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National Safe Routes to School Program and Risk of School-Age Pedestrian and Bicyclist Injury

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Introduction

Motor-vehicle crashes are a major source of injury mortality. Although rates and frequencies of motor-vehicle occupant deaths have decreased markedly in recent years, similar declines have not occurred in pedestrian and bicyclist fatalities.[1, 2] Children are at particularly heightened risk of significant harm and are subject to more severe injuries following a collision as a result of anatomical factors.[3] In 2011, pedestrians accounted for nearly 20% of traffic injury fatalities in children aged 5 to 9 years compared to 5% in adults.[4] Pedestrian injury is the leading cause of traumatic brain injury for 5 to 9 year olds,[5] and contributes to over half of all trauma-related hospital admissions for children in the Untied States.[6] In addition, an estimated 23% of children struck by motor vehicles will suffer psychological sequelae.[7]

Concern about the potential dangers of walking and biking may contribute to childhood obesity and its attendant morbidities.[8,9] In response to these concerns, the US Congress funded the federal Safe Routes to School (SRTS) program in 2005 as part of the federal Safe, Accountable, Flexible and Efficient Transportation Equity Act. The program was intended to encourage children to walk and bike to school and was allocated $612 million for fiscal years 2005 to 2009 for state departments of transportation to build sidewalks, bicycle lanes, and safe crossings and to improve the built environment to allow children to more safely travel to school. Legislation requires that the majority (70%–90%) of funds be used for engineering and infrastructure projects (e.g. sidewalk construction, traffic calming measures, and capital improvements) for pedestrian and bicycle access and the remaining

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Author Contribution Statement:
Dr. DiMaggio conceived the study, acquired and had full access to the data, obtained IRB approval, conducted all analyses, wrote the initial draft of the manuscript, interpreted the results, made critical revisions, and had final approval of the version to be published.
Dr. Frangos contributed to the interpretation of the results, and critical revisions.
Dr. Li contributed to the study design, statistical analysis, interpretation of the results, drafting of the manuscript, and critical revision of the manuscript for important intellectual content.

10% to 30% be used for education, encouragement, and enforcement activities.[10,11] As of 2012, departments of transportation in all 50 states and the District of Columbia had introduced safety improvements at 10,400 of the nations 98,706 elementary and secondary schools for a total cost of $1.12 billion with nearly half of all available funds allocated.[12]

The distribution of projects mirrors the population density of school-age children across the US.[13] While schools which received SRTS funds were more likely to be located in dense urban environments with a higher proportions of disadvantaged and Latino students, 20% of SRTS schools were located in rural areas indicating attention to geographic equity in funding.[14] State departments of transportations have generally adhered to federal administrative guidance on the type and scope of interventions intended by the original legislation, with the large majority of proposed projects involving capital construction and engineering interventions.[12]

SRTS programs have had a demonstrable positive effect on travel behavior as measured by both self-report and socioecological models of public health interventions.[15, 10] In the relatively few states that have laws requiring traffic calming, there has been an increase in active travel to school.[15] Another study that looked at pre- and post-project active school-travel survey data at 53 schools in Mississippi, Wisconsin, Florida and Washington found statistically significant increases in walking (9.8% in the pre-project period versus 14.2% in the post-project period). While there were relatively smaller increases in bicycling (2.5% pre-project versus 3.0% post), the researchers concluded that the projects were especially effective at introducing bicycling to those communities where it had been rare.[16]

Despite the importance of traffic safety in child health and the potential impact of SRTS programs in reducing injury risk, few studies have assessed these programs from the perspective of injury control and prevention. Studies examining the impact of SRTS on pedestrian injury have often been based on behaviors and perceptions linked to pedestrian safety[17] or have been based on literature reviews.[18] There is a need for additional studies based on data analysis of crash and injury records. As part of a series of studies aimed at closing this research gap, our group has documented the safety benefit and cost effectiveness of the SRTS program in New York City (NYC).[19,20,21] However, the effectiveness of SRTS in reducing school-age pedestrian injury in NYC may not be generalizable to other geographic regions. The objective of this study is to extend our investigations of the effects of the SRTS program on school-age pedestrian and bicyclist injuries to a nationwide sample which includes distinct traffic environments, travel patterns, population densities, and demographic characteristics.

Methods

Individual-level pedestrian and bicyclist injury data for a 16 year period (1995–2010) were obtained from the US Department of Transportation National Highway and Traffic Administration State Data System (SDS)[22] for 18 states: Arkansas, California, Connecticut, Florida, Illinois, Kansas, Kentucky, Maryland, Michigan, Missouri, Nebraska, New Mexico, New York, Ohio, Pennsylvania, South Carolina, Virginia, and Washington. States were chosen based on their participation in SDS and their consent to share data. The analysis accounts for approximately 55% of the nation's 62 million school-age children. The inclusion of both pedestrians and bicyclists was based on the intent of the SRTS program to encourage both forms of active travel. Data on SRTS funding allocations were obtained from the National Center for Safe Routes to School.[23] Data on the number of roadway miles in each state were obtained from the US Department of Transportation Federal Highway Administration.[24] The most recent data on roadways were from 2008 and contained variables on types of roads categorized by rural versus urban. Population data were obtained from the US Census.[25]

Initial descriptive statistics of all-age, all-hour pedestrian and bicyclist injuries and fatalities were conducted. Data were then restricted to a school-age group (5 to 19 years) and an adult group (30 to 64 years) for weekdays during school-travel hours (7AM–9AM and 2PM–4PM) throughout the year. The time of injury is based on the police report and reflects the time at which the injury occurred. The decision to include the full year was purposeful and intended to capture all possible school terms. Summary quarterly counts of pedestrian injuries and fatalities for each state, classified by school-age vs. adult groups were calculated. Based on previous studies of NYC[19,20,21] and changepoint analyses of pedestrian and bicyclist injury rates and funding allocations (See Appendix), an indicator variable for whether the injury or fatality occurred before or after an estimated 2008 SRTS intervention changepoint year was created. State-level variables on per student SRTS spending and total number of roadway miles in a state were merged to the injury and fatality files.

After descriptive statistics were assessed, data were modeled using a negative binomial formulation that followed an approach taken from our study of Texas state-level data.[26] 11 Eleven models were fit to assess the effect of an indicator variable for the post-SRTS intervention time period on the risk of pedestrian and bicyclist injury in school-age children:

$$log(InjCount_i)=\beta_0+\beta_1*agegroup+\beta_2*SRTS+\beta_3*agegroup*SRTS+\beta_i*VAR_i+log(population)$$

where, $InjCount_i$ is the count of pedestrian and bicyclist injury in quarter *i*, *agegroup* is a binary variable (1 for ages 5–19 years and 0 for ages 30–64 years), *SRTS* is an indicator of whether the injury occurred before or after the SRTS program was implemented (0 for prior to January 2008, 1 for after), and *population* is an offset variable based on yearly state-level census data and allows the exponentiated coefficients to be interpreted as incidence rate ratios (IRR). VAR_i represents a vector of additional explanatory variables, i.e. state-level SRTS allocation per student, and number and type of roadway miles in a state.

In the interpretation of this model, β_0 is the intercept; β_1 is the logarithm of the estimated IRR of pedestrian and bicyclist injury in school-age children versus adults before implementation of the SRTS program (January 2008–December 2010); β_2 is the logarithm of the estimated IRR of pedestrian and bicyclist injury in adults after versus before implementation of the SRTS program; $\beta_1 + \beta_3$ is the logarithm of the estimated IRR of pedestrian and bicyclist injury in school-age children versus adults after implementation of the SRTS program (January 2008–December 2010); and $\beta_2 + \beta_3$ is the logarithm of the estimated IRR of pedestrian and bicyclist injury in school-age children after versus before implementation of the SRTS program. The regression coefficient for the interaction term, β_3, is the linear contrast of $(\beta_2 + \beta_3) - \beta_2$ and thus can be interpreted as the net effect of the SRTS program on the risk of pedestrian and bicyclist injury in school-age children.

Following an approach described by Gelman and Hill,[27] the modeling procedure consisted of evaluating completely pooled models of injury risk that ignored state grouping and treated the data as arising from a single population or process, followed by completely un-pooled analysis of each individual state, proceeding to a series of multilevel models that incorporate variation at both the national and state levels. We evaluated multilevel models with varying intercepts and fixed slopes, and models with varying intercepts and varying slopes. State-level predictors for per-student spending and the proportion of urban roads in a state were added and evaluated for their informativeness as well as their effect on multi-level model fit and precision. Akaike information criterion (AIC) and deviance information criterion (DIC) were used to estimate the fit of the models to the data. An over-dispersion parameter was calculated from the "lmer"[28] model summary. Values over two were considered problematic.

The (non-exponentiated) coefficients and standard errors for the fixed effects of the intercept and slopes for the explanatory variables (SRTS, change point and interaction between SRTS and changepoint) were interpreted as the "overall" effect averaged over all the states. They represent a compromise between the completely pooled and non-pooled models. "Error Terms", or the estimated variation for state or group and for the individual data points were considered analogous to between (group) and within (individual) error terms in the ANOVA setting. The models were run using the R "lme4" package.[28] The study protocol was approved by the (*redacted for peer review*) Institutional Review Board as exempt.

Results

There were a total of 1,638,735 pedestrian and bicyclist injuries for all ages in the 18 states during the study period. (Table 1) Overall, the mean age of an injured pedestrian/bicyclist was 31 years (SD = 20.0 years). The mean age for a child pedestrian/bicyclist (restricted to under age 20) was 11.8 (SD = 4.6 years). Of the total injured pedestrians and bicyclists, 63.1% were male.

Of the injured individuals, 1,067,264 (65.1%) were listed as pedestrians, 518,505 (31.5%) as bicyclists or pedal-cyclists, 51,783 (3.2%) as other personal conveyances such as a ridden animal, horse-drawn carriage, train or in a building, and 1,183 entries (0.07%) as unknown. There were 46,421 deaths for all ages during the study period, for an overall pedestrian-bicyclist case fatality ratio of 2.8%. The case-fatality ratio varied across states, ranging from 1.6% in Nebraska to 7.5% in South Carolina.

During 1995 through 2010, there were a total of 518,331 pedestrian/bicyclist injuries to school-age children and 575,150 pedestrian/bicyclist injuries to adults aged 30–64 years, including 5,725 fatalities to school-age children and 22,150 fatalities to adults aged 30–64 years. Adult injury rates appeared fairly constant over time compared to school-age children. (Figure 1)

In a completely pooled negative binomial model of all-hour injury counts comparing school-age children to adults in the pre and post SRTS intervention period, the exponentiated coefficient for the interaction term between age group and intervention time period was 0.77 (95% CI 0.65, 0.93), indicating an approximately 23% greater decline in all-hour injury risk for children compared to adults following the SRTS intervention time period. In a similar model for fatalities, the interaction term was 0.80 (95% CI 0.68, 0.94) In a completely pooled model of injuries restricted to school-travel hours, the exponentiated coefficient for the interaction term between age group and intervention time period was 0.85 (95% CI 0.75, 0.97). (Table 2).

In a multi-level varying intercept, varying slope model restricted to school-travel hours, the interaction term between age group and intervention time period was 0.84 (95% CI 0.65, 0.92), indicating an approximately 16% greater decline in school-hour injury risk for children compared to adults following the SRTS intervention time period. (Table 3) A similar model was run for each set of individual state data. The SRTS intervention was associated with a statistically significant decline in the risk of school-age school-travel pedestrian/bicyclist injury in four states (Florida, Maryland, New York and South Carolina) (Table 4).

Discussion

The decline in traffic-related injuries in the US is a public health success story.[29] Drivers and motor vehicle occupants have accrued the most benefit. The challenge remains to enhance the safety of the most vulnerable roadway users, especially children and older adults, through improved engineering and infrastructure.[29] There is also concern that some of the decline in pediatric pedestrian risk may have come at the expense of healthy, active behaviors.[8,9] It is becoming increasingly apparent that the national SRTS program has been successful in encouraging active travel and in addressing parents' concerns about their children's safety getting to and from school.[12, 30] The results of this study further support the second perception. Controlling for the temporal trend represented by the reduction in adult injuries, and restricting to school-travel hours, we found evidence that SRTS was associated with a 14% to 16% decline in pedestrian and bicyclist injury risk and a 13% decline in pedestrian and bicyclist fatality risk in 18 US states. This finding is consistent with the experience of NYC[19] and the state of Texas.[21] The safety benefit of SRTS programs reported in this study is likely conservative because the incidence rates based on population data do not take into account the increased exposure to walking and bicycling associated with SRTS programs.

The built environment is tied to child pedestrian injury risk. In a Toronto study investigating the association of the directly-measured proportion of children walking to school with overall child pedestrian injury risk, a statistically significant crude IDR of 3.5 reduced to 0.8 once the built environment was accounted for.[31] Manipulating the built environment has been called a "logical but often overlooked" area of injury control that may generate the most beneficial interventions.[32] Recommended actions include those that are commonly part of SRTS projects, such as separating play areas from roadways, improving visibility at intersections, establishing conspicuous stop signs, enhancing pavement markings, and improving lighting.[33]

The national SRTS program represents perhaps the largest expenditure on school-age pedestrian safety in US history, and therefore it is not accidental that it is associated with meaningful reductions in school-travel, school-age pedestrian injuries. In this report, we add to our previous findings which demonstrated a nearly 40% decline in school-travel, school-age pedestrian injuries in SRTS-targeted areas in a dense urban environment.[19] By looking at the effect of SRTS from both a state and national perspective through multilevel modeling across a variety of diverse settings, we find evidence that the performance of SRTS does not depend on location.

This study has a number of limitations. While SRTS is primarily an engineering intervention, it includes an appreciable and meaningful educational component whose effects cannot be easily parsed. In a survey of 699 children who participated in a bike safety educational program funded through SRTS, there were statistically significant post-intervention improvements in knowledge about bike safety, including traffic rules and helmet use, with students scoring an average of four points higher on a 13-point scale instrument.[34] Similarly, the effects of SRTS cannot easily be separated from overall secular trends. Indeed, as demonstrated in the time series we presented, in a number of states, declines in overall pedestrian injury rates predated the SRTS program, making it difficult to tease out or isolate the effects of this single program. Additionally, ascribing causation on pre-post comparisons can be subject to *post-hoc ergo propter hoc* errors. Our use of difference-in-difference modeling was an attempt to address this issue through statistical means. Despite these efforts, it is exceedingly difficult to ascribe all the declines in school-travel, school-age pedestrian and bicyclist injuries to the SRTS program.

We chose a difference-in-differences analytic framework using adult injury rates to help control for temporal trends that could confound our results over time. It is though, a compromise based on limitation of the data. Because the study period was relatively short, we did not have adequate data to control for temporal trends using a more refined approach like interrupted time series. While difference-in-differences models have been proposed as a way to tease out policy impacts, in this case data limitations restrict interpretation to association rather than causality. Our choice of adults for comparison was based on initial descriptive analyses looking at different age groups. We believe the adult age group which we selected differed sufficiently by age and travel patterns from the target school-age group so as to be considered a separate population, but one which could reasonably be expected to have exposure to traffic as pedestrians. Additional comparisons could have theoretically been based on sub-categories such as urban vs. rural or availability of mass transit, but the necessary data at smaller geographic units such as county or census tracts would not support that level of analysis.

Data limitations did not allow us, as in our previous studies, to spatiotemporally restrict our analyses to areas with SRTS interventions and compare them to areas without SRTS interventions exclusively during school-travel times. Also, in keeping with prior analyses, pedestrian and bicyclist injuries were analyzed collectively. This could underestimate the effect if, for example, interventions were primarily aimed at preventing pedestrian injuries. Given that up to 30% of SRTS projects include educational activities aimed at encouraging children to bike to school,[23] we believe our approach is consistent with the goal of SRTS to advance both safe walking and bicycling jointly. We also realize that we are probably including some non-school trips in our analysis. We believe that this measurement error would most likely be non-differential and bias our results toward the null. Finally, SRTS programs were implemented over time, and we did not consider this lag effect in these models. Since the post-SRTS time period was relatively short in these data, we chose to restrict the analyses to a single time period chosen through changepoint analyses. With additional years of data, future analyses may examine the impact of lagging the indicator by additional months or years.

Despite these limitations, we believe these analyses indicate that children can be encouraged to be active and still remain safe. While our results cannot be considered causal, the association of the SRTS time period with reductions in school-travel related child pedestrian injury is consistent with findings that optimizing the physical environment is an effective, albeit complex and expensive, approach to injury control for vulnerable roadway users. These data support the premise that the SRTS program, which is primarily a series of changes to the built environment, may have contributed to declines in school-age, school-travel pedestrian and bicyclist injuries in 18 US states over 16 years. We conclude that expanding the kinds of interventions represented in SRTS programs to all schools may be expected to have important benefits for all children.

Supplementary Material

Refer to Web version on PubMed Central for supplementary material.

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Abbreviations

CI	confidence interval
IRR	incidence rate ratio
SRTS	Safe Routes to School

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Highlights

Concerns about motor-vehicle related pedestrian and bicyclist injuries, which are an important cause of morbidity and mortality among school-age children, may lead to decreased active travel to school and contribute to childhood obesity.

The Safe Routes to School program (SRTS) was intended to increase active travel to school in the United States, and at $1.12 Billion the represents perhaps the largest expenditure on school-age pedestrian safety in US history.

Although there is evidence that Safe Routes to School (SRTS) programs increase walking and bicycling in school-age children, their impact on pedestrian and bicyclist injury has not been adequately examined.

In this investigation, based on data from 18 states representing 55% of the nation’s 62 million school-age children over a 16-year period, SRTS was associated with a 23% reduction in pedestrian and bicyclist injuries, and a 20% decrease in fatalities in school-age children compared to adults.

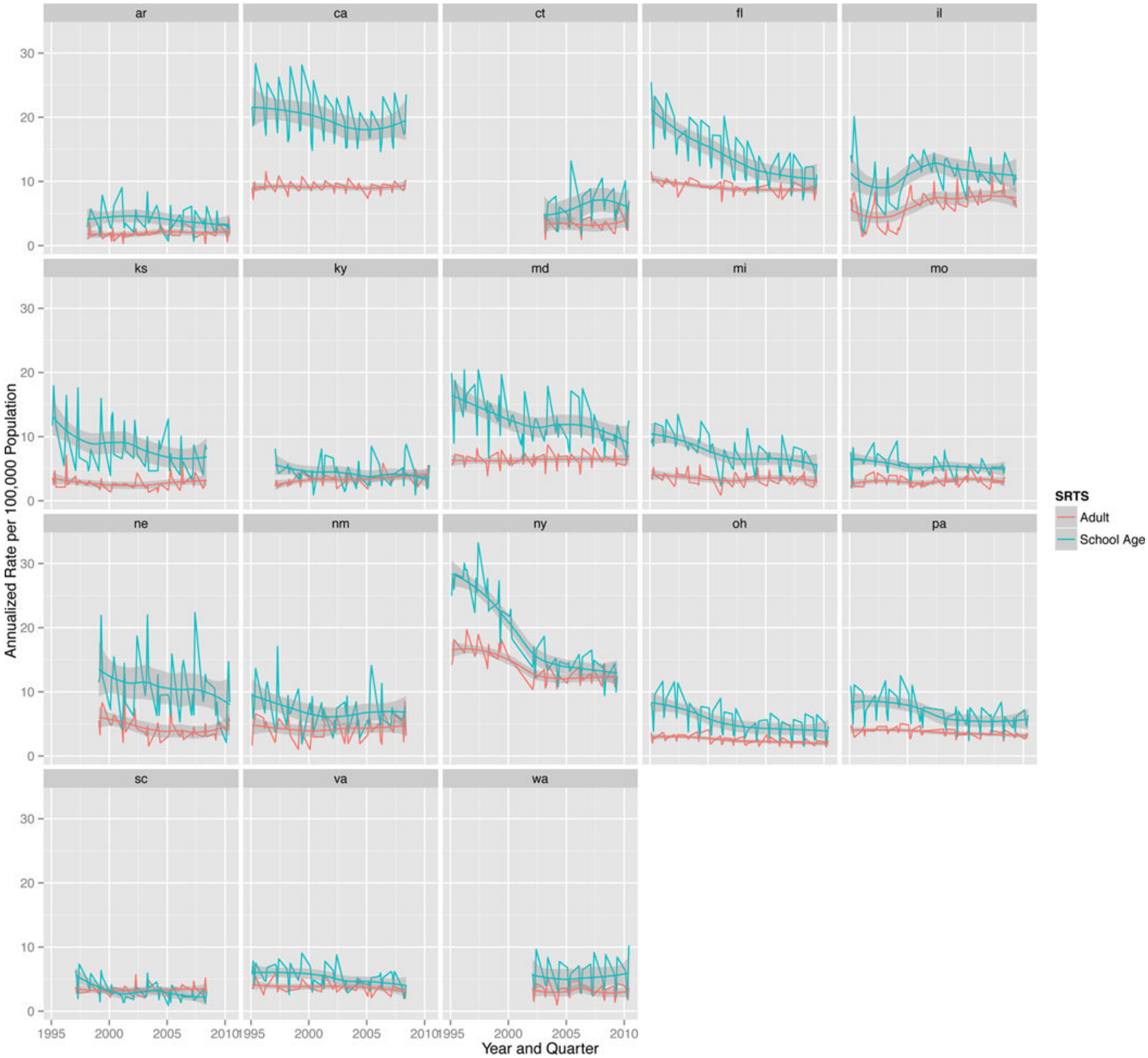

Figure 1.
Time Series School-Age vs. Adult Quarterly Annualized Rates of Pedestrian and Bicyclist Injuries During School Travel Hours by State

Table 1

All-Age Yearly Pedestrian and Bicyclist Injury Counts by State, United States 1995 – 2010.

Year	AR	CA	CT	FL	IL	KS	KY	MD	MI	MO	NE	NM	NY	OH	PA	SC	VA	WA
1995	NA	35747	NA	16697	12110	1300	NA	4761	7329	2130	NA	1176	30068	4858	6432	NA	3399	NA
1996	NA	35220	NA	16313	2132	1179	NA	4874	7080	2135	NA	1079	29059	5120	6116	NA	3394	NA
1997	NA	34893	NA	15445	8790	1119	1897	4580	6689	2160	NA	1064	29156	4684	6261	1828	3294	NA
1998	648	33351	NA	15046	5078	1032	1724	4348	6999	2134	NA	941	28072	4431	6138	1775	3166	NA
1999	574	32857	NA	14126	4738	1019	1817	4439	6491	2053	1116	790	27872	4111	6103	1558	3118	NA
2000	598	32753	NA	14200	10543	945	2176	4350	5188	1859	1081	748	26550	3377	5760	1542	2993	NA
2001	661	32012	NA	14207	9994	974	1911	4126	3517	1825	1014	882	NA	3492	5463	1513	3094	NA
2002	727	34586	NA	14251	10094	956	1891	4023	4675	2545	1049	882	24346	3226	NA	1531	2856	2042
2003	799	32867	1229	14238	9472	896	1859	4123	5250	2398	1029	775	23454	3012	5229	1545	2831	2127
2004	794	32464	1114	14060	9295	902	1841	3824	5192	2409	935	924	22574	2884	5168	1493	2849	1994
2005	722	31091	1154	14358	9442	879	1842	3883	4829	2334	828	857	22431	2868	4969	1492	2773	2136
2006	712	30608	1129	13710	9670	830	1792	3917	4720	2262	827	900	22172	2913	4985	1527	2888	2255
2007	673	30537	1342	13629	10332	824	1860	3876	4686	2203	866	876	22118	2583	5122	1580	2728	2162
2008	653	31372	1223	14026	10397	759	1936	3764	4437	2212	903	948	22160	2743	4556	1607	2126	2153
2009	596	NA	1216	13795	8832	NA	1841	3592	4355	NA	837	NA	22127	2645	4403	NA	NA	2048
2010	652	NA	1334	NA	NA	NA	1967	3659	NA	NA	807	NA	NA	2640	4670	NA	NA	2271

Table 2

Exponentiated Coefficients and 95% Confidence Intervals, Completely Pooled Negative Binomial Models of Effect of Age Group* and Safe Routes to School Intervention Year on Pedestrian and Bicyclist Injuries and Fatalities.

	All-Hour Injuries	All-Hour Fatalities	School-Hour[1] Injuries	School-Hour Fatalities
(Intercept)	0.01 (0.01, 0.01)	0.00 (0.00, 0.00)	0.00 (0.00, 0.00)	0.00 (0.00, 0.00)
School Age vs. Adult	2.07 (1.89, 0.01)	0.59 (0.55,0.64)	1.82 (1.71, 1.94)	0.59 (0.52, 0.66)
SRTS Intervention Pre vs. Post	0.82 (0.73, 2.26)	0.80 (0.72,0.89)	0.91 (0.84, 1.00)	0.88 (0.77, 1.01)
Interaction Age*SRTS	0.77 (0.65, 0.93)	0.80 (0.68,0.94)	0.85 (0.75, 0.97)	0.92 (0.69, 1.21)

*School-Age (5–19) vs. Adults (30–64), School Hours, 7AM–9AM, 2PM–4PM

Table 3

Fixed Effects and 95% Confidence Intervals. Multilevel Varying-Slope, Varying-Intercept Negative Binomial Model of Effect of Safe Routes to School Intervention Year on School-Travel Pedestrian and Bicyclist Injuries School-Age (5–19) vs. Adults (30–64) Injuries

	Point Estimate	Lower 95% CI	Upper 95% CI
(Intercept)	0.00	0.00	0.00
School Age vs. Adult	1.82	1.80	1.85
SRTS Intervention Pre vs Post	0.97	0.96	0.99
SRTS Spending per Student	1.03	1.00	1.06
Proportion of Roads Designated Urban	1.01	1.00	1.02
Interaction Age*SRTS	0.84	0.82	0.87

Table 4

Exponentiated Coefficients and 95% Confidence Intervals, Non-Pooled, Individual State-Level Negative Binomial Models, Safe Routes to School Intervention. (Statistically significant interactions in boldface)

	State	Age	Change	Interaction
1	AR	2.22 (1.82, 2.71)	1.01 (0.78, 1.3)	0.79 (0.54, 1.14)
2	CA	2.17 (2.05, 2.30)	1.02 (0.92, 1.14)	0.94 (0.81, 1.09)
3	CT	1.61 (1.21, 2.14)	1.07 (0.82, 1.40)	1.18 (0.79, 1.75)
4	**FL**	**1.63 (1.51, 1.76)**	**0.95 (0.84, 1.07)**	**0.75 (0.62, 0.89)**
5	IL	1.80 (1.53, 2.12)	1.31 (1.02, 1.70)	0.80 (0.55, 1.15)
6	KS	3.17 (2.70, 3.73)	1.13 (0.83, 1.53)	0.66 (0.43, 1.02)
7	KY	1.36 (1.17, 1.58)	1.17 (0.99, 1.39)	0.77 (0.59, 1.02)
8	**MD**	**2.07 (1.90, 2.26)**	**1.03 (0.92, 1.16)**	**0.75 (0.63, 0.89)**
9	MI	2.23 (1.97, 2.53)	0.90 (0.74, 1.10)	0.86 (0.65, 1.14)
10	MO	1.80 (1.62, 2.01)	0.97 (0.80, 1.17)	0.92 (0.69, 1.22)
11	NE	2.39 (1.97, 2.90)	0.85 (0.66, 1.09)	1.00 (0.71, 1.41)
12	NM	1.71 (1.46, 2.00)	1.10 (0.83, 1.44)	0.82 (0.54, 1.24)
13	**NY**	**1.40 (1.28, 1.54)**	**0.86 (0.75, 1.00)**	**0.77 (0.63, 0.95)**
14	OH	2.25 (1.97, 2.57)	0.75 (0.61, 0.91)	0.90 (0.68, 1.19)
15	PA	1.90 (1.71, 2.12)	0.88 (0.76, 1.02)	0.87 (0.71, 1.08)
16	**SC**	**1.01 (0.87, 1.16)**	**1.04 (0.85, 1.26)**	**0.67 (0.45, 0.97)**
17	VA	1.40 (1.26, 1.55)	0.82 (0.68, 0.98)	0.99 (0.74, 1.31)
18	WA	1.62 (1.28, 2.05)	0.91 (0.71, 1.16)	1.18 (0.83, 1.68)