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Systems-Level Evaluation of Safe Routes to School Policies in El Paso, Texas – A Modeling Study on Health and Economic Outcomes

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Abstract

Safe routes to school (SRTS) policies are linked to physical health benefits for school-age children; however, few studies have assessed long-term impacts on cardiovascular disease (CVD). This study used systems science methods to predict long-term health and economic impact of SRTS among school-aged children in El Paso County, Texas. We developed an agent-based model containing two modules: the pedestrian injury module and the CVD module. We simulated 10,000 school-aged children under two scenarios—SRTS policies implemented and no SRTS policies implemented—then calculated pedestrian injuries, pedestrian injury-related deaths, coronary heart disease (CHD) and stroke events, and healthcare costs. When SRTS policies were implemented, the model estimated 157 fewer CHD cases and 217 fewer stroke cases per 10,000 people and reduced CVD-related healthcare costs ($13,788/person). The model also predicted 129 fewer pedestrian injuries and 1.3 injury-related deaths per 10,000 people and $2,417 savings in injury-related healthcare costs. SRTS could save an estimated $16,205 per person in healthcare costs. This simulation shows SRTS in El Paso County could prevent pedestrian injuries among school-aged children and protect cardiovascular health in the long term. Our findings provide evidence for practitioners and policymakers to advocate for SRTS policies at the local level.

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INTRODUCTION

Despite known physical and cognitive health benefits of physical activity for youth, approximately 81% of adolescents worldwide do not attain sufficient levels of activity.[1–3] Since habits developed during childhood typically transfer into adulthood, this lack of youth activity has long term health implications.[4] One strategy to increase opportunities for youth to be physically active is through active travel to school by walking or bicycling.[5] Children spend the majority of their time per week in school; thus, incorporating active transportation methods into their daily routines would increase physical activity during the school day and potentially improve their overall health.[6] Research shows that participation in active transportation helps children achieve up to 30% of their recommended 60 minutes/day of moderate-to-vigorous physical activity, which is associated with increased fitness levels, reduced perceived stress, generation of positive emotions, and improved mental health.[7] However, despite potential benefits, active travel to school has declined substantially over the last 50 years in the United States. In 1969, nearly 90% of school-aged children who lived within a mile of school and approximately 40% of all students, walked or biked to school.[8] Recent data indicate that only 17% of all youth and 21.9% of children who live within one mile of their school use active transportation to travel to and from school.[9–10]

In 2005, the Safe, Accountable, Flexible, Efficient Transportation Equity Act was enacted in the United States. Through this policy, the Safe Routes to School (SRTS) program was created to facilitate the planning, development, and implementation of projects in the vicinity of schools. Most notably, this program focused on expanding the federal government's role in transportation to address physical inactivity as well as traffic and environmental concerns. The Federal Highway Administration (FHWA) was tasked with allocating funds to states proportional to their percentage of the national total of school-aged children enrolled in kindergarten through eighth grade. The FHWA provided flexible guidance to states, allowing each state to determine how to structure their program and the relevant policies and procedures that would be developed as part of the program. Funds could be used toward physical infrastructure improvements, such as the building of sidewalks, traffic calming, speed reductions, and the installation of bicycle racks or facilities, and non-infrastructure efforts, such as public awareness campaigns, traffic education, enforcement efforts, walking school buses, and other walk-to-school promotional efforts.

In 2018, the American Heart Association (AHA) was funded by the Centers for Disease Control and Prevention to implement culturally tailored initiatives that improve health, prevent chronic diseases, and reduce health disparities in El Paso County, Texas, USA. This five-year initiative, called Heart Racial and Ethnic Approaches to Community Health (Heart REACH), focused on active transport through policymaking, among other initiatives, to improve health outcomes and reduce health disparities. As part of this effort, the AHA engaged researchers from Texas A&M University and Icahn School of Medicine at Mount Sinai to investigate the potential long-term health and economic impacts of SRTS policies in El Paso County using agent-based modeling. This paper presents the findings from this study with the goal to further the literature on SRTS policies and provide information for policymakers to make informed decisions regarding SRTS policy implementation.

MATERIALS AND METHODS

We used systems science to model the complex interactions within SRTS policies in El Paso County, TX and to estimate the long-term impacts on health and economic outcomes as a result of SRTS policies. Agent-based modeling is a systems science methodology that can be used to predict the long-term impacts of public health policies, such as SRTS, with minimal costs. Agent-based modeling is a computational approach in which simulated agents (e.g., individuals) behave according to predefined rules.[11–13] Agents may experience changes in behaviors and health conditions, as well as decease as the model runs. Agent-based models in public health have been used to conduct virtual experiments to estimate the impact of interventions and policies on population disease burden. This approach is beneficial because it allows for the implementation of counterfactual simulations that may be infeasible, lengthy, or too costly when carried out in the real world.[11] For example, Li and colleagues used an agent-based model of dietary behaviors to predict how a mass media and nutrition education campaign could increase consumption of the recommended servings of fruits and vegetables in New York City, NY, USA.[14] Their findings estimated a substantial increase in daily fruit and vegetable consumption, but found that the campaign may be less effective in neighborhoods with relatively low education levels and relatively high proportions of male residents. Findings like these provide insight into the potential impact of the intervention prior to implementation and shed light on the important factors that should be taken into account to ensure its efficacy.[14]

In this study, our agent-based model focuses on school-aged children (ages from 5 to 19 years) in El Paso County as the target population for SRTS policies. The majority of the studied population are racial and ethnic minorities, with 82.9% Hispanic, 4.2% Black, 1.4% Asian, and 11.4% non-Hispanic White. As such, results from this study will provide insight on the impact of SRTS policies on racial and ethnic minorities. The agent-based model contains two modules: the pedestrian injury module, which projects the incidence of pedestrian injuries and their related healthcare costs, and the cardiovascular disease (CVD) module, which estimates the incidence of coronary heart disease (CHD) and stroke and their related healthcare costs. These two modules capture the two primary benefits of SRTS policies, including injury prevention and improved cardiovascular health (as a result of increased physical activity). We programmed the agent-based model using AnyLogic 8, an advanced simulation development platform that offers robust support to the development of agent-based models.[15]

This agent-based model generates a group of simulated individuals with predefined characteristics (e.g., age, sex, race, ethnicity) and when the model runs, simulated individuals can change their health states, such as from non-injury to injury or from CVD-free to CVD, or stay in the same health states. Agents may also die from injury- or CVD-related causes or from other causes. Using this agent-based model, we simulated the same group of individuals under different policy scenarios, allowing us to compare the impact of different policies in a virtual, no-risk environment. Figure 1 shows the model schematic. Details about each module are presented in the following.

Pedestrian Injury Module

The pedestrian injury module estimates the number of pedestrian injuries and their related healthcare costs. There are three states in this module, including “no-injury,” “injury,” and “death.” A simulated individual starts from no-injury and may experience a pedestrian injury as the model runs. The annual probability of pedestrian injury for school-aged children was estimated to be 0.0008 based on the literature.[16–17] An individual who is in the “injury” state may die from the injury with the probability of 0.001;[16–17] otherwise, the individual recovers and transitions back to the “no-injury” state. Individuals may also die from other causes following probabilities based on the US Life Tables.[18]

We estimated the average cost of a pedestrian injury to be $7,129 per year based on a previous study.[17] This cost was calculated as a weighted sum of the average healthcare costs for those hospitalized and not hospitalized after the injury. The impact of SRTS policies was measured by the reduced risk of pedestrian injury. Based on a study that analyzed traffic crash data in Texas, SRTS policies were associated with a 42.5% reduction in pedestrian injury risk among school-aged children (5–19 years old).[19]

CVD Module

The CVD module estimates the number of coronary heart disease (CHD) and stroke and their related healthcare costs, as well as mortality due to CVD or non-CVD causes. The CVD Module was adapted from a standalone agent-based model of CVD, which was used in a previous study to assess the impact of the Tobacco 21 Law on CVD outcomes and related healthcare costs[20]. The CVD Module contains five states: “no CVD,” “CHD,” “stroke,” “CHD + stroke,” and “death.” A simulated individual starts from the “no CVD” state and may transition to the other disease states or death as the model runs. We used Cox proportional hazards regression functions for estimating CVD risks that are available in the literature to estimate annual probabilities of developing CHD and stroke for a simulated individual.[21] The annual probabilities of death due to CHD or stroke were calculated in a similar manner. Details about estimation of annual transition probabilities are presented in our previous study.[20] We also estimated that SRTS policies could increase walking and bicycling to school by 15%.[22]

We estimated the healthcare cost parameters for different CVD disease states based on the Medical Expenditure Panel Survey (MEPS) data.[23] When a simulated individual develops CHD or stroke, the person will incur a specific healthcare cost for treating or managing the disease. Because the treatment is often more intensive, and thus more expensive, during the first year of the CHD or stroke event, we used different cost estimates for the first versus subsequent years of the disease event. For CHD, the treatment cost for the first year was estimated to be $13,273, and for the subsequent years to be $2,711. For stroke, the treatment costs for the first year and subsequent years were estimated to be $20,538 and $5,707, respectively. All healthcare costs were discounted at 3% and converted to 2020 US dollars.[24] Table 1 provides a list of key model parameters and their sources.

Simulation Experimental Design

In our simulation experiment, we compared two simulation scenarios—implementing SRTS policies (intervention scenario) and no SRTS policies (the baseline scenario). In each of the simulation scenarios, we simulated 10,000 school-aged children based on population characteristics in El Paso County, Texas. The agent-based model tracks the number of injuries and the numbers of CHD and stroke events for each simulated child over his or her lifetime. The model then calculates the total numbers of pedestrian injuries, deaths due to pedestrian injury, CHD events, and stroke events, as well as the total healthcare cost for the simulated population. This would allow us to calculate the averted cases of injuries, CHD, and stroke, as well as the potential cost saving if SRTS policies were implemented.

We conducted one-way sensitivity analyses to assess the impact of parameter uncertainty on total cost saving. Specifically, for each of the key variables, we increased and decreased it by 25% to create the variable range and then calculated the range in total cost saving under each variable. This would allow us to identify the variables that may have the largest impact on total cost savings. We also reported 95% confidence intervals in our simulation results based on 1,000 simulation iterations to account for stochastic uncertainty inherent in the simulation model.

RESULTS

Table 2 reports the projected lifetime health and economic outcomes among school-aged children in El Paso County, Texas, with and without SRTS policies. We categorized the simulation results into CVD related outcomes and pedestrian injury related outcomes. Under CVD related outcomes, the model estimated that there would be 3,252 (95% CI: 3148, 3356) cases of CHD and 1,795 (95% CI: 1737, 1852) cases of stroke per 10,000 people if SRTS policies were not implemented. With SRTS policies, the estimated numbers of CHD and stroke would be 3,095 (95% CI: 2996, 3194) and 1,578 (95% CI: 1528, 1629), respectively, per 10,000 people. Thus, SRTS policies could reduce CHD by 157 cases per 10,000 people and reduce stroke cases by 217 per 10,000 people if they were implemented. The policy was also estimated to reduce CVD related healthcare costs by $13,788 per person.

As to pedestrian injury related outcomes, the model estimated that there would be 316 (95% CI: 293,340) pedestrian injuries and 3.2 (95% CI: 3.0, 3.4) deaths due to pedestrian injuries per 10,000 people if SRTS policies were not implemented. By implementing SRTS policies, we projected 129 pedestrian injuries and 1.3 deaths due to pedestrian injuries could be averted per 10,000 people over their lifetime. SRTS policies could also reduce pedestrian injury related healthcare costs by $2,417 per person. Considering the benefits of SRTS policies on the prevention of both CVD and pedestrian injuries, the policy could save a total healthcare cost of $16,205 per person.

Figure 2 presents results from our one-way sensitivity analyses. We varied the value of several key model variables by ±25% and assessed their impact on the total healthcare cost saving from the implementation of SRTS policies. As the results show, the relative risk of pedestrian injury under SRTS policies versus no policy has the largest influence on the total healthcare cost saving. Decreasing the variable by 25% could reduce the total healthcare cost saving from the baseline value of $16,205 to $13,149 and increasing the variable by 25% could increase the total healthcare cost saving to $21,261. The percentage increase in active travel due to SRTS policies and per-capita cost of pedestrian injury also play an important role in determining the total healthcare cost saving. In contrast, the discount rate and probability of pedestrian injury play a less important role in determining the total healthcare cost saving.

DISCUSSION

Using an agent-based model, we showed that in El Paso County, Texas, SRTS policies would prevent pedestrian injuries among school-aged children and reduce the incidence of CHD and stroke in the long term. The policy would also save healthcare costs related to pedestrian injuries and long-term CHD and stroke outcomes. Given that the majority of the population in El Paso County are racial and ethnic minorities, in particular Hispanics, SRTS policies would mostly benefit Hispanics. This outcome aligns well with the goal of the Heart REACH Initiative, which is to promote healthy behaviors and improve health equity. These findings provide valuable information on the long-term impact of SRTS policies, which would not have been available without the use of advanced systems science approaches such as agent-based modeling. To our knowledge, our study is the first to assess the long-term impact of SRTS policies on both injury and CVD outcomes.

There are several barriers for parents to permit their children to walk or bicycle to school. The complex factors include distance to school, child age, perceptions of traffic safety, social concerns with strangers, and bullying.[25–26] Furthermore, high intersection density and unsignalized intersections are examples of built environmental factors that hinder active transport to school.[27] Consequently, studies indicate inequities exist between high- and low-resource communities with regard to the supports needed for active, safe routes to school.[28] In particular, residents from high resource communities reported more pedestrian/ bicycling facilities, safety from traffic, and safety from crime than residents of low income areas.[29] Hence, a wide adoption of SRTS policies could reduce active transportation-related disparities and provide safe, convenient, and accessible places for walking and bicycling to school regardless of resource availability.

Despite the benefits of SRTS policies, there are significant challenges associated with garnering buy-in, implementation, and sustaining such policies. Road improvements and infrastructure changes require large upfront costs, and at the micro-level, the chance of one child being severely injured is relatively small. Furthermore, federal SRTS funding as a stand-alone program was eliminated with the passing of the federal transportation bill, Moving Ahead for Progress in the 21st Century.[30]

Evaluations of state-level SRTS programs are critical for state policymakers to determine the levels of continued funding for program allocation. However, previous evaluations of these programs are limited and are primarily descriptive and qualitative,[31–32] aimed at relaying the program history, trends, or funding and expenditures. Other studies only focused on the impacts of SRTS programs related to active transportation (i.e., the number of children that walk or bicycle to school) and injuries and did not provide any information on the long-term impact of SRTS programs.[22, 33] Our study fills these important research gaps by quantifying the long-term impact of SRTS programs on both disease outcomes and healthcare costs.

The current study provides another example of using a systems science approach (agent-based modeling) to answer complex public health policy questions. We have previously used agent-based modeling to assess the long-term impact of the Tobacco 21 Law on CVD outcomes and related healthcare costs.[20] Different from the previous study in which CVD was the only health outcome of interest, the current study has a more innovative design by simulating both pedestrian injuries and CVD outcomes simultaneously. This design of simulation is rarely seen in the literature but is necessary for capturing the health outcomes of SRTS policies. As many public health policies impact more than one health outcome, we, thus, call for an increasing development of multi-outcome agent-based models for future policy evaluation. Furthermore, future systems science models should consider the fact that many designated outcomes may intersect. Given that the field of health policy evaluation moves toward more complex understandings of interrelated determinants across social ecology, the development of multi-outcome interaction models could represent a significant advance in the science.

Limitations

Although this study provides valuable information related to the potential impact of SRTS policies for public health policymakers and practitioners, it is not without limitations. First, our agent-based model does not consider distance between home and school in the adoption of active travel to school because we do not have this geographical data. However, by counterfactually simulating SRTS policies and no policy, we assumed that the distance between home and school remains constant and, thus, would have minimal impact on our results. Second, we did not consider peer influence or social norms on how they would influence active travel. Agent-based modeling allows integration of peer influence into the model when data are available. Scientists could collect data related to peer influence among school-aged children to further improve the model. Finally, our estimates of the total cost saving due to SRTS policies may be an underestimation because we did not consider other health benefits (e.g., reduced body weight, improved mental health) in the model.

Despite these limitations, this study suggests that in the long term, there will be notable reductions in the incidence of pedestrian injury and CVD as well as substantial healthcare cost savings from SRTS policy implementations. The policy would be cost saving as it will both improve health outcomes and reduce costs. This study provides additional evidence for policymakers and practitioners to advocate for SRTS policies at the local level.

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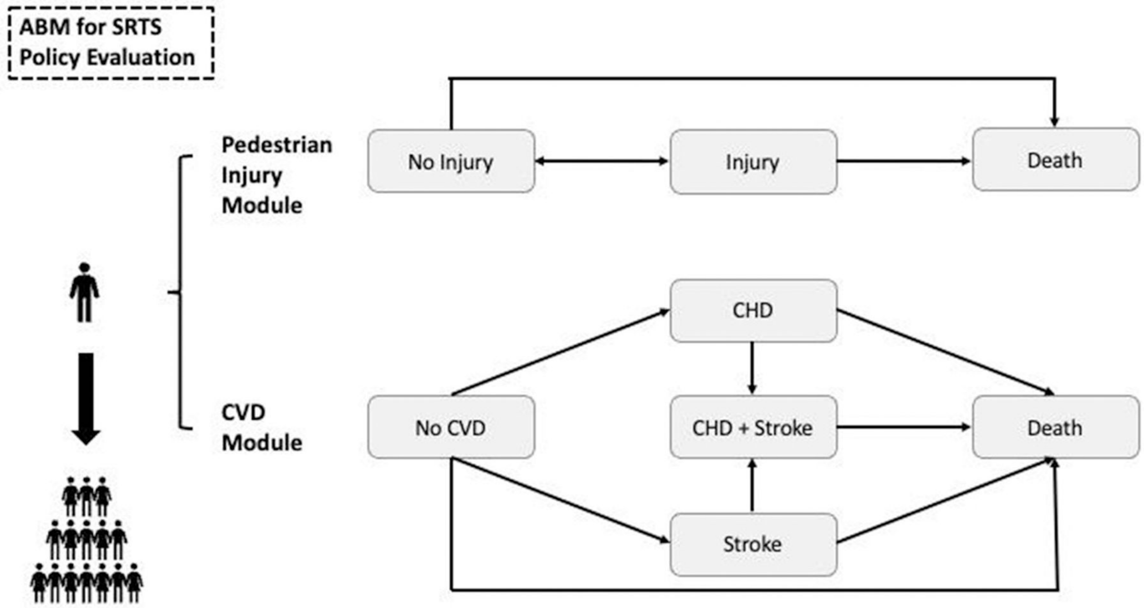

Figure 1. Agent based model schematic.
ABM indicates agent based model; SRTS, Safe Routes to School; CHD, coronary heart disease; CVD, cardiovascular disease.

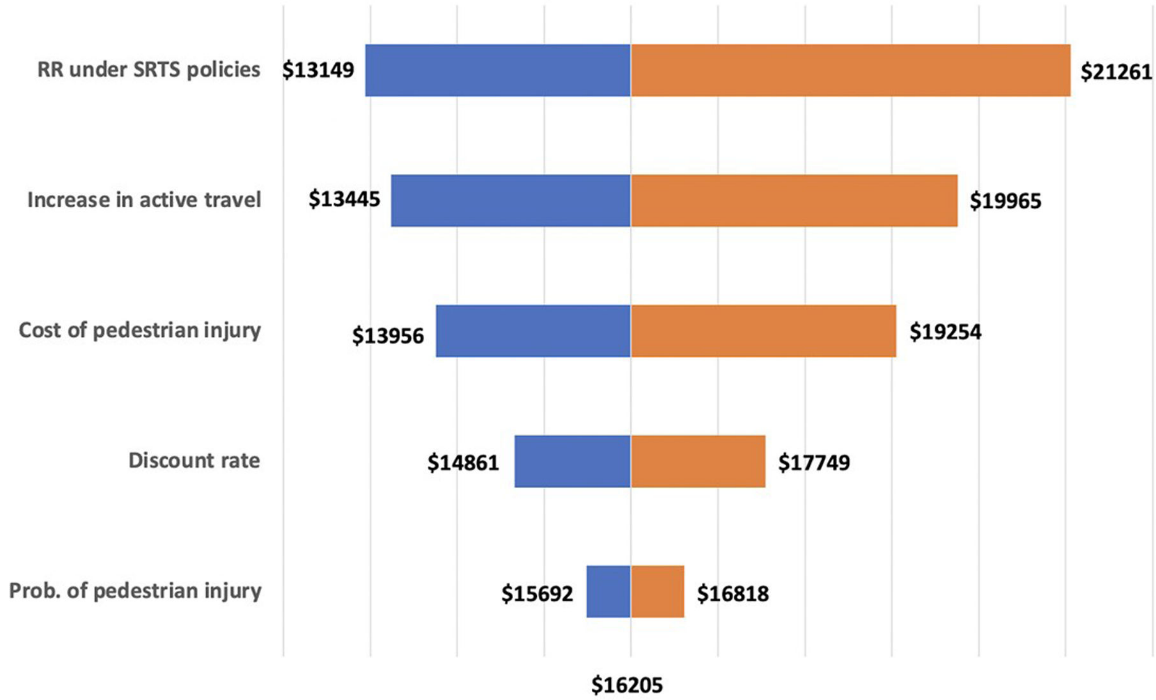

Figure 2. One-way sensitivity analysis for health care cost savings and SRTS policies.

RR indicates the relative risk of pedestrian injury; SRTS, Safe Routes to School.

Table 1.

Key model parameters used in the agent-based model and their sources

Model parameters	Value	Sources
Pedestrian injury module		
Annual probability of pedestrian injury	0.0008	DiMaggio et al. (2012); Muennig et al. (2014)
Probability of death due to pedestrian injury	0.001	DiMaggio et al. (2012); Muennig et al. (2014)
Probabilities of death due to other causes	Age-specific	Arias & Xu (2022)
Relative risk of injury under SRTS policies	0.575	DiMaggion et al. (2015)
Average cost of a pedestrian injury, $/person	7129	Muennig et al. (2014)
CVD Module		
Transition probabilities among disease states	Age-specific	Garney et al. (2022); Zhang et al. (2019)
Increase in active travel due to SRTS policies	0.15	Boarnet et al. (2005)
CHD treatment cost (first year), $/person	13,273	MEPS data
CHD treatment cost (subsequent years), $/person	2,711	MEPS data
Stroke treatment cost (first years), $/person	20,538	MEPS data
Stroke treatment cost (subsequent years), $/person	5,707	MEPS data
Other parameters		
Initial simulation population size	10,000	
Discount rate	0.03	Sanders et al. (2016)

Table 2.

Projected lifetime health and economic outcomes with and without SRTS policies among school-aged children in El Paso County, TX

Health and economic measures	No SRTS policies		SRTS policies		Difference
	Mean	**95% CI**	**Mean**	**95% CI**	
CVD related outcomes					
No. of CHD, per 10,000 people	3252	(3148, 3356)	3095	(2996, 3194)	157
No. of stroke, per 10,000 people	1795	(1737, 1852)	1578	(1528, 1629)	217
CVD related healthcare costs, $/person	453701	(439183, 468219)	439913	(425836, 453990)	13788
Pedestrian injury related outcomes					
No. of pedestrian injuries, per 10,000 people	316	(293, 340)	188	(174, 202)	129
No. of pedestrian injury deaths, per 10,000 people	3.2	(3.0, 3.4)	1.9	(1.8, 2.0)	1.3
Pedestrian injury related healthcare costs, $/person	5732	(5308, 6156)	3315	(3070, 3560)	2417
					Total saved costs = $16,205