

Unintentional Home Injuries Across the Life Span: Problems and Solutions

Andrea C. Gielen,¹ Eileen M. McDonald,¹
and Wendy Shields²

¹Department of Health, Behavior and Society, ²Department of Health Policy and Management, Johns Hopkins Center for Injury Research and Policy, Bloomberg School of Public Health, Johns Hopkins University, Baltimore, Maryland 21205; email: agielen1@jhu.edu, emcdona1@jhu.edu, wshield1@jhu.edu

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Abstract

Home injuries cause more than 30,000 deaths and 12 million nonfatal injuries annually in the United States. They generate an estimated \$222 billion in lifetime costs annually. Despite some data limitations in documenting home as the location of an injury, much progress has been made in identifying effective prevention strategies that reduce injury or mitigate risk behaviors.

The current interest in public health in the role of housing in health offers unparalleled opportunities for injury prevention professionals concerned with home injuries. Sharing the science of injury prevention with the wide array of professionals—such as architects, home builders, home visitors, and fire and emergency medical services providers—who create home environments and interact with residents could be a useful approach. A collaborative national effort to reduce the burden of home injuries is needed.

INTRODUCTION

Two separate but related strands of research have led to a new appreciation of the importance of the magnitude of home injuries in the United States and the need to prevent them. First is the emphasis in public health on social determinants of health, which have been incorporated into the US Department of Health and Human Services (DHHS) 2020 health objectives for the nation. The objectives specifically include safe and healthy housing as an indicator (108). According to the World Health Organization, social determinants of health are “the circumstances in which people are born, grow up, live, work and age These circumstances are in turn shaped by a wider set of forces: economics, social policies, and politics” (130). Related to housing and health, social determinants can include characteristics of the physical environment where there are clear injury risks, such as lack of working smoke alarms, tap water that is too hot, deteriorating stairs, and poor-quality electrical wiring.

Contemporary public health’s second related area of research important to home injury prevention is the environmental health field’s inclusion of injury in the conceptualization of healthy housing (14, 84, 103). With extensive input from a national committee and technical review group, the National Center for Healthy Housing (NCHH) and the American Public Health Association (APHA) issued the 2014 National Healthy Housing Standard (92). This standard incorporates many elements of the physical environment that convey injury risk, such as electrical hazards that can cause fires and sources of carbon monoxide (CO) poisoning.

Home injuries result from interactions between individuals and their physical and social environments, which is why there are natural synergies among social determinants of health, environmental health, and injury prevention. With more than 30,000 home injury deaths annually in the United States (75), the growing support for and interest in comprehensive and collaborative efforts to prevent home injuries are warranted. Moreover, for every home injury death, many more nonfatal home injuries occur; from 1997 to 2001, there were, on average, 12.4 million nonfatal home injuries annually (100). These injuries were estimated to cost \$222 billion annually in medical care alone (100). Fortunately, many of these injuries are preventable through the use of injury prevention countermeasures and principles of practice, as we show below.

The aims of this article are (*a*) to describe the epidemiology of home injuries; and (*b*) to summarize the evidence on prevention strategies that address the groups most at risk for four of the leading causes of home injury (i.e., infant sleep-related deaths, house fires and burns, poisonings, and falls). A robust body of literature provides evidence for the preventability of many of these injuries, and we draw on existing reviews of it, including for instance the Cochrane Collaboration Reviews (e.g., 45, 58, 71, 126, 127) and national-level policy recommendations (e.g., 23, 34, 90, 95). We categorize the prevention strategies as follows.

- Strong evidence: The prevention strategy has been extensively documented with empirical research and/or Cochrane Reviews.
- Promising evidence: The prevention strategy has some positive evaluation data to support it.
- Recommended practice: The prevention strategy has no or very limited research evidence, but it is recommended by relevant professional organizations and/or national policy documents.

EPIDEMIOLOGY OF HOME INJURIES

In 2002 the Home Safety Council commissioned the first comprehensive study of home injuries in the United States; this study was updated in 2004 (55, 100). These landmark reports compiled national data from multiple sources to document the prevalence of and risk factors for fatal and

HOME SAFETY

Following are recommendations from the 2004 report, *The State of Home Safety in America: Facts About Unintentional Injuries in the Home* (excerpted from 100, pp. 13–15).

1. Multiple organizations should commit to a collaborative national effort to address the home safety problem.
2. Congress should allocate increased resources to support injury prevention efforts.
3. Federal agencies responsible for injury data should examine how to improve the quality and completeness of data about injury in the home environment.
4. Injury researchers and practitioners should work together to develop research priorities to better understand the nature and magnitude of injury in the home environment; Congress should fund initiatives to address these priorities.
5. Designers, architects, and engineers as well as policy makers need to be supported in applying existing knowledge to the development of new interventions, with particular attention to improvements in the design, manufacture, and marketing of safe consumer products; development and enforcement of improved regulatory standards for home safety design, construction, and maintenance, including monitoring of adherence to standards at the time homes are sold or rented; universally applied safety standards, as well as allowance for enhanced measures appropriate to address specific geographic and population needs; laws and social norms that relate to intervention acceptance and success; and strategies to modify human behaviors to be more conducive to home safety.
6. Funding agencies and organizations should require well-designed evaluations as an essential component of funding intervention efforts.
7. Funding agencies and organizations should support development of more effective ways to disseminate information about home safety to the general population as well as to decision makers.

nonfatal home injuries, as well as the use of safety products and behaviors to reduce those risks. The national experts contributing to these reports concluded with a strong set of recommendations (see sidebar, Home Safety) to address what they showed to be a large and substantially preventable problem, despite having limited surveillance data that detail the location of injury incident. Even today, there are issues related to obtaining data on the location of the injury incident. The Agency for Healthcare Research and Quality's Healthcare Cost and Utilization Project provides extensive data on hospitalizations and emergency department visits, but because the coding is done for billing purposes, codes with no financial incentive, such as the location of injury incident, are usually underreported (62). Even for injury deaths, Mack et al. (77) found that the location of injury incident was missing for 31% of the death certificates they reviewed from 2000 to 2008. The National Health Interview Surveys (26), however, include detailed questions about injuries that required medical attention as well as the cause and the location of the injury incident, specifying inside the home or outside the home (e.g., porches). In the next sections, we present currently available data on fatal and nonfatal home injuries.

Fatalities

From 2000 to 2008, an average of 30,569 home injury deaths occurred annually (**Table 1**). Adults made up the largest proportion of these deaths; 21.9% occurred among those 80 years of age and older, who also had the highest death rates by an enormous margin (65.3/100,000) (many of these

Table 1 Average annual unintentional home injury deaths by age group and ratio of males to females: United States, 2000–2008.^a Data excerpted from Reference 77 and include injuries occurring inside and outside the home

Age group (years)	Average number of injury deaths per year			Rate ratio male:female
	Total number of injuries	Percent	Rate ^b (95% CI)	
<1	725	2.4	17.7 (17.2, 18.1)	1.3
1–4	688	2.3	4.3 (4.2, 4.4)	1.6
5–9	254	0.8	1.3 (1.2, 1.3)	1.4
10–14	203	0.7	1.0 (0.9, 1.0)	1.8
15–19	588	1.9	2.8 (2.7, 2.9)	3.2
20–29	2,729	8.9	6.8 (6.7, 6.8)	3.0
30–39	3,593	11.8	8.7 (8.6, 8.8)	2.1
40–49	5,778	18.9	13.0 (12.9, 13.1)	1.8
50–59	3,987	13.0	11.1 (11.0, 11.2)	1.8
60–69	2,161	7.1	9.5 (9.4, 9.6)	1.8
70–79	3,150	10.3	19.5 (19.3, 19.7)	1.6
≥80	6,708	21.9	65.3 (64.8, 65.8)	1.5
All^c	30,569	100.0	10.4 (10.4, 10.5)	1.5

^aAbbreviation: CI, confidence interval.

^bRate is crude rate per 100,000 people.

^cAge groups do not sum to total because age was missing for a small number of deaths ($n = 56$).

deaths are due to falls, as discussed below). Infants experienced home injury deaths at the next highest rate of 17.7 per 100,000; the most common cause of injury death in this age group is due to unsafe sleep environments (discussed below). The male–female ratio of home injury deaths was consistently higher in males than in females, with the largest discrepancy among those 15–29 years of age.

Nonfatal Injuries

In 2012, there were 19.4 million episodes of medically attended home injuries (**Table 2**), most of which happened inside the home (11.8 million). In contrast with the death data, more females than males experienced injuries inside the home. Similar to the death data, injury rates were highest among those 75 years of age and older. Rates differed by ethnicity, although for several groups the numbers were too small to have reliable estimates. Poverty status seems to be associated with higher rates, particularly for in-home injuries where the rate is 8.24 for those classified as poor, 6.95 for near-poor, and 2.90 for the nonpoor. Geographic variation was not striking, except that those in large metropolitan statistical areas and those in the south had the lowest rates of home injuries.

Causes of Home Injuries

Poisonings, at 43.1%, make up the largest proportion of fatal home injuries (**Table 3**); falls are second, at 33.9%. At 41.2%, falls also cause the largest proportion of nonfatal home injuries. Fires

Table 2 Frequency and age-adjusted rates of medically consulted injury episodes occurring in the home: United States, 2012.^a Data excerpted from Reference 2

Selected characteristic	Total number of injuries ^b	Inside home		Outside home	
		Number of injuries ^b	Rate (SE) ^c	Number of injuries ^b	Rate (SE) ^c
Total	19,420	11,816	37.35 (2.38)	7,604	24.17 (1.97)
Sex					
Male	8,509	4,455	29.93 (3.13)	4,054	27.39 (3.10)
Female	10,911	7,362	44.23 (3.43)	3,549	21.48 (2.41)
Age					
Under 12 years	2,825	1,721	35.25 (5.19)	1,104	22.62 (4.23)
12–17 years	1,203	602	24.25 (6.14)	601	24.20 (6.74)
18–44 years	5,089	3,060	27.56 (3.44)	2,029	18.28 (2.93)
45–64 years	6,150	3,732	45.50 (5.03)	2,418	29.49 (4.06)
65–74 years	2,060	1,370	57.63 (10.78)	690	29.05 (8.29)
≥75 years	2,093	1,332	73.70 (13.19)	761	42.07 (10.75)
Race					
One race	19,052	11,551	37.31 (2.41)	7,501	24.36 (2.01)
White	16,569	9,820	39.32 (2.81)	6,749	26.83 (2.41)
Black or African American	1,540	1,020	26.99 (4.65)	520	12.95 (3.15)
American Indian or Alaska Native	*528	*327	*164.74 (65.44)	*201	*65.79 (29.17)
Asian	*384	*384	*27.06 (8.95)	*	*
Native Hawaiian or Other Pacific Islander	0	0	0	0	0
Two or more races	*368	*266	*40.71 (16.04)	*102	*
Hispanic or Latino origin and race					
Hispanic or Latino	2,291	1,387	27.80 (4.68)	904	18.90 (3.62)
Not Hispanic or Latino	17,130	10,430	39.08 (2.69)	6,700	25.56 (2.31)
Education					
Less than a high school diploma	2,054	1,459	52.36 (9.19)	595	21.35 (5.60)
High school diploma or GED	3,684	2,623	43.30 (5.70)	1,061	18.84 (3.90)
Some college	5,000	2,662	47.39 (6.63)	2,338	41.13 (6.48)
Bachelor's degree or higher	3,299	1,869	32.18 (5.24)	1,430	23.85 (4.77)
Family income					
Less than \$35,000	7,999	5,439	58.14 (5.45)	2,560	26.93 (3.26)
\$35,000 or more	10,088	5,703	30.68 (2.85)	4,385	23.16 (2.69)
\$35,000–\$49,999	2,489	1,114	27.49 (5.38)	1,375	36.56 (8.32)
\$50,000–\$74,999	2,235	1,436	28.70 (4.99)	799	15.68 (3.53)
\$75,000–\$99,999	2,087	1,103	36.64 (8.33)	984	26.34 (6.07)
\$100,000 or more	3,278	2,051	31.13 (5.20)	1,227	19.35 (4.17)

(Continued)

Table 2 (Continued)

Selected characteristic	Total number of injuries ^b	Inside home		Outside home	
		Number of injuries ^b	Rate (SE) ^c	Number of injuries ^b	Rate (SE) ^c
Poverty status					
Poor	3,981	2,800	69.62 (8.24)	1,181	28.59 (4.80)
Near-poor	3,591	2,159	43.85 (6.95)	1,432	28.49 (5.09)
Not poor	9,856	5,727	30.81 (2.90)	4,129	22.67 (2.72)
Place of residence					
Large MSA	9,090	5,779	34.51 (3.13)	3,311	19.81 (2.57)
Small MSA	6,617	3,815	39.43 (4.70)	2,802	28.78 (3.97)
Not in MSA	3,713	2,222	43.11 (5.91)	1,491	29.70 (4.74)
Region					
Northeast	3,136	2,132	37.47 (6.25)	1,004	18.89 (4.90)
Midwest	4,665	2,652	39.06 (5.17)	2,013	28.31 (4.68)
South	6,975	3,899	32.99 (3.54)	3,076	26.15 (3.37)
West	4,643	3,133	43.17 (5.15)	1,510	21.14 (2.98)

^aAbbreviations: GED, general education development; MSA, metropolitan statistical area; SE, standard error.

^bNumbers of injuries are in thousands.

^cRates are per 100,000 population.

*Estimates are considered unreliable. Data have a relative standard error (RSE) greater than 30% and less than or equal to 50% and should be used with caution. Data not shown have an RSE greater than 50%.

and burns, at 9.3%, are the third highest cause of fatal injuries, whereas nonfatal home injuries are more likely due to being struck by/against, cut/pierce, or overexertion.

Prevention of Home Injuries

In the next sections, we briefly describe the epidemiology of specific injury causes: sleep-related deaths in infants, fires and burns, falls in children, falls in older adults, and poisoning. We also summarize the evidence supporting selected prevention strategies for each of these causes. **Table 4** lists the prevention strategy, whether the outcomes evaluated are injuries or safety behaviors, and the strength of the evidence according to the definitions presented previously (strong evidence, promising evidence, recommended practice).

SLEEP-RELATED DEATHS IN INFANTS

Who Is at Risk, and How Do These Injuries Occur?

Sleep-related deaths, for the purpose of this section, include sudden unexpected infant death (SUID), accidental suffocation and strangulation in bed (ASSB), sudden infant death syndrome (SIDS), and other unknown causes. Protocols for distinguishing among these deaths are improving; the resulting diagnostic shift may explain the recent decrease in SIDS and the increase in ASSB (86). Unfortunately, strict adherence to classification definitions is not yet universal. Therefore, this section has been framed as sleep-related deaths and not just suffocation.

Sleep-related deaths are higher in nonwhites compared with whites. According to the most recent data, 3,610 SUID occurred in 2010, 15% of all deaths in children younger than one

Table 3 Percentage distribution of causes for nonfatal and fatal home injuries

Cause of injury	Percentage nonfatal, 1997–2001 ^b N = 12,395,864	Percentage fatal, 2000–2008 ^c N = 30,569
Fall	41.2	33.9
Struck by/against	11.8	1.0
Cut/pierce	11.3	0.2
Overexertion	10.2	0.0
Poisoning	5.9	43.1
Natural/environmental	4.7	1.6
Miscellaneous/not elsewhere	4.5	0.9
Unspecified	3.8	0.8
Fire/burn	2.1	9.3
Pedal cyclist, other	1.4	NA ^a
Transport, other	1.1	NA
Machinery	1.0	0.4
Motor vehicle	0.7	NA
Pedestrian, other	0.2	NA
Choking/suffocation	0.1	5.0
Firearm	0.1	1.1
Near-drowning/submersion	<0.1	2.7
Total	100.0	100.0

^aNA, not available^bReference 100^cReference 77

year of age (44). Compared with non-Hispanic whites (0.94 per 100,000 live births), American Indian/Alaska Natives (2.14 per 100,000 live births) and non-Hispanic blacks (1.92 per 100,000 live births) have higher mortality rates (44). The high-risk age group is infants three months and younger (15, 107, 111). Modifiable risk factors include parental smoking (76), maternal alcohol and drug consumption (18), low birth weight or premature birth (79), sleeping in an adult bed (15, 75, 105, 107, 109), soft or excess bedding (87, 98, 105), bed sharing (especially on a couch) (121), and nonsupine sleep position (51, 74).

In the search to understand the cause of SIDS and other sleep-related deaths, Filiano & Kinney (50) offer the “triple risk model,” which posits that death results when risk factors converge from three areas: a vulnerable infant (e.g., premature or low birth weight), outside stressors (e.g., prone sleep position), and a critical development period (e.g., 1–4 months). The exact mechanisms that lead to respiratory and cardiac distress and ultimately death are not yet fully understood. However, the model suggests that interrupting or removing any of the modifiable risk factor areas could be protective of infants during sleep.

Prevention Strategies

National sleep campaign (promising evidence). The American Academy of Pediatrics (AAP) first linked sleep position and infant death in 1992 (122). Owing to the strength of the research demonstrating this association, the AAP and the National Institute of Child Health and Human Development, along with other partners, initiated the Back to Sleep campaign in 1994

Table 4 Prevention strategies for home injuries by type of injury, outcomes studied, and level of evidence

Prevention strategies	Outcomes studied ^a	Level of evidence
Safe sleep		
National Sleep campaign	Injury	Promising
Crib distribution programs	Behavior	Recommended practice
Parent/caregiver education	Behavior	Promising
Health care settings that model safe sleep practices	Behavior	Promising
Fires and burns		
Working smoke alarms	Injury	Strong
Smoke alarm installation and education programs	Behavior	Strong
Residential sprinkler technology	Injury	Strong
Sprinkler mandates for new home construction	Behavior	Promising
Reduced ignition propensity cigarettes	Injury	Promising
Fire escape planning interventions	Behavior	Strong
Interventions for safe storage of matches	Behavior	Recommended practice
Child-resistant cigarette lighters	Injury	Promising
Interventions for safe hot water temperature	Behavior	Strong
Interventions for keeping hot drinks and foods out of reach	Behavior	Recommended practice
Falls (children)		
Mandated redesign of baby walkers	Injury	Promising
Reduction of baby walker possession and use	Behavior	Strong
Stair gate education and distribution	Behavior	Strong
Window guard mandates	Injury	Strong
Falls (older adults)		
Medication review	Falls	Strong
Strength and balance exercise programs	Falls	Strong
Home modification	Falls	Strong
Yearly vision screening	Falls	Promising
Multicomponent interventions	Falls	Strong
Poisoning (children)		
Safe storage of medication away from children	Behavior	Strong
Child-resistant and sublethal dose packaging	Injury	Strong
Poison control centers	Injury	Strong
Poisoning (adults)		
Safe storage, use, and disposal of opioid pain relievers	Behavior	Recommended practice
Control of supply and dispensing of opioid pain relievers	Injury	Promising
Carbon monoxide alarms	Behavior	Recommended practice

^aOutcomes studied were classified as the reduction of injury or falls, or improved injury risk behavior.

(<http://www.nichd.nih.gov/sts/campaign/moments/Pages/default.aspx>). Annual surveys of infant care practices were used to monitor the impact of the campaign; they found that between 1992 and 2001 supine sleep position increased from 13% to 72%, and SIDS rates declined 53%. Since then, rates of supine sleep position seem to have plateaued (123). The Academy strengthened recommendations in 2005 and 2011 to further emphasize supine sleep position and

other environmental factors to protect against sleep-related deaths, such as room sharing but not bed sharing; ensuring a firm sleep surface that is free of soft objects; and avoiding alcohol, illicit drugs, and smoke (122). How best to translate and to disseminate these recommendations so that all babies benefit from safe sleep practices has been studied, albeit not through any randomized controlled trials (RCTs) that we could identify. Results from other types of studies are categorized in **Table 4** and described below.

Crib distribution programs (recommended practice). A review of the literature revealed no examples of evaluated crib distribution programs despite the existence of various programs across the country. Medical societies, government agencies, and safety advocate organizations encourage the use of cribs that meet the newest safety standards (39) or other approved sleep spaces, such as bassinets, playpens, portable cribs, or play yards. Having a safe crib is necessary but insufficient to ensure safe sleep practices: Li (75) reported that a crib was found in homes of 90% of infants who died in Maryland while cosleeping; Brixey (15) found a crib in the home of more than half (55%) of all infant suffocation deaths.

Parent/caregiver education (promising evidence). A review of the literature revealed one RCT to test the best methods for educating parents of newborns about safe sleep. Goetter & Stepans (59) found that using a single nurse educator to review safe sleep education systematically with first-time mothers during the postpartum recovery period compared with usual (nonstandardized) discharge instructions resulted in significantly higher rates of reported supine sleeping during the first week after discharge but no difference 6–7 weeks postpartum. In a quasi-experimental evaluation of a 15-min health educator–led session on safe sleep practices for groups of 3–10 parents attending a Women, Infants and Children clinic, Moon et al. (88) found pre- to posttest improvements in self-reported safe sleep behaviors and knowledge immediately after the session and at six months, when compared with an untreated comparison group, although there was substantial attrition. Using a historical control group, Colson & Joslin (32) found that training nursing staff to deliver safe sleep education prior to discharge resulted in significant increases in reported safe sleep behaviors at the time of the infant’s two-week pediatric visit.

Health care settings model safe sleep (promising evidence). We found two studies that used quality-improvement strategies to enhance safe sleep practices in the hospital setting, one that involved seven hospitals in Michigan (110) and another that focused on a neonatal intensive care unit in Texas (54). Both used nurse in-service trainings, crib audit forms, and parent surveys to measure change, and both found some significant improvements in safe sleep of the infants in the hospital setting.

FIRE AND BURN INJURIES

Who Is at Risk, and How Do These Injuries Occur?

Home fire deaths were at their peak in 1978 with 6,015 deaths, but since 2001 they have ranged between 2,380 and 3,200 (67). Despite the decline, in 2012 a death occurred every 221 minutes and an injury every 41 minutes owing to a fire in the home (67). Various other nonfire events also lead to burn-related death and injury in the home, including contact with electricity, scalding liquids, or hot surfaces. Fire and burn deaths are usually combined because deaths from burns in fires cannot always be distinguished from deaths from toxic smoke or other nonburn causes (1). Injury results either from respiratory distress or thermal injury to the skin. During a house

fire, noxious gases—most notably CO—are released and reduce available oxygen levels, either by consuming the oxygen or by displacing it with these toxicants (93). Thermal injury to the skin, a burn, results when an external heat source raises the temperature of the skin and causes either tissue cell death or charring (68).

Injury and deaths from house fires vary by sex, race, and age. Males compared with females face increased risk: 29% higher risk of death and 16% higher risk of injury. Black individuals compared with whites and Hispanics are at higher risk for home fire deaths. The risk of death is highest among the very old and the very young. Compared with the general population average, children younger than 5 years old are ~1.5 times more likely to die from a residential fire; adults 75 years and older are 3 times more likely; and those 85 years and older are 3.5 times more likely (52). Burns caused by cooking are 50% more likely to occur among young adults ages 20–24 compared with the general population average for all ages (52).

Fire and burn injuries appear to be overrepresented among communities with low education, poverty, and high unemployment. Those who live in older homes (63) and rental properties are at an increased risk for fire and burn injuries (112). Manufactured homes, most especially single detached mobile homes, have been linked to higher fire death rates than other types of one- and two-story family homes (91). Those who live in the Midwest and the South face the highest regional home fire death rates; rural communities compared with suburban and urban areas also have increased risk (52).

Smoking causes most home fire fatalities, and cooking is responsible for the most home fires (3). Other common fire and burn causes are matches and lighters (72, 117), faulty electrical equipment (52), candles, stoves and microwave ovens, wood burning stoves, and fireplaces (47). One study found that kitchen-related items and household electrical appliances combined were responsible for 54% of all burn-related injuries to individuals ages 0–20 (41). Both children and adults have been burned by hot grease from cooking (49) and from soup (96). Water and other liquids that reach temperatures above 125°F can produce a serious burn in less than two minutes; thus setting water heater thermostats to temperatures at or below 120°F is important (113). Other causes of burns to children and adults in the home include friction burns from treadmills (31, 78) and hair curling irons (35). Among older adults with home burn injuries, most occurred in the kitchen or bathroom (43).

Prevention Strategies

Working smoke alarms and installation/education programs (strong evidence). Working, residential smoke alarms are a cost-effective way to reduce fire-related injury, and door-to-door distribution programs are an effective way to get them into homes (45, 97, 120, 126). Kendrick and colleagues' (71) review of home safety education and provision of safety products found 17 studies that promoted smoke alarm use among 5,107 participants. Across the studies, families who received interventions compared with controls were significantly more likely to possess a working smoke alarm [odds ratio (OR) 1.81, 95% confidence interval (CI) 1.30–2.52], and the effect size was generally larger when smoke alarms were provided. The Centers for Disease Control and Prevention (CDC)-sponsored Smoke Alarm Installation and Fire Safety Education program recommends the installation of lithium-battery smoke alarms with a hush feature for high-risk households (6, 64). DiGuseppi and colleagues (46) found that families who had their smoke alarm directly installed were much more likely to have a functioning alarm six months later as compared with families who received a voucher for a free smoke alarm. More recently, Gielen and colleagues reported higher rates of participation in a fire department home-visiting program when community health workers provided advanced notice to residents about the upcoming visits (56).

Residential sprinkler technology (strong evidence) and sprinkler mandates for new home construction (promising evidence). Data have shown that sprinklers reduce fire fatalities by 100% and property damage by 72% (17). The International Residential Code includes a provision for requiring sprinklers in new one- and two-family homes, although some states have adopted laws excluding this provision. Research is still needed to better understand ways to facilitate adoption of residential sprinkler policies across the United States, as well as to encourage retrofitting in existing homes.

Reduced ignition propensity cigarettes (RIPC) (promising evidence). All 50 states have adopted laws requiring all cigarettes sold in their state to be RIPC, known more commonly as fire-safe cigarettes. New York, whose law was effective June 2004, reported experiencing a 35% reduction in fire deaths in the first year the law was enacted. Although it may take a decade to see the full benefits of the legislation on fire-related deaths, one published evaluation demonstrated a 28% reduction in house fires but no statistically significant reduction in injuries (4).

Fire escape planning interventions (strong evidence). Despite recommendations to develop and practice residential fire escape plans so that all household members will know how to react in a house fire, only 52% of homes report having a fire escape plan, and only 16% of them report practicing it every 6 months (7). Remembering When is a program developed by the CDC and the National Fire Protection Association (NFPA) for older adult home safety; two of their eight key fire prevention messages relate to fire escape planning, including developing the plan around the abilities of the older adult and practicing it (94). Kendrick et al.'s 2012 meta-analysis of home safety education and provision of safety equipment included four studies that promoted fire escape plans, and it found that the interventions were successful in increasing the proportion of families with such plans (OR 2.01, 95% CI 1.45–2.77) (71). Although these studies demonstrate changes in behavioral outcomes, we could find no studies of the impact of fire escape planning on injury or death in the event of a fire.

Interventions for safe storage of matches (recommended practice). Using a combination of self-reported and observed definitions of “storing matches out of reach,” six studies were included in Kendrick et al.'s meta-analysis of home safety interventions (71). Analysis revealed a lack of evidence that home safety interventions were effective in achieving this outcome.

Child-resistant cigarette lighters (promising evidence). The Consumer Product Safety Commission (CPSC) safety standard requires that cigarette lighters be inoperable by children younger than age 5; this standard, when applied to national fire loss data, was credited with preventing an estimated 3,300 fires, 100 deaths, 660 injuries, and \$52.5 million in property loss in 1998 (117).

Interventions for safe hot water temperatures (strong evidence). According to Kendrick et al.'s 2012 meta-analysis (71), 16 studies included a safe hot water focus with 3,727 subjects. Although the studies varied in terms of study setting, definition of safe temperature, distribution of thermometers to test water, and follow-up period, families in the home safety intervention arms were significantly more likely to have safe hot water temperatures (OR 1.41, 95% CI 1.07–1.86). Whether having the temperature set at 120°F can effectively reduce scald burns is an open question, and recent data from home observations found substantial discrepancies between the thermostat settings and the actual tap water temperatures (113).

Interventions for keeping hot drinks and food out of reach of children (recommended practice). The six studies on this topic in Kendrick et al.'s review (71) defined "keeping hot food and drinks out of reach" differently, and no statistically significant differences were found between families in the intervention and those in the control groups.

FALLS

Who Is at Risk and How Do These Injuries Happen?

A fall is an event that results in a person coming to rest inadvertently on the ground or on the floor or other low level. Falls can occur on the same level, for example, when an older adult trips or loses his/her balance, and falls can occur from one level to another, for example when a child falls from a window, down the stairs, or off furniture (81, 129). When these events result in the need to seek medical care or are fatal, they are coded as fall injuries. The degree to which an injury results from a fall depends on many factors, most importantly the distance of the fall and the landing surface (9). Shorter distances and more energy-absorbing surfaces typically result in less severe injury. Individual differences in anatomy also affect fall injuries. Bone structure and fat composition affect injury severity and depend in part on the individual's age. For instance, an infant's head is proportionally larger relative to his body than is an adult's, and his bones are still soft. These contribute to making an infant particularly susceptible both to falling over and to suffering head injury as a result (27, 33, 132).

Falls are a leading cause of unintentional morbidity and mortality in the United States (25). Most unintentional fall deaths occur in homes (102). Of all home-related injuries, falls are a leading cause of emergency department visits; children under 18 and adults over 65 are at increased risk (101). Because of the different etiologies and intervention strategies for falls in children and older adults, we examine each age group separately.

Falls in children. Unintentional falls are the number one cause of nonfatal injury for children (23). Most serious falls happen at home (12). In 2010, 127 children in the United States died from a fall-related injury. Boys are at an increased risk for both fatal and nonfatal falls (23). Children of low socioeconomic status and ethnic minorities are at increased risk (12). Falls are also a significant cause of morbidity in children. In 2011, falls accounted for 2.8 million pediatric emergency room visits (23). Children's age, size, and stage of development are all associated with risk. Children under age 4 account for 39% of all fall-related injuries in children (23). Falls down stairs are a significant contributor to falls in the home. Some of the most dangerous falls down stairs involve baby walkers (116). Though less common, falls from windows are particularly dangerous owing to the height of the fall. More than 3,000 children fall from windows annually in the United States (40). Window falls occur more frequently in large urban areas and low-income neighborhoods (33, 119). Another contributor to fall-related injuries in the home is falls from furniture, which result from infants rolling over or older children climbing. Currently, no prevention strategy has been evaluated to reduce the incidence of these injuries, and adequate caregiver supervision is recommended.

Falls in older adults. Falls are a leading cause of morbidity and mortality for older adults (20). Each year ~2.3 million older adults are treated in the hospital for a fall. In 2010, 21,000 older adults died as the result of a fall (25). Beyond the risk of morbidity and mortality, falls are the leading contributor to loss of independence in older adults. Fears of falling and of losing independence contribute to decreased mobility and physical activity in older adults, which in turn increase the risk of falls (13, 106). Falls among older adults are an expensive contributor to health care costs. Using

data from falls in 2010, direct medical costs were estimated to total \$0.2 billion for fatal injuries and \$19 billion for nonfatal injuries (20). Multiple factors contribute to older adult fall risks, including tripping hazards within the home, lack of grab bars in the bathroom, use of medications that can cause dizziness or hypotension, and diminished eyesight and physical strength. The interaction of these risk factors is thought to contribute to an older adult's risk of falling (58, 90).

Prevention Strategies: Children

Mandated redesign of baby walkers (promising evidence). The CPSC has taken the lead to reduce the risk of falls associated with baby walkers by issuing regulations mandating the redesign of the product. The voluntary standard is credited with an 88% reduction in baby walker–associated falls between 1994 and 2008 (38).

Reducing baby walker possession and use (strong evidence). A cluster RCT involving 64 general practices and 1,174 expectant mothers in the United Kingdom sought to evaluate the effectiveness of an educational package in reducing baby walker possession and use. The intervention significantly reduced both possession and use of baby walkers and positively influenced knowledge and attitudes about them (70).

Stair gate education and distribution (strong evidence). Home safety interventions have proven effective at increasing the use of fitted stair gates in homes, which are a recommended practice; the pooled result of 12 studies showed that families participating in home safety observations were 61% more likely to use stair gates than were nonparticipating families (71). These educational interventions have been most effective when combined with a physician recommendation and access to the product through a clinic-based safety center (28). No studies of the impact of increasing the use of stair gates in populations on injury rates were found.

Window guard mandates (strong evidence). Mandating the use of window guards is an example of an effective policy intervention to reduce falls from windows. In response to injury incidence data, the New York City Board of Health passed a law requiring property owners of multiple-story buildings to provide window guards for all dwellings with children under 10 years of age. This effort resulted in a 96% reduction in hospital admissions for falls from windows (99). Window guards are recommended for windows on the first floor over 12 feet high and on all windows above the first story.

Prevention Strategies: Older Adults

Medication review (strong evidence). Medication review by a physician or pharmacist is recommended to minimize interactions of both prescription and over-the-counter medication that may contribute to falls by causing dizziness or changes in blood pressure. Reductions in the rate of falls have been demonstrated with particular attention to psychotropic medication and prescription modification programs (90).

Strength and balance exercise programs (strong evidence). Exercises, such as multiple-component group exercise (16 trials; 3,622 participants) and home exercise (7 trials; 951 participants), significantly reduced the rate of falls. Strength and balance training, particularly tai chi, has been effective in decreasing falls in older adults (6 trials; 1,625 participants). It is important

that programs focus on increasing leg strength and that programs are made more challenging over time (58, 90).

Home modification (strong evidence). Home safety assessment and modification interventions to reduce trip hazards and to install grab bars in bathrooms are recommended and have reduced both the risk (7 trials; 4,051 participants) and rate of falling (6 trials; 4,208 participants) (58).

Yearly vision screening (promising evidence). Vision screening is recommended yearly to maximize vision with particular attention to wearers of multifocal glasses and those in need of cataract surgery (58). The provision of new glasses (single lens distance glasses) for older adults showed a significant reduction of falls among the more physically active subgroup of the intervention group (61).

Multicomponent interventions (strong evidence). Comprehensive interventions incorporating multiple prevention strategies are perhaps the most promising, compared with interventions that focus on only a single strategy. A systematic review examined the effects of multiple interventions to prevent falls in older adults (60) and found that multicomponent interventions that were not tailored to individual risk factors were effective at reducing both the number of people who fell (pooled rate ratio = 0.85, 95% CI 0.80–0.91) as well as their rate of falls (pooled rate ratio = 0.80, 95% CI 0.72–0.89). This review presented the results of 17 trials with 5,034 participants.

POISONING

Who Is at Risk, and How Do These Injuries Happen?

A poison exposure is defined as an ingestion of or contact with a substance that can produce toxic effects (21). In the absence of any universally agreed on definition of a poisoning from either a clinical or epidemiological perspective (34), we define a poisoning as the result of “either a brief or long-term exposure to a chemical agent” that results in physical harm (21). Physical harm can range in severity from mild to fatal, and the physical effects of nonfatal injuries caused by poisonings can be temporary in nature or can result in lifelong disability. The sources of poisonings differ by age group, and here we address common poisonings in children and adults, as well as CO poisoning, which can affect all members of a household.

Among children, 90% of the poisoning exposures occur in the home (22). More than half of all calls to poison control centers are for children younger than six years old (16). Children account for the highest rates of nonfatal poisonings owing to their high exposure to common household products such as personal care products, household cleaners, pesticides, and medications (16). The most common household product associated with a potentially toxic exposure is bleach, and the most common method of exposure is a spray bottle (82). In addition, 150 pesticides that may be used in the home were implicated in calls to poison control centers in a 2-year period (118). Forty percent of pediatric calls to poison control centers resulted from children’s exposure to medications (16), and one study found that medications were involved in almost 60% of pediatric emergency department visits for a poisoning exposure (53). In another study of children younger than 2 years old, the most common types of medications responsible for fatal poisonings were prescription medications for asthma, heart disease, and psychiatric problems (8).

Unintentional poisonings, mostly due to prescription drug overdose, have been rising steadily, and in 2010 they were the leading cause of injury death in the United States for adults ages 25–64 (24). In 2011, 1.4 million adult emergency room visits were attributed to prescription pain

medication misuse and abuse (104). Prescription drugs were associated with more than 22,000 overdose deaths in 2010, 75% of deaths involved opioid pain relievers, and 30% involved benzodiazepines (66). People who died of overdose often had a combination of opioid pain relievers and benzodiazepines in their bodies. The annual cost of prescription medication abuse is estimated at \$57 billion, which includes costs associated with loss of work productivity, criminal justice costs, and health care costs (10).

CO is a colorless, odorless gas produced from the incomplete combustion of carbon-containing substances. In addition to being present during house fires, common sources of CO include wood-burning or gas fireplaces that are improperly vented, car exhaust, and malfunctioning furnaces, gas space heaters, and stoves (134). CO exposure has also occurred during periods of power failure when people use generators that are not properly ventilated. CO is absorbed through the lungs and displaces oxygen in the body. Depending on the amount and duration of exposure to CO, symptoms can range from headache and dizziness to convulsions, loss of consciousness, and, in severe cases, loss of life. Annually, CO exposure results in 400 deaths, 20,000 emergency room visits, and more than 4,000 hospitalizations. Fatality is highest among adults 65 and older (19).

Prevention Strategies: Children

Safe storage of medications away from children (strong evidence). Childproof locks can be installed on cabinets or drawers, or families can use a lock box. Home safety interventions have been effective at increasing the correct storage of household products and medications. A systematic review showed that families participating in home safety interventions were 53% more likely to store medicines safely (13 studies) and 55% more likely to store cleaning products safely (15 studies) than were nonparticipating families (71). We could find no studies demonstrating the relationship between safe storage practices and reduced rates of poisoning or exposures.

Child-resistant packaging and sublethal dose packaging (strong evidence). The United States Poison Prevention Packaging Act of 1970 required certain household chemicals and medicines to be packaged in a way that is difficult for children under age 5 to open. Although this legislation was originally limited to aspirin, other prescription medicines, over-the-counter drug products, and household chemicals have been added over time (11, 124, 36, 37, 128). Utilization of childproof caps on medications has resulted in a decrease in pediatric medication ingestions (83). Limiting the number of tablets per bottle to a nonlethal dose, when combined with improved packaging and education, was successful in reducing deaths from baby aspirin (30).

Poison control centers (strong evidence). In the United States, poison control center staff are available 24 hours per day at an emergency hotline to dispense information and treatment advice. Poison control centers have effectively reduced medical utilization costs due to poisonings (73). Recognizing the importance of poison control centers, the Institute of Medicine (IOM) outlined 12 specific recommendations to improve the system, including that all poison control centers should perform a core set of functions, be better integrated into the public health system, and be supported by sufficient and stable funding to fulfill their mission (34). Miller & Lestina (85) conducted a cost-benefit analysis showing that the average public call to a poison control center prevented \$175 in other medical spending. Overall, data have indicated that the poison control system saves more than \$1.8 billion per year in the United States, reducing costs by avoiding medical utilization, reducing the lengths of hospital stays, and reducing work-loss days (73). Caregivers should be educated about poison control centers so they know what to do in the event of an accidental poisoning. Kelly and colleagues (69) created a nine-minute videotape

(available in both English and Spanish) that improved the knowledge, attitudes, behaviors, and behavioral intentions regarding the use of poison control centers.

Prevention Strategies: Adults

Safe storage, use, and disposal (recommended practice). Increasing attention is being paid to adults' use of opioid pain relievers (OPRs) for the reasons described above. The CDC recommends that patients who are prescribed OPRs be counseled against sharing medications, about proper storage and disposal, and about compliance with use according to the prescribing physician's instructions (22). A nonrandomized pilot intervention demonstrated promising results at improving knowledge around storage and disposal as well as self-reported misuse behaviors at one-month follow-up (80).

Controlling the supply and dispensing of opioid pain relievers (promising evidence). Numerous efforts are under way to control the supply of OPRs and improve physicians' prescribing practices (78, 125, 131). One major initiative undertaken to tackle the supply of OPRs is the state-level prescription drug monitoring program (PDMP), now in effect in nearly every US state. Preliminary evaluations are under way in several states. Early evaluations demonstrate that these programs have been effective at reducing the diversion of controlled substances (29, 42, 89, 133). For example, policy changes in Florida from 2010 to 2012, which resulted in the shutdown of pain clinics and prescribing dispensers statewide, resulted in a significant decrease in deaths resulting from prescription drug overdoses (65). In addition, PDMPs have been credited with improving clinical decision making by providing clinicians with timely information about their patients (5, 48). Other efforts using a computerized decision support system have successfully improved prescribing practices by making patient-specific guidance-based recommendations available in real time during a clinic visit (125).

Carbon monoxide alarms (recommended practice). CO alarms are designed to provide an early warning alerting occupants to when CO accumulates in a home. CO alarms are recommended on each level where people sleep and have been mandated by legislation in some jurisdictions (93). Proper maintenance of potential sources of CO in the home is the best way to avoid CO exposure (93). Proper maintenance includes routine servicing of appliances and ensuring that CO-producing appliances are properly vented. Although no formal evaluations have been completed on the effects of CO alarm distribution programs on health, we know that CO alarms provide the only possible protection from a CO leak in a home. We found no studies that explored the most effective strategies to increase the use of CO alarms in homes.

CONCLUSION

We have demonstrated the extent to which injuries that occur in the home continue to be a significant public health problem across the life span, with particular importance to young children and older adults. Home injury surveillance, intervention development, and evaluation are still hampered by insufficient data. Better data would allow for more in-depth understanding of the myriad factors that contribute to home injuries and better ability to prioritize the development and delivery of evidence-based solutions to the populations that need them.

Even in the absence of adequate surveillance data, research has identified numerous preventive strategies: for instance, supine sleeping for infants, working smoke alarms, residential sprinkler technology, reduced ignition propensity cigarettes, child-resistant packaging of cigarette lighters

and medications, fall prevention programs for older adults. A remaining challenge is to ensure more widespread adoption of proven effective strategies. We need to find effective ways to reach those who do not have access to or do not fully embrace the behavior changes required to utilize the behaviorally focused prevention strategies. Doing so will require putting in place programs that effectively deliver safety products and safety information using evidence-based approaches to health promotion programming (57, 115). We also need to identify effective strategies to increase uptake of the technological and policy strategies that have shown promise (e.g., residential sprinklers and mandates). Public health and injury prevention professionals will need to work with new partners (e.g., home builders and code developers) and learn new advocacy and policy development skills. As this review shows, another challenge is the variability in the outcomes that have been assessed across the various prevention strategies. In some cases, we still need evidence beyond how to change safety behaviors to demonstrate impacts on injuries (e.g., fire escape planning), and in other cases, we need to find effective strategies to increase adoption of proven prevention strategies (e.g., window guards).

The current interest in public health circles in the role of housing in health offers unparalleled opportunities for injury prevention professionals who are concerned with home injuries. Collaborating with our environmental health and healthy housing colleagues is one important approach to reducing home injuries. Their access to homes and ability to influence housing policy can play significant roles in reducing home injuries. Sharing the science of injury prevention (114) with the wide array of professionals who create home environments and who interact with people in their homes (e.g., architects, home builders, home visiting programs, fire and emergency medical service providers) could be a useful approach. As originally recommended in 2004 (100), we believe there continues to be an urgent need for multiple organizations committing to a collaborative national effort to reduce the burden of home injuries in the United States.

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