Accident Analysis and Prevention 119 (2018) 50–57

Contents lists available at ScienceDirect

Accident Analysis and Prevention

journal homepage: www.elsevier.com/locate/aap

The impact of booster seat use on child injury and mortality: Systematic review and meta-analysis of observational studies of booster seat effectiveness

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ARTICLE INFO

Keywords:
Child safety
motor vehicle collisions
Booster seats
Injury prevention
Systematic review

ABSTRACT

Objective: To determine through systematic review and meta-analysis of observational studies if booster seats, compared to seatbelts alone, reduce injury and mortality from motor vehicle collisions among child passengers four to eight years of age.

Methods: A comprehensive search of several data sources (including Medline, Embase, and PsycINFO) was conducted from inception to December 2016, to retrieve relevant publications in any language and from any geographic region. Data extraction was completed by two independent reviewers, capturing: study details, population characteristics, exposure (booster seat compared to seat belt use), outcomes (injury and fatality), and all associations reported between the exposure and outcomes. Risk of bias assessment was completed by two reviewers using the QUIPS tool. Meta-analysis of sufficiently similar studies was conducted using random effects models.

Results: Eleven observational studies were included in qualitative syntheses. The systematic review and meta-analysis found no association between booster seat use, compared to seatbelts, and reduced injury (4 studies, OR 1.03; 95% CI 0.53–1.99) or fatality (2 studies, OR 0.91; 95% CI 0.73–1.13).

Conclusions: Evidence on booster seat effectiveness to protect against injury and mortality in real-world conditions is limited. This review identified the need for high quality studies assessing the effects of different models of booster seats on children of varying ages and weights.

1. Introduction

1.1. Background

Child passenger injuries and deaths resulting from motor vehicle collisions (MVC) remain a significant public health problem in Canada (Canadian Council of Motor Transport Administrators, 2016; Parachute Canada, 2017). Between 2008 and 2012, there were 398 motor vehicle deaths among Canadian children aged 0–14 years, with 119 of those deaths in children aged 5–9 years (Statistics Canada, 2017). In the United States, MVCs are the leading cause of death for children under 13 years of age, resulting in 938 fatalities in 2015 (Centers for Disease Control and Prevention, 2017). Importantly, most injuries and deaths involve unrestrained or incorrectly restrained child passengers (Durbin et al., 2015).

Child booster seats are part of a suite of regulated safety products (Government of Canada, 2017; National Highway Traffic Safety AdministratCion - Parents Central, 2017) targeted at reducing MVC-related morbidity and mortality. While seat belts were designed to accommodate motor vehicle passengers over four foot nine inches in height, booster seats refer to a heterogeneous group of products whose intent is to elevate children and youth to improve seat belt fit (Government of Canada, 2017). Three main configurations of booster seats are on the market: backless booster seats (specialised cushion with armrests that serve to guide the lap belt to an appropriate position); belt-positioning boosters (like backless booster, but with back and head support and a built-in shoulder belt guide); and combination boosters (a child safety seat with seat belt guides so once the five-point harness is removed the child is restrained using the vehicle's seat belt).

While booster seats are mandatory across much of North America, each jurisdiction establishes its own regulations for use, with specific combinations of height, weight, and age restrictions. Booster seat laws are consistent in their criteria for transitioning from a child safety seat to a booster seat, and generally recommend commencing use when the

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https://doi.org/10.1016/j.aap.2018.07.004
Received 12 February 2018; Received in revised form 19 June 2018; Accepted 1 July 2018

child reaches 40 pounds. Laws differ, however, regarding the criteria for when a child can transition out of a booster seat to a seat belt alone, with varying weight (40–81.5lbs) and height (25″ seated height or 57 inch) minimums. Parents are generally recommended to begin booster seat use between the ages of 4 and 6, and graduate children to seatbelts between the ages of 6 and 10 (CLEK Inc, 2015).

Considerable energy has been directed toward encouraging the use of booster seats, supported by systematic reviews of promotion strategies to improve booster seat uptake (Turner et al., 2005; Ehiri et al., 2006). Booster seats continue to be evaluated through laboratory (i.e. sled test, crash test) and simulation (i.e. modelling) studies, before and after market use, to evaluate their efficacy, and to improve their structure to most benefit child safety. (Malott et al., 2004; Menon et al., 2018) At the same time, evidence of booster seat effectiveness in reducing injury in motor vehicle crashes is inconsistent. Research studies have reported reduced injuries and death for children five years of age and under (Winston et al., 2000), and six to eight years of age (Arbogast et al., 2009a; Durbin et al., 2003) when using a booster seat with a seat belt compared to a seat belt alone; however, mixed findings have also been reported (Rice et al., 2009; House et al., 2012). Evidence is unclear for children of differing heights and weights and for specific kinds of injury (Stewart et al., 2013).

1.2. Importance

No systematic review of booster seat effectiveness, compared to seatbelts alone, has been completed to date. This work is important, as booster seats may perform differently in vehicles involved in real-world crashes than in compliance testing, sled tests, and simulation studies (Transport Canada. Booster Seat Testing, 2017). The variability in guidelines for booster seat use, coupled with the inconsistent findings of research studies, creates confusion for parents, for child safety advocates, and for those working in road safety. These limitations have been addressed in the present study through a rigorous review of the existing evidence about booster seat effectiveness to reduce injury morbidity and mortality in child passengers in real-world crashes.

1.3. Objectives

A systematic review and meta-analysis of observational studies was conducted to answer the question: “Among child passengers aged four to eight years old, does the use of booster seats reduce injury morbidity and mortality from motor vehicle collisions, compared to seatbelts alone?” Our secondary objective was to identify key characteristics associated with booster seat effectiveness to reduce injury and death among child passengers, including age, seat position, and booster seat design. General methods advocated by Cochrane (Higgins and Green, 2008) were employed. Our report adheres to the PRISMA guidelines.

2. Methods

2.1. Data source

A comprehensive search was conducted of several data sources to retrieve relevant publications, in any language and from any geographic region. A medical librarian conducted electronic searches of the following databases: Medline (see example, Table 1), Embase, CINAHL, PsycINFO, Proquest, Sociological Abstracts, Social Services Abstracts, PAIS International, Social Work Abstracts, Transport Research International Documentation (TRID) Online, Web of Science, Canadian Public Policy Collection, Canadian Health Research Collection, ProQuest Dissertations & Theses Database, and Scopus (all databases from inception to December 2016). The search also included manual searches of reference lists of all included studies and related systematic reviews (Turner et al. (2005); Ehiri et al. (2006)), contact of specialists in the field, and review of the personal libraries of the research team.

Table 1
MEDLINE search strategy: (inception to 2016/12/02).

#	Search Terms	Search Results
1	Child Restraint Systems/	204
2	Accidents, Traffic/	35204
3	exp Motor Vehicles/	15462
4	(accident* or crash* or collision* or collide* or incident*).mp.	264128
5	(accident* or crash* or collision* or collide* or incident*).tw.	202412
6	mva.tw.	2269
7	(car or cars or automobile* or vehicle* or traffic* or road or "off-road" or vehicular or motor*).tw.	409044
8	3 or 7	416800
9	8 and 5	29023
10	9 or 2	49696
11	((child* or tween) adj2 (safety or restraint or seat* or passenger* or occupant*)).tw.	2210
12	((car or booster or safety) adj2 seat*).tw.	899
13	1 or 11 or 12	2739
14	10 and 13	826

2.2. Study selection

Observational studies of children aged four to 10 years who had been involved in a MVC were identified. Studies were included if the exposure assessed was the clear use of a booster seat of any style by child passengers of the motor vehicles, compared to other restraint. Our primary outcomes of interest were child passenger injury and mortality resulting from a MVC. Studies were included if they reported on fatal or non-fatal injuries, measured with a standard injury scale [e.g., Abbreviated Injury Scale (AIS) Injury Severity Score (ISS)] or reported severity. Designs included original, peer-reviewed studies that used a population-based comparative approach, including cross-sectional, case-control, or cohort studies. Experimental laboratory and simulator studies, and case reports were excluded. Eligible studies recruited participants from hospital, insurance or police databases, or roadside surveys.

2.3. Risk of bias assessment

Risk of bias was assessed for all included studies using the Quality in Prognosis Studies (QUIPS) tool (Hayden et al. 2013), through consensus by two reviewers. There is currently no gold standard for assessing risk of bias in observational studies, and the QUIPS tool offered the most robust assessment of the factors in our review. QUIPS assesses bias across six aspects of a study: participation, attrition, prognostic factors, outcomes, confounding, and statistical analysis. Studies were judged to have low risk of bias if five or more categories were assessed as low and no categories were assessed as high risk of bias. Studies were identified as having a moderate risk of bias if two or more categories were assessed as moderate, but no categories were assessed as high risk of bias. Finally, studies were identified as having a high risk of bias if any category, other than statistical analysis, was assessed as high risk of bias.

2.4. Data extraction and synthesis

Data extraction was completed by two independent reviewers for all selected studies, including: relevant study details (e.g. authors, year, geographic area, study design, sample size), population characteristics (e.g. child age, height, weight, seating), exposure (type of booster seat), outcomes (including measures assessed), and all bivariate and multivariate associations reported between the exposure of interest and outcome (and variables controlled for). Study authors were contacted via email and asked to provide any missing information after first extraction. When studies did not present estimates of risk, raw data were extracted to allow for the calculation of risk estimates.