A Systematic Review of Longitudinal Cohort Studies Examining Unintentional Injury in Young Children

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Abstract
Objective. Injury is the leading cause of death and long-term disability in children. Longitudinal cohorts are designed to follow subjects longitudinally in order to determine if early-life exposures are related to certain health outcomes. Methods. We conducted a systematic review to identify studies of children from birth through 5 years who were followed longitudinally with unintentional injury as an outcome of interest. Results. Of the 1892 unique references based on the search criteria, 12 (published between 2000 and 2013) were included. The studies varied on the population of focus, injury definition, and incidence rates. Existing studies that longitudinally follow children aged 0 to 5 years are limited in number, scope, and generalizability. Conclusions. Further study using population-based longitudinal cohorts is necessary to more comprehensively estimate incidence of injury in young children.

Keywords
childhood injury, longitudinal cohort study, birth cohort

Introduction
Injury results in significant morbidity and mortality in young children. Injury incidence is typically estimated using visits to the emergency department and primary care settings. However, these methods do not capture non-medically attended injuries nor represent a true population-based incidence. There is a need to follow young children prospectively and longitudinally in order to maximize identification of injury incidents, ideally also including “near misses.” Birth cohorts are used to collect data longitudinally and estimate true incidence or prevalence of disease, as well as identify the influence of various exposures. A prior systematic review of such cohort studies focused on school-age children and adolescents 5 to 18 years old, but no prior study has summarized similar literature for infants, toddlers, and pre-school-age children. Therefore, the goal of this systematic review was to identify longitudinal studies of children birth through 5 years with unintentional injury captured as an outcome to better estimate injury incidence in this subgroup.

Methods
Inclusion and Exclusion Criteria
Inclusion criteria for selected studies were the following: (1) subjects from birth through 5 years, including part or all of this age range (eg, 0-2 years) without overlapping older age groups without specific subgroup data (eg, not 3-6 years); (2) observational study (not interventional); (3) study of injury patterns and/or risk factors; (4) must examine overall or specific type of injury frequency with population-based (or cohort-based) rate (or with the ability to recalculate a rate based on the injury frequency and

Received March 28, 2018. Accepted for publication March 30, 2018.
denominator); and (5) must follow a group longitudinally. Studies were excluded if the injury was intentional (assault or abuse) or if participants were recruited because of a specific diagnosis or because they participated in an activity that put them at risk of injury.

Search Process

An initial search was conducted to determine whether a birth cohort systematic review regarding injury patterns in children ages 0 through 5 years had been previously conducted. Using the Mytton et al protocol as a guide, PubMed and Medline databases were searched using the search terms that had been identified and agreed on by the investigators (Table 1). Furthermore, potentially relevant articles were found in PubMed while searching for abstracts using the selected terms. Any eligible articles in the database published through April 2016 were included.

All duplicate articles that appeared in both databases or appeared in the same database multiple times were removed and the resulting article abstracts were scanned first by research assistants for relevance using the inclusion and exclusion criteria outlined above (Figure 1). The remaining abstracts were then divided among the 3 injury prevention physician researchers for further screening. During this second phase of abstract review, the physician researchers identified several abstracts that were of questionable relevance. These abstracts were discussed as a group and were excluded if irrelevant. If a determination could not be made by review of the abstract, full-text versions of the article were reviewed.

Table 1. Search Criteria.

| Search Criteria                                                                 |
|---------------------------------------------------------------------------------|
| 1. (cohort adj1 stud$).mp. [mp=title, abstract, original title, name of substance word, subject heading word, keyword heading word, protocol supplementary concept word, rare disease supplementary concept word, unique identifier] |
| 2. (longitudinal adj1 stud$).mp. [mp=title, abstract, original title, name of substance word, subject heading word, keyword heading word, protocol supplementary concept word, rare disease supplementary concept word, unique identifier] |
| 3. exp Cohort Studies/                                                          |
| 4. exp Longitudinal Studies/                                                    |
| 5. exp Prospective.mp [mp=title, abstract, original title, name of substance word, subject heading word, keyword heading word, protocol supplementary concept word, rare disease supplementary concept word, unique identifier] |
| 6. 1 or 2 or 3 or 4                                                             |
| 7. 5 and 6                                                                       |
| 8. exp Newborn/ or exp Newborn, Hospitalized/                                   |
| 9. exp Infant/ or exp Infant, Hospitalized/                                     |
| 10. exp Preschool/ or exp Preschool, Hospitalized/ or exp Preschool, Institutionalized |
| 11. exp Pediatrics/                                                              |
| 12. exp Disabled Children/                                                       |
| 13. 8 or 9 or 10 or 11 or 12                                                     |
| 14. exp accident prevention/ or exp accidental falls/ or exp accidents, home/ or exp accidents, traffic/ or exp drowning/ |
| 15. exp “Wounds and Injuries”/ep [Epidemiology]                                 |
| 16. 14 or 15                                                                    |
| 17. 7 and 13 and 16                                                             |
| 18. exp accident/ or exp unintentional injury/                                  |
| 19. “incident”                                                                  |
| 20. exp Animal/ OR exp Bite/ OR exp Burn/ OR exp Fire/ OR exp Firearm/ OR exp “Foreign body”/ OR exp Homicide/ OR exp Motor Vehicle/ OR exp Pedestrian/ OR exp Sting/ OR exp Trauma/ |
| 21. “chok*” OR “daycare” OR “gun” OR “gym” OR “overexert*” OR “cut*” OR “pierce” OR “playground” OR “poison” OR “struck by” OR “struck against” OR “suffocat*” OR “traffic” |
| 22. 22 and 23                                                                   |
| 23. 7 and 13 and 14                                                             |
| 24. 7 and 13 and 15                                                             |
| 25. 7 and 13 and 18                                                             |
| 26. 7 and 13 and 19                                                             |
| 27. 7 and 13 and 20                                                             |
| 28. 7 and 13 and 22                                                             |
Figure 1. Flow chart of search strategy.
Table 2. Study Characteristics, Potential Biases, Results, and Rates of Injury.

| First Author | Year of Publication | Aim of Study | Data Source and Population | How Subjects Chosen | Country | Exposure | Outcome (Injury Definition) | Follow-up: Interval Frequency and Duration | Potential Biases | Detailed Description of Total Number Included | Rate Calculated/Reanalysis Required |
|--------------|---------------------|--------------|-----------------------------|---------------------|---------|----------|-----------------------------|-------------------------------------------|----------------|-----------------------------------------------|----------------------------------|
| O'Connor⁶    | 2000                | • Determine whether family type and psychosocial risks associated with differences in health outcomes in children | Avon Longitudinal Study of Pregnancy and Childhood (ALS PAC) from 1991 to 1992 | Sample of pregnant women, their partner, and an index child | United Kingdom | Family type and psychosocial risks | Parent-reported burns, scalds, falls requiring medical attention | 9 months (between 15 months and 24 months old) | One health district in the UK | Total Number Included: 10,431 families | Rate Calculated/Reanalysis Required: Burn or scalding (785 per 10,431 families per year) |
| Alkon⁷       | 2000                | • Examine child characteristics (age, gender) and child care center environments that predict injury | Preschool-aged children from day care centers from 1990 to 1991 | Sample of children from day care centers | United States | Amount of time (hours) in daycare | Teacher-reported event resulting in bodily harm, reflected by physical mark or sustained complaint more than 5 minutes in duration | 2-year period | Only 4 centers, all private | Number of children: 360 | No |
| Dal Santo⁸   | 2004                | • Examine relationships between maternal perceptions of risk, stress, social support, safety-proofing behaviors, supervision practices and unintentional injuries to children | Child Safety Study (telephone survey) and Home Safety Survey (in-home subsample) from 1988 to 1989 Random-digit dial in a single southeastern US metropolitan area | Mothers with at least one child between 6 months and 5 years old | United States | Endogenous: Perceived risks of hazards and injury, perceived child behavioral characteristics, parental safety behaviors, and injury history | Mother-reported (from their diaries) a discrete event that produced pain lasting at least 10 minutes or discernable tissue damage | 1 year | Bias of original sample (including those who did not agree to participate or without a telephone) | Number of children: 159 | Injury event rate: 1273 per 159 children per year |

(continued)
| First Author | Year of Publication | Aim of Study | Data Source and Population | How Subjects Chosen | Country | Exposure | Outcome (Injury Definition) | Follow-up Interval Frequency and Duration | Potential Biases | Detailed Description of Total Number Included | Included | Main Results; Include Serial Longitudinal Subresults | Rate Calculated/Reanalysis Required |
|--------------|---------------------|--------------|----------------------------|--------------------|---------|---------|---------------------------|------------------------------------------|----------------|-------------------------------------------|----------|---------------------------------------------|-------------------------------|
| Schwebel9    | 2004                | Determine interactions between child behavior patterns and parenting and unintentional injury | Study 1: Incoming kindergarteners from National Head Start/ Public School Early Childhood Transition Demonstration Study from 1992 to 1994; Study 2: Sample from hospitals from a Study of Early Child Care Institute of Child Health and Human Development (NICHD) | United States | Child behavior (hyperactivity) and parenting resources | United States | Caregiver-reported medically attended injury | Study 1: one time (in previous year); Study 2: over a 30-month period | Study 1: Injury reported by caregivers; Study 2: Not clear who followed-up and injury reported by caregivers | Study 1: 10,829 children; Study 2: 1041 children | Study 1: 2523 (with at least 1 injury) | Study 2: 46 (with at least 1 injury) | Study 1: Rate 2523 per 10,829 per year; Study 2: Rate 18.4 per 1041 per year |
| Soubhi10     | 2004                | Examine independent and combined effects of child, family, and neighborhood on childhood injuries | National Longitudinal Survey of Children and Youth from 1996; Sample of children from households | Canada | Individual, family, and neighborhood characteristics | 2 years | Self-reported injury | 10,261 households | Injuries (in <2 years): 58,380; Injuries (in 2-3 years): 47,389 | 47,389 | Rate (in <2 years) 29.190 per 507,654 per year; Rate (in 2-3 years) 22.694 per 473,893 per year | Injury rate: 338 per 394 children per year |
| de Lourdes Drachler11 | 2007                 | Examine effects of home environment on unintentional domestic injury and related health care attendance | Cohort of patients recruiting from trial of breast feeding advice and weaning from 2001 to 2002; Sample of women in maternity wards | Brazil | Socioeconomic factors, family characteristics, household psychosocial aspects | 12 months (at 1 year of age) | Breastfeeding study; Mechanisms not granular | 394 children | Injuries: 338 | Injury rate: 338 per 394 children per year |

(continued)
### Table 2. (continued)

| First Author | Year of Publication | Aim of Study | Data Source and Population | How Subjects Chosen | Country | Exposure | Outcome (Injury Definition) | Follow-up Interval Frequency and Duration | Potential Biases | Detailed Description of Total Number Included | Main Results | Rate Calculated/ Reanalysis Required |
|--------------|---------------------|--------------|----------------------------|---------------------|---------|----------|----------------------------|-------------------------------------------|----------------|------------------------------------------|--------------|---------------------------------------|
| Erkal12 | 2008 | Determine rates of occurrence, consequences of, and risk factors for animal-related injuries | Regional Rural Injury Study from 1999 and 2001 Random selection from agricultural operations in each of 5 US states involved | Household with operation that included children <20 years Actively farming/ ranching since first of year eligibility or involved in conservation reserve program Produced or had sales of at least US$1000 Willingness to complete phone interviews every 6 months | United States | Participating in an active agricultural operation | Parent-reported event resulting in one or more of: (1) restriction from normal activities for 4+ hours; (2) loss of consciousness/ awareness or amnesia for any duration; (3) use of health care | 6 months to 3 years (two 6-month recall periods during 2 phases of study in 1999 and 2001) | Recall bias Injury misclassification | 4402 eligible operations (farms/ranches) in Phase I 3765 participated in full study 2301 children 0-4 years exposed | Injuries in children 0-4 years old: 17 (7.7 per 1000) (4.7, 12.8) | No |
| Koulougliotis13 | 2009 | Explore relationship between lack of everyday routines and children's unintentional injury; examine how children's sleep and maternal supervision could influence lack of routines; explore influence of maternal fatigue in routines and supervision | Rochester Preschool Children Injuries Study from 2001 to 2004 Cohort from study of mother-child dyads | Selected for prior prospective, longitudinal descriptive study | United States | Maternal supervision, maternal fatigue, and child temperament at age 3; children's routines and sleep at age 4 | Mother-reported medically attended injury | 30 months (between 18 months and 4 years old) | Lack of injury detail and meaning of medically attended injury | 278 mother-child dyads completed first interview 264 completed 1-year follow-up interview | 78 injuries 31.2 injuries per 264 per year | |
| Hallal14 | 2009 | Evaluate the incidence of and effect of early life variable on the risk of fractures | All hospital delivered children born in 1993 in a single city Cohort of mothers and their newborns | Hospital delivered mother and their newborn child | Brazil | Maternal age, BMI, smoking during pregnancy and family income; child's birth weight and length | Mother-reported fracture in child | 11 or 12 years | Single location and only hospital births Recall bias Unreported or nonaccidental fractures, including undiagnosed minor fractures; intentional injury; pathological fractures | Patients who died 5249 children 141 died 636 lost to follow-up | In those <5 years, 156 fractures 14 fractures per 5249 children per year | |

(continued)
### Table 2. (continued)

| First Author | Year of Publication | Aim of Study | Data Source and Population | How Subjects Chosen | Country | Exposure | Outcome (Injury Definition) | Follow-up Interval Frequency and Duration | Potential Biases | Detailed Description of Total Number Included | Main Results; Include Serial Longitudinal Subresults | Rate Calculated/Reanalysis Required |
|--------------|---------------------|--------------|-----------------------------|---------------------|---------|----------|-----------------------------|----------------------------------|----------------|-------------------------------------------|-----------------------------------------|----------------------------------|
| Fujiwara5    | 2010                | Investigate influence of paternal involvement in childcare on childhood injury | Longitudinal Survey of Babies in 21st Century in 2001 | Returned mailed questionnaire sent to them | Japan | Parental involvement in childcare | Parent-reported fall, near drowning, ingestion, foreign body, burn | 6-month questionnaire for parental involvement, 18-month questionnaire for injury | Self-reported injury | 53,575 eligible children | 67.8 injuries per 100 person-year | No |
| Darling6     | 2011                | Determine if programs that allow body checking in hockey have increased injury rates, and to describe the nature of those injuries | Sample of youth hockey players from 2002 to 2007 | Participation in youth hockey program | Canada | Hours at play | Trainer and physician-reported injury resulting in at least 24 hours of missed activity | 3-year period | Limited to one league | 13,292 player-years of data | Rates (in 4-5 year olds): 0.00 injuries per 1000 game hours and 0.10 injuries per 1000 practice hours | No |
| Shah7       | 2013                | Identify risk factors for scald injury | The Health Improvement Network (THIN) from children born between 1998 and 2004 | Child identified from mother’s health records, cases and controls chosen from prior study exploring risk factor for injury | United Kingdom | Individual, maternal, and family factors | Scald read codes in the health records based on ICD-10 categories | Continuous, 5 years | Biases inherent to this sample | 180,064 eligible mother-child dyads | 986 with scald | 197 per 180,064 per year |

Abbreviations: BMI, body mass index; ICD, International Classification of Diseases.
by the group to determine if it met eligibility. The remaining selected articles were screened and additional potentially relevant articles were extracted from the references of those articles.

For purposes of this review, we summarized study characteristics including the study aim, data source and population, how subjects were chosen, country of study, exposure, outcome (injury definition), follow-up frequency/duration, potential biases, total number included, and rates of injuries. We included studies and injury outcomes only for those with clear definitions and excluded any incidents that were solely injury mechanisms. We included information available only in the articles reviewed. Similarly, we included only injury-related outcomes (ie, no other study results) and frequencies/rates of injuries for the age groups of interest (ie, not for children 6 years or older). All time periods of injury surveillance were adjusted to 1-year increments, with corresponding adjustment to the injury frequencies, when this information was available. If there was a range of time periods of surveillance (eg, 3 to 4 years of follow-up), the average of the time periods was used for the previously mentioned adjustments.

Results

Figure 1 shows a flow chart of the search strategy. There were 1892 unique references based on the search criteria, with 12 ultimately included in the analysis, published between 2000 and 2013. Table 2 lists the study characteristics and injury results. Of the studies, 5 were from the United States, 2 from the United Kingdom, 2 from Brazil, 2 from Canada, and 1 from Japan. Eleven of the studies had participant-reported injury outcomes, either from parents/caregivers (9), a trainer/physician (1), or daycare worker (1), while one study used documented injuries in the health record as outcomes.

There were a variety of populations, injury definitions, and injury rates among the 12 studies. Eleven of the studies used reported injuries (either through guardians, caregivers, or by athletic team leadership) with only one based on medical records.

Discussion

We found 12 eligible studies, all published within a contemporary 14-year time period. Most included a subgroup of the 0- to 5-year-old age range but not the entire group. Many of the studies were limited by either incomplete definition of injury and self (guardian)-reported injury. Also, notably missing was the lack of “near miss” information (mechanisms and scenarios that almost resulted in injury). The studies were fairly heterogeneous in nature: some focused on very specific injury types (eg, agricultural, sports-related) and with a limited target population (eg, focused in one specific city or district), which inherently limits generalizability. In addition, while some studies included child and family demographic information associated with injury, many lacked environmental information including family composition and dynamic (eg, if single parent, multiple siblings, etc), which is also known to influence injury.8 Similar to the findings in the Mytton et al article, few studies were conducted in low- to middle-income countries with higher injury burden.

Limitations of the review included the heterogeneity of the studies, especially in the cohort or sample population, and the injury type studied. Multiple potential biases in the individual studies included lack of detail in the methods (specific inclusion/exclusion criteria, information about those who declined or withdrew) and the challenges of self-reported injury.

Conclusion

The existing longitudinal cohorts captured in this systematic review and focused on the outcome of injury in children aged 0 to 5 years are limited in number, scope, well-defined and objective injury outcomes, and generalizability. There is opportunity to expand on this literature by conducting a longitudinal population-based birth cohort study with comprehensive measures and injury outcomes in order to estimate accurate rates of injury in young children.

Author Contributions

MRZ: Contributed to conception or design; contributed to acquisition, analysis, and interpretation of data; drafted the manuscript; gave final approval; agrees to be accountable for all aspects of work ensuring integrity and accuracy.

JGL: Contributed to conception or design; contributed to acquisition, analysis, and interpretation of data; critically revised the manuscript; gave final approval; agrees to be accountable for all aspects of work ensuring integrity and accuracy.

ESY: Contributed to conception or design; contributed to acquisition of data; critically revised the manuscript; gave final approval; agrees to be accountable for all aspects of work ensuring integrity and accuracy.

MJJ: Contributed to conception or design; contributed to acquisition, analysis, or interpretation; critically revised the manuscript; gave final approval; agrees to be accountable for all aspects of work ensuring integrity and accuracy.

Declaration of Conflicting Interests

The author(s) declared no potential conflicts of interest with respect to the research, authorship, and/or publication of this article.
Funding
The author(s) received no financial support for the research, authorship, and/or publication of this article.

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