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ABSTRACT

A dramatic decline in walking and cycling to school has been observed in many geographic and cultural regions, and most children in the US are now driven to school in private vehicles. There are a number of health implications associated with the choice of commute mode, including traffic safety, exposure to air pollution, and levels of physical activity and obesity, and the risks and benefits of each must be weighed. This paper reviews current evidence on these risks and benefits for each health topic area. From a traffic safety perspective, buses are best, while the risks of private vehicle and walking are roughly comparable. Less apparent is the observation that one student's travel choice will affect another student's risk, because changes in mode share alter the overall risk profile. Walking to school has been associated with higher levels of physical activity, although it is unclear whether this association is causal, or merely reflects a preference for walking among active children. Current evidence does not support a link between walking to school and reduced body-mass index or levels of obesity. A discussion of concurrent health effects in all areas has implications both for programs promoting walking to school and for individuals choosing among commute modes.

INTRODUCTION

Attention has recently been focused on the precipitous decline in the number of children walking to school. This decline is dramatic and pervasive, and has been echoed across cities, states and nations. The decline in walking has been complemented by increases in other modes of travel, most notably in private vehicles driven by a parent or teenager.

This shift of children from an active commute (walking or cycling) into cars raises a number of possible public health concerns. This paper will explore four areas of health that are impacted by this shift: traffic safety, air quality, physical activity and obesity. While all three of these areas have been considered separately with regard to the school commute, they have not previously been examined jointly. This paper evaluates the current published evidence on the health risks and benefits associated with each of these topic areas. The concurrent review enables the weighing of various risks and benefits from the perspective of the individual student, and promotes discussion of the true 'cost' of active vs. passive commuting.

BACKGROUND

There are a number of ways in which children commute to and from school. These include: walking (12% of school trips in the US), cycling (2%), school bus (25%), other public transit (2%), private vehicle driven by an adult (45%), and private vehicle driven by a teenage student (14%) (*i*). There is large regional variation in mode share within and between nations (*ii*). Nevertheless, despite this variation, there has been a decline in active commuting to schools in most parts of the Western world. In the USA over the last 35 years, the mode share for walking has fallen from 50% to 12% for all children and from 87% to 31% for those that live within one mile of school (*1*). From 1991 to 1999 in New South Wales, Australia, there was a drop in the proportion of children walking to school from 32% to 24% with a corresponding increase in those traveling by car from 41% to 51% (*iii*). In the UK, the proportion of children traveling to school by car increased from 16% to 30% between 1986 and 1998 (*iv*). Similar trends are projected to occur in parts of the developing world as well (*v*). The universality of the decline in active commuting to school suggests a social phenomenon that belies easy explanation.

Meanwhile, more and more attention has been focused on the potential health benefits of physical activity. Many of the chronic diseases burdening society, including diabetes, depression, heart disease, some cancers, and osteoporosis, are mitigated by physical activity (*vi*). Increasing levels of physical activity is a public health priority.

While increasing exercise *per se* has been problematic, walking is seen as an ideal public health intervention. Exercise programs are limited by cost, access, ability and adherence. Walking, on the other hand, is readily available, inexpensive and easy, with few people incapable of participating. Utilitarian walking, such as for shopping, visiting the post office or for traveling to work or school is particularly desirable, as it may be associated with higher adherence rates than deliberate exercise or walking for fitness (*vii*). Unfortunately, utilitarian walking has been on the decline along with active commuting, and in many communities the built environment makes the experience unattractive and unproductive (*viii*). Today, the primary reason that Americans walk is to exercise their dogs.[1]

Currently there is a public health push to increase utilitarian walking in general and walking and cycling to school in particular (*ix*). Health benefits are expected from improved air quality and increased physical activity. Especially for children, additional consideration must be

given to traffic safety. The evidence for a health impact of increased active commuting in each these areas is discussed below.

This paper reviews the currently available evidence that has been published on the association between commute mode and traffic safety, air pollution, physical activity and obesity. For traffic safety and air pollution, we included evidence from recent reviews and relevant primary sources. For physical activity and obesity, a systematic review was conducted of all primary evidence.

HEALTH EFFECTS

Traffic Safety

Traffic safety in this context refers to injuries and fatalities sustained by children during their travel to and from school. All modes of transport convey some degree of risk and the assessment of traffic safety related to the school commute is complex. The most basic approach is to start with the relative risk of each mode of travel. The Transportation Review Board published a review (*x*) of the relative risks of school travel modes based on three well-known and comprehensive data sources: the Nationwide Personal Transportation Survey has data regarding mode share; the Fatality Analysis Reporting System (FARS) describes all traffic fatalities in the country, and the National Automobile Sampling System General Estimates System (GES) is a national stratified sample of injury accidents. One limitation of this analysis is that trip purpose is rarely recorded in the FARS or GES databases, so that injury or fatality accidents were deemed to have been school trips if they involved a student and occurred during usual school travel hours. The results are presented in Table 1.

TABLE 1: Injury and fatality rates per 100 million student trips by mode, 1991 – 1999

Travel Mode	Mode share	Injury rate	Fatality rate
Walking	12%	310	4.6
Bicycle	2%	1610	9.6
School bus	25%	100	0.3
Other bus	2%	120	0.1
Passenger vehicle	59%	919	4.4
Adult driver	*45%*	*490*	*1.6*
Teen driver	*14%*	*2300*	*13.2*

Adapted from: The Relative Risks of School Travel: A National Perspective and Guidance for Local Community Risk Assessment: Transportation Review Board; 2002.

With regard to traffic safety, buses are clearly best. Walking poses a lower risk of injury than transport by passenger vehicle driven by an adult, but a higher risk of fatality. Bicycling, though limited in this data set due to its extremely low mode share, has a higher risk of both injury and fatality. Teen drivers stand out as presenting by far the highest risk of all school travel options. The injury and fatality rates per trip for those driven by teens are 7.4 and 2.9 times greater than for walkers respectively. Fully 51% of all school commuting injuries and 55% of fatalities are associated with teenage drivers, despite the fact that they constitute only 14% of all

school trips.

This data presents the risk to any one individual student, based on their mode of travel. The complexity arises from what is less apparent: that one student's travel choice will subsequently affect another student's risk, because changes in mode share will alter overall the risk profile. For instance, it is known that the density of cyclists and pedestrians is inversely correlated with the risk of injury and fatality (*xi*), *(xii)*. Therefore the decline in the proportion of children walking and cycling to school likely has shifted a higher burden of traffic injury onto the remaining walkers/cyclists. This effect is probably even more pronounced in the closed-system environment of the school commute. In this closed system, students who do not walk arrive instead in vehicles, thus increasing the vehicle density around the school, and further increasing pedestrian risk beyond what would be expected from a decreased pedestrian density alone. Interventions to increase active commuting, if successful, may similarly decrease the risk faced by walkers and cyclists.

Additionally, the issue of teen drivers must be considered since this mode presents the highest risk of both injury and death. One concern of transporting younger children to school in private vehicles, even though relatively safe when an adult is driving, is the possibility that it will make them more likely to drive themselves or ride with friends when they become teens. It is not known whether being driven to school by an adult leads to an increased likelihood of driving as a teen. However, if this association exists, the low risk of being driven by an adult would be offset somewhat by increased risk in the teenage years.

AIR QUALITY

Air quality is another factor that is impacted by the school commute and that can have an effect on children's health. While the health effects of motor vehicle emissions have been extensively studied, the literature on the effect of active commuting has tended to ignore this subject.

The major components of air pollution associated with automobile exhaust include nitrogen dioxide, ozone, and particulate matter. All three pollutants have been associated with adverse health outcomes in children, including decreased growth of lung function, bronchitis, allergies, and immune system suppression *(8)*. However, the overwhelming concern regarding air quality in childhood is asthma—the evidence that poor air quality exacerbates asthma is irrefutable and some evidence suggests exposure to ozone may contribute to the development of the condition (*xiii*). Emergency room visits and hospital admissions for asthma are strongly linked to motor vehicle emissions (*xiv*).

There are two ways in which the school journey and air quality are linked. The first is through opportunities for direct exposure of children. The second is through the commute vehicle's contribution to total emissions.

All children will be exposed to some level of pollutants during the school commute whether they are active commuters or motor vehicle passengers. It can be postulated that walkers/cyclists might have a longer commute time and higher minute ventilation from the exertion, resulting in a higher exposure to emissions. On the other hand, walkers/cyclists may have the flexibility to choose routes or pathways that have light or no traffic, minimizing their exposure compared to students traveling in private vehicles stuck in heavier traffic. No studies appear to have measured relative exposure of active commuters versus passengers in private vehicles. School bus interiors have been studied and appear to present a concentrated source of

exposure (*xv*). The school bus ride may therefore comprise a significant component of total daily exposure, despite its limited duration, as is shown in Table 2. The relative exposures of each mode of travel would best be compared through personal monitoring of commuting children.

TABLE 2: Contribution to overall exposures (24 hr) by pollutant and microenvironment

Microenvironment	Time spent, hr (%)	Mean Concentration			Exposure			Contribution to Overall Exposure		
		Black Carbon (BC) ($\mu g\ m^{-3}$)	NO_2 (ppb)	$PM_{2.5}$ ($\mu g\ m^{-3}$)	BC ($\mu g\ m^{-3}$ hr)	NO_2 (ppb hr)	$PM_{2.5}$ ($\mu g\ m^{3}$ hr)	BC (%)	NO_2 (%)	$PM_{2.5}$ (%)
Indoors at home	12 (50)	3	100	30	30	1200	360	45	70	55
Indoors at school	7 (30)	2	35	15	10	260	110	15	15	20
Outdoors at home	1.2 (5)	2	50	20	3	60	25	4	3	4
Outdoors at school	1.2 (5)	2	35	20	3	45	25	4	2	4
Bus commutes	2.5 (10)	8	75	45	20	180	110	30	10	15
Total	24 (100)				65	1800	630			

Source: Behrentz E. et al. Relative importance of school bus-related microenvironments to children's pollutant exposure. J Air Waste Manag Assoc. 2005 Oct;55(10):1418-30.

Buses and cars used in the school commute may affect air quality on both a local and regional scale. Outdoor air near the school entrances may be highly polluted if there are many vehicles idling in the area—as happens when a large number of parents are waiting in their vehicles to drop off or pick up their children. Although the children's exposure at this location may be brief, it may still be a significant trigger of both airway hyper-reactivity and inflammation in asthma (*xvi*). Interventions to reduce high emissions levels around school entrances that have been implemented include anti-idling campaigns, separation of buses and pedestrians, and angled parking of school buses to prevent the passengers from one bus being directly exposed to the tailpipe emissions of another *(8).*

Air quality inside schools may be affected by commute vehicles, particularly if the vehicles are allowed to drive or idle near air intake locations. Carbon monoxide is an additional concern if emissions are being drawn into the school. If the indoor air quality is poor, the exposure will be large due to the relatively long time children spend in school each day, as seen in Table 2. Interventions such as those mentioned above, along with care to separate vehicles from air intake locations, are important to reduce in-school exposure.

Finally, the contribution of the school commute to total motor vehicle emissions should not be overlooked. With 59% of children being driven to and from school in private vehicles and another 27% traveling by bus, a significant proportion of all motor vehicle trips during school hours result from the transportation of children. The emissions from these journeys contribute to poor air quality across the community, affecting all children regardless of their mode of travel to school.

PHYSICAL ACTIVITY AND WEIGHT

Two of the most commonly cited reasons for encouraging children to walk to school are

increasingly sedentary lifestyles and obesity. National and international programs such as Safe Routes to School and International Walk to School Day cite increasing childhood obesity rates and declining physical activity as part of the rationale for encouraging children to walk to school. Active commuting has been promoted in both adult and child populations as a means to increase physical activity and through physical activity to improve health. However, the evidence supporting this chain of reasoning is far from clear.

Theoretically, walking or cycling to school could increase total activity in a number of ways. First, the act of commuting itself could be a significant source of activity. Second, opportunities may arise during the commute—especially on the return home—for extra activity and spontaneous play. Third, walking or cycling may encourage active behavior in other areas of the child's life. Remarkably, despite the broad support for interventions to increase physical activity through increasing walking and cycling to school, there are relatively few studies examining the association. The evidence to date is reviewed below and is summarized in Table 3.

An early questionnaire based study of 7–13 year olds in Russia suggested that 40–50% of the total physical activity in those who walk to school could be ascribed to the commute itself (*xvii*). Because this figure is so high, it implies that the trip to school may make a substantial contribution to overall physical activity levels, and the figure has been cited frequently. However, this strong result has not been reproduced in any subsequent study, and could be due to the study design (which relied on self-reporting of physical activity levels) or to particular artifacts of the population such as very long commutes and/or low overall activity levels. Three subsequent studies have used accelerometers to quantify the contribution of the commute itself to total physical activity, and these studies do not support the contention that the walk to school is a significant contributor to total activity, finding the walk to and from school comprised only 11-12% (*5)*, 2% (*xviii*), or a negligible portion (*xix*) of total activity. However, these studies were conducted under very different social and built environment conditions, making it difficult to generalize the findings or predict what contribution the active commute makes to total physical activity levels.

The possibility that active commuting may be related to total physical activity has been examined in thirteen studies. These studies assessed the association of active commuting as a binary variable with the child's overall levels of total physical activity—usually moderate-to-vigorous activity. The results are fairly consistent, with eight of the 13 studies finding a positive association between walking to school and higher overall levels of activity, and two additional studies finding mixed results for different groups of children. Several of the studies showing an association demonstrated increased activity persisting even into the weekend. The magnitude of the difference in activity between walkers and non-walkers varied greatly. Among the studies that found a significant difference in activity levels, the difference ranged from an additional 4.7 minutes per day of moderate-to-vigorous activity to a high of an additional 45 minutes per day, with an average finding of approximately 25 additional minutes of moderate-to-vigorous activity per day.

Although the association between walking to school and total physical activity appears consistent, this association does not help determine causality. Does active commuting lead to increased physical activity or are physically active children simply more likely to walk or cycle

to school? Interventional studies examining what effect a change in commute mode has on total physical activity are clearly needed. Interventions have shown success in increasing the proportion of children walking to school (*xx*), suggesting that such studies are feasible. Until such results are available, however, it is premature to suggest that promotion of active commuting will necessarily by itself result in an increase in physical activity.

A separate but equally important question is whether a potential increase in physical activity of the type encountered through active commuting is likely to improve health outcomes in children. In adults, there is a substantial body of literature to support the positive effect of physical activity on health. Physical activity has been associated with multiple health benefits including reduced rates of cardiovascular disease, diabetes and depression, and protection from some forms of cancer, such as breast and colon (*6*). Active commuting in adults has also been directly linked to some of these same health benefits. In children, however, the links between physical activity and health benefits have been less well established, and no studies have directly linked active commuting to health benefits.

In particular, the current literature does not support the use of walking to school as a means to reduce body mass index (BMI) values or overweight/obesity. Of twelve studies examining the relationship between active commuting and BMI, only one found an association with lower BMI values. Two studies found a positive correlation between active commuting and *higher* BMI values, and the remaining studies found no association or mixed results. Similarly, no trend has been found supporting a link between walking to school and reduced rates of overweight/obesity, or reduced BMI among overweight children.

Despite the lack of evidence from both parts of this equation (active commuting leads to increased activity and increased activity leads to improved health), active commuting is heavily promoted for children primarily because of the perception of anticipated health benefits. Many interventions to increase walking to school imply that increasing physical activity and preventing childhood obesity is their primary goal. Current evidence, however, does not support this link.

TABLE 3 Summary of Literature on Active Commuting in Children and Total Physical Activity / Weight

Studies reporting a statistically significant association		
	Active commuting and higher PA	**Active commuting and lower weight**
Positive	Landsberg, 2007 Saksvig, 2007 Alexander, 2005 Fulton, 2005 Sirard, 2005 Cooper, 2003 Michaud-Thomson, 2003 Tudor-Locke, 2003	Li, 2007

Inverse		Klein-Platat, 2005
No Association	Rosenberg, 2006 Santos, 2005 Metcalf, 2004	Landsberg, 2007 Saksvig, 2007 Cooper, 2006 Fulton, 2005 Sirard, 2005 Cooper, 2003
Mixed	Cooper, 2006 Heelan, 2005	Rosenberg, 2006 Evenson, 2003 Heelan, 2005 Tudor-Locke, 2003
Not reported	Tudor-Locke, 2002	

DISCUSSION

The trend away from walking and cycling to school has been pervasive, fast and dramatic. In the words of Rob Moodie from VicHealth in Australia, it would have been a remarkably successful intervention had we planned it. Now, public health agencies are faced with the task of trying to design interventions to reverse the trend. In the USA, a target has been set to have 50% of children who live within a mile of school walking or cycling to school by 2010 (*xxi*).

The promotion of walking to school has been approached from a number of different health, social and environmental perspectives, including traffic safety, congestion, air pollution, community building, and reduced vehicle dependence. For an individual, personal factors such as convenience, cost and appropriateness for the child must also be considered.

From a health and safety perspective, there are still many unknowns. Nonetheless, the promotion of walking to school makes sense from a safety and air quality perspective. It fits well with broader community initiatives to decrease car dependency and increase utilitarian walking. However, it is unclear whether higher physical activity levels observed in walkers are caused by the walk to school, or are merely correlated with it. This uncertainty has implications for whether or not an intervention to increase walking is likely to result in increased overall activity. Furthermore, there is good evidence to suggest the walk to school itself is insignificant with regard to total physical activity, and interventions focused narrowly on increasing activity as part of the commute, such as the so-called walking school bus, are unlikely to have much impact on activity or health. Nonetheless, childhood physical activity is modeled into adulthood (*xxii*); if active commuting is similarly carried over into adulthood, health benefits might be expected then.

CONCLUSIONS

The decline in walking and cycling to school has been broadly observed in many geographic and cultural regions. The causes of this transition are multi-factorial and likely include elements of the built environment, policy, economy and changes in social mores. Interventions to reverse the trend are sensible in the context of other community efforts to reduce car dependence and increase utilitarian walking. There may be some benefit from a public health perspective with regard to air quality and traffic safety. Additionally, physical activity may be higher among

walkers than among students who are driven, but it is not known whether this association is causal. Active commuting to school appears unrelated to obesity or overweight. At this time, it is uncertain whether an intervention to increase active commuting in children would by itself impact activity-related health outcomes.

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