks—was found to be positively associated with ATS in about half the studies they were tested. Five of the twelve significant associations were found in a study that only included students who lived within 2 miles of their school (Kweon et al. 2007), which suggested that non-motorized transportation infrastructure was more effective at distances that could readily be walked or biked. But other literature suggested that urban form played a greater role in influencing trips at the margin of what was considered walkable, while mediating and moderating factors had a greater influence on trips that could easily be walked (McDonald 2007b).

Three studies examined the specific route a child would travel on the way to school from his or her house (Bringolf-Isler et al. 2008; Timperio et al. 2006; Schlossberg et al. 2006). Major road crossings were twice found to have a negative association with ATS (Bringolf-Isler et al. 2008; Timperio et al. 2006) and steep slopes were negatively associated with ATS for young children, aged five and six (Timperio et al. 2006). Timperio et al. (2006) also found direct routes to school were negatively associated with ATS. The authors speculated this was because more direct streets carried a heavier volume of traffic, which would inhibit walking and biking.

Neighborhood characteristics including street network connectivity (Kweon et al. 2007; Schlossberg et al. 2006; Mota et al. 2007; Kerr et al. 2006), mix of land uses (Martin, Lee, and Lowry 2007; Saksvig et al. 2007; Kerr et al. 2006; Kweon et al. 2007; McMillan 2007; McDonald 2007b), and population density (Nelson et al. 2008; McDonald 2007b, 2008a, 2008b; Kerr et al. 2006; Kweon et al. 2007) were associated with greater ATS. The density and street connectivity trends make intuitive sense. Neighborhoods with dense populations and well-connected street networks are likely to have a larger portion of children who live within easy walking or biking distances of schools and routes to school that carry less traffic. The significance of mixed land use is more difficult to interpret. It is often associated with walking for transportation in the general population due to the close proximity of potential destinations (Saelens and Handy 2008). For ATS, however, school and home are the only destinations necessary. The influence of mixed land use on ATS may be due to children and parents who are accustomed to walking to other neighborhood destinations and are therefore comfortable with walking or biking to school. The links between these neighborhood urban form characteristics and active transport to school was reinforced by the

Table 2 (continued)

Urban Form Variable	Associated with ATS	Measurement	Reference Code
Destinations within walking distance of home	None	Child Survey	10
Destinations, access to stores	None	Child Survey	27
Destinations, access to transit	None	Child Survey	27
Downtown school location	None	Parent Survey	39
Employment within ¼ mile	None	GIS/Govt. data	40
Job mix in TAZ	None	GIS/Govt. data	11
Jobs-resident balance in TAZ	None	GIS/Govt. data	11
Land use mix	None	GIS/Govt. data	15
Land use mix within ¼ mile of home	None	GIS/Govt. data	40
Land use mix, diversity	None	Parent Survey	15
Many recreation facilities in neighborhood	None	Child Survey	27
Density (nine variables)			
Population density	+	Govt. data	28
Population density	+	Travel Diary	21
Population density	+	Travel Diary	22
Population/residential density	+	GIS/Govt. data	20
Population/residential density	+	GIS/Govt. data	15
Population/residential density in 2-mile walk zone	+	GIS/Govt. data	12
Overall residents and job density in TAZ	None	GIS/Govt. data	11
Population density	None	GIS/Govt. data	4
Population/residential density	None	Parent Survey	15
Walkability (three variables)			
Walkability, individual	+	GIS/Govt. data	15
Walkability, neighborhood	+	GIS/Govt. data	15
Walkable neighborhood	+	Parent Survey	39
Urbanization (ten variables)			
Urbanization, urban (referent is rural)	− (only for girls)	Parent Survey	38
Urbanization, suburb/small town (referent is rural)	+	Parent Survey	13
Urbanization, urban (referent is metro suburban, second city, town, or rural)	+	GIS/Govt. data	18
Urbanization, urban (referent is rural)	+	Child Survey	29
Urbanization, urban (referent is rural)	+	Parent Survey	19
Urbanization, urban (referent is rural)	+	Survey	33
Regional accessibility of TAZ	None	GIS/Govt. data	11
Urbanization, urban (referent is rural)	None	GIS/Govt. data	40
Urbanization, urban (referent is rural)	None	Parent Survey	3
Urbanization, urban (referent is suburban)	None	GIS/Govt. data	34

Note: ATS = active transportation to school; PA = Physical activity; FAR = floor area ratio; TAZ = traffic analysis zone.

finding that a "walkability" index—an aggregate measure of residential density, retail floor area ratio, intersection density, and land use mix—was positively associated with ATS (Kerr et al. 2006). Walkability measured through a parent survey was also associated with ATS (Yang et al. 2008). It came as no surprise that areas of greater urbanization, where these walking-supportive urban form characteristics were commonly found, were often associated with greater rates of ATS (Fulton et al. 2005; Martin, Lee, and Lowry 2007; McDonald 2007a; Pabayo and Gauvin 2008; Schofield, Schofield, and Mummery 2005). The single study that found a significant negative association between urbanization and ATS was carried out in the Philippines; the finding was attributed to lower socioeconomic status, and therefore fewer transportation options, of rural Filipinos (Tudor-Locke et al. 2003).

Discussion. Distance was the most consistent correlate of ATS, and children were more likely to walk or bike to school in dense, urban, mixed use, and highly connected neighborhoods. Many of these neighborhoods may already have complete and safe pedestrian and bicycle infrastructure and high rates of walking and biking to school. These places would benefit little from a SRTS project. But dense, urban, mixed use, and highly connected neighborhoods without complete pedestrian and bicycle infrastructure and low rates of walking to school would be highly effective locations for a SRTS project. In areas such as these, strategically placed infrastructure improvements could fill missing gaps in otherwise robust pedestrian or bicycle transportation networks and low-cost non-infrastructure activities to encourage walking and biking would reach the greatest number of children that could potentially walk or bike safely to school. Additionally, SRTS infrastructure improvements in urban areas would affect the greatest percentage of the general population (Watson and Dannenberg 2008).

Schools in nonurban areas that tend to lack the built environment features that support walking and biking may have a great need for SRTS infrastructure improvements. But because distance is such a strong influence on walking and biking, they will get little use unless there is a substantial child population near the school. Additionally, most SRTS project budgets can only afford to make minor improvements to the pedestrian and bicycle environment, not systematic overhauls to an entire neighborhood's street network. Smart growth strategies to maintain existing neighborhood schools and contain residential development within these already built-up neighborhoods could be effective at supporting ATS in the long term. These strategies could maintain, and eventually increase, the population of children that could safely walk or bike to an existing school.

Sidewalks and traffic signal improvements were found to result in increased ATS and safer pedestrian–auto interactions (Boarnet et al. 2005). These features were also frequently found to be associated with ATS in the correlational research reviewed. SRTS planners should focus on these engineering improvements but not at the neglect of a detailed assessment to identify the unique pedestrian infrastructure needs of a specific community.

Mediating Factors

Mediating factors had a direct influence on a parent's choice of their child's travel mode to or from school. Mediating factors included direct effects of the social and natural environments—such as crime rates, traffic collision rates, or the weather—and the way in which parents and children interpreted their environment—such as perceived risks of crime or traffic. Also included in this category were factors that had a direct effect on a child's transportation options, such as the availability of a car or extracurricular activities that might require additional travel. Mediating variables were classified into the nine following subcategories: general safety, traffic, crime, neighborhood characteristics, school characteristics, transportation options, schedule constraints, and weather. Six additional variables were categorized as miscellaneous mediating factors (table 3).

In the correlational research reviewed, safety concerns were only sometimes found to have a significant negative association with ATS. Concerns for general safety and traffic safety were more often associated with actual walking and biking than concerns about crime.

In almost half the studies that tested household access to automobiles, a significant negative relationship with ATS was found. Schedule constraints that limited transportation options, such as after school activities or full-time employment, were also occasionally associated with less ATS. This might be due to parents who found it convenient to drive their children to school on their way to other destinations or did not have the extra time needed to accompany their children on the walk to or from school.

School characteristics that impact transportation also appeared to influence ATS. The most obvious example was school policies that restricted ATS. Parents who reported a school policy that acted as a barrier to walking or biking to school were less likely to have children who did so (Martin and Carlson 2005). Perceived parking problems at school were also associated with ATS (Black, Collins, and Snell 2001). This finding came from an urban sample of households where distances to school were generally short. In these areas, the added time necessary to find a parking space when driving a child to school may make non-motorized modes more appealing. Children at public schools were more likely to walk or bike than students at private (diGuiseppi et al. 1998; Merom et al. 2006) or alternative schools (Yang et al. 2008). Because private schools typically draw students from a larger area, distances from residences to private schools are likely too far to walk for most students.

Just as children living in more walkable neighborhoods were more likely to use ATS, children and parents who reported what could be considered "nicer" neighborhood characteristics were found to be more likely to walk or bike to school. Perhaps, the most comprehensive measurement of a "nice" neighborhood used in these studies was social control and cohesion as reported in the 2003 California Health Interview Survey. In this survey, respondents were asked how strongly they agreed or disagreed with statements such as "people in my neighborhood are willing to help one another," "people in this neighborhood generally do not get along with each other," "people in this neighborhood can be trusted," and "most people in this neighborhood know each other" (McDonald 2007b). These individual-level responses were transformed to census tract-level aggregates. In a San Francisco Bay Area study, social control and cohesion was the strongest social environment correlate of ATS, with greater rates of social control and cohesion associated with greater rates of ATS (McDonald 2007b).

Discussion. Transportation options clearly influence ATS. SRTS projects in areas with less car ownership should be prioritized because more children are likely to already walk or bike to school in these places. Securing the safety of these children that have few travel options other than walking should be a priority for SRTS programs. To encourage non-motorized trips to school for households that do have an option, SRTS projects should modify the school environment to ensure it supports walking and biking and discourages children arriving in the family car—removing any policies that discourage walking to school and expanding bicycle parking at the expense of auto parking, for example. District-wide policies such as courtesy busing and school choice should also be reviewed from the perspective of encouraging ATS. SRTS programs should also consider the broader community surrounding a school. Community building efforts that improve aesthetics, encourage social interactions, and promote outdoor activities in a neighborhood could result in parents perceiving their neighborhood as one that could support a walk or bike trip to school.

Because parents' and children's travel schedules are closely linked (Yarlagadda and Srinivasan 2008), SRTS programs could be more effective if they focus on transportation mode shifts for the entire household, not simply children. Policies aimed at reducing driving alone or increasing commute flexibility for parents, such as commute trip reduction (CTR) and transportation demand management (TDM) programs, might result in greater rates of walking and biking to school for children. Further research on household transportation patterns could be useful for identifying broader policies that facilitate active commuting for the entire household. In the meantime, public participation processes could be carried out at the city, school district, neighborhood, or school level to identify programs that would complement SRTS programs by giving parents the flexibility necessary to walk or bike with their children to school.

Safety concerns were only sometimes found to have a significant negative association with ATS. They were, however, frequently reported. A 2004 Centers for Disease Control and Prevention (CDC) survey found that 30.4 and 11.7 percent of parents reported traffic and crime danger, respectively, as a barrier to their child walking or biking to school (Martin and Carlson 2005). Traffic safety concerns for child bicyclists and pedestrians were not without good reason. Although child pedestrian and bicyclist injury rates have declined, it was attributed to less exposure—fewer children walking and biking—not increased safety (CDC 2007a). Bicycling and walking were the two most dangerous commute modes to and from school when analyzed on the basis of exposure (Transportation Research Board [TRB] 2002). Crime concerns may be based more on social norms than actual risk. No trend data exist on violent crimes (homicide, rape, robbery, and simple and aggravated assault) against young children; however, the rate of violent crime against twelve- to nineteen-year-olds has declined (CDC 2008a). From 1973 to 2005 the rate of these crimes dropped from about 80 to 44 cases per 100,000 children (U.S. Department of Justice 2006). Kidnapping makes up only 2 percent of violent crimes against youth and only 4 percent of all kidnappings occur around schools (Finklehor and Ormrod 2000). And children, like adults, are statistically much more at risk of being harmed by people they know (Valentine 1997). An English qualitative study revealed that parental concern of "stranger danger" was often based on media coverage of a single case of abduction and that letting a child travel alone is an indicator of neglectful or irresponsible parenthood (O'Brien et al. 2000).

It appeared that practical constraints like distance and transportation options were more likely to be related to walking and biking to school than safety concerns. But this may be because households with children that must walk or bike to school did so despite a perception of unsafe conditions. These cross-sectional studies cannot examine the direction of any relationship. It could be that households became more aware of potential dangers of walking and biking to school when the child actually did so. This might explain why parents who said their child thought it was safe to play in their neighborhood were less likely to have children that walked or biked to school (Fulton et al. 2005).

SRTS programs must address safety concerns—real or perceived. The dangers for child pedestrians and bicyclists and the tendency for parents to react to media reports of kidnappings means that SRTS programs must truly succeed at making a safe environment for child pedestrians and bicyclists if they are to realize a mode shift toward active transportation. Additional research that examines the relationship between ATS and objectively measured crime rates, traffic volumes, or pedestrian safety indicators could be useful in determining to what extent SRTS projects should focus on real or perceived dangers.

Moderating Factors

Moderating factors encompassed all factors external to the immediate travel mode decision. Moderating variables covered a wide range of characteristics—from a child's height to a parent's employment status. For discussion, these variables were classified into sixteen subcategories: age, gender, culture (foreign and regional), race/ethnicity, income, employment, education, socioeconomic status, household size (absolute, parents, and siblings), child's independence, attitude toward ATS, attitude toward physical activity, and attitudes toward driving. Twelve additional variables could not be neatly grouped and were classified as miscellaneous factors (table 4).

Findings from studies that examined age were mixed. Generally, those studies showing a negative correlation between age and ATS included only older children, aged nine to eighteen (Pabayo and Gauvin 2008; Tudor-Locke et al. 2003;

Table 4 (continued)

Moderating Variable	Associated with ATS	Measurement	Reference Code
Education, mother	None	Parent Survey	4
Education, parent	None	Child Survey	9
Education, parent	None	Parent Survey	39
Education, parent	None	Parent Survey	13
Education, parent	None	Parent Survey	12
Education, parent	None	Parent Survey	23
Education, parent	None	Parent Survey	15
Neighborhood socioeconomic status (three variables)			
Neighborhood disadvantage	+ (only for Hispanics)	Parent Survey	22
SES level, school area	None	Govt. data	36
SES level, school area	None	Unspecified	34
Household size, absolute (one variable)			
No. of household members	None	Parent Survey	11
Household size, parents (eight variables)			
Marital Status, Divorced	+	Parent Survey	18
Single-parent, parent not currently married	+	Parent Survey	13
Marital status, widowed, separated, or never married	None	Parent Survey	18
Single parent, child lives in female headed household	None	Census	20
Single parent, parent not currently married	None	Parent Survey	25
Single-parent, lives with one parent	None	Parent Survey	4
Single-parent family	None	Parent Survey	36
Single-parent, no. of parents living at home	None	Parent Survey	13
Household size, siblings (seven variables)			
Siblings, no. of children in household	+	Parent Survey	24
Siblings, no. of children in household	+	Parent Survey	12
Siblings, presence of	+	Parent Survey	21
Siblings, no. of children in household	None	Parent Survey	18
Siblings, presence of	None	Parent Survey	36
Siblings, presence of	None	Parent Survey	2
Siblings, presence of	None	Travel diary	40
Child's independence (eight variables)			
Child's level of independence	+	Parent Survey	25
Child perceives self as a leader	None	Child Survey	18
Child perceives self as confident	None	Child Survey	18
Parent allows unsupervised play	None	Parent Survey	13
Parental Restrictions	None	Parent Survey	4
Parents allow biking alone	None	Child Survey	10
Parents allow use of public transit alone	None	Child Survey	10
Parents allow walking alone	None	Child Survey	104
ATS attitude (seven variables)			
Family approval of walking to school	+	Parent Survey	24
Family approval of walking to school	+	Parent Survey	23
Intended on child using ATS when chose residence	+	Parent Survey	39
Parents prefer ATS	+	Parent Survey	39
Parents value interaction on trip to school	+	Parent Survey	24
Parents walked to primary school	+	Parent Survey	42
Child is unwilling to use ATS	None	Parent Survey	12
Physical activity (PA) attitude (forty variables)			
Child participates in >1 organized PA session/week	−	Child Survey	18
Child can be physically active if it is hot or cold outside	+	Child Survey	18
Parent got >5 days of PA in the past 7 days	+	Parent Survey	18
Parent perceives child as too overweight for PA	+	Parent Survey	13
Parents value PA	+	Parent Survey	42
Parents value the health benefits of walking	+	Parent Survey	25
PE class 1–4 days a week (referent is no PE)	+	Child Survey	9
PE class 5 days a week (referent is no PE)	+	Child Survey	18
Child does not enjoy PA	None	Parent Survey	36
Child enjoys being active	None	Parent Survey	13

(continued)

Table 4 (continued)

Moderating Variable	Associated with ATS	Measurement	Reference Code
Child enjoys PA	None	Parent Survey	42
Child expects positive outcomes from PA	None	Parent Survey	18
Child has no energy	None	Parent Survey	36
Child has time for PA	None	Parent Survey	13
Child has transportation for PA	None	Parent Survey	13
Child not keen on walking	None	Parent Survey	25
Child participates in free time PA 3 or more times/week	None	Child Survey	18
Child perceives self as athletic	None	Child Survey	18
Child perceives self as lazy	None	Child Survey	18
Child screen time, TV/Movie watching	None	Child Survey	18
Child screen time, Video/computer time	None	Child Survey	27
Child screen time, Video/computer time	None	Child Survey	14
Parent believes he/she can influence child's participation in free time PA	None	Parent Survey	18
Parent believes he/she can influence child's participation in organized PA	None	Parent Survey	18
Parent believes PA is important	None	Parent Survey	13
Parent has favorable attitude toward PA	None	Parent Survey	18
Parent participated in PA with child >1 day/week	None	Parent Survey	18
Parent provides support for PA	None	Parent Survey	13
Parent thinks free time PA is important	None	Parent Survey	18
Parent thinks organized PA is important	None	Parent Survey	18
Parent time spent walking	None	Parent Survey	23
Parent's attitude supports PA	None	Child Survey	18
Parent's attitudes act as barrier to PA	None	Parent Survey	18
Participation in school sponsored sports teams	None	Parent Survey	13
PE class 1–4 days a week (referent is no PE)	None	Child Survey	18
Peers participate in PA everyday	None	Child Survey	18
Peers think PA is fun	None	Child Survey	18
Peers think PA is important	None	Child Survey	18
Sports equipment at home	None	Child Survey	10
Taking part in any in school sport/exercise	None	Child Survey	38
Auto attitude (three variables)			
Car-centeredness	−	Parent Survey	2
Concern, effects of driving on environment, safety	+	Parent Survey	2
Concern, environment	None	Parent Survey	2
Miscellaneous (twelve variables)			
Height	+	Parent Survey	12
Age, parent	None	Parent Survey	13
Age, parent	None	Parent Survey	2
BMI, parent	None	Parent Survey	13
Child perceives self as popular	None	Child Survey	18
Evening meals eaten as a family	None	Parent survey	18
Gender, parent	None	Parent Survey	15
Gender, parent	None	Parent Survey	13
Height	None	Parent Survey	41
Homeowner	None	Parent Survey	39
Live in same house as 1995	None	Census	20
TV limitations from parents	None	Parent Survey	18

Note: BMI = body mass index; SES = socioeconomic status.

Fulton et al. 2005; Evenson et al. 2003; Schofield, Schofield, and Mummery 2005). Studies showing a positive relationship focused primarily on younger children, aged five to fourteen (Merom et al. 2006; McDonald 2008a; Bringolf-Isler et al. 2008; Timperio et al. 2006; Kweon et al. 2007; Martin, Lee, and Lowry 2007). These results supported the suggestion that children were more likely walk or bike to school up until they received a driver's license, at which point ATS began to decline (McDonald 2007b). Other researchers speculated that older youth lived further away from their schools than younger students, with distance being an important barrier to ATS (Fulton et al. 2005). A study that distinguished between walking with a parent and walking alone found that younger children were more likely to walk with their mother, while older children were more likely to walk alone (Yarlagadda and Srinivasan 2008).

Girls were also found to be more likely to walk to school when they were accompanied by their mothers (Yarlagadda and Srinivasan 2008). In all other studies that found a significant relationship between gender and ATS, boys were more likely to walk or bike to school than girls.

No clear results emerged from correlational research on race and culture. Children in the Southern United States were less likely to walk or bike to school, possibly because of environmental constraints such as hotter climates and sprawling development patterns rather than regional cultural norms (Martin, Lee, and Lowry 2007). Two studies using separate, nationally representative samples initially found significant differences in rates of ATS by racial groups, but found no differences after controlling for several individual and neighborhood covariates such as distance to school, household income, and density (McDonald 2008b; Martin, Lee, and Lowry 2007).

Fewer household resources appeared to be consistently associated with greater ATS. Income, employment, education, socioeconomic status, and number of parents in a household were all found to be significantly negatively associated with ATS.

Attitudes toward transportation seemed to be a factor influencing ATS. Parents who had walked to their primary school were more likely to have children that walked or biked to school (Ziviani, Scott, and Wadley 2004). This suggested that current efforts to encourage children to walk to school could have long-lasting effects. Yang et al. (2008) found that parents sometimes considered the mode of transport their child would use for the trip to and from school when they purchased a home. Parents who intended for their children to walk or bike to school when purchasing a home were found to be more likely to have children that actually used these modes. A single British study examined the relationship between parental attitudes regarding cars and the effects of driving and the prevalence of children walking and biking to school in urban areas (Black, Collins, and Snell 2001). The authors found that higher levels of individual responsibility for the environment and lower levels of a car-centered lifestyle were correlated with more walking. General environmental awareness had no significant association with walking and biking to school.

The relationship between attitudes toward physical activity and ATS was less clear. Four studies found an association between positive attitudes in children or parents toward physical activity and ATS (Ziviani, Scott, and Wadley 2004; Merom et al. 2006; Evenson et al. 2003; Martin, Lee, and Lowry 2007). Fulton et al. (2005) found parental perception that their child was too overweight for physical activity was associated with a greater likelihood of walking and biking to school. This suggested that ATS was a viable option for physical activity for children who could not easily participate in recreational forms of physical activity. Martin, Lee, and Lowry (2007) also found that children who participated in organized physical activities at least once a week were less likely to use ATS. This could be due to the need to travel long distances to sports facilities at specific times that could make walking or biking to school unfeasible. Most physical activity variables tested, however, were not significantly associated with ATS.

A single study found parents' assessment of their child's level of independence was positively associated with ATS (Merom et al. 2006). Four other studies, however, found no association between various measures of children's independence and ATS (Bringolf-Isler et al. 2008; Evenson et al. 2006; Fulton et al. 2005; Martin, Lee, and Lowry 2007).

Discussion. Results from research on variables that moderated the parent–child decision to use ATS could help identify locations where more students would be likely to walk or bike to school and, therefore, where SRTS infrastructure improvements, pedestrian and bicyclist safety education, and traffic enforcement could benefit more potential child pedestrians and bicyclists. Based on the findings related to the children's age, middle schools would have more potential walkers and bikers than high and elementary schools. And based on findings from research on income, employment, education, household size, and neighborhood socioeconomic status, more disadvantaged areas would likely have a higher portion of children using active commute modes to school than their wealthier counterparts. The finding that children from lower-income households or areas of greater disadvantage were more likely to walk or bike to school was troubling considering that schools in more impoverished areas were often surrounded by greater crime and traffic dangers (Zhu and Lee 2008) and encountered greater institutional barriers to accessing SRTS funding (National Safe Routes to School Task Force 2008). SRTS administrators should take steps to ensure that lower-income areas can access the SRTS program.

Conversely, high income neighborhoods may be capable of generating a greater mode switch from the family auto to active transportation. Schools in wealthier neighborhoods could benefit from SRTS projects that focused on encouragement.

Findings that girls were less likely to walk or bike to school than boys confirmed other research indicating that girls spent less time in the public urban setting than boys, were more likely to be supervised; and had a more restricted home range (O'Brien et al. 2000, Valentine 1997). SRTS projects should direct extra effort toward supporting ATS for girls.

The conceptual framework used in this analysis suggested that the parent played a greater role than the child in deciding the mode of travel to school and all research on attitudes toward travel modes to school was based on parent surveys. SRTS projects should focus efforts on addressing parental attitudes toward active travel. SRTS practitioners could also benefit from research on children's attitudes toward commute modes and how these attitudes are related to the actual travel mode. Further research should explore this relationship.

Outcomes

ATS has been thought to result in numerous positive outcomes, such as reduced congestion, less air pollution, better health, and cognitive development (National Safe Routes to School Task Force 2008). Physical health factors were the only variables found to be tested in correlational research. Studies tested the hypothesis that children who walked or bicycled to or from school were more physically active and healthier than students who were driven or drove. Outcome variables were organized into four subcategories: physical activity, obesity, weight, and fitness (table 5).

ATS was associated with more physical activity in children and youth, especially those who regularly walked or biked to school. Little evidence was found linking ATS with a lower prevalence of obesity. A North Carolina survey found that ATS was negatively correlated with BMI in sixth to eighth graders but not in high school students (Evenson et al. 2003). Direct obesity measurements using both BMI and skinfold tests of fourth and fifth graders in Southern California found that boys who walked or biked to school had a significantly lower BMI than those who did not, but no significant relationship was found for girls (Rosenberg et al. 2006). Several other studies using objective measurements (Heelan et al. 2005; Sirard, Riner et al. 2005; Tudor-Locke et al. 2003; Saksvig et al. 2007) and surveys (Fulton et al. 2005; Yeung, Wearing, and Hills 2008) found no significant relationship between obesity and ATS. However, surveys and other self-report methods for measuring BMI can be inaccurate (Molaison et al. 2006).

Two studies measured the health effects of active commuting over a two-year period (Heelan et al. 2005; Rosenberg et al. 2006). Neither found a significant decrease in BMI among students who walked or biked to school. In fact, Heelan et al. (2005) reported an increase in BMI among overweight children that walked or biked to school.

One Danish study found that children that biked to school were more physically fit than both walkers and students that used inactive modes of travel (Cooper et al. 2006).

Discussion. Because higher levels of physical activity were more commonly found in children who regularly walked and biked to school (Sirard, Riner, et al. 2005; Fulton et al. 2005; Saksvig et al. 2007), SRTS programs should focus on establishing stable, long-term walking or biking to school behaviors. Encouragement activities that infrequently promote ATS, like an annual walk to school day, may be less effective at increasing children's health than activities designed to instill regular walking and biking commute habits in children.

SRTS programs have the potential to increase children's physical activity but appear insufficient to address the childhood obesity epidemic alone. Physical activity expends calories but weight loss only occurs when calories expended exceed calories consumed. Calorie intake was not included in the studies reviewed. Children who walked or biked to school may have been consuming more calories than they were burning. SRTS programs paired with nutrition education or policies that encouraged healthy, reasonable diets for children could be more effective at combating childhood obesity.

The studies on childhood health impacts identified in this literature review were limited to correlational research or longitudinal studies that lasted only a few years. Physical activity behaviors were found to often track into adulthood (Kuh and Cooper 1992) and transportation habits and attitudes during childhood (Baslington 2008). This suggests that SRTS programs could have long-term benefits. Extended longitudinal research could illuminate any long-term effects of walking or biking to school.

Methodological Limitations and Missing Evidence

The classification system used in this literature review proved to be an effective tool for understanding the findings of a large amount of correlational research and operationalizing the findings in order to guide and improve future SRTS programs and projects. The framework had methodological limitations in that it only focused on the significance of association between a single variable and ATS. It did not account for strengths or weaknesses of individual study design. Another literature review on children's active transportation examined the methodological quality of each publication (Pont et al. 2009). It included research on children's active transportation to any location and found that increasing distance, income, and car ownership had convincing negative associations with children's active transportation while non-white ethnic background had a convincing positive association.

Evaluations of SRTS programs in place before the FHWA-funded SRTS program was implemented suggest that SRTS projects may result in increases in children walking and biking to school, reductions in parents driving students to school, safer travel behavior, no increase in child pedestrian or bicyclist collisions, and increased community cohesion. Evaluations of FHWA-funded SRTS programs using robust experimental designs, particularly control schools, are necessary to ensure that the requirements of this program are delivering positive results. Detailed evaluations could help isolate particularly effective program elements, administrative procedures, or grant selection criteria. To facilitate this research, detailed data on SRTS projects, student travel behaviors, and child pedestrian and bicycle collisions are necessary. The NCSRTS, State DOTs, and local SRTS programs can all play a part in gathering these data.

No correlational research was identified that examined the effects of walking or biking to school on hypothesized outcomes other than physical health. The effects of greater rates of ATS and lower rates of children arriving to school in family vehicles have been estimated for air pollution, traffic congestion, and children's respiratory health (National Safe Routes to School Task Force 2008; EPA 2003). But no research was identified that explored the direct relationship between ATS and these outcomes or on children's cognitive development. Research on these topics would help accurately account for the full range of potential impacts of SRTS projects.

Conclusion

This review revealed several factors that appear to commonly influence a child's commute mode to or from school. Shorter distances from home to school, and therefore shorter travel times for non-motorized transportation modes, were clearly related to a greater likelihood of children walking or biking to school. Children were also more likely to walk or bike to school in neighborhoods that were densely populated, were in an urban location, featured mixed land uses, and had a highly connected street network. Findings from research that examined car ownership, income, employment, education, the number of parents in a household, and neighborhood socioeconomic status suggested that disadvantaged areas likely had a higher portion of children using active commute modes to school than their wealthier counterparts. This may reflect fewer transportation options, and therefore greater use of walk and bike modes for the school commute, for households with limited financial resources. Another resource that frequently had the opposite relationship with ATS was time—households with fewer schedule constraints and more time were more likely to have children that walked or biked to school. Favorable attitudes toward active travel modes were also related to walking and biking to school.

These factors associated with walking and biking to school can be used by SRTS planners to identify areas where a SRTS project would benefit a large number of children that would walk or bike to school given the proper safety education, encouragement, and infrastructure improvements. Conversely, SRTS projects in areas that lack these characteristics—where families live far from school, have ample resources, limited time, and no interest in active commuting—would require a substantial level of effort and resources to overcome these barriers. SRTS funding is limited and SRTS project budgets may not be sufficient to address all these barriers. SRTS planners should assess the extent to which these factors are present in a school-based community and develop projects that address, or at least acknowledge, them. Whatever various barriers or facilitators of walking and biking to school are identified in a given community, it is clear that all SRTS projects must address the real and perceived dangers for child pedestrian and bicyclists.

Based on findings from SRTS evaluations, SRTS projects may result in more children walking and biking to school without increasing rates of collisions. Increases in ATS have been shown to result in increases in physical activity for children. Additional research is necessary to accurately assess these and immediate results and any corollary benefits SRTS projects may have on health, the environment, traffic congestion, and physiological development. Additional SRTS evaluations are also necessary to confirm the effectiveness of the program and pinpoint project characteristics that are most effective in accomplishing the program's primary goals of supporting more children walking and biking safely to and from school.

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