Systematic review of child passenger safety laws and their associations with child restraint system use, injuries and deaths

Emma B Sartin 1, 1 Leah R Lombardi, 1 Jessica H Mirman 2

ABSTRACT
Background and objective Many countries and all US states have legislation that mandates how children of certain ages and/or sizes should be restrained in vehicles. The objective of the current systematic review was to describe the associations between legislation and three outcomes: child restraint system use, correct child restraint system use and child passenger injuries/deaths.

Methods Included studies were published between 2004 and 2020 and evaluated associations between child passenger safety laws and the outcomes described above. Three literature searches using three search terms (child passenger safety, car seat use, booster seat use) were completed in PubMed and PsycINFO, with the last search occurring in January 2021. Studies are presented based on the outcome(s) they evaluated. The original protocol for this review is registered with PROSPERO (ID: CRD42019149682).

Results Eighteen studies from five different countries evaluating a variety of different types of legislation were included. Overall, positive associations between legislation and the three outcomes were reported. However, there were important nuances across studies, including negative associations between booster seat legislation and correct child restraint use. Further, there were also negative associations between various types of legislation and outcomes for populations with less formal education and lower incomes, and for racial and ethnic minorities.

Conclusion Overall, child passenger safety legislation appears to be positively associated with child restraint system use, correct child restraint use and child passenger injuries/deaths. However, there is a need to more comprehensively characterise how different types of legislation influence child passenger safety outcomes to promote equitable effects across populations.

INTRODUCTION
Despite substantial reductions over the last several decades, motor vehicle crashes remain a leading cause of injury and death for children less than 15 years old.1 One way to reduce children’s risk of being injured or killed in a crash is by restraining them in child restraint systems (CRS), or car seats and booster seats.2,3 However, despite the effectiveness of CRS and decades of awareness and intervention efforts, the majority of caregivers either do not use a CRS and/or continue to misuse them (ie, they do not use the CRS correctly according to best practice, legislation mandates or the manufacturer’s guidelines). This is especially true within racial and ethnic minority families (eg, black and/or Hispanic/Latino), who—compared with their White peers—remain much less likely to use any CRS,4 are up to three times more likely to misuse a CRS,5 and are up to twice as likely to be killed in a crash.3

To improve CRS awareness, uptake and use, many countries and all states and territories in the USA currently have some type of child passenger safety legislation. Importantly, there have been no recent attempts to review studies evaluating the effects of these various policies. Understanding the association between legislation and CRS behaviours and crash outcomes, as well as how these associations vary across populations, can inform the development or adaptation of future policies and is therefore a critical step in further reducing the burden of motor vehicle crashes on children worldwide. With this in mind, the objective of the current systematic review was to identify and characterise studies evaluating the effects of different child passenger safety policies. More specifically, we identified and characterised studies published between 1 January 2004 and 31 December 2020 that examined legislation’s impact on three outcomes: (1) CRS use, (2) correct or appropriate CRS use and (3) crash injuries and fatalities.

METHODS
Search and screening process
To be included, studies had to assess the impact of legislation on at least one of three outcomes: CRS use, correct or appropriate CRS use and crash injuries and/or fatalities. All results related to each of these outcomes, including those within studies assessing multiple outcomes, were included in this review. Literature searches were conducted in PsycINFO and PubMed and restricted to studies published between 1 January 2004 and 31 December 2020. The initial search and screening process was completed between 25 May 2018 and 1 April 2019, and is described in a different systematic review of CRS interventions.6 In this initial search, three reviewers completed literature searches in each database, using the following search strings: (1) child passenger safety, (2) booster seat use and (3) car seat use. In PsycINFO, searches were restricted to peer-reviewed articles with an age group criterion of childhood (birth to 12 years). In PubMed, searches were restricted to human species and an age group criterion of birth to 18 years. Any identified articles that were literature reviews were examined to ensure that all articles possible were
found and included in this analysis. All search result references were downloaded and entered into an Excel file that included detailed information about the study’s aims, outcomes, participant population, findings and a ‘relevancy’ score determined by the reviewer (1=extremely relevant, 2=maybe relevant and 3=not at all relevant). A total of 1240 abstracts were found; however, after the initial review of abstracts for relevancy and duplicates, and further examining articles deemed ‘extremely’ or ‘maybe’ relevant, only 16 articles focused on child passenger safety legislation were included in this review.

A second literature search completed independently by the second author to update and supplement the first search was conducted in January 2021 and identified 62 potential studies; however, none were deemed relevant or added to this review.

Therefore, 18 studies were included in this systematic review (table 1). Originally, we sought to also complete a meta-analysis and assess each study for bias; however, the majority of studies were pre-post designs, and very few presented their data or conducted their evaluations according to the standards outlined by Cochrane, limiting the utility or informativeness of any results produced. Therefore, we opted not to proceed with the meta-analysis or risk of bias assessment, and instead focused on providing more details of each study included in this systematic review. With these exceptions in mind, we followed the Preferred Reporting Items for Systematic Reviews and Meta-Analyses guidelines. Patients and the public were not involved in any aspect of this systematic review.

### RESULTS

#### Included studies

Figure 1 depicts the search and screening process. Nineteen studies from five different countries (USA, n=9; Australia, n=3; Canada, n=3; Chile, n=2; and New Zealand, n=1) were included in this review. As shown in table 1, outcomes measured across the studies (with some assessing multiple outcomes)
The majority of studies examining the association of legislation with correct or appropriate CRS use reported positive findings, most notably in booster seat use. Before and after the enactment of enhanced child passenger safety legislation in Nova Scotia, Canada, Yanchar et al13 conducted telephone surveys with caregivers of children less than 12 years old and found that appropriate use of forward-facing car seats increased from 74% to 92%, while correct booster seat use increased from 58% to 95%. Also in Canada, Simniceanu et al completed roadside observations and reported that provinces with specific booster seat legislation had higher rates of correct restraint use among 4–8 years old child passengers than provinces without legislation. Similarly, Winston et al8 compared insurance claims and caregiver self-reports across multiple states in the USA and found that 4–7 years old were 39% more likely to be appropriately restrained in states with booster seat legislation than in states without booster-specific legislation.

Several studies in Australia have also reported positive associations between appropriate CRS use and legislation. In New South Wales, Australia, Brown et al completed observations of child passengers aged 2–5 years old at preschools and daycare centres in lower-socioeconomic status (SES) communities before and after new age-based mandates. Compared with pre-legislation odds, the odds of children being appropriately restrained according to the legislation’s age-based mandates were 2.3 times greater post-legislation, while the odds of children being correctly restrained according to manufacturers’ instructions were 1.6 times greater. Similarly, Keay et al17 conducted a survey with 1160 caregivers of children aged 2–5 years enrolled at one of 28 early childhood centres in lower SES areas of metropolitan Sydney and found that overall, there was an improvement in appropriate CRS use based on children’s age when compared with historic data; the authors concluded these improvements in appropriate CRS use indicated the new legislation produced enacted booster seat legislation) and 2009 (postbooster seat legislation), while controlling for temporal and socioeconomic factors. By age, booster seat use among fatally injured children increased from 9% to 41% among 4–5 years old, from <0.9% to 23% among 6 years old, and from 0.1% to 12% among 7 years old.

Legislation has also had positive associations with rates of CRS use in other countries. In New Zealand, Singh et al conducted a survey of restraint use within paediatric inpatients and found that a larger proportion of children were restrained than what was reported before new age-and-CRS-type mandates were introduced. In Canada, Snowdon et al reported that 24.6% of 4–8 years old children in Canadian provinces covered by booster seat legislation were restrained compared with only 16.6% in provinces without similar legislation; several years later Simniceanu et al13 reported that overall CRS use was higher among 4–8 years old in Canadian provinces with legislation than those without.

**CORRECT USE**

Ten studies examined the association of legislation with correct or appropriate CRS use, defined as one or more of the following (depending on the study): (1) the CRS use is correct based on child-seat fit mandates established by legislation or best practice, (2) the actual use of the CRS is accurate (eg, child is correctly harnessed into seat) and (3) the CRS is correctly installed into the vehicle. In these studies, appropriate CRS use was measured using caregiver self-report7–9 13 19 and observations.10 11 18 21 24 7–11 13 18 19 21 24

![Figure 1](image-url)
a positive impact. However, this study also reported a low rate of age-appropriate restraint use in 3 years old, with nearly half prematurely transitioned to a booster seat or adult seat belt postlegislation. In addition, Koppel et al.\textsuperscript{16} analysed multiple years of observational data collected both prelegislation and postlegislation (total observations=2674), mainly focusing on errors in child harnessing and the CRS’s installation to the vehicle. They reported that 79% of the CRS inspections conducted post-legislation still had at least one error in use.

Importantly, several studies reported striking nuances in how legislation may be influencing correct CRS use among specific populations. While Brixey et al.\textsuperscript{21} found that booster-seat legislation in Wisconsin increased the overall number of children travelling in any type of CRS, Brixey et al.\textsuperscript{19} did not find meaningful differences in how many children 0–7 years old were appropriately restrained, and the majority of urban children remained inappropriately restrained postlegislation. In addition, Brixey et al.\textsuperscript{21} reported important racial and ethnic groups differences: white caregivers’ proper booster use increased from 48% to 68%, black caregivers’ proper use dropped from 18% to 7%, and Latino caregivers’ proper use rates were stable at 10%. Based on these findings, the authors concluded that while the booster seat legislation increased the overall number of children travelling in booster seats, it had null or potentially negative consequences for lower SES and racial/ethnic minority families’ appropriate use, with many prematurely transitioning their young children to booster seats. Similarly, Gunn et al.\textsuperscript{2} completed community observations before and after Tennessee enacted an enhanced child safety restraint law in 2004 that included new requirements for booster seat use among 4–8 years old passengers. The authors reported appropriate booster seat use increased from 29% prelegislation to 39% postlegislation; however, black children did not have meaningful increases in booster seat use and remained twice as likely to be unrestrained than their white peers postlegislation. In addition, this study reported that booster seat legislation decreased appropriate CRS use for children younger than 4 years (ie, encouraged premature transitions). Lastly, Snowdon et al.\textsuperscript{18} found that though the majority of Canadian children were restrained, only about 60% were correctly restrained according to the child’s height and weight and manufacturer’s instructions. As a result of these nuances in appropriate CRS use post-legislation, many studies highlight the need for tailored, effective messaging and education to accompany changes made to existing or introductions of new child passenger safety legislation. More specifically, there appears to be a need for child passenger safety information to be disseminated in multiple languages and via different platforms (eg, online, paper, in-person) to ensure accurate information reaches at-risk populations, particularly racial/ethnic minority and lower SES or income families.

**Injuries and fatalities**

We identified six papers that examined the association between legislation and rates of child passenger injury and/or fatality using national crash databases, fatality data, hospital discharge data and hospital inpatient data.\textsuperscript{14,16,17,20,22,23} With respect to crash-injuries, Sun et al.\textsuperscript{20} reported an 18% reduction in the traffic injury rate for children 4–6 years old following the implementation of legislation in New York focused on booster seat use; there were no pre–postlegislation differences in the traffic injury rate of children <3 years old (ie, those not covered by the booster seat mandates). Eichelberger et al.\textsuperscript{22} evaluated similar booster seat-focused legislation across multiple states and reported a 5% reduction in the per capita rate of child passengers (of booster seat age, which varied by state requirements) who sustained any crash-injury (regardless of severity) and a 17% reduction in those who sustained fatal or incapacitating injuries. In addition, Eichelberger et al.\textsuperscript{22} also reported that 3–8 years old who were covered by booster seat legislation were less likely to be hospitalised for crash injuries than children in those states not covered by laws (ie, children 9–12 years old). Similarly, using the Kids Inpatient Database, Presley et al.\textsuperscript{14} found that children covered by booster seat legislation were 22% less likely to be hospitalised for crash-injuries than children not covered. Importantly, this study found both income and racial/ethnic disparities, leading them to conclude that access to booster seats, quality of affordable seats and proper use/enforcement strategies may impede the universal effectiveness of legislation.

Further, Martínez and Contreras\textsuperscript{16} conducted a pre–poststudy of legislation in Chile mandating seatbelt use for all passengers and CRS use for children under the age of 4 years. They reported the number of deaths for child passengers ages 0–14 years decreased from 1.71 deaths per 100 000 vehicles prelegislation to 0.89 deaths per 100 000 vehicles postlegislation. However, Nazif-Muñoz et al.\textsuperscript{14} evaluated the same legislation’s influence on the number of fatalities for child passengers ages 0–4 years and found that despite there being a 35% reduction in severe injuries only 3 years after implementation, there was no substantial difference in this age group’s fatality rate. The main difference between these studies is who was included in the analysis, with Martínez and Contreras\textsuperscript{16} incorporating a much larger age range, including adolescents who should be restrained in adult seat belts. In the USA, Mannix et al.\textsuperscript{23} analysed FARS data (controlling for SES and temporal factors) and found that states with booster seat laws had fewer child fatalities than states without booster seat laws. More specifically, states with booster seat legislation had adjusted incidence rates of 0.89 (95% CI 0.81 to 0.99) for fatalities of 4–5 years old, while states without booster seat legislation that covered 6 years had an adjusted incidence rate ratio of 0.77 (95% CI 0.65 to 0.91) for fatalities of 6 years and those that included 7 years had an adjusted incidence rate ratio of 0.75 (95% CI 0.62 to 0.91) for fatalities of 7 years.

**DISCUSSION**

This is the first systematic review of studies evaluating associations between child passenger safety legislation and CRS use, correct CRS use, and child passenger injuries and fatalities conducted in the last 15 years. Overall, reviewed studies reported positive associations between legislation and these child passenger safety outcomes. Despite this overall trend, several studies reported important nuances in how legislation may influence behaviours in specific populations, especially those that are racial and ethnic minorities, have lower-income or have attained lower levels of education. In addition, there were multiple studies that reported important caveats about how legislation may impact correct CRS use specifically, with several warning that booster seat-specific legislation may prompt premature transitions for younger children. Lastly, there was a wide variety in the types of legislation and the methods used to evaluate each outcome. Taken together, these findings support the need for continued research on the effects of child passenger safety legislation. Specifically, future work must more clearly elucidate nuances in the effects of legislation across populations, with a particular focus on how child passenger safety laws influence lower SES and racial/ethnic minority populations’ behaviours and outcomes. Our findings also underscore the need for initiatives and efforts that minimise...
adverse effects (eg, premature booster seat transitions) to accompany legislation changes, implementations and enforcements.

Strengths of this study include its rigorous search and screening methods and its international focus. However, the variability in study designs and the methods used to assess each legislation’s impact do not allow for the authors to make any direct conclusions about the effect of legislation on different outcomes. For example, we were unable to compare differences in the impacts of legislation on CRS behaviours and injury outcomes based on whether studies used observational or self-report methodologies; this factor was a moderator of caregiver-targeted CRS interventions’ effect sizes in a recent meta-analysis.8 Thus, the reported effect sizes described this review were likely influenced by how the study measured CRS behaviours and crash injuries/fatalities. To ensure accurate conclusions about how efforts like legislation influence real-world outcomes, child passenger safety researchers and stakeholders must improve the rigour and reliability of CRS-related data. One way to do this includes bolstering the accuracy and level of detail collected from crash reports (eg, include more specific information about the CRS’s installation/type, the child’s weight/height, etc). Additionally, in this review, we were unable to determine how differences in legislation enforcement (ie, primary vs secondary laws) influence reported associations. Further, all studies included in this review are from developed countries; more information on what legislation exists in less developed countries—as well as how legislation affects child passenger safety outcomes—are needed. Moving forward, there is a need for a comprehensive meta-analysis to determine what types of legislation are most effective. Doing so will allow researchers to not only directly compare how different types of child passenger safety laws influence various outcomes, especially across populations or communities, but also inform the development or adaptation of laws to support equity in transportation

What is already known on the subject

► In the past several decades, many countries and all US states have enacted various types of child passenger safety laws.
► There is currently no review of studies evaluating associations between child passenger safety legislation and child restraint use, correct child restraint use or child passenger injuries and fatalities.

What this study adds

► Overall, legislation is associated with positive child passenger safety outcomes; however, important nuances exist, especially for how legislation may influence correct or appropriate restraint use or restraint use among at-risk populations.
► There is a need for studies that more closely evaluate what types of legislation produce the most equitable results across populations.

Acknowledgements The authors would like to thank Marlon Goering, Brailey Busby, and Julia DeMichele for their contributions related to the initial literature review.

Contributors EBS, LRL and JHM contributed to the conception or design of the work. EBS and LRL contributed to the acquisition, analysis and interpretation of data. EBS, LRL and JHM drafted the manuscript and helped revise it critically for important intellectual content. EBS, LRL and JHM provided final approval of the manuscript submitted and agree to be accountable for all aspects of the work and in ensuring that questions related to the accuracy or integrity of any part of the work are appropriately investigated and resolved.

Funding The authors have not declared a specific grant for this research from any funding agency in the public, commercial or not-for-profit sectors.

Competing interests None declared.

Patient and public involvement Patients and/or the public were not involved in the design, conduct, or reporting, or dissemination plans of this research.

Patient consent for publication Not required.

Provenance and peer review Not commissioned; externally peer reviewed.

Data availability statement Data are available upon request.

ORCID iD Emma B Sartin http://orcid.org/0000-0002-0609-8235

REFERENCES

1 Centers for Disease Control and Prevention. Web-Based injury statistics query and reporting system (WISQARS), 2019. Available: www.cdc.gov/injuryprevention/wisqars/2019. doi:10.1136/injuryprev-2021-044196

2 Rice TM, Anderson CL. The effectiveness of child restraint systems for children aged 3 years or younger during motor vehicle collisions: 1996 to 2005. Am J Public Health 2009;99:252–7.

3 Hertz E. Revised estimates of child restraint effectiveness. Washington, D.C 1996.

4 Li H, Pickrell TM. The 2017 national survey of the use of booster seats. Washington, D.C, 2018.

5 Macy ML, Cunningham RM, Resnicow K, et al. Disparities in age-appropriate child passenger restraint use among children aged 1 to 12 years. Pediatrics 2016;138:262–71.

6 Sartin E, Bell TR, McDonald CC, et al. Assessment of Caregiver-Targeted Interventions for use of motor vehicle passenger safety systems for children: a systematic review and meta-analysis. JAMA Netw Open 2019;2:2.

7 Gunn VL, Phillips RM, Cooper WO. Improvement in booster seat use in Tennessee. Pediatrics 2007;119:e131–6.

8 Winston FK, Kallan MJ, Elliott MR, et al. Effect of booster seat laws on appropriate restraint use by children 4 to 7 years old involved in crashes. Arch Pediatr Adolesc Med 2007;161:270–5.

9 Keay L, Hunter K, Brown J, et al. Child restraint use in low socio-economic areas of urban Sydney during transition to new legislation. Accid Anal Prev 2013;50:984–91.

10 Koppel S, Chafston JL, Rudin-Brown CM. The impact of new legislation on child restraint system (CRS) misuse and inappropriate use in Australia. Traffic Inj Prev 2015;14:387–96.

11 Simmiceana A, Richardson SA, Snowdon A, et al. Child restraint use in Canadian provinces with and without legislation in 2010. Traffic Inj Prev 2014;15:734–9.

12 Violano GM. Determinants of usage of age-appropriate child safety seats in Connecticut. Diss Abstr Int Sect B Eng Sci 2015:76 https://linkinghub.elsevier.com/retrieve/pii/S0898159715307553.

13 Yanchar NL, Young JB, Langelie DB. Knowledge and practice of childhood motor vehicle restraint use in nova scotia: phase II. Accid Anal Prev 2015;74:150–6.

14 Nazif-Muñoz JI, Falconer J, Gong A. Are child passenger fatalities and child passenger injuries more severely injuries equally affected by child restraint legislation? the case of Chile. Int J Child Saf Promot 2017;24:501–9.

15 Singh N, Chambers L, Hamill J. Car seat survey at a children’s hospital: need a booster? NZ J Med J 2019;132:59–60.

16 Martinez P, Contreras D. The effects of Chile’s 2005 traffic law reform and in-country socioeconomic differences on road traffic deaths among children aged 0-14 years: A 12-year interrupted time series analysis. Accid Anal Prev 2020:136.

17 Pressley JC, Trieu L, Barlow B, et al. Motor vehicle occupant injury and related Hospital expenditures in children aged 3 years to 8 years covered versus uncovered by booster seat legislation. J Trauma 2009;67:520–9.

18 Snowdon A, Rothman L, Slater M, et al. A comparison of booster seat use in Canadian provinces with and without legislation. Inj Prev 2009;15:230–3.

19 Brixey S, Ravindran K, Guse CE. Legislating child restraint usage - Its effect on self-reported child restraint use rates in a central City. J Safety Res 2010;41:47–52.

20 Sun K, Bauer MJ, Hardman S. Effects of upgraded child restraint law designed to increase booster seat use in New York. Pediatrics 2010;126:484–9.

21 Brixey SN, Corden TE, Guse CE, et al. Booster seat legislation: does it work for all children? Inj Prev 2011;17:233–7.

22 Eichelberger AH, Chouinard AO, Jermakian JS. Effects of booster seat laws on injury risk among children in crashes. Traffic Inj Prev 2012;13:631–9.

23 Mannix R, Fleegler E, Meehan WP, et al. Booster seat laws and fatalities in children 4 to 7 years of age. Pediatrics 2012;130:1056–1062.

24 Brown J, Keay L, Hunter K, et al. Increase in best practice child CAR restraint use for children aged 2-5 years in low socioeconomic areas after introduction of mandatory child restraint laws. Aust N Z J Public Health 2013;37:272–7.
Systematic review

Moher D, Liberati A, Tetzlaff J, et al. Preferred reporting items for systematic reviews and meta-analyses: the PRISMA statement. Ann Intern Med 2009;151:264–9.