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REVIEW

What types of unintentional injuries kill our children? Do infants die of the same types of injuries? A systematic review

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The objective of this study was to review mortality from external causes (accidental injury) in children and adolescents in systematically selected journals. This was a systematic review of the literature on mortality from accidental injury in children and adolescents. We searched the PubMed, Latin-American and Caribbean Health Sciences and *Excerpta Medica* databases for articles published between July of 2001 and June of 2011. National data from official agencies, retrieved by manual searches, were also reviewed. We reviewed 15 journal articles, the 2011 edition of a National Safety Council publication and 2010 statistical data from the Brazilian National Ministry of Health Mortality Database. Most published data were related to high-income countries. Mortality from accidental injury was highest among children less than 1 year of age. Accidental threats to breathing (non-drowning threats) constituted the leading cause of death among this age group in the published articles. Across the pediatric age group in the surveyed studies, traffic accidents were the leading cause of death, followed by accidental drowning and submersion. Traffic accidents constitute the leading external cause of accidental death among children in the countries under study. However, infants were vulnerable to external causes, particularly to accidental non-drowning threats to breathing, and this age group had the highest mortality rates for external causes. Actions to reduce such events are suggested. Further studies investigating the occurrence of accidental deaths in low-income countries are needed to improve the understanding of these preventable events.

KEYWORDS: Wounds; Injuries; Accidents; Multiple Trauma; Mortality.

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INTRODUCTION

Although mortality from infectious diseases has decreased in many countries, mortality from external causes currently has a major impact on the pediatric population worldwide (1). The costs related to external causes of morbidity and mortality are comparable to the costs related to cancer treatment and stroke treatment, representing one of the highest financial burdens to health care systems worldwide, and they also have a major impact on global public health (2). In addition to being among the leading causes of death worldwide, injuries represent a major external cause of early loss of years of life and productivity, principally in younger individuals (3-6).

Accidents account for nearly 90% of all external causes of morbidity and mortality and constitute a major cause of death in the pediatric population; they are the leading cause

of death in children age 10–19 years worldwide (7). Cases of unintentional injury are not uniformly distributed throughout the world and are heavily influenced by the socio-economic status of the nation (8).

For operational and analytical purposes, the World Bank principally classifies economies (and, consequently, countries) by per capita gross national income. Therefore, every economy is classified as low income, middle income (subdivided into lower middle income and upper middle income), or high income (9).

According to the World Health Organization (WHO), more than 95% of all deaths from external causes among children occur in the poorest countries (7). Despite the false belief of inevitability, unintentional injuries are currently considered to be understandable, predictable, and preventable (5), and they also affect high-income countries (7).

Most of the trauma deaths in children and adolescents can be prevented by means of well-known preventive strategies (10). Because such deaths occur worldwide and because their numbers can be reduced in every country, there is a need for studies in this area (7,11). Etiologic studies are essential to reduce the occurrence of such events, and they entail understanding the causes of injury and the resulting mortality. The objective of these studies is to eliminate the

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causal factors that can cause injuries and their consequences (12). To gain a deeper understanding of the external causes of accidental death among children and adolescents, we conducted a systematic review of the international medical literature on this subject. We attempted to synthesize the data obtained and contextualize the mortality rates found to provide a better appreciation of the current state of such mortality worldwide.

METHODS

The literature review was carried out by searching electronic databases for articles published in the scientific journals indexed and by manually searching the references in those articles for studies that were often cited. We also included preliminary (2010) data from the Brazilian National Ministry of Health Mortality Database - Information Technology Department of the Brazilian Unified Health Care System regarding specific mortality from external causes among individuals under 15 years of age (13).

We searched the following databases: PubMed, which is developed and maintained by the National Center for Biotechnology Information at the United States National Library of Medicine; *Literatura Latinoamericana y del Caribe en Ciencias de la Salud* (LILACS, Latin-American and Caribbean Health Sciences Literature); and *Excerpta Medica* Database (Embase), which is produced by Elsevier. We used the search terms "injuries or accidents or trauma" and "mortality," which were adjusted to optimize the search strategies in the different databases.

The terms used to search the PubMed database were the keywords found with the following Medical Subject Headings (MeSH) terms: ("Wounds and Injuries"[MeSH] or "injuries"[Subheading] or "Accidents"[MeSH] or "Multiple Trauma"[MeSH]) AND ("Mortality"[MeSH]).

The terms used to search the LILACS database were the advanced search keywords found with the following descriptors: ("EXTERNAL CAUSES" or "INJURIES" or "INJURIES, multiple" or "WOUNDS and injuries" or "WOUNDS, multiple" or "ACCIDENTS" or "TRAUMA" or "multiple TRAUMA" or "TRAUMA, multiple" [Subject descriptor]) AND ("MORTALITY" or "child MORTALITY" or "hospital MORTALITY" or "in-hospital MORTALITY" or "indicators of morbidity and MORTALITY" or "infant MORTALITY" or "late infant MORTALITY" or "neonatal MORTALITY" or "neonatal MORTALITY (public health)" or "child MORTALITY by geographic zone" or "infant MORTALITY by specific risk" or "MORTALITY rate" or "infant MORTALITY rate" or "MORTALITY registries" or "MORTALITY, hospital" or "infant MORTALITY, late" [Subject descriptor]).

The terms used to search the Embase were the advanced search keywords found with the following *Excerpta Medica* Tree terms: ("INJURY" or "WOUND" or "ACCIDENT") AND ("NEWBORN MORTALITY" or "INFANT MORTALITY" or "CHILDHOOD MORTALITY").

The inclusion criteria were as follows: studies involving children and adolescents; articles published in Portuguese, English, or Spanish between July 1, 2001 and June 30, 2011; and articles other than editorials, letters, notes, case reports, comments, and abstracts. The outcomes studied were the types of unintentional injuries leading to death.

For standardization purposes, we used the designations of external causes of morbidity and mortality found in

chapter XX (External causes of morbidity and mortality) of the 2010 version of the tenth revision of the International Statistical Classification of Diseases and Related Health Problems (ICD-10). We used the term "accidents" for unintentional events (traffic accidents and other external causes of accidental injury) in accordance with ICD-10 (14).

We excluded articles that did not provide national data regarding unintentional injury deaths and those articles that provided data that were not from official agencies. In addition to the articles retrieved from the databases searched, we included studies found by manually searching the references cited in the articles retrieved and data retrieved from related databases.

After the initial search, the studies were classified by country of origin, age bracket under study, and type of unintentional injury leading to death. If a given study had not provided the mortality rate per 100,000 people for the corresponding age bracket, we calculated it (whenever we obtained enough data to do so). Studies investigating children and adults were included only if the age bracket of interest had been identified and the data had been established specifically for the age bracket(s) under study. To calculate the rates of mortality from external causes in Brazil and Spain, we used data from the Brazilian Institute of Geography and Statistics (15) and the National Statistics Institute of Spain (16), respectively.

RESULTS

We retrieved 2,091 eligible articles from the electronic databases searched. Of those articles, 1,484 were retrieved from PubMed, 595 were retrieved from Embase, and 12 were retrieved from LILACS. Our review included data from 15 journal articles, one publication from the National Safety Council (2011) and preliminary (2010) statistical data from the Brazilian National Ministry of Health Mortality Database - Information Technology Department of the Brazilian Unified Health Care System (13) (Table 1).

The Information Technology Department of the Brazilian Unified Health Care System is an official body of the Brazilian Ministry of Health that provides mortality data among other health indicators (13).

The primary types of studies excluded from electronic databases involved treatments and interventions, protocols and injury severity classification and studies of other pathologies or specific pathologies in patients who were the victims of external causes (Table 2).

Data obtained from journals originated from notices of government bodies that recorded data for mortality due to external causes in participating countries.

High-income countries included in the review were Canada, Scotland, Spain, the United States and Estonia; upper-middle-income countries included were Lithuania, Mexico, Brazil, Chile and Iran; India was included as a lower-middle-income country; and Bangladesh was included as a low-income country.

Data on injury deaths in Canada were obtained from an article that assessed the trend of mortality from external causes in children less than 15 years in 1979-2002. Injuries were classified using the codes for external cause of injury and poisoning by intent and by mechanism, which were obtained from Canada's Central Statistical Office. The main cause of injury death among all injuries was injury from

Table 1 - Authors, years of publication, and sources of statistical data

Author	Year of publication	Source of statistical data
DATASUS (13)	2011	Information Technology Department of the Brazilian Unified Health Care System
Pan SY (17)	2006	Statistics Canada, Canadian Vital Statistics System
Pearson J (18)	2009	General Register Office for Scotland
Ramos MR (19)	2001	National Statistics Institute of Spain
Tomashek KM (20)	2003	US Centers for Disease Control and Prevention, National Vital Statistics System
Vyrostek SB (21)	2004	US Centers for Disease Control and Prevention, National Vital Statistics System
Philippakis A (22)	2004	US Centers for Disease Control and Prevention, Injury and Violence Prevention and Control
Pressley JC (23)	2007	US Centers for Disease Control and Prevention, National Vital Statistics System
National Safety Council (24)	2011	Injury Facts®
Väli M (25)	2007	Estonian Bureau of Forensic Medicine
Naghavi M (26)	2010	Iranian National Ministry of Health and Medical Education
Strukcinskienė B (27)	2008	Lithuanian Department of Statistics (Statistics Lithuania)/Lithuanian Health Information Centre Archives
Celis A (28)	2001	Mexican National Ministry of Health/Mexican National Institute of Public Health/Mexican National Institute of Statistics and Geography
Baqui AH (29)	2001	Bangladesh Demographic and Health Survey/Bangladesh Bureau of Statistics
Rahman F (30)	2004	Bangladesh Demographic and Health Survey
Szot J (31)	2003	Certificados Médicos de Óbito (Death Certificates)/Chilean National Ministry of Health, National Statistics Institute of Chile
Jagnoor J (32)	2011	Registrar General of India

motor vehicle accidents, followed by suffocation, drowning and burning. However, suffocation was the main cause of death for infants aged less than 1 year (17).

Data on injuries in Scotland were derived from an article about the pattern of injury by age-group in children and its implications for prevention. The mortality data were analyzed in terms of number of deaths, leading causes of death and causes of injury-induced death, and they were grouped into age categories. In Scotland, 186 children less than 14 years of age died from injuries, including poisoning, in the period 2000-2006. The most common cause of injury death was road traffic injuries (pedestrian and non-pedestrian) (18).

The article on the data from Spain included the causes of death from unintentional external causes in children aged 1 to 14 years. The indicators were calculated based on the official death statistics of accidental deaths and populations in Spain and their Autonomous Communities. In the period

1975-1994, the leading external cause death was motor vehicle-related injuries (19).

Regarding the United States, four articles were found addressing unintentional injuries in children with information based on data from the Centers for Disease Control and Prevention (CDC). The trend in postneonatal mortality attributable to injury was analyzed in an article. The information was obtained from United States death certificate data among infants aged 28 to 364 days in the period 1988-1998. In this article, the majority of postneonatal deaths were attributable to unintentional injury. The main cause was a combination of mechanical suffocation, obstructive suffocation and deaths related to motor vehicle accidents. The mortality rate attributable to injuries in infants declined over this period, but the rates of mechanical suffocation increased (20).

Surveillance for fatal and nonfatal injuries in the United States was published with information from the CDC's

Table 2 - Characteristics of studies found in 3 electronic databases.

Types of studies	PubMed	LILACS	Embase	TOTAL
Studies adequate for systematic review	8	1	3	12
Studies of treatments and interventions	197	0	120	317
Studies of protocols and injury severity classification	285	0	12	297
Studies of other pathologies and specific pathologies in external causes	172	0	120	292
Studies of preventive measures, risks and predisposition	127	2	62	191
Case studies	158	0	12	170
Diagnostic and forensic studies	78	0	66	144
Studies of specific external causes	28	1	81	110
Studies of mortality due to other causes	79	0	29	108
Studies of external causes in specific locations	70	6	7	83
Studies in specific populations	59	0	21	80
Studies of intentional external causes	55	0	22	77
Studies of public health and ethical and legal issues	56	1	17	74
Studies of assessment of trauma care and pre-hospital care centers	31	0	8	39
Studies of patient safety	26	0	9	35
Studies of data collection methods and reporting systems	15	0	1	16
Studies of death among adults due to external causes	14	0	0	14
Comments	14	0	0	14
Studies of all unspecific external causes	4	1	5	10
Studies of financial costs of external causes	4	0	0	4
Letters	4	0	0	4

National Vital Statistics System that was obtained from official death certificates. The leading cause of fatal injuries was unintentional motor vehicle-related injuries, including during childhood, as a motor vehicle occupant (21).

A quantification of unintentional childhood injury mortality by cause in the United States was obtained from the National Center for Injury Prevention and Control. The National Center for Injury Prevention and Control publishes extensive and detailed information concerning deaths from unintentional injuries from external causes on the internet. This article showed that the unintentional childhood injury mortality rate declined in the country, and the main responsible cause of childhood mortality was motor vehicle injuries (22).

Another study examined all-cause, unintentional and intentional injury-related mortality in children aged 0 to 4 years to investigate racial disparities in United States by injury mechanism in the period 1981-2003. During this period, there were 3,524 injury deaths with 2,701 unintentional injury deaths. The injury mortality rates declined over the time period, and the leading cause of death in children was unintentional injury, mainly by motor vehicle traffic. Black and American Indian/Alaskan Native children had higher injury mortality for intentional and unintentional injury than other racial groups (23).

Data from the National Safety Council, entitled Injury Facts®, 2011 edition, report on the status of injuries in 53 countries with a predominance of data from developed countries. Data were collected from the World Health Organization from 2004 to 2008. The report also describes the burden of choking in children under one year and the burden of motor vehicle accidents in the general pediatric population in the United States in 2007 (24).

Childhood deaths from external causes in Estonia were studied in an article providing data on causes of all child deaths abstracted from the autopsy protocols. Unintentional injury accounted for 80% of 211 deaths in children less than 14 years old who died from external causes. The main causes of injury deaths were asphyxia and transport-related injury, followed by poisonings and other unintentional injuries (25).

The trend of child injury mortality in Iran was studied and computed using death records from the Iran registration data. The aim was to estimate the morbidity, mortality and disease burden caused by child injuries. This study revealed that injuries were the most important health problem of children in Iran in 2003 and 2005. Road transport injuries had the highest death rate in children and were the main concern among all types of injuries (26).

Information on unintentional injury mortality trends in children and adolescents in Lithuania were studied in an article with population data obtained from Statistics Lithuania and the Health Information Centre. This article revealed that unintentional injury mortality rates due to road traffic were declining but that their rates remained the highest of all causes of unintentional injury (27).

Injury mortality in persons less than 19 years of age in Mexico was discussed in an article, and the cause-specific mortality data were obtained from the Health Ministry. In 1997, the first causes of unintentional injury mortality among children and teenagers were events with motor vehicle traffic, suffocation and drowning (28).

The causes of childhood deaths and the magnitude of child injuries in Bangladesh were discussed in 2 articles

with data obtained from the Bangladesh Demographic and Health Survey. The authors studied the cause of child deaths and revealed acute respiratory infection as the most important known cause of death, but most of the injury deaths among children were worrisome, particularly due to drowning (29). Another study focused on the dynamic changes in child mortality to provide a basis for the projection of future mortality and disability in children in Bangladesh. In this article, injury was identified as a major cause of child deaths, in particular deaths caused by drowning, which are emerging as the leading cause of child mortality. The reduction of infectious causes of fatal diseases in infants and children made the non-communicable causes of injury, especially drowning, more visible (30).

An article studied the mortality in infants less than 1 year of age from injuries in Chile to characterize the infant mortality caused by external injury. Data were obtained using death certificates, and the aim was to provide basic information for the prevention of injury mortality. The main cause of injury mortality was asphyxia caused by foreign body inhalation, secondary to inhalation and regurgitation of food (31).

In India, death registration systems are usually limited or non-existent. In the absence of reliable data for cause-specific mortality in India, an article discussed the results of verbal autopsies conducted by the Registrar General of India for all deaths in a nationally representative sample of over 1.1 million homes in 2001-2003 to determine the mortality burden associated with unintentional injuries among children younger than 5 years of age in India. These verbal autopsy reports were coded by two of 130 trained physicians who independently classified each death according to the ICD-10 (14). Discrepancies were resolved through reconciliation and, if necessary, adjudication. The results of this study showed that unintentional injuries were the sixth-leading cause of death among children less than 5 years of age, especially due to drowning and falls. In the article selected, India conducted the first study of estimates of unintentional injury mortality in young children from a nationally representative sample, and unintentional injury deaths were estimated to constitute 9% of all deaths among children aged 1 to 4 years in 2005 (32).

Table 3 shows the infant mortality rates due to external causes, which are broken down into unintentional external causes and causes of undetermined intention in countries whose studies provided these data.

The preliminary data (13) showed that 10.9% of the deaths among children ≤ 14 years of age in Brazil in 2010 were from external causes. Among all deaths from external causes among children ≤ 14 years of age, 16.1% were from intentional injury (assault or intentional self-harm), 8.6% were from events of undetermined intent, and 74.2% were from accidents (Table 4).

In Brazil, the number of deaths from external causes among children within the age bracket under study (13) was highest among those children in the 10-14 year age bracket. In addition, the numbers of accidental deaths, deaths from events of undetermined intent, and deaths from intentional injury were highest among children in the 10-14 year age bracket (Table 4).

However, the mortality rates per 100,000 people in Brazil for all external causes, unintentional events, and events of undetermined intent were highest among children under 1 year of age, with rates of 34.7, 27.3 and 3.9 per 100,000

Table 3 - Mortality rate (per 100,000 population) from external causes†

Country	Year	Age bracket	Mortality from all external causes			
Brazil (13)*	2010	0 -14yr	13.37			
Scotland (18)	2002-06	0 - 14yr	4.3			
USA (21)	2001	0 - 14yr	11.71			
Estonia (25)	2001-05	0 - 14yr	19.1			
Iran (26)	2001-06	0 - 14yr	35.5			
Mexico(28)	1997	0 - 14yr	20.2			

Country	Year	Age bracket	Mortality from unintentional injury			
Brazil (13)*	2010	0 -14yr	9.9			
Canada (17)	2002	0 - 14yr	5.8			
Scotland (18)	2002-06	0 - 14yr	3.4			
Spain (19)	1994	1 - 14yr	6.4			
USA (21)	2001	0 - 14yr	9.1			
USA (22)	1989-98	0 - 14yr	11.9			
USA (22)	1996-98	0 - 14yr	10.5			
USA (24)	2007	0 - 14yr	8.32			
Estonia (25)	2001-05	0 - 14yr	15.3			
Lithuania (27)	2003-05	0 - 14yr	15.77			
Mexico (28)	1997	0 - 14yr	17.4			

Country	Year	Age bracket for mortality from events of undetermined intent				
		< 1yr	1-4yr	5-9yr	10-14yr	0 -14yr
Brazil (13)*	2010	3.9	1.1	0.7	1.2	1.1
Estonia (25)	2001-05	24.3	1.6	0	0.4	2
Mexico (28)	1997	3.5	0.7	0.4	0.7	0.8

Abbreviations and notes: yr, year(s); † mortality by age bracket; *preliminary data.

people, respectively (Tables 3 and 4). Most of the accidental deaths among children in this age bracket were deaths due to "other accidental threats to breathing" (i.e., threats other than drowning and submersion), which accounted for 69% of all accidental deaths among children under 1 year of age in Brazil (Table 4).

Although the external causes of accidental injury varied across the countries under study, certain events predominated. The data obtained (Tables 3 and 5) show that external causes of accidental injury constitute a worldwide problem, with the most commonly reported accidents fitting into one of the six following categories:

- traffic accidents
- accidental drowning and submersion
- falls
- exposure to smoke, fire, and flames
- accidental poisoning by and exposure to noxious substances
- other accidental threats to breathing

In Chile and Canada, countries for which we were unable to obtain sufficient information to calculate the mortality

rates, suffocation and foreign body aspiration were most common in infants, in whom the risk of accidental death was higher than in the other age brackets (17,31). For some countries, we were able to obtain the mortality rates among children less than 1 year of age for deaths due to "other accidental threats to breathing," which falls under the category "other external causes of accidental injury" (Table 6). We found that the mortality rates were higher for other accidental threats to breathing in children less than 1 year of age than for other external causes of accidental injury studied in other age brackets in our review (Table 6).

Traffic accidents, including those accidents involving pedestrians and occupants, constituted the leading external cause of accidental death in children and adolescents in this review. Traffic accidents as a cause of death were most common among children of preschool age or older in Brazil, Scotland, United States, Estonia, Iran and Mexico (Table 5).

Traffic accidents were the leading external cause of death among children in Brazil. Of children ≤14 years of age who died from traffic accidents in Brazil, 50.3% died at the scene of the accident without receiving hospital care (13).

Among children ≤14 years of age in Brazil, deaths from traffic accidents accounted for 30.4% of all deaths from external causes and 41% of all accidental deaths (13). Of all

Table 4 - Number of child deaths in Brazil in 2010*.

Age bracket	Total	External causes	Transport accidents (Pedestrian)	Accidental drowning and submersion	Other accidental threats to breathing	Event of undetermined intent	Accidents	Intentional (assault/self-harm)/ others
< 1 year	39,572	941	115 (22)	24	510	107	740	71 (71/0)/23
1-4 years	6,970	1,469	446 (194)	389	103	119	1,239	101 (101/0)/10
5-9 years	4,129	1,329	547 (230)	294	47	99	1,114	105 (102/3)/11
10-14 years	5,685	2,404	761 (226)	435	44	205	1,468	711 (622/89)/20
Total	56,356	6,143	1,869 (672)	1,142	704	530	4,561	988 (896/92)/64

*Preliminary data from the Information Technology Department of the Brazilian Unified Health Care System (13).

Table 5 - Mortality (per 100,000 population) from specific external causes.

Cause/Age bracket	Country					
	Brazil	Scotland	USA	Estonia	Iran	Mexico
	2010 (13)	2002–2006 (18)	2007 (24)	2001–2005 (25)	2001–2006 (26)	1997 (28)
Traffic accidents						
< 1 yr	4.2	NA	2.9	3.0	25.3	3.4
1–4 yr	4.0	0.8	3.2*	5.2	16.1	6.5
5–9 yr	3.7	1.6	2.6	5.2	16.3	5.2
10–14 yr	4.4	2.0	3.8	5.4	13.1	5.5
0–14 yr	4.0	1.4	3.2	5.2	NA	5.5
Accidental drowning and submersion						
< 1 yr	0.9	0.7	1.3	1.5	4.3	2.2
1–4 yr	3.5	0.2	2.5*	5.2	4.2	5.0
5–9 yr	2.0	0.2	0.6	4.0	1.8	1.8
10–14 yr	2.5	0.3	0.5	1.3	1.9	2.4
0–14 yr	2.5	0.3	1.2	3.0	NA	3.2
Falls						
< 1 yr	1.4	0.7	0.56	0	4.6	1.7
1–4 yr	0.6	0.2	0.29*	0.8	1.9	1
5–9 yr	0.3	0.2	0.05	0.6	1	0.4
10–14 yr	0.3	0.4	0.1	0.2	0.7	0.4
0–14 yr	0.4	0.3	0.15	0.5	NA	0.7
Exposure to smoke, fire, or flames						
< 1 yr	0.4	0.4	0.88	NA	8.5	1.2
1–4 yr	0.5	1.2	1.15*	NA	4.3	1.1
5–9 yr	0.3	0.3	0.67	NA	1.4	0.4
10–14 yr	0.1	0.1	0.38	NA	1.8	0.2
0–14 yr	0.3	0.5	0.74	NA	NA	0.6
Accidental poisoning by or exposure to noxious substances						
< 1 yr	0.1	NA	0.44	1.5	6.8	2.2
1–4 yr	0.1	0.09	0.25*	2.8	1.2	0.9
5–9 yr	0.03	0.07	0.06	1.5	0.5	0.2
10–14 yr	0.03	0.06	0.34	0.6	0.5	0.2
0–14 yr	0.06	0.07	0.22	1.4	NA	0.6

Abbreviations and notes: yr, year(s); NA, not available; *0–4 year age bracket.

deaths from traffic accidents, 40.7% occurred among children in the 10–14 year age bracket. In addition, 35.9% of the deaths from traffic accidents fell under the category "pedestrian injured in traffic accident," which mostly involved children in the 5–9 year age bracket (Table 4).

Accidental drowning and submersion constituted another major external cause of accidental death in children (Table 5). Despite not having provided sufficient data to calculate the rates of mortality from external causes, two studies conducted in Bangladesh (29,30) and one study conducted in India (32) revealed that accidental drowning and submersion constituted a major external cause of accidental death among children in those countries. In 2005, accidental drowning and submersion constituted the

second-leading external cause of accidental death in Brazil (24). In 2010, accidental drowning and submersion continued to be the second-leading external cause of death in Brazil, after traffic accidents and were particularly prevalent among children in the 1–4 year age bracket (Table 5).

Among children ≤14 years of age in Brazil, falls, accidental poisoning by and exposure to noxious substances, and exposure to smoke, fire, and flames collectively accounted for 7.7% of all accidental deaths from external causes in 2010, individually accounting for 198, 28, and 125 deaths, respectively (13). The mortality rates due to these categories of external causes of accidental deaths were also lower according to the selected articles from other countries, and deaths from those causes occurred principally among children ≤4 years of age (Table 5). Despite the low mortality rates for these events, they were of note and, together with traffic accidents and accidental drowning and submersion, constituted the principal external causes of death among children in this review.

Table 6 - Accidental threats to breathing in children under 1 year of age.

Country	Year	Mortality rate per 100,000 population
Brazil (13)*	2010	18.8
Scotland (18)	2002–06	1.5
USA (20)	1998	7.1 (mechanical suffocation) 1.4 (obstructive suffocation)
USA (24)	2007	22.4
Estonia (25)	2001–05	39.4 (aspiration)
Iran (26)	2001–06	13.4
Mexico (28)	1997	31.2

*Preliminary data.

DISCUSSION

Injuries account for 12% of the total burden of disease worldwide and are noteworthy in the pediatric population for their high frequency and serious risk (24,33).

Factors such as time and place influence epidemiological studies and should be considered when comparing data sets (34). We found that there were few studies investigating external causes of morbidity and mortality in children living

in the countries with the lowest incomes, where childhood mortality from external causes is highest (7).

Publications such as Injury Facts (24) present alarming data for 2011, with the highest unintentional external cause mortality rates in southern Asia.

Although differences in the grouping of age brackets make it difficult to draw comparisons across studies, we were able to identify the principal external causes of accidental injury and death among children worldwide. Even in low-income countries, such as Bangladesh and India, where diseases resulting from nutritional and sanitation problems are still responsible for high mortality rates, external causes of accidental injury and death are recognized as major public health problems. In Bangladesh, unintentional injuries—principally accidental drowning—proportionally constitute the leading cause of death in children in the 1–4 year age bracket (29,30,35,36). In India, unintentional injuries kill more children than nutritional deficiencies, congenital anomalies, and malaria (37).

We found this concern about injuries in articles from Bangladesh and India, where injuries were discussed as the new non-communicable disease burden in childhood. The reduction of deaths due to infectious causes in infants and children had allowed injury, especially due to drowning, to become more visible (29,30,32,36,37).

Although data on the causes of death in countries with the highest mortality rates are still lacking, deaths in India and China account for 32% of all estimated deaths from external causes in children less than 5 years of age in the world (38).

In our study, we found different external causes of accidental injury leading to death among children in different countries.

In Canada, Scotland, Spain, the United States, Estonia, Iran, Lithuania and Mexico, mortality from external causes was high compared to other causes, especially among children of preschool age or older, as a result of events due to traffic (17,18,19,21–24). Data from the WHO confirm that traffic accidents in which children are passengers in motor vehicles involved in collisions and accidents in which children are pedestrians or cyclists are undeniably relevant in the pediatric population because they represent the leading cause of violent death in most countries (7).

Even with the adoption of measures that have been proven to effectively reduce traffic accidents (7,39,40), we found that traffic accidents still constitute the leading external cause of death among children in the countries evaluated and constitute the leading cause of morbidity in children worldwide (10), although traffic safety is commonly considered to be a transport issue rather than a public health issue (40). The WHO report includes data on overall mortality and corroborates the role of traffic accidents as the leading cause of death among children and adolescents (7). Even in developed countries, traffic accidents continue to represent a major public health problem and result in high costs to the health care systems. Data from the continuous monitoring of traffic accidents allow the adaptation of measures and protocols as needed (41). One article on victims of traffic accidents revealed that the mortality rate was significantly higher for victims trapped in the wreckage, with such victims being 8.2 times more likely to die at the scene compared to victims who were not trapped; this finding indicates the need for vehicle rescue and safety strategies and for roads designed to minimize the risk of such accidents (41).

We found that accidental drowning and submersion constituted the second-leading cause of death among children ≤ 14 years of age, a finding that was confirmed by the WHO data (7), which indicate that the mortality rates for accidental drowning and submersion are high worldwide. Data in the literature indicate that cultural and religious factors play a significant role in the high frequency of drowning among children in Asia, as is the case in Bangladesh. In Bangladesh, beliefs in “bad spirits” and community perceptions hinder prevention measures. Bangladesh and India are countries with similar risk factors for fatal drowning (32,35–37).

Several studies and publications have explored five primary external causes of death in children. However, little attention has been paid to infants, who present the highest rates of death due to external causes, especially as a result of choking or suffocation.

Suffocation is a general term that includes many forms of asphyxia due to scarcity of oxygen. It can happen when there is a lack of gas to breathe, or it can be due to an interruption of breathing due to obstructions of the external airways (smothering) or the internal airways (choking). Suffocation can also occur from pressure on the chest or abdomen (traumatic asphyxia) or immobilization of the body with restriction of breathing movement (positional asphyxia) (42). Strangulation occurs when there is external compression of the airways (43).

The factors that predispose infants to these risks is the fact that they often bring objects to their mouth, have an inadequate process of chewing food before swallowing (due to immature neuromuscular mechanisms of deglutition and airway protection) and have incomplete development of posterior dentition with an absence of molars (43,44). The consequences of foreign body aspiration such as asphyxia and cardiopulmonary arrest are very serious and can lead to death or sequelae, which are mostly neurological (44).

Very few studies have focused on the determinants of death in infants due to external causes, particularly the unintentional events where preventive measures could be implemented. Due to this lack of ancillary data, infants were not included in the latest (2008) world report on injury prevention (7).

In our review, a Chilean article studied the external causes of mortality in children less than 1 year and identified the inhalation of gastric contents as the main cause of death. Among children under 1 year of age, accidental threats to breathing, which exclude accidental drowning and submersion, represented the leading external cause of accidental death (31). In addition to the aforementioned obstructive choking, reports of mechanical suffocation were also reported by the articles from Canada and the United States, which state that suffocation was the principal cause of unintentional death from external causes in infants less than 1 year (17,20).

The various types of threat to breathing, with the exception of drowning, are classified in ICD-10 as the other accidental threats to breathing. These other accidental threats to breathing include accidental events such as suffocation; strangulation; hanging; being confined to or trapped in a low-oxygen environment; and airway obstruction with asphyxia by food, objects, or other substances (14). Airway obstruction is a major determinant of death from accidental threats to breathing in children less than 4 years of age (43). The external causes other than drowning that may cause death by asphyxiation can occur due to obstruction of the

airway by a foreign body, strangulation, obstruction, facial or chest compression or lack of oxygen (46).

There are descriptions of death by suffocation due to unsafe sleeping environments such as bed-sharing and the use of adult beds, when adults may lie over or roll on top of or against the infant while sleeping, or the adult may wedge and entrap an infant between two objects. Suffocation also can occur from plastic bags, pillows, soft bedding with oronasal obstruction, or the aspiration of foreign bodies with respiratory obstruction (47-49).

Entrapment with suspension, hanging and entanglement can also lead to death. Strangulation by asphyxiation can happen when an infant's head and neck become caught between the crib railings. These events may occur in cribs with structural problems that allow passage of the head through the cradle structures. Blind cords, necklaces and pacifier cords are also hazardous (48,49).

A publication from the Czech Republic analyzed deaths from external causes that occurred between 1989 and 1992 among all live births registered between 1989 and 1991. Data from the national database revealed that 73% of 195 deaths were from obstruction of the respiratory tract by food or from mechanical suffocation. Postmortem examination was conducted in more than 97% of deaths (50).

A study of accidental death by suffocation in infants younger than 1 year was conducted in the United States. This study included 513 cases between 1980 and 1983 and 883 cases between 1995 and 1998 and found that the deaths of infants who suffocated on beds not designed especially for infants were increasing. The risk for suffocation among infants in adult beds was 40 times higher than the risk for suffocation while on sleep surfaces designed for infants. This risk may be higher because the small child has no motor skills to escape from potential threats within the sleep environment (51).

The authors of a study conducted in San Diego, California between January of 2000 and December of 2006 analyzed deaths from external causes among children and adolescents ≤ 17 years of age and showed that deaths from road traffic accidents were the most prevalent, followed by deaths from asphyxia. It is important to note that cases of asphyxia included accidental drowning, suffocation, and strangulation, and suffocation was the leading external cause of death in children less than 1 year of age (45).

Among children, unlike what occurs in adults, deaths from hanging are generally accidental and typically occur in the bedroom as a result of a variety of situations that are principally related to how the child habitually sleeps. Hangings are described involving pacifier cords; clothing or necklaces; drapery or blind cords; neck entrapment by bars; or strangulation by a cord, string or ribbon. In many households in Turkey, there is a habit of using swing-like cradles, where bands and cords are used to prevent the child from falling; such bands and cords can accidentally wrap around the neck of the child, thereby causing asphyxia (48,52).

The mortality from events leading to strangulation is high, and brain injury or brain death is due to vascular and airway obstruction leading to mixed acidosis, hypoxia, and cerebral congestion (53).

The limitation of the inevitable and questionable classification of the documented external causes of accidental injury (7) lies in the fact that the data are typically dubious or incomplete, and it is impossible to be certain of the

unintentional nature of the injury (54). The diagnosis is often questionable, and it is particularly difficult to determine the intent of death in children less than 1 year of age. The intent of death is commonly determined only at autopsy, and the rates of infanticide are therefore almost certainly underestimated because autopsy is rare (25).

Because of the legal and judicial implications and because unintentional and intentional injuries present different scenarios and risk factors, there is a need to improve the differentiation between the two types of injuries, thus reducing the number of events of undetermined intent.

Standardized data collection at the death scene is an extremely important procedure in the analysis of causal factors and aids in understanding the circumstances of the event. It is also important for determining and classifying the cause of death on death certificates (for legal purposes) and has implications for public health policies (49,52). However, because the quality of the information regarding those deaths is generally poor due to having few details available, it is impossible to determine exactly what transpired immediately prior to the time of death.

Some of the limitations of the present review include underreporting and the questionable reliability of death certificates.

As occurs in many public health areas, the ability to identify and report injuries and deaths varies widely across countries and generally correlates with the overall economic development of a given country (3).

In Brazil, the Brazilian Institute of Geography and Statistics and the Brazilian National Ministry of Health Mortality Database are the two national systems providing mortality data. However, the underreporting of deaths is still one of the major factors limiting the analysis of mortality, particularly among children less than 1 year of age, and principally in northern and northeastern Brazil (55).

Countries need to improve the analysis of epidemiological information, so that better public health strategies can be planned and implemented. In countries where mortality rates are high, vital statistics are generally unavailable, which makes it impossible to know the causes of death in many circumstances (7). Bangladesh, for instance, does not have a system of registering vital statistics, and there is a lack of physicians who are qualified to provide appropriate care (29). In addition to the lack of medical care in those countries, the determination of the cause of death is complicated because the information provided by family members often constitutes the only available data indicating the cause of death (7). Few countries in sub-Saharan Africa have access to autopsy information, and much of that information is obtained by "verbal autopsies" (38).

Another important issue is the fact that mortality rates can vary according to the protocols used, the provision of treatment at referral centers, the medical transportation conditions, and the national investment in health (56-58). The quality of care for multiple trauma patients can be improved by triage and rapid assessment of trauma severity as a strategy to guarantee the appropriate planning and resources for on-scene emergency and hospital care and to evaluate the prognosis (41).

It is important to recognize that the size of the samples and the quality of the data vary significantly from database to database (12). However, the burden of traffic accidents remains high worldwide, particularly in developing countries, where the associated mortality rates are higher.

Because the present review was based exclusively on mortality data (i.e., morbidity data were not included), the data obtained, although undeniably important, reflect only part of the problem of accidental injury in the pediatric population.

Our review of the medical literature of external causes of accidental death among children revealed that although the types of unintentional injuries vary from country to country, unintentional injuries occur worldwide and are life-threatening, principally in children. Our data are similar to the 2008 WHO data showing that traffic accidents, drowning, burns (fire or scalds), falls, and poisoning collectively accounted for 60% of all child injury-related deaths worldwide (7). If preventive measures similar to those adopted by countries with low rates of mortality from accidental injury—such as Sweden—are taken in other countries, the worldwide rates might be reduced (59).

Many solutions are easy to apply and require no expenditures of time or financial resources to be implemented.

Here, we provide the following recommendations from the medical scientific literature for safe environments that can be implemented by health care professionals or by pediatricians during routine visits, particularly for infants at risk of accidental threats to breathing:

- Avoid offering infants pieces of food or seeds (60)
- Do not allow easy access to small objects, and do not allow infants to play with small pieces of plastic or metal objects (60)
- Prevent sharing of the parents' bed, pillows or soft bedding due to the risk of crushing or suffocation; there is also the risk of overheating, buildup of carbon dioxide and inhalation of cigarette smoke (46,48)
- Avoid ropes, chains, cords, ribbons or tapes close to infants (46)
- Remove the bib after meals (46)
- The distance between the bars of windows and doors must not exceed 8 cm to prevent the head of a child from passing between these bars (46)
- Avoid baggy clothes and excessive bedding in the crib (46)
- Do not allow more than 3.8 cm from one end of the mattress to any of the four sides of the cradle (46)
- The thickness of the mattress should not exceed 15 cm (46)
- The cradle should be close to the wall or far enough away, so a child cannot get caught between the cradle and the wall (46)
- Cribs must have structural integrity according to standard rules; the recommended distance between cradle bars should not exceed 6 cm to prevent trapping the infant between them, and they should be unadorned (46)
- Cribs and other baby products that are especially designed for use by children, according to mandatory standards with manufacturing standards and mandatory warning labels on products, are recommended (46,51)

Injury prevention should be researched and become an area of focus. Prevention measures should be recognized and effectively applied, particularly for infants who are

vulnerable to overlooked hazards. Above all, care practices and continued supervision of children are essential to prevent deaths from external causes.

Further studies investigating the occurrence of accidental deaths, particularly in low-income countries, are needed to improve the understanding of those events. Such studies will allow us to compare the causes and frequencies of accidental deaths and to determine the risk factors for and the occurrence of accidental deaths in the various age brackets, therefore allowing preventive measures to be taken. Although this poses a major challenge, principally in low-income countries, the possibility of saving lives, especially those of children and adolescents, is a motivating factor.

AUTHOR CONTRIBUTIONS

Imamura JH searched the databases, selected the articles, and wrote the manuscript. Troster EJ guided the methodology, the selection of the articles, and the writing of the manuscript. Oliveira CA guided the methodology and the writing of the manuscript.

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