Child Passenger Safety: An Evidence-Based Review

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Statement of the Problem

Motor vehicle crashes are the number 1 cause of death in the United States in children age 14 and under. They are the number 2 cause of death in toddlers and the number one cause of death in the 5 to 14 year old age group.

There is literature that shows that proper restraint use can reduce these injuries and fatalities. However, according to SAFE KIDS study, 81% of children are incorrectly restrained (Child Passengers at Risk in America: A National Study of Restraint Use, National SAFE KIDS Campaign, 2002).

Legislation has attempted to reduce these numbers. Two means to this end are primary and secondary laws. A primary law allows motorists to be pulled over and cited if noted to be in violation of that law. A secondary law does not allow motorists to be stopped for violating that law but instead mandates the motorists be stopped and cited for another violation before dealing with the one in question. All 50 states and the District of Columbia (http://www.iihs.org/laws/restraintoverview.aspx) have some form of child restraint laws, only half are primary and none have detention options. There are data in adults to show primary laws are more effective in increasing compliance.

Despite the above, passenger vehicle occupant deaths among children were only 16% lower in 2004 than in 1975 (http://images.businessweek.com/autos/pdfs/children.pdf). In 2004, five children died and 586 were injured *each and every day* in motor vehicle crashes in the United States. Of those killed, *half were unrestrained*. In 2005, 29% or almost one-third of children *younger than age one* who were killed in motor vehicle crashes were *totally unrestrained*. Fifty-six percent of children ages 9 -12 who were killed in motor vehicle crashes that

same year were also totally unrestrained (http://www.iihs.org/research/fatality_facts_2005/children.html).

This is obviously a public health issue of the greatest magnitude. The safety of our children is paramount. Therefore, we in the Child Passenger Safety Workgroup of the EAST Practice Management Guideline Committee will examine the literature concerning the following questions to be answered

Questions to be addressed

1. What is the effectiveness of child passenger restraints in reducing morbidity and mortality?
2. What is the effectiveness of legislation in the reduction of injuries and/or mortality?

Process

We conducted a Medline search for human, English language literature from 1980 to 2006 on child passenger restraints. Child passenger restraints as keyword only yielded four results. Using “Protective Devices” or “Seat Belts” and combining that with “infant” over similar dates and restrictions, 491 references resulted, with toddler, six resulted, with “child,” 827 references resulted and with “adolescent,” 842 resulted. Studies from other countries that involved legislation were dropped due to issues of generalizability. Fifty-nine were deemed appropriate to answer the above questions, 55 of these were available for review. Fourteen articles examined legislation and 41 articles examined restraint effectiveness with relation to outcomes. We did not utilize technical reports or

engineering literature, but felt these were not relevant to the endpoints of morbidity or mortality and many could not be subject to scientific review**.**

Scientific Foundation

Restraint effectiveness

Three class II and 21 class III articles demonstrate reduction of injury and/or injury severity with restraint use in children. Two class II and 10 class III articles demonstrated reduction of mortality with automotive restraint use in children as compared to unrestrained children. The risks of injury follow a continuum, with unrestrained children faring worse in a crash than improperly restrained children faring worse than restrained. Unrestrained 0-4 year olds had relative risks (RR) of 4.4 for broken bones, 2.7 for concussions, 2.5 for open wounds and 2.5 for hospitalization (O-30) compared to restrained children. In children aged 2-5 years, premature graduation of children to seat belts had a RR for injury of 2.5 compared to those still in child safety seats. The RR was 4.2 for head injury in this study. The RR of injury was higher for 2-3 years olds (4.0) than 4-5 years olds (2.4) (O-40). In children age 4 and above, restrained children fared better than unrestrained (O-2). Compared to children in proper restraints, unrestrained children had 3 times the risk of injury. Inappropriate restraints also increased the risk of injury, doubling that risk compared to appropriate restraints (O-20). One large retrospective study of 5751 children showed that among those children age 0-4, 27% were unrestrained compared to 44% of children age 5-11 and 52% of children age 12-14. In the same study, overall figures showed that 38% of children were optimally restrained and 34% suboptimally restrained. Those with restraint devices were 2.7 times more likely

not to have a serious injury (O-10). Another study of 600 children showed that age-appropriately restrained children had a significant reduction in severe injuries in every anatomic site except the back. This study also showed a reduction in solid and hollow visceral injuries as well as mortality with age-appropriate restraints (O-39).

Other studies corroborated this risk reduction for age-appropriate, optimal restraints with a three-fold decrease in significant intra-abdominal injury and a 28% reduction in mortality risk (O-21,29). Forward-facing restraint systems were found to reduce injury compared to seat belts in the 1-4 year age range (O-7,8). Lap belts only are associated with increased spinal cord injury (O-25). Facial fractures are also increased in inappropriately restrained and front seat children, RR 1.6 and 1.8, respectively (O-6). Suboptimal restraint use has a RR of hollow viscus injury of 4.4 compared to appropriate restraint use (O-26). Improper use is cited in a class II article comparing restrained to unrestrained children, showing that restrained children were less injured than unrestrained. Serious injuries in this study resulted from improper use, using seat belts at an inappropriate age or unavoidable circumstances such as intrusion or being struck by non-stationary objects (O-1).

Belt-positioning booster seats reduce injury by 58 to 70% in children age 4-8 while mortality is also reduced by 61% (O-4,17). Backless booster seats were found to be no different than seatbelts in risk (O-4). Only one class III article showed an increase in head and cervical spine injuries with restraint devices in children 0 to 8 years of age compared to those from 9-18 (O-41). Many have explained this predisposition by the anatomic differences in the developing pediatric C-spine. However, their evaluation was limited in that they could not determine if the restraints systems were used properly or

were appropriate to the weight and age of these younger children. Only one class III article addressed cost and showed a decrease in healthcare costs in Arizona with use of child passenger restraints (O-15). There were not enough articles to develop a recommendation on this topic.

Seven class III articles supported rear seat position for children 12 and under. Risk of injury and/or mortality in the front seat was 40% to 70% higher than the rear seat (O-6,9,10,11,14,22,36). One article documented risk reductions for fatal injury with rear seat position of 41% from age 1-4, 30% from age 5-12, and 32% from age 13-18. The center rear seat was the safest with a 9-24% risk reduction for fatal injury compared to the outboard seats. Risk reductions applied to all but rear impact collisions. Restraints also reduced fatal injury risk in this study as well (O-11).

Seven studies (1 class II, 6 class III) showed increased injuries and mortality from airbags in children up to 12 years old (O-5, 9, 14,18,19,22,36). One class II study showed as high as 84% mortality for unrestrained children and 31% mortality for restrained children with airbag deployment (O-22). This is even higher for restrained infants who are at 254% increased risk of dying in the front seat with an airbag compared those without airbag. This was the only study not to find increased mortality in children 9-12 from airbags. Two class III articles suggested that second-generation airbags may result in less injury than first-generation airbags (O-5,9).

Legislation Effectiveness

Seven articles, three Class II, and four Class III, demonstrated increased (perceived or observed) compliance with child restraint use (L-1,2,4,9-12). Four studies showed

decrease in injury (L-1,6-8) and three a decrease in mortality (L-4,7,8)with enactment of child restraint legislation. The magnitude of the decrease in injury and death ranged from 10% to 50%. Ages in the studies were not uniform and ranged from 0 to 15.

Recommendations

Level 1 Standards

1. Child restraint and restraint systems reduce injury and injury severity in all ages reported and are recommended for use.
    a. The highest reductions come from age appropriate, properly used restraints, as per the American Academy of Pediatrics guidelines on selection and use of car safety seats.

Please note that these recommendations rose to Level 1 standards based on the preponderance of available literature, including well-done Class II data, that supports the age-appropriate use of child restraints and restraint systems as successful in the reduction of morbidity and mortality.

Level 2 Guidelines

1. Rear seat position reduces injury at all ages studied and is recommended especially for those less than or equal to 12 years of age.
2. Airbags can cause injury and/or death to children less than or equal to 12 years of age and thus seating position with exposure to airbags should be avoided in that age range.

3. Child restraint laws help reduce injury and mortality and increase compliance with restraint use.

Summary

Child restraints are clearly effective in injury prevention and reduction of injury severity at all ages examined. Rear seat position is also effective, especially when used in conjunction with child restraints. Legislation is also effective in improving compliance and even reducing injury. There are some data showing that primary laws are the most effective form of legislation. Further research is required on the effectiveness of legislation on injury and mortality.

References

Outcomes

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Legislation

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Appendix

http://www.aap.org/healthtopics/carseatsafety.cfm

Car Safety Seats: A Guide for Families 2009

2009 American Academy of Pediatrics

Age	Type of Seat	General Guideline
Infants	Infant seats and rear-facing convertible seats	All infants should *always* ride rear-facing until they are at least 1 year of age *and* weigh at least 20 pounds.
Toddlers/Preschoolers	Convertible seats	It is best to ride rear-facing as long as possible. Children 1 year of age *and* at least 20 pounds can ride forward-facing.
School-aged children	Booster seats	Booster seats are for older children who have outgrown their forward-facing car safety seats. Children should stay in a booster seat until adult belts fit correctly (usually when a child reaches about 4' 9" in height and is between 8 and 12 years of age).
Older children	Seat belts	Children who have outgrown their booster seats should ride in a lap and shoulder belt in the back seat until 13 years of age.

First Author	Year	Reference	Class	Conclusion	Do the conclusions seem justified?
Agran PF	1985	Motor vehicle accident trauma and restraint usage patterns in children less than 4 years of age. Pediatrics. 76(3):382-6.	II	Restrained children less injured than unrestrained and serious injuries in restrained children were from improper restraint use, using seat belts at an inappropriate age or unavoidable circumstances such as intrusion or being struck by a nonstationary object in the vehicle.	Yes

Agran PF	1992	Comparison of Motor Vehicle Occupant Injuries in Restrained and Unrestrained 4- to 14-Year-Olds. Accid Anal Prev. 24(4), 349-355.	III	1) Restrained children do better than unrestrained; 2) rear seat passengers do better than front seat; though no significant difference noted in 4- to 9-year-olds in the front seat; 3) presumed to be a function of the 5th-percentile female limitation of (front) lap-shoulder belt design.	Yes, but study seems limited, especially given low ISS scores of population.
Anonymous	1991	Child Passenger Restraint Use and Motor-Vehicle-Related Fatalities Among Children - United States, 1982-1990. MMWR Morb Mortal Wkly Rep. 40(34), 600-602.	III	An estimated 1546 lives were saved from 1982-1990 by the usage of restraints in children <4 years	Yes

Arbogast KB	2005	Effectiveness of high back and backless belt-positioning booster seats in side impact crashes. Annu Proc Assoc Adv Automot Med. 49:201-213.	III	Kids 4 - 8 in belt positioning booster seats(BPB) vs. wearing seat belts had reduced injury	Yes
Arbogast KB	2003	Effect of vehicle type on the performance of second generation air bags for child occupants. Annu Proc Assoc Adv Automot Med. 47:85-99.	III	Use of second generation airbags is associated with decreased injury vs. first generation for front seat child occupants in passenger cars, trend in minivans but not significant, and worse in SUVs.	Yes

Arbogast KB	2002	The role of restraint and seat position in pediatric facial fractures. J Trauma. 52(4):693-8.	III	1) Unrestrained children have much higher rate of facial fracture; 2) Inappropriately restrained children had RR 1.6 higher for facial fracture than appropriately restrained; 3) Front seat had RR 1.8 v. rear seat.	Yes
Arbogast KB	2004	Evaluation of pediatric use patterns and performance of lap shoulder belt systems in the center rear. Annu Proc Assoc Adv Automot Med. 48:57-72.	III	Forward facing child restraint systems lower the risk of serious injury (78% reduction of risk) and hospitalization (79%) in the center rear.	Yes

Arbogast KB	2004	An evaluation of the effectiveness of forward facing child restraint systems. Accid Anal Prev. 36(4):585-9.	III	Use of forward-facing restraint systems compared with seat belt use only in children aged 12 to 47 months, reduced the risk of serious injury by 80%, and the risk of hospitalization by 82%. There was no difference in the risk of minor injury.	Yes
Arbogast KB	2005	Field investigation of child restraints in side impact crashes. Traffic Injury Prev. 6(4):351-60.	III	Children exposed to second generation airbag had fewer injuries compared to first generation airbag. Still safer in rear seat for children <13.	Yes

Berg MD	2000	Effect of seating position and restraint use on injuries to children in motor vehicle crashes. Pediatrics. 105(4 Pt 1):831-5.	III	Rear seat position in a MVC provides a significant protective effect. Restraint use furthers this effect, and usage rates of restraint devices are low.	Yes
Braver ER	1998-1999	Seating positions and children's risk of dying in motor vehicle crashes.[see comment]. Comment in: Inj Prev. 5(1):77; PMID: 10323578, Comment in: Inj Prev. 5(1):78; PMID: 10323579. Injury Prev. 4(3):181-7.	III	Children and infants should be restrained in the back seat.	Yes, see data points.

Caviness AC	2003	Pediatric restraint use is associated with reduced transports by emergency medical services providers after motor vehicle crashes. Prehospital Emerg Care. 7(4):448-52.	III	Children wearing safety restraint devices were 60% less likely to be transported by EMS than those who were not.	Yes
Centers for Disease Control and Prevention (CDC).	2006	Nonfatal injuries and restraint use among child passengers--United States, 2004. MMWR Morb Mortal Wkly Rep. 55(22):624-7.	III	In children <12 injured in MVC 45% were not or improperly restrained, hospitalization rates 3 times higher in unrestrained kids. Restraint use should be promoted vigorously and enforced.	Yes

Centers for Disease Control and Prevention (CDC).	1996	Update: fatal air bag-related injuries to children--United States, 1993-1996.[erratum appears in MMWR Morb Mortal Wkly Rep 46(2):40]. MMWR Morb Mortal Wkly Rep. 45(49):1073-6.	III	32 air bag related fatalities reported over 4-year period. 21 were unrestrained or incorrectly restrained; 9 were rear-facing in front seat. Recommended that all children age 12 and under sit in rear seat.	Yes
Chan L	2006	Odds of critical injuries in unrestrained pediatric victims of motor vehicle collision. Pediatric Emerg Care. 22(9):626-9.	III	Critical injuries and cost of care are higher in unrestrained children in Arizona.	Yes
Corden TE	2005	Analysis of booster seat and seat belt use: how many Wisconsin childhood deaths and hospitalizations could have been prevented in 1998--2002? WMJ. 104(1):42-5.	III	Increased restraints use could decrease morbidity and mortality.	Yes

Durbin DR	2003	Belt-positioning booster seats and reduction in risk of injury among children in vehicle crashes. JAMA. 289(21):2835-40.	III	1) Booster seats reduced risk 61% v. seatbelt alone in children ages 4-7 (1.95% to 0.77%); 2) In 4 year old this was 56%; 3) In 6 year old it was 81% reduction; 4) This persisted when adjusted for front or rear seat position, or airbag exposure.	Yes
Durbin DR	2003	Risk of injury to restrained children from passenger air bags. Traffic Injury Prev. 4(1):58-63.	III	12.3% of all children involved in motor vehicle crashes are at risk of passenger air bag (PAB) injury. Children exposed to PAB were twice as likely to suffer serious injuries. Overall risk of any injury was higher for children exposed to PAB.	Yes
Durbin DR	2002	Risk of injury to restrained children from passenger airbags. Annu Proc Assoc Adv Automot Med. 46:15-25.	III	1) Significantly higher risk of injury to face and UE; 2) Almost significant chest (p 0.06); 3) Nonsignificant for head injury; 4) Recommendation: keep children away from airbags and redesign to decrease injury in children.	Yes

Durbin DR	2005	Effects of seating position and appropriate restraint use on the risk of injury to children in motor vehicle crashes. Pediatrics. 115(3):e305-9.	III	Inappropriately restrained children had nearly twice the risk of injury compared to properly restrained. Unrestrained children had >3 times the risk compared to proper restraints. Front seat was about 40% higher risk than back seat.	Yes
Elliott MR	2006	Effectiveness of child safety seats vs. seat belts in reducing risk for death in children in passenger vehicle crashes.[erratum appears in Arch Pediatr Adolesc Med. 160(9):952]. Arch Pediatr Adolesc Med. 160(6):617-21.	III	Efforts to promote use of CPS systems should be promoted through increased laws and with education.	Yes
Glass RJ	2000	Child passenger safety: decisions about seating location, airbag exposure, and restraint use. Risk Analysis. 20(4):521-7.	II	Restraint use and rear seat position were associated with a statistically significant reduction in the odds of a child dying in a crash.	Yes

Halman SI	2002	Are seat belt restraints as effective in school age children as in adults? A prospective crash study.[see comment]. Comment in: BMJ. 324(7346):1108-9; PMID: 12003867. BMJ. 324(7346):1123.	III	Seat belts provide as good protection in children as they do in adults overall, and even more protection (percentage improvement b/w belted and unbelted) in front seat passengers. This did not address booster seats.	Yes
Johnston C	1994	Children in car crashes: analysis of data for injury and use of restraints. Pediatrics. 93(6 Pt 1):960-5.	II	Use of car seat would reduce injury by 60% for age 0-4 subset; lap-shoulder harness reduces injury 38% for ages 5-14.	Yes, however, conclusions were based on a statistical sampling technique
Lapner PC	2001	Children in crashes: mechanisms of injury and restraint systems. Can J Surg. 44(6):445-9.	III	1) Risk of spinal fracture in child wearing lap belt v. lap/shoulder belt is OR 24; 2) Pediatric 3-point belts should be used.	Yes, but again no cost/benefit analysis.

Lutz N	2003	Suboptimal restraint affects the pattern of abdominal injuries in children involved in motor vehicle crashes. J Pediatr Surg. 38(6):919-23.	III	1) Use of sub-optimal restraint system increased RR of hollow viscus injury to 4.14 vs. optimal restraint system; 2) No difference in rate of solid organ injury.	Yes
Miller B	2006	Injury outcomes in children following automobile, motorcycle, and all-terrain vehicle accidents: an institutional review. J Neurosurg. 105(3 Suppl):182-6.	II	Protective devices were underutilized in all three motor vehicle categories but, when used, were associated with significantly higher GCS scores, ISS, and shorter LOS among patients admitted after automobile accidents. The correlation of seat belt use with better outcomes underscores the necessity to improve motor vehicle safety education for children, who are less likely to be restrained as they age.	

Muszynski CA	2005	Risk of pediatric head injury after motor vehicle accidents. J Neurosurgery. 102(4 Suppl):374-9.	III	Unrestrained children had higher risk of mod-max head injury compared to properly restrained. Infant restraint system was most effective in reducing injury risk. Improper restraint use protective compared to unrestrained.	Yes
Nance ML	2004	Optimal restraint reduces the risk of abdominal injury in children involved in motor vehicle crashes. Ann Surg. 239(1):127-31.	III	Based on the American Academy of Pediatric guidelines, children who were optimally restrained for their age were 3 times less likely to sustain significant intra-abdominal injuries vs. those who were suboptimally restrained.	Yes
Niemcryk SJ	1997	Motor vehicle crashes, restraint use, and severity of injury in children in Nevada. Am J Prev Med.13(2):109-14.	III	Use of restraint devices in children remain low. There appears to be a relationship with specific demographics. Mortality was unaffected. African American kids are often unrestrained. Unrestrained children suffer more severe injuries.	Yes, see data points.

Osberg JS	1992	Morbidity among pediatric motor vehicle crash victims: the effectiveness of seat belts. Am J Pub Health. 82(3):422-5.	II	Unrestrained passengers have a higher mortality and higher morbidity except for abdominal injury area.	Yes, however study was limited to patients surviving to hospitalization and to those institutions submitting data to the NPTR,
Quinones-Hinojosa A	2005	Airbag deployment and improperly restrained children: a lethal combination. J Trauma. 59(3):729-33.	III	Head and spine injuries most common. Of those fatally injured by airbag deployment, only 0.6% were properly restrained. Only 4.8% of those with non-fatal injuries were properly restrained. Proper restraint use and seating position could significantly reduce airbag associated injuries.	Yes
Ruta D	1993	A prospective study of non-fatal childhood road traffic accidents: what can seat restraint achieve?[see comment]. Comment in: J Public Health Med. 15(4):368; PMID: 8155379. J Public Health Med. 15(1):88-92.	III	46% of 91 patients were unrestrained. Risk Ratio for injury = 1.7; with RR of unrestrained for head injury = 3.1. Estimated that 24% of non-fatal injuries and 49% of head injuries could be prevented by use of seat restraints.	Unclear. Limited size study based at one facility. No data on appropriateness of seat restraint use.

Scherz RG	1981	Fatal motor vehicle accidents of child passengers from birth through 4 years of age in Washington State. Pediatrics. 68(4):572-5.	III	Restraint usage dropped mortality rate from 1:227 to 1:3150.	Yes
Sherwood CP	2003	Factors leading to crash fatalities to children in child restraints. Annu Proc Assoc Adv Automot Med. 47:343-59.	III	No real recommendations. Found that misuse of child restraint contributed to death in 12% of cases. 50% of crashes were unsurvivable no matter what.	Very difficult to get data, relied on untrained investigator reports. Many missing data points.
Smith KM	2006	Passenger seating position and the risk of passenger death in traffic crashes: a matched cohort study. Inj Prev. 12(2):83-6.	III	Matched cohort compared RR of death from rear seat vs. death from front seat of all ages. This study shows that although children 0-12 should be in backseat, adults in front seat with airbags and restraints are NOT at increased risk of death.	Yes, interesting take on topic. Children can be safe in back while not sacrificing adult safety, other studies show rear seat safer for all.

Sweitzer RE	2002	Children in motor vehicle collisions: analysis of injury by restraint use and seat location. J Forensic Sci. 47(5):1049-54.	III	1) For children 0-3 years, risk of mortality, head, and external injury was higher and statistically significant in no use vs. misuse vs. proper restraint (trend to higher abdominal injury in misuse but ns); 2) In 4-9 year old, same pattern AND misuse of restraint had a statistically significant increase in abdominal injury; 3) For all comers 0-3 year old (front and back seat) MAIS and ISS were lowest in properly restrained, but significance disappeared when split into either front or back seat; 4) For all comers 4-9 year old MAIS and ISS were lowest in properly restrained, significance remained when split up front/back.	Yes
Tingvall C	1987	Children in cars. Some aspects of the safety of children as car passengers in road traffic accidents. Acta Paediatrica Scandinavica – Suppl. 339:1-35.	II	Use of restraints effective, rear-facing most effective, head and neck most common from contact with side of car interior.	Yes, bit mixed adult restraints in some groups, not powered for difference between types of forward restraints.

Tyroch AH	2000	Pediatric restraint use in motor vehicle collisions: reduction of deaths without contribution to injury. Arch Surg. 135(10):1173-6.	III	Age-appropriate restraint devices decrease mortality and reduce the incidence of significant injury in MVCs for all anatomic sites in young children	Yes, see data points.
Winston FK	2000	The danger of premature graduation to seat belts for young children. Pediatrics. 105(6):1179-83.	III	Premature graduation of young children from CRS to seat belts puts them at greatly increased risk of injury in crashes. A major benefit of CRS is a reduction in head injuries.	Yes, see data points.
Zuckerbraun BS	2004	Effect of age on cervical spine injuries in children after motor vehicle collisions: effectiveness of restraint devices. J Pediatr Surg. 39(3):483-6.	II	27 pediatric MVC patients with cervical spine injuries were divided into young (0 to 8 years) and old (9 to 18) and compared. Young patients had an increased incidence of more severe injuries, permanent cord deficit, and closed head injury even when wearing restraint devices, suggesting inadequacy of current restraint devices.	Yes