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To cite this article: David C. Schwebel, W. Douglas Evans, Stephen E. Hoeffler, Barbara L. Marlenga, Simone P. Nguyen, Emil Jovanov, David O. Meltzer & Beverley J. Sheares (2017) Unintentional child poisoning risk: A review of causal factors and prevention studies, *Children's Health Care*, 46:2, 109-130, DOI: [10.1080/02739615.2015.1124775](https://doi.org/10.1080/02739615.2015.1124775)

To link to this article: <https://doi.org/10.1080/02739615.2015.1124775>



Published online: 11 May 2016.



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Unintentional child poisoning risk: A review of causal factors and prevention studies

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ABSTRACT

Unintentional child poisoning represents a significant public health priority in the United States and globally. This article was written to accomplish three goals: (a) outline and discuss a conceptual model of factors that lead to unintentional poisoning incidents among children under 5 years of age, including the roles of individual people, the environment, packaging and labeling of toxic products, and community and society; (b) review published literature concerning interventions designed specifically to reduce unintentional child poisoning; and (c) draw conclusions about what is known and what gaps exist in the current literature on unintentional child poisoning prevention to inform development, evaluation, and implementation of empirically supported, theoretically based prevention programs. The need for multi-faceted, multi-disciplinary, team-based approaches to prevention is emphasized.

Unintentional child poisoning represents a significant public health problem in the United States and globally. Data from the National Center for Injury Prevention and Control, Centers for Disease Control and Prevention (CDC) indicate there were over 36,000 emergency department visits among U.S. children ages 0–4 as a result of unintentional poisoning in 2013, and 35 deaths (NCIPC, 2015). Further, nearly 50% of the 2.4 million people in the United States with poison exposure reported to poison control centers annually are children under 6 years of age (Mowry, Spyker, Cantilena, Bailey, & Ford, 2013). Since not all poison exposures are reported to poison control centers, experts presume those numbers—which total over 1.1 million pediatric exposures annually—are underestimates (Mowry et al., 2013). Epidemiological data from other nations is

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comparable, and often elevated in low- and middle-income nations (National Safety Council, 2015; World Health Organization, 2008).

There are reasons for concern that unintentional child poisoning incidents may grow and that new products may create new risks. For one, consumer product trends such as the increased use of concentrated products to reduce shelf space and an emphasis on attractive (e.g., novel colors) and convenient (e.g., individual laundry/detergent pods) packaging and product forms may increase the likelihood and severity of child poisoning incidents. Second, emerging risks from common products new to the market, such as e-cigarette liquids, laundry pods, edible marijuana products, and caffeinated energy drinks, have received prominent attention and present substantial poisoning risk to young children that did not exist a decade ago. Anecdotal evidence and published scientific research suggest that perhaps national attention to child poisoning prevention has waned in the United States since the initiation of widespread child-resistant cap use following the Poison Prevention Packaging Act of 1970 and the comparatively unsuccessful Mr. Yuk initiative in the 1980s. However, new and innovative breakthrough child poisoning prevention strategies are urgently needed, especially given the advent of new and emerging risks.

We have three goals in this article: (a) outline and discuss a conceptual model of factors that lead to unintentional poisoning incidents among children under 5 years of age; (b) review published literature concerning interventions designed specifically to reduce unintentional child poisoning; and (c) draw conclusions about what is known and what gaps exist in the current literature on unintentional child poisoning prevention to inform development, evaluation, and implementation of empirically supported, theoretically based prevention programs.

Circumstances of unintentional child poisoning

Most child poisoning events occur at home. Recent data suggest 94% of human poisoning events occurred in residences, and over 99% involving young children were unintentional (Mowry et al., 2013). There is evidence of repeat poisoning risk also, with 30% of children under 6 years in one study having repeated poison events (Litovitz, Flagler, Manoguerra, Veltri, & Wright, 1989). The most common substances involved in pediatric poisoning events are cosmetics and personal care products (14%), analgesics (10%), and household cleaning substances (10%), with about 20 other product categories (e.g., vitamins, pesticides, cardiovascular drugs, arts/crafts/office supplies, alcohols) encompassing a wide range of products commonly found and stored in residential homes and leading to 1% or more of pediatric poisoning events (Glenn, 2015; Mowry et al., 2013).

As an example, consider a recent case in Alberta. The parents had illegally imported a pesticide called phosphine to Canada to kill bedbugs. Phosphine pellets were distributed throughout the house but especially concentrated in one bedroom. Possibly disturbed during routine vacuuming, the pesticide released poisonous phosphine gases, which are odorless when pure, into the air. All five of the family's children, believed to be more vulnerable than adults because they played on the floor where the heavy poisonous gas concentrated, were hospitalized with critical injuries. Two of the children died (CBC News, 2015; Ellwand & Klinkenberg, 2015).

Also common is unintentional child poisoning from medicinal and non-medicinal household liquids and solids. Cleaning fluids, fuels, and other products are highly toxic and many can be fatal to children if consumed. Both prescription and over-the-counter medications can be dangerous to young children. Highly publicized recent cases include deadly consumption of laundry pods (Christensen, 2014) and e-cigarette liquids (Jackson, 2014) by children. In the prototypical situation, a toddler is left unsupervised, sometimes asleep. Adults are preoccupied elsewhere in the home and the child discovers something that is appealing, either because of the way it looks or because they have seen adults using it. In some cases, that product has been left accessible on a "temporary" or unintentional basis; in other cases, that may be the product's permanent storage location in the home. In either case, the child consumes the product and is poisoned. The consequences of the poisoning injury depend on a number of factors, including the product's toxicity, the child's weight, the amount of the substance ingested, the adult's response time, and the medical treatment provided.

A conceptual model of pathways to unintentional child poisoning risk

Theorists offer many conceptualizations that apply to understanding causal pathways that may lead to unintentional pediatric poisoning. Among the models proposed are: ecological systems theory (Bronfenbrenner, 1977) which highlights contextual influences of home, school, community, social setting, and culture, and the interactions among them, more recently expressed in the Social Ecological Model of Health (Green & Kreuter, 2005); process analysis (Peterson, Farmer, & Mori, 1987), which emphasizes the behavioral antecedents and consequences of incidents to understand how rewards and motivations influence children and the adults supervising them); the Haddon Matrix (Haddon, 1980), which considers pre-event, event, and post-event factors from an injury prevention perspective; the Safety Hierarchy (Barnett & Brickman, 1986), which illustrates priorities for injury prevention ranging from elimination of the hazard to use of warning signs and training/education; and, the "injury iceberg" model (Hanson et al., 2005), which proposes hierarchical influences on injury risk

beginning at the individual, intrapersonal level and extending to interpersonal influences and then up to community and society influences. In all cases, these theoretical conceptualizations point to multiple contributing factors that together precipitate individual, unintentional child poisoning events. The factors are similar for multiple household hazards, and the causal factors, which range from individual to societal levels, interact and overlap. Successful poisoning prevention approaches must consider multiple aspects of the biopsychosocial pathway that lead to individual poisoning incidents.

Figure 1 applies existing theory to unintentional child poisoning risk and conceptualizes graphically primary factors that precipitate unintentional child poisoning incidents. As it illustrates, poisoning events emerge from combined and interacting influences that range from individual children and adults to societal-level infrastructure, economics, industry, and policy. We

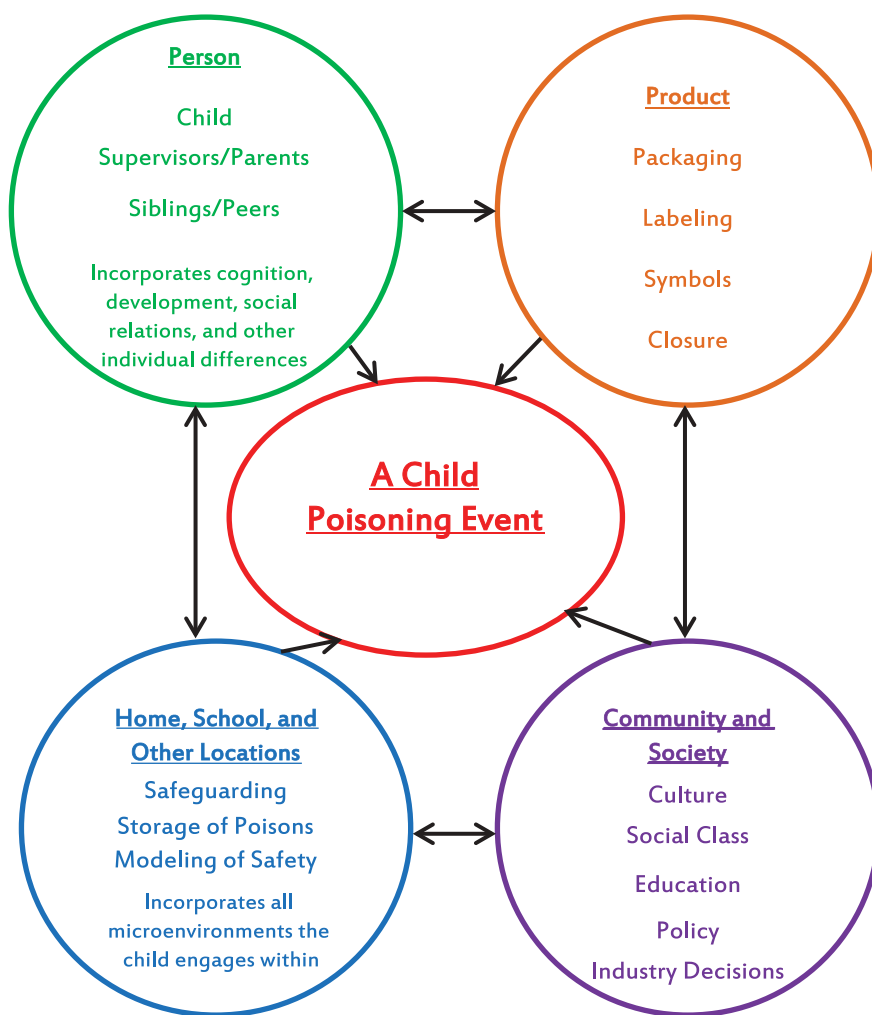


Figure 1. Conceptual model.

conceptualize that not all influences will be present in all poisoning events, but all aspects of the model will contribute to some events. Prevention can occur at multiple levels and locations in the conceptual model. In some cases, prevention efforts may address multiple causal pathways and “block” events by changing circumstances at multiple locations in the model. In other cases, a successful prevention program may focus on just a single pathway.

In the following, we discuss each aspect of the conceptual model by addressing the hypothesized causal factors that lead to unintentional poisoning incidents. Following those discussions, we review the current published literature evaluating interventions specifically targeting unintentional child poisoning prevention and then conclude with a discussion about the implications of both the conceptual model and existing intervention research to develop child poisoning prevention programs that are empirically supported and theoretically based.

The person: Children, supervisors, and siblings/peers

Much has been written about individual differences that influence a child's risk for unintentional injury; among the most prominent risk factors are male gender, impulsive or undercontrolled temperament/personality, externalizing psychopathology, and underdeveloped cognitive capacity (Morrongiello & Schwebel, *in press*; Schwebel & Gaines, 2007). Although the body of research focused specifically on risk for unintentional child poisoning is smaller than that of broad unintentional injury, preliminary evidence, sometimes from samples that include children extending older than age 5, suggests the risk factors for general child injury are true also for child poisoning risk (Brayden, MacLean, Bonfiglio, & Altemeier, 1993; Jawadi & Al-Chetachi, 1994; Petridou et al., 1996; Schmertmann, Williamson, Black, & Wilson, 2013; Soori, 2001).

A child's developmental stage plays a significant role in poisoning risk, with the early years of development representing higher vulnerability than later in childhood (Agran, Winn, Anderson, Trent, & Walton-Haynes, 2001, 2003; NCIPC, 2015). During early development, children experience rapid cognitive, social, perceptual, and physical development. The growth is reasonably predictable and creates elevated risk of poisoning due to the confluence of several developmental milestones. Specifically, children are newly mobile and able to travel from room to room on their own. Children of this age also are naturally curious (Jirout & Klahr, 2012). They want to learn about the world and do so by placing things in their hands and their mouths. They have newly developed fine and gross motor skills and want to test and hone these skills, creating a situation whereby children manipulate and move items and item parts (e.g., lids) they discover and are attracted to. Categorization and symbol recognition skills are developing, allowing children to seek and consume products they believe will taste good. Self-regulation and impulse control are poor, so children may break

rules, underestimate negative consequences, and experiment with unfamiliar items. Teeth are emerging and need soothing. Moreover, a desire for independence leads children to embark on activities without parental assistance. For these reasons, epidemiological data indicate unintentional child poisoning morbidity and mortality is highest during the first 6 years of life and peaks especially dramatically between the ages of about 15 and 30 months, with rates substantially lower both prior to infant mobility (0–12 months) and also following development of more substantial cognitive and motor skills (around 42 or 45 months of age) (Agran et al., 2001, 2003).

In many poisoning events, the child accesses the poison him or herself. In other cases, the child is unknowingly exposed to the poisonous substance. In almost all cases, however, the sphere of individuals a child interacts with contributes to unintentional poisoning risk. For example, parents and other supervising adults play a significant role through their supervision. Experts classify supervision based on attention, proximity, and continuity (Morrongiello, 2005; Saluja et al., 2004); a less attentive, less proximal, or less continuous supervisory situation may elevate risk of unintentional poisoning (Ozanne-Smith, Day, Parsons, Tibballs, & Dobbin, 2001; Petridou et al., 1996; Soori, 2001). Empirical research supports this hypothesis as well. In an elaborate case-control study, for example, Schmertmann and colleagues (2013) found that children who had been poisoned were supervised less carefully by their mothers during risky activities compared to children in control groups. The mothers of children who had been poisoned also reported less parenting stress and more psychological distress.

Peers, siblings, and other children may also play a role in unintentional poisoning risk, both directly through persuasion, bets, or dares and indirectly through modeling and leading. This risk is demonstrated in other injury-risk situations (e.g., risk-taking tasks in laboratory), mostly for older school-aged children (Christensen & Morrongiello, 1997; Morrongiello & Sedore, 2005; Plumert & Schwebel, 1997), and may apply to some unintentional poisoning situations. The influence among younger children like toddlers and preschoolers, who have particular risk for unintentional poisoning, is not yet demonstrated empirically.

The environment: Home, school, and other locations

At least three aspects of the environments children engage within are relevant to unintentional child poisoning risk: where dangerous products are stored, how the environment is safeguarded, and how trusted adults in those settings interact with dangerous products.

Almost half of parents admit that they store cleaning supplies or other poisonous household products in places their 19–30 month old toddlers might reach (Morrongiello & Kiriakou, 2004; Roddy, O'Rourke, & Mena,

2004). It is unclear, however, why parents may store dangerous products within reach of children. Some argue that parents incorrectly assume child-resistant packaging is fool-proof and will always restrict access to young children, and therefore they feel comfortable storing dangerous products with child-resistant packaging within reach of children (Viscusi, 1984). Others suggest parents may simply be apathetic, careless, or even ignorant, storing frequently used, dangerous products in a convenient manner and neglecting to consider the negative consequences that could occur (McKendrick, 1960). A third perspective suggests parents do not perceive high risk from poisons like medications, especially those that are obtained over-the-counter and considered unlikely to cause a serious poisoning event, so therefore do not store them safely (Rosenberg, Wood, Leeds, & Wicks, 2011). No matter what the reason, convincing adults to store poisonous household products in locations where children cannot access them—with recognition that young children have the capacity to climb, reach, and search—is a straightforward prevention mechanism with high efficacy. Also relevant and effective, but not consistently practiced, is safeguarding the home through strategies such as cabinet locks (Gibbs et al., 2005; Kendrick et al., 2008).

Another influence on children's behavior near poisons is how parents model use of poisonous products. Are children present when dangerous cleaning supplies are used? Is use of safety gear such as gloves or eye protection modeled? Do children develop safety habits based on watching their parents engage in safe habits? As an example, consider a parent who consumes opioid medications and then exhibits positive emotions following consumption, as the medication relieves pain. Children could witness the parent's positive affect following consumption, intuit the parent's positive emotions, and then model the behavior to achieve similar positive affect.

The product: Packaging, labeling, closures, and more

Human behavior is malleable and can be altered with proper intervention. However, human behavior is imperfect, and inevitably, unsupervised children will be exposed to poisonous products. When that happens, children must make decisions themselves about whether and how they interact with such products. Those decisions have implications to the child's safety.

Packaging and labeling likely play a role in how children engage with products they encounter (Schneider, 1977; Schwebel, Wells, & Johnston, 2015). There is evidence that children are attracted to brightly colored products and that the shape, size, coloring, and material of products play a role in how children engage with unknown and known products (Schwebel et al., 2015). For example, substantial recent media attention has focused on the frequency and toxicity of pediatric poisoning from laundry (Beuhler, Gala, Wolfe, Meaney, & Henretig, 2013; CDC, 2012; Forrester, 2013; Schneir,

Rentmeester, Clark, & Cantrell, 2013) and dishwasher (Gray & West, 2014) detergent pods. A 2014 report documented over 17,000 exposures to laundry detergent pods among children under age 6 years over the 2 years since the product was introduced into the U.S. market in early 2012. Critics claim laundry pods look remarkably like candy (Valdez et al., 2014).

Implementation of symbols to signify danger to children has been proposed on multiple occasions. Perhaps best known is the Mr. Yuk symbol of a green face sticking out its tongue. Research on the efficacy of Mr. Yuk, as well as alternatives such as a skull and crossbones, generally suggests the symbols are ineffective in signifying danger to young children (Fergusson, Horwood, Beautrais, & Shannon, 1982; Pooley & Fiddick, 2010; Vernberg, Culver-Dickinson, & Spyker, 1984). Experts have suggested the efficacy of alternative symbols that invoke biologically and evolutionary based fears and cautions (LoBue & DeLoache, 2008, 2011; LoBue, Rakison, & DeLoache, 2010), such as a coiled snake (Braden, 1979; Schwebel et al., 2015), but rigorous tests of this hypothesis are not published.

Unlike the situation with labeling, packaging, and symbols, the use of closures that reduce child access to dangerous products is well established and widely implemented. Beginning most dramatically with the passage of the Poison Packaging Prevention Act of 1970, although child-resistant lids are not perfect (federal law in the United States requires them to keep most but not all children from opening the package), there is strong evidence that use of child-resistant lids has reduced child poisoning rates in the United States substantially (Rodgers, 1996; Walton, 1982).

Community and society: Culture, social class, policy, and industry

Ecological models of development point to the influences of culture, social class, and society (e.g., Bronfenbrenner, 1977), and child poisoning risk is inevitably influenced by the broader context within which a child lives. As an example, and corresponding to the broader child injury literature (Schwebel & Brezausek, 2009; Schwebel, Brezausek, Ramey, & Ramey, 2005), in a study along the U.S.–Mexican border, young children in families who were more acculturated into U. S. culture had higher risk of poisoning (Roddy et al., 2004), perhaps due to cultural differences in quality and quantity of parent supervision and the increased presence of cigarettes and other poisonous products in the home of more acculturated families. As another example, the culture and circumstances of low-income non-electrified communities, where kerosene is used broadly, leads to high risk of unintentional poisoning to young children under age 5 from kerosene (e.g., Tshiamo, 2009). Interventions have shown some promise in reducing kerosene poisoning risk, however. For example, as detailed in the following, distribution of kerosene containers with child-resistant lids in a South African community greatly decreased poisoning incidents compared to

a similar community where containers were not distributed (Krug, Ellis, Hay, Mokgabudi, & Robertson, 1994).

Prevention: Current status of the field

Given the multiple factors that contribute to unintentional child poisoning risk, prevention programming is complicated. To evaluate the current status of the field, we conducted a review of the published scientific literature. Searches in PsycINFO and in PubMed were conducted using the keywords ((child or pediatric or paediatric) and poison and (strateg* OR intervention* OR program* OR prevent*)), including suffixes and located in article titles or abstracts for all dates through July 31, 2015. This search yielded 294 potential articles for inclusion; titles and abstracts were reviewed for inclusion, and full manuscripts reviewed if abstracts provided insufficient information. We also followed references in relevant manuscripts and review papers and searched our own personal libraries. We included studies in all languages listed in the databases. Studies of environmental poisoning (e.g., lead poisoning, smoke from house fires) were omitted as were those not reporting quantitative results and those reporting poisoning occurring through medical errors (e.g., in hospital settings). We included both primary and secondary prevention programs.

Our review yielded several manuscripts that incorporated poisoning prevention into broader child injury prevention programs (see Achana et al., 2015; Kendrick et al., 2008, 2012, 2013; Nixon, Spinks, Turner, & McClure, 2004; for reviews). In these cases, the approach focused on multiple injury types in the context of a single prevention program, a valuable strategy but one that may suffer from diminished efficacy to reduce unintentional poisoning risk. We uncovered 18 empirical studies offering quantitative outcome data evaluating prevention programs designed specifically and solely to reduce child poisoning risk (See Table 1). In these cases, the strategy was to focus on reduction of risk from one or more pathways to child poisoning. We review them as follows.

Published first chronologically and representing the progress that has occurred in medical aspects of poisoning prevention, Alpert and Heagarty (1966) evaluated a state-wide campaign to distribute ipecac syrup to Massachusetts families with small children. Ipecac syrup is no longer recommended in secondary poisoning prevention (Krenzelok, McGuigan, & Lheur, 1997; Manoguerra, Cobaugh, & The Members of the Guidelines for the Management of Poisonings Consensus Panel, 2005), but the behavioral aspects of the campaign have contemporary relevance. In the campaign, complimentary ipecac syrup bottles were offered to families via pharmacies following a physician prescription. Publicity was distributed via pharmacists, advertising to medical associations, and mass media (radio, newspaper, television). The campaign was mostly unsuccessful, with inadequate reach and many bottles undistributed.



Table 1. Characteristics of intervention studies included in systematic review.

Author(s), year	Sample	Intervention description	Comparison groups	Outcomes
Alpert & Heagarty, 1966	Statewide in Massachusetts	Distribution of ipecac syrup; media coverage	NA	Survey: pharmacists and physicians; syrup distribution; success was not achieved on any measures 1 week later
Cooper et al., 1988	Statewide in Rhode Island	Distribution of ipecac syrup and poison control information to families of newborns upon discharge after birth	Standard discharge care	Moderate primary and secondary poison prevention benefit among families exposed to intervention
Dancho et al., 2008	15 children ages 3–5	Semi-structured group training on risk of consuming ambiguous substances	NA; pre-post design	No evidence of improved safety post-intervention
Dershewitz et al., 1983	78 parents of 9-month-olds at well-child check-up, U.S.	Pediatrician counseling on ipecac storage and use	NA; pre-post design	Increased knowledge following counseling
Fergusson et al., 1982	1,156 2-year-olds in New Zealand	Parent pamphlets and Mr. Yuk stickers	No poisoning prevention education	No evidence of reduced poisoning risk in intervention group over subsequent year
Lacoutre, Minisci, Gouveia, & Lovejoy, 1978	Population of Wilmington, MA (and nearby control community)	Educational program delivered by multiple parties primarily to grade and junior high school students	Only “standard” statewide poison prevention program	Modest evidence of increased knowledge about poison control in intervention community compared to control
Kelly et al., 2003	289 low-income families with children ages 6 months–6 years at two WIC clinics in San Mateo City, CA	Educational video, pamphlet, and poison control stickers	Regular educational classes on health and immunizations	After 2–4 weeks, improved knowledge, attitudes, behaviors, and behavioral intentions among intervention group compared to control
Kelly et al., 2014	297 low-income parents attending parenting class in Houston, TX area	Educational video including testimonials, handout, and poison control stickers	“Typical” parenting course	After 2–4 weeks, improved knowledge, presence of poison control number, behavioral intention to use poison center among intervention group compared to control
Krenzlok & Garber, 1981	Sub-sample of 30–60 month old preschoolers in Hennepin County, Minnesota	Preschool-based active learning program delivered at school	NA; pre-post design	Increase in knowledge about poisons and poisoning post-intervention

Krug et al., 1994	Large South African residential districts, > 20,000 people	Distribution of child-resistant containers; Poisoning education	Poisoning education only	Poisoning education	Kerosene poisoning rates decreased over next 14 months in intervention district but not control
Liller et al., 1998	378 kindergartners and 3rd graders in Hillsborough County, FL schools	Interactive classroom-based lessons on poison prevention	No-contact control	No-contact control	Increase in most aspects of knowledge about poison prevention
Lovegrove et al., 2013	Children ages 3–4 years in convenient preschools; Atlanta, GA area	Flow restrictor placed on neck of bottle to limit liquid release to suggested dose	Incompletely capped both without flow restrictors	Incompletely capped both without flow restrictors	Children removed less liquid from cap with flow restrictor compared to both controls
Maisel et al., 1967	All children under age 5 years in Charleston County, SC	Community-wide programming including meetings, mass media, signs	NA	NA	Reduced hospitalizations 3 years later; inconsistent results from community survey on storage/accessibility
Scherz, 1968	Children of military personnel served at Madigan General Hospital, WA	Changes in medication size and packaging	NA	NA	Reduced treatment for child poisoning resulting from larger medication and child-resistant caps
Steele & Spyker, 1985	Populations in three locales: Virginia, Massachusetts, and San Diego, CA area	Community-based educational strategies	No education	No education	Modest positive results in knowledge about poison control; no impact on poisoning incidents
Vernberg et al., 1984	20 toddlers ages 12–30 months	5-minute educational training on meaning of Mr. Yuk stickers	No educational training	No educational training	From observation of behavior, trained children interacted more with Mr. Yuk-labeled packages than untrained children
Wolff et al., 1987	202 consecutive referrals with non-urgent condition in Children's Hospital Boston ED	Brief (< 5 min) counsel on poison prevention and treatment; bottle of ipecac; poison control center phone number stickers	Group 1: survey completion pre-intervention; Group 2: none	Group 1: survey completion pre-intervention; Group 2: none	After 4–6 months, increased storage and knowledge about ipecac among intervention group; inconsistent results on other measures
Wolff et al., 1992	301 children ages 0–5 years whose families called poison control center in MA following poisoning incident	Mailed packet with poison prevention information, cabinet lock, ipecac coupon, poison center phone number stickers	No-contact control group	No-contact control group	After 3 months, intervention group used cabinet lock and posted poison control phone number more than control; no difference in ipecac storage or poisoning incidence between groups

Maisel and colleagues (1967) reported the results of a multi-faceted, community-wide poisoning prevention program in the early 1960s. Mass media radio and television announcements, pamphlets and billboards, community meetings, and school-based education were implemented. Efficacy was demonstrated through a reduction in poisoning-related hospitalizations at the local hospital as well as survey data indicating changes in behavior and knowledge about child poisoning risk. Similarly, Scherz (1968) reported success from community-wide interventions on military bases. He shared evidence that changing from smaller pills to larger capsules that were harder for young children to swallow unintentionally reduced poisoning from medications, and that use of child-resistant caps (a prelude to institution of them nationally in the 1970s) was effective in reducing child poisoning rates among military families.

Lacoutre and colleagues (1978) conducted a community-wide intervention in Massachusetts, with poison control information distributed primarily through elementary and junior high schools. Compared to a nearby control community, there was modest increase in knowledge about poison control following the intervention. Krenzelok and Garber (1981) also conducted a school-based intervention, albeit one geared directly to young children in Minnesota preschools. Following exposure to an intervention in the classroom, children ages 30–60 months demonstrated greater knowledge about poisons and poisoning. Steele and Spyker (1985) described three demonstration projects conducted in Massachusetts, California, and Virginia communities. In each case, community-based education on poisoning prevention was conducted and survey data collected. Modest and inconsistent but relatively positive results were reported; in particular, the efforts seemed to improve parent's knowledge about child poisoning risk and their intention to call the poison control center if needed.

Research in the 1980s moved largely from societal- and community-level to individual-level intervention. Fergusson and colleagues (1982) conducted an experimental trial with over 1,000 two-year-olds and their families, half of whom received pamphlets about toddler poisoning risk and a set of Mr. Yuk stickers to place on toxic household products and half of whom received no poisoning prevention education. Families were followed for a year, and results indicated that the intervention had no effect on poisoning risk among children in families exposed to the intervention. A small laboratory-based study confirmed these null findings (Vernberg et al., 1984). Following a five-minute educational session teaching children that Mr. Yuk means “no, do not touch”, 10 toddlers ages 12–30 months were exposed to packages labeled with Mr. Yuk stickers and interacted with them more often than toddlers who did not receive the training.

Dershewitz and colleagues (1983) conducted a small within-subjects pre-post study of 78 parents attending 9-month-old well-child check-ups. During

the visit, pediatricians counseled the parents on how to store and use syrup of ipecac in case of unintentional poisoning. A significant increase in knowledge about ipecac was achieved.

Wolff and colleagues (1987) used a randomized design to test a brief intervention delivered to families with children under age 5 years visiting a children's hospital emergency room with non-urgent symptoms. Those assigned to the intervention group received an intervention lasting less than 5 minutes from health professional staff on poisoning prevention and treatment. They also received a bottle of syrup of ipecac and stickers with the Poison Control Center phone number on them. Those assigned to the control group only answered survey questions. Both groups were followed for 4–6 months and completed a second survey after that time period. A second control group was recruited subsequently to reduce potential bias of answering the survey. The intervention successfully increased knowledge of poisoning prevention and presence of prevention and intervention tools in the home compared to both control groups.

Cooper and colleagues (1988) evaluated the efficacy of distributing syrup of ipecac and poison control information to families of newborns upon discharge after birth. All discharges over 9 months from one hospital in Rhode Island were given the syrup, while discharges from other area hospitals were not. Over a four-month period during which the infants were 3–16 months of age, calls to the Rhode Island Poison Center were tracked and follow-up assessments made of families calling plus control families. Results indicated that the intervention had moderate success in reducing primary and secondary poisoning risk among the families who received it.

Wolff and colleagues (1992) recruited families of children under age 5 years who had called a poison control center following an exposure incident and did not have syrup of ipecac present. Consenting families were randomly assigned to an intervention group that received a mailing consisting of information about child poisoning prevention, cabinet locks, poison control center stickers, and a coupon for syrup of ipecac, or a control group that received nothing. Three months later, all families were followed-up by telephone. The intervention effectively increased use of cabinet locks and posting of poison control center stickers among the intervention group, the two items that were included in the mailed packet. Other behaviors—including presence of syrup of ipecac in the home and recurrence of poisoning incidents—did not differ post-intervention across the two groups.

A study by Krug and colleagues (1994) was the only one in our review based in a low- or middle-income country. Community-based and focused on poisoning from kerosene (called paraffin in South Africa), the program replicated and improved upon early ideas in the United States. It targeted low-income communities where kerosene served as a primary fuel and implemented a clustered random design. Child-resistant containers for kerosene storage were distributed to 20,000 households in one district but not to

the control district. Both communities received education about poisoning prevention. Following the intervention, kerosene poisoning rates were monitored in each area for 14 months and discovered to decrease sharply in the intervention district but not in the control district. The authors conclude that kerosene be sold and stored in containers with child-resistant caps.

In the late 1990s and into the 2000s, researchers began evaluating broader and wider-ranging techniques to reduce pediatric poisoning risk, often with more sophisticated research designs and data analysis strategies. Liller and colleagues (1998), for example, evaluated a school-based poison prevention training program used in Hillsborough County, Florida kindergarten and third grades. The 40-minute program, which varied for the 2 grade levels, generally used interactive lessons to teach developmentally appropriate poison prevention strategies and lessons in a classroom setting. A clustered trial evaluated the outcome via a knowledge-based questionnaire administered to children in six schools, three control and three experimental, and found that children learned most but not all of the information taught.

Kelly and colleagues (2003) recruited a sample of 289 low-income, predominantly Spanish-speaking families in Northern California and randomly assigned them to an intervention consisting of viewing an educational video on the poison control centers and receiving a pamphlet on poison control centers and stickers with the relevant phone numbers or a control group that received education on nutrition and immunizations. The intervention, which included poison victim testimonials and emotion-producing footage, was highly successful in changing knowledge, attitudes, behaviors (posting of poison control stickers in home), and behavioral intentions among the group exposed to it compared to those not exposed to it.

Using behavior analysis strategies, Dancho, Thompson, and Rhoades (2008) exposed 15 children ages 3–5 to a “baited” situation where they were given a snack and left alone for five minutes while being monitored through a one-way window. During that time, two containers were left on the table that contained ambiguous but appealing substances that might represent poison. Following that baseline assessment, the children were given group training about the risks of consuming ambiguous substances and then exposed to a series of various covert observations with potential poisonous substances present. The intervention failed to produce safer behaviors in the sample.

A study by Lovegrove and colleagues (2013) evaluated the role of product closures to reduce poisoning risk from liquid medications. A randomized trial was conducted comparing 3- and 4-year-old children’s ability to remove a tasty liquid from either an uncapped bottle equipped with a flow restrictor, a capped bottle without a flow restrictor, or an incompletely closed bottle with a cap without a flow restrictor. The flow restrictor was successful in reducing the amount of liquid consumed by children compared to both control bottles.

Finally, a randomized controlled trial by Kelly and colleagues (2014) evaluated a video designed to teach parents about the function, qualifications, and services of poison centers and their personnel. The video, delivered in both Spanish and English, incorporated testimonials featuring diverse actors discussing the benefits of calling poison centers. In a randomized controlled trial delivered to parenting courses serving low-income families, participants randomly assigned to view the video showed significant increases in knowledge about poison centers, storage of the poison center number at home, and intention to use the poison center if needed compared to a control group exposed only to “typical” parenting courses.

In summary, a range of intervention programs have targeted poisoning prevention in young children. Early work focused on community- and state-wide programs and produced inconsistent results. In the 1980s and 1990s, several individual-level interventions were evaluated. Mr. Yuk stickers were demonstrated ineffective, but other programs successfully increased parental knowledge about poisoning safety and distributed safety devices and phone numbers that were used when provided at no cost. As the field matured, a wide range of interventions have been evaluated. Several studies were more closely grounded in behavior change theory, for example using emotion-arousing testimonial videos to educate parents as well as distributing poison control phone number stickers (Kelly et al., 2003, 2014), while others used applied behavior analysis techniques (Dancho et al., 2008) or evaluated engineering manipulations to reduce poisoning risk (Lovegrove et al., 2013).

Prevention: Future directions

Poison prevention programs have successfully increased parental knowledge about poison prevention and treatment. Increased use of primary and secondary prevention devices (e.g., poison control stickers, cabinet locks, ipecac storage) has been accomplished only through free distribution of those devices. Children’s knowledge about poisoning has increased through intervention, but no program to date has successfully reduced children’s behavior around poisons, and few have attempted to do so. No program has been successful in accomplishing significant and pervasive change on the part of adult supervisors. Passive interventions driven by policy and/or engineering, such as use of child-resistant containers, have been demonstrated effective (Walton, 1982).

Taken together, we might conclude from our review that some effective poison prevention strategies exist but that the field faces significant challenge in developing, evaluating, and then implementing strategies that target the multiples spheres of influence on individual unintentional poisoning events. The conceptual model pictured in Figure 1, combined with existing empirical evidence and on-going research (e.g., Majsak-Newman et al., 2014), offers direction for what successful prevention programs might look like in the future.

Child-focused prevention programs

Efforts to prevent unintentional child poisoning by educating the child him/herself are challenging, largely because of the developmental barriers to learning complex cognitive lessons. An 18-month-old is unlikely to understand cause-and-effect of how poison consumption may lead to a permanent death, for example, no matter what lessons are offered (Nguyen & Gelman, 2002). Instead, teaching of basic rules (only play with toys; only eat/drink what an adult gives you) may be more fruitful.

Parent-focused prevention programs

Attempts to improve parental supervision in the home are urgently needed—research indicates parents have a poor understanding of poisoning prevention strategies (Gutierrez, Negrón, & García-Fragoso, 2011)—but such attempts are few and unsuccessful in the published literature (Kendrick et al., 2008). Experts argue alternative means of unintentional poisoning prevention (e.g., labeling and packaging design, regulatory changes) are likely to be much more fruitful than increasing quantity or quality of parental supervision (Ozanne-Smith et al., 2001).

Beyond supervision, the challenge of reaching parents with messages that might improve their children's safety via environmental change is well documented in the health behavior change literature (e.g., Gielen & Sleet, 2003; Schwarzer, 2008). Once parents are reached, efforts to provide free or low-cost products such as poison control number stickers can be successful (Cooper et al., 1988; Kelly et al., 2014; Wolff et al., 1992), but efforts to change parental habits are more challenging (Gibbs et al., 2005). For these reasons, and in line with health behavior change theory, among the strategies that may effectively help individuals engage in healthier behavior patterns are increased self-efficacy, changes in perceived susceptibility and vulnerability and removal of perceived barriers to change (Bandura, 2004; Strecher, DeVellis, Becker, & Rosenstock, 1986).

Product manufacturing and packaging prevention programs

Careful consideration and alteration of how toxic products are packaged, labeled, and closed is likely to yield reduced risk of poisoning (Lovegrove et al., 2013; Walton, 1982). Also likely to be effective is reducing toxicity of products. The burden of such consideration falls largely on industry and must be balanced with profit-driven decisions such as manufacturing costs, shipping costs, and commercial appeal. An example of an industry-level decision designed to reduce poisoning risk was the voluntary agreement by the pressure-treated wood industry to stop using toxic arsenic compounds in their products designed for residential and playground use beginning in 2003 (Hsueh, 2012).

Also relevant is policymaking. Government bodies require safe packaging, and the implementation of the Poison Packaging Prevention Act of 1970 is estimated to have prevented hundreds of thousands of unintentional ingestions, and hundreds of lives since its institution (Rodgers, 1996; Walton, 1982). New legislation has potential to extend such success and protect public health dramatically, as in the case of policy to set safety standards for liquid detergent pods and e-cigarettes.

Multi-faceted and multi-disciplinary prevention programs

Ultimately, successful multi-faceted prevention programs are needed that address multiple contributing factors that together precipitate individual unintentional child poisoning events. As depicted in [Figure 1](#), these factors, which range from individual to societal levels, are interacting and overlapping, and the most successful prevention programs are likely to intercede at multiple causal pathways. To create such programs, experts from multiple disciplines must collaborate. As an example, engineers might consult with behavioral scientists to consider new strategies for child-resistant containers that improve upon existing technology. Child poisoning remains a vexing public health problem, but with multi-disciplinary expertise developing multi-faceted interventions that address the varying causal factors for child poisoning incidents, society may achieve continuing reduction in the burden of poisoning on pediatric health.

Conclusions

As depicted in [Figure 1](#), there are multiple pathways to each child poisoning event. Successful prevention efforts are achievable. They require multi-faceted and multi-disciplinary efforts to discover effective prevention strategies, nimble implementation of effective programs, and attention to cost-efficiency for consumers, manufacturers, and government bodies. The effort must be team based and interdisciplinary.

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