

# Pediatric Firearm-Related Injuries in the United States

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## ABSTRACT

Pediatric firearm-related deaths and injuries are a national public health crisis. In this Special Review Article, we characterize the epidemiology of firearm-related injuries in the United States and discuss public health programs, the role of pediatricians, and legislative efforts to address this health crisis. Firearm-related injuries are leading causes of unintentional injury deaths in children and adolescents. Children are more likely to be victims of unintentional injuries, the majority of which occur in the home, and adolescents are more likely to suffer from intentional injuries due to either assault or suicide attempts. Guns are present in 18% to 64% of US households, with significant variability by geographic region. Almost 40% of parents erroneously believe their children are unaware of the storage location of household guns, and 22% of parents wrongly believe that their children have never handled household guns. Public health interventions to increase firearm safety have demonstrated varying results, but the most effective programs have provided free gun safety devices to families. Pediatricians should continue working to reduce gun violence by asking patients and their families about firearm access, encouraging safe storage, and supporting firearm-related injury prevention research. Pediatricians should also play a role in educating trainees about gun violence. From a legislative perspective, universal background checks have been shown to decrease firearm homicides across all ages, and child safety laws have been shown to decrease unintentional firearm deaths and suicide deaths in youth. A collective, data-driven public health approach is crucial to halt the epidemic of pediatric firearm-related injury.

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Firearm-related injuries and fatalities are a dangerous reality for children and adolescents in the United States. The firearm-related fatality rate is 49 times higher for 15- to 24-year-olds in the United States than in other high-income countries.<sup>1</sup> Globally, 9 out of 10 children <15 years of age killed by firearms reside in the United States.<sup>1</sup> Data from the Centers for Disease Control and Prevention (CDC) reveal that firearm-related injuries are leading causes of injury deaths in youth.<sup>2</sup> Homicide by firearms is the fourth leading cause of injury death in 5- to 9-year-olds and 10- to 14-year-olds and the second leading cause in 15- to 19-year-olds. In addition, suicide by firearm ranks as the third most common cause of death in children 10 to 14 and 15 to 19 years of age.<sup>2</sup> Across all ages, in 2014 firearm injuries were responsible for the same number of deaths in the United States as motor vehicle crashes.<sup>3</sup>

The morbidity, mortality, and financial costs of firearm-related violence demonstrate why guns have become a public health issue. The rate of firearm-related injuries in the United States has remained stable since the 1990s, whereas this rate in other countries has decreased during the same time period.<sup>4</sup> Firearm-related injuries were responsible for >35 000 deaths (all ages, 2015 data) in the United States, and the medical cost of treating firearm-related injuries in children and young adults <21 years old was >\$330 million (2010 cost data)<sup>2</sup> (Table 1). This review discusses the available evidence on the epidemiology of firearm-related injuries in pediatrics and the public health interventions,

the role of pediatricians, and the impact of legislation.

## PEDIATRIC FIREARM-RELATED INJURIES AND HEALTH CARE UTILIZATION

In 2015, there were 4500 deaths from firearm violence in children and young adults <21 years of age.<sup>2</sup> Firearm-related mortality is one of the top 4 causes of death in American youth.<sup>2</sup> In pediatric firearm injuries presenting to US emergency departments (EDs) or ambulatory care centers from 2001 to 2010, one-third were related to homicide or suicide, but the majority of firearm-related injuries were unintentional or accidental injuries.<sup>5</sup> Younger children are more likely to be unintentionally injured, and the majority of these accidental shootings occur in the home.<sup>6</sup> Homicide and suicide by firearms are the second and third leading causes of death, respectively, for adolescents 15 to 19 years of age.<sup>2</sup>

EDs are an important point of entry into the health care system for victims of firearm-related injuries. Approximately 20 000 children present for care to the ED for firearm-related injuries every year.<sup>5</sup> Children <12 years of age account for 10% of all firearm-related ED visits by children and adolescents, and those 12 to 19 years of age account for the remaining 90%.<sup>5</sup> For every child killed, a substantially greater number are seriously injured, and ~50% of children hospitalized for a firearm-related injury are discharged from the hospital with a disability.<sup>7</sup>

Pediatric ED evaluations and hospitalizations due to firearm-related injuries are a health care and financial

burden.<sup>5</sup> Hospitalization data from the Agency for Healthcare Research and Quality Healthcare Cost and Utilization Project Kids' Inpatient Database revealed that there were >7000 hospitalizations for firearm-related injuries in US children and adolescents in 2009.<sup>8</sup> On average, 20 US children and adolescents were hospitalized each day for firearm-related injuries. Hospitalizations due to injuries from assault were the most frequent (61.7%), whereas hospitalizations due to suicide attempt were infrequent (3.7%). In children <10 years of age, hospitalization due to unintentional firearm injuries was most common (74.2%); in contrast, in adolescents (ages 15–19 years), the majority of hospitalizations were related to assault (66.8%).<sup>8</sup>

## FIREARM ACCESS IN CHILDREN AND ADOLESCENTS

An understanding of routes of firearm access in the pediatric population is important to help guide interventions. Surveys conducted in different parts of the United States demonstrate significant variability in firearm ownership among families with children.<sup>9–11</sup> In a survey of 424 parents of children 4 to 12 years of age in suburban areas by Atlanta, Georgia, >25% of parents reported having firearms in their homes; however, <50% reported storing them safely.<sup>10</sup> In another survey of 314 families with children 5 to 14 years of age in rural Alabama, 64% reported the presence of ≥1 firearm in the home.<sup>11</sup> In a larger survey of >5000 fifth-graders and their caregivers from 3 different US metropolitan areas (conducted 2004–2006), 18% of surveyed families reported firearms in their homes.<sup>9</sup> According to that survey,

**TABLE 1** Total Medical Cost and Number of Nonfatal and Fatal Firearm Injuries for Ages 0–21 in the United States, 2010

	Unintentional, Cost (No.)	Other Assault, Cost (No.)	Self-Harm, Cost (No.)	Total, Cost (No.)
ED treat and release (nonfatal)	\$4 893 000 (2513)	\$28 249 000 (9837)	\$63 000 (23)	\$34 204 000 (12 374)
Hospitalization (nonfatal)	\$23 312 000 (1316)	\$205 791 000 (9074)	\$25 458 000 (571)	\$254 561 000 (10 962)
Death (fatal)	\$2 152 000 (166)	\$33 168 000 (2894) <sup>a</sup>	\$6 560 000 (1218) <sup>b</sup>	\$41 881 000 (4 278)
Total				\$330 646 000

Cost expressed in 2010 US prices. Source: National Center for Injury Prevention and Control, CDC, National Center for Health Statistics, National Vital Statistics System.

<sup>a</sup> Includes homicide, undetermined, and legal intervention categories.

<sup>b</sup> Includes suicide category.

families with African American and Hispanic children had lower odds of firearm ownership than families of non-Hispanic white children, and only 6% of families with firearms stored firearms safely (locked, unassembled, with trigger locks, and with ammunition locked up). Families of non-Hispanic white children were less likely than families with African American children to engage in safer storage practices. Protection from crime and hunting were reported as the most common reasons for ownership.<sup>9</sup>

A few surveys have also reported on the behavior of young children who encounter household guns. In 1 survey, when asked what their child would do if he or she encountered a gun, nearly 75% of parents reported that the child would not touch the gun.<sup>10</sup> However, in another observational study of gun behavior among school-age boys, the majority of the boys handled a gun after discovering it hidden in a drawer, and almost 50% pulled the trigger.<sup>12</sup> In another study, 73% of children <10 years old living in homes with guns reported knowing the location of their parents' firearms, and 36% admitted they had handled the weapons.<sup>11</sup> Of note, 39% of parents from that study who reported that their children did not know the storage location of household guns and 22% of parents who reported that their children had never handled a household gun were contradicted by their child's report. These studies reinforce the need for safe storage practices for household guns and the need for parents to talk to their children about firearms.

The 2011 National Youth Risk Behavior Surveillance reported that ~5% of students in grades 9 through 12 had carried a gun in the past month.<sup>13</sup> Furthermore, a recent survey of >3000 high school seniors found that 65% reported having  $\geq 1$  gun in their household. The likelihood of gun ownership was higher among white men and boys, and gun access was not associated with mental health status.<sup>14</sup> There have been few studies evaluating screening practices and firearm access among adolescents in the health care setting. One study of pediatric residents from various residency programs found that only 50% reported screening for

firearm access during routine adolescent health visits.<sup>15</sup> An ED-based survey that enrolled 300 adolescents presenting for care regardless of presenting complaint found that 16% reported having a gun in their home, and 28% stated they could access a loaded gun within 3 hours.<sup>16</sup> Furthermore, >50% of adolescents screened for firearm access stated that they had a friend or relative who owned a gun, and almost 50% reported that they knew someone who had previously been shot.<sup>16</sup> Interestingly, a study evaluating differences in firearm accessibility between patients in the ED who presented for violence-related injuries and non-violence-related concerns found no difference in access to firearms between the 2 groups.<sup>17</sup> Given the high prevalence of firearm access among adolescents, universal screening for access to firearms in adolescents may be a beneficial strategy.

## INTERVENTIONS TO IMPROVE FIREARM SAFETY

Firearms are common in US households with children, and some studies have shown that counseling parents can improve gun safety in the home.<sup>18,19</sup> Most families are willing to discuss gun safety with health care providers,<sup>20</sup> and counseling by health care providers results in safer storage practices in the home.<sup>21</sup> Interventions targeting counseling can take place in the ED, outpatient, or inpatient settings, and Tables 2 and 3 describe interventions focused on improving gun safety. Table 2 describes 6 studies with positive impact on increased gun safety in the home, and Table 3 describes 7 studies with null findings. Of note, 3 of the 6 interventions with positive findings provided free gun safety devices (locks or cabinets) to families, whereas the null studies involved interventions focused on verbal and written counseling for firearm safety.

Many ED-based public health interventions have capitalized on the notion of a "teachable moment," or an event that motivates people to adopt risk-reducing behaviors. In a random sample of emergency physicians, the majority surveyed did not believe that their patients would be receptive to firearm safety

counseling.<sup>22</sup> However, studies demonstrate that parents who are advised by ED clinicians or mental health clinicians to restrict access to firearms after a child presents with a mental health concern are more likely to do so than parents who are not advised to restrict access.<sup>23,24</sup> Furthermore, several ED and inpatient-instituted youth violence intervention and counseling programs have been successful in decreasing the frequency of violent aggression and criminal justice involvement.<sup>25-27</sup>

Community and clinic-based interventions have also been successful at improving firearm safety. Table 2, adapted from a systematic review that analyzed community and clinic-based studies examining safe firearm storage interventions,<sup>28</sup> describes a few of these studies. Barkin et al<sup>21</sup> conducted a large cluster randomized controlled multicenter study via the Pediatric Research in Office Settings network to analyze the efficacy of office-based counseling focused on violence prevention, specifically media use, corporal punishment, and firearm access. These authors highlighted health care clinicians' struggles with their role in addressing violence prevention, specifically lack of time, inadequate training, and uncertainty of impact. In response, the investigators conducted a study to compare a bundle of interventions focusing on violence prevention with usual care. The interventions included the use of a previsit summary by parents to assess behaviors and concerns about media use, discipline strategies, and children's exposure to firearms; brief motivational interviewing by clinicians; the provision of tangible tools for parents (ie, gun cable locks); and referral to local agencies for behavioral or aggression concerns.<sup>21</sup> The authors reported that the odds of storing all firearms with a gun lock in the intervention group was twice that of the nonintervention group.<sup>21</sup> In addition, investigations by Carbone et al<sup>29</sup> and Grossman et al<sup>30</sup> reported increased gun safety after family education and provision of gun safety devices. Interventions in high-risk populations (eg, children with mental health disorders or families who own guns) by Kruesi et al,<sup>23</sup> Albright and Burge,<sup>31</sup> and

**TABLE 2** Studied Interventions With Positive Findings (ie, Improved Gun Safety)

First Author, Year	Study Design	Study Setting	Study Population	Intervention Group	Results	Limitations	Key Conclusions
Kruesi, 1999 <sup>23</sup>	Quasiexperimental	Midwest rural ED, Illinois	Parents of 6- to 19-y-old patients seen in the ED for a mental health assessment	Means restriction verbal counseling to limit access to lethal weapons targeting parents of youth at risk for suicide ( $n = 41$ )	Increased likelihood of locking up or disposing of firearms in those who had guns in the home 0 of 7 control, 5 of 8 intervention ( $P < .05$ )	Not randomized, small sample size, self-reported data	Means restriction counseling delivered to parents of children seen for mental health assessment in an ED may increase likelihood of decreasing access to firearms.
Albright, 2003 <sup>51</sup>	Quasiexperimental (3-arm)	Family practice clinic, urban community-based, university affiliated teaching clinic, Texas	Adult patients or families of children attending clinic visits (mostly female and Hispanic); restricted to gun owners	Group 1: survey and verbal counseling ( $n = 36$ ) Group 2: survey, verbal counseling, and written counseling ( $n = 52$ )	Made safe changes: 31% control, 64% group 1, 58% group 2 ( $P = .02$ ) Made an unsafe change: 31% control, 22% group 1, 31% group 2 ( $P = .09$ )	Not randomized, small sample size	Office-based verbal counseling with or without written materials improved safe firearm storage habits.
Carbone, 2005 <sup>28</sup>	Quasiexperimental	Pediatric clinic, urban community health center, Arizona	Families at clinic visits (mostly Hispanic); restricted to gun owners	Physician-delivered 1- to 2-min verbal counseling, gun safety brochure, and free gun lock ( $n = 73$ families)	Improvement in gun safety practices: 27% control, 62% intervention ( $P < .001$ ) Improvement in gun safe storage: 12% control, 51% intervention ( $P < .001$ )	Time series design, small sample size, self-reported data, social desirability bias	Office-based safe storage counseling with written materials and a free gun lock led to significant improvements in safe gun storage behaviors (but not removal of firearms from home).
Barkin, 2008 <sup>21</sup>	Randomized controlled trial	Pediatric clinics in 41 US states, Canada, and Puerto Rico participating in practice-based research network of the AAP	Families of children 2–11 y old for well child visit Safe firearm outcomes only analyzed by gun owners	Physician-delivered counseling using motivational interviewing with provision of free cable locks ( $n = 68$ practices, 470 families)	Using firearm cable locks at 1 mo: 59% control, 64% intervention ( $P = .006$ ) Using firearm cable locks at 6 mo: 54% control, 68% intervention ( $P < .001$ )	Self-reported data	Office-based counseling with provision of free cable firearm locks significantly increased safe firearm storage in firearm-owning families.
Grossman, 2012 <sup>30</sup>	Randomized controlled trial	6 villages in 2 regions, Alaska	Gun-owning households with no operational gun safe for storage	Stepped wedge design in 2 phases (early vs late), installation of a free metal gun cabinet with verbal and written instructions on use, and safety message about safe storage of guns and ammunition (early $n = 129$ , late = 126)	Report both gun and ammunition unlocked at 12 and 18 mo: 23% control, 78% intervention ( $P < .001$ )	Lack of generalizability of the intervention and results to other settings and populations	Community-based intervention to install gun cabinets along with verbal and written safety messages increased safe firearm storage practices.
Zatzick, 2014 <sup>32</sup>	Randomized controlled trial	Inpatient setting in a level 1 trauma center, Washington	Inpatient adolescents (12–18 y old) hospitalized for both intentional and unintentional injuries	Stepped collaborative care intervention including motivational interviewing targeting risk behavior and substance abuse, and cognitive-behavioral therapy targeting PTSD and depression ( $n = 59$ )	Collaborative care intervention: Patients had reduced weapon carrying at 1 y 21% control, 7% intervention, odds ratio = 0.31 (95% confidence interval, 0.11–0.9)	Primary outcome was not specific to carrying weapons, but the study did include weapon carrying at 1 y as a secondary outcome; small sample.	Stepped collaborative care intervention for assault-injured teens reduced likelihood of carrying a weapon at 1 y.

Table adapted from Rowhani-Rahbar et al.<sup>28</sup> and Roszko et al.<sup>61</sup> AAP, American Academy of Pediatrics; PTSD, posttraumatic stress disorder.

**TABLE 3** Studied Interventions With Null Findings (ie, Did Not Improve Gun Safety)

First Author, Year	Study Design	Study Setting	Study Population	Intervention Group	Results	Limitations	Key Conclusions
Oatis, 1999 <sup>62</sup>	Quasiexperimental	Midwest urban pediatric clinic, Ohio	Parents of pediatric patients (median age 2 y, range 0–17 y) seen for annual school physical clinic visit	Clinician-delivered verbal and written counseling on firearm safety ( <i>n</i> = 1617, 381 with complete follow-up data)	No change in prevalence of guns in the home, guns stored unlocked or guns loaded	Self-reported, low follow-up rate, underpowered	Office-based clinician-delivered verbal and written counseling on firearm safety did not improve safe storage of firearms.
Brent, 2000 <sup>63</sup>	Quasiexperimental	Psychiatry clinic, Pennsylvania	Parents and families of adolescents with diagnosis of major depression	Repeated firm recommendations by provider to remove guns for parents reporting firearms in the home ( <i>n</i> = 29)	No difference in families of depressed teens who removed guns from home	Small sample size, post hoc analysis, not standardized intervention, self-report, social desirability bias	In a high-risk group of parents of teens receiving psychotherapy for depression, the majority did not comply with office-based provider's verbal recommendations to remove firearms from the home.
Grossman, 2000 <sup>64</sup>	Randomized controlled trial	9 urban and suburban family medicine and pediatric practices, Washington	Families of children 2 mo–18 y old for well child visit	Practitioner-delivered verbal and written gun safety counseling, with coupons for obtaining discounted trigger locks and lockboxes for firearm-owning families ( <i>n</i> = 309), counseling to not acquire a gun for non-gun-owning families	No difference in firearm acquisition between groups, rates of firearm removal, or rates of purchase of firearm safety equipment among firearm owners	Difficulty assessing whether intervention was delivered, self-reported outcomes, not a validated questionnaire	Office-based practitioner's verbal and written counseling along with coupons for safety devices did not improve safe storage or removal of firearms from homes.
Stevens, 2002 <sup>65</sup>	Randomized controlled trial	12 pediatric clinics, mostly rural New England	Gun-owning and non-gun-owning families of fifth- and sixth-graders seen for well child visits	Practitioner-delivered counseling on safety, including gun safety, clinic support, and written materials ( <i>n</i> = 6 practices)	No difference in safe storage of guns at 12, 24, or 36 mo	Multiple-injury prevention intervention, self-reported outcomes, low baseline report rate of gun ownership	Office-based counseling with long-term reinforcement did not improve safe storage of guns.
Johnston, 2002 <sup>66</sup>	Randomized controlled trial	Urban level 1 trauma center pediatric ED Pacific NW, Washington	12- to 20-y-old medically stable and cognitively able patients presenting with an injury	20-min behavior change counseling by a trained therapist regarding injury risk behaviors ( <i>n</i> = 318)	No difference in likelihood to carry a weapon at 3 and 6 mo	Intervention targeting multiple risky behaviors, low baseline rates, secondary outcome self-reported data	ED-based behavior change counseling for adolescents seen for injury on overall injury risk reduction does not reduce the likelihood of carrying a weapon.

Zatzick et al<sup>32</sup> showed increased gun safety through verbal or written counseling alone. Although the heterogeneity of these studies makes some conclusions difficult, 3 of these studies provided free safe firearm storage devices to participants. This finding suggests that combining both counseling interventions with provision of free safe storage devices may be a successful method by which to increase the safe storage of firearms.<sup>28</sup> Table 3 describes interventions that focused on verbal and written counseling and 1 that provided coupons for discounts on gun safety devices; none of these studies demonstrated significant changes in gun safety practices. More studies in this area are necessary to better understand why some interventions work in certain settings and others fail to improve firearm safety in the homes with children.

The interventions above targeted parents and caregivers rather than the children themselves. Although programs designed to educate children and adolescents on firearm safety exist, these programs have failed to demonstrate a reduction in risky behaviors.<sup>33,34</sup> One explanation for the lack of efficacy is that these programs focus on gun safety instruction but not behavioral skills. The National Rifle Association sponsored a program to instruct children on gun safety; however, a 2004 study showed that although children in this program were able to talk about gun safety, they failed to demonstrate gun safety in a simulation exercise.<sup>35</sup> The risk of these programs is that by relying on a child's verbal report of gun safety knowledge, parents may overestimate their child's understanding of gun safety in practice.

Although the previously mentioned studies were conducted mainly in ED, outpatient, or community settings, to our knowledge interventions related to firearm safety have yet to be studied in the inpatient setting. As with other educational initiatives in the inpatient setting, such as smoking cessation,<sup>35,36</sup> hospitalists often have different availability of time and resources to engage patients and caregivers on topics such as gun safety. Given the results of studies conducted in the outpatient setting, an effective inpatient intervention would

include verbal and written counseling coupled with the provision of safe storage devices.

## **ROLE OF PEDIATRICIANS IN CURTAILING FIREARM-RELATED INJURIES**

The American Academy of Pediatrics (AAP) strongly supports the prevention of firearm-related injuries with an emphasis on safety counseling during routine health maintenance visits, reduced access, safe storage, and stronger regulations on the sale and purchase of firearms.<sup>37</sup>

### **Educating Physicians and Trainees**

The AAP encourages the education of physicians on gun violence prevention, including gun safety and strategies for anticipatory guidance with patients and families.<sup>37</sup> However, a recent systematic review found that students and trainees rarely receive training on firearm-related injury prevention and firearm safety.<sup>38</sup> Although there are limited studies on pediatric resident perspectives, 1 study reported that the likelihood of residents asking parents about guns and providing counseling relates to level of comfort and previous education on the topic.<sup>15</sup> Pediatricians have an opportunity to educate trainees about gun safety strategies and model ways to speak with patients and families about firearm safety. One study found that a Web-based gun violence curriculum for pediatric residents successfully increased feelings of self-efficacy in providing firearm injury prevention guidance.<sup>39</sup> Given that increased confidence on the topic increases the likelihood that residents will provide gun safety counseling,<sup>40</sup> incorporating such curricula for pediatric residents at the national level may be a promising strategy to improve counseling for families.

### **Discussing Anticipatory Guidance With Families**

The lack of training on firearm safety in medical education has affected practice. In the audio recordings of >170 well child visits with pediatric residents, firearms were not discussed in a single encounter.<sup>41</sup> Pediatricians discuss a variety of safety and

injury prevention topics at routine visits, including risks of lead paint exposure, bicycle helmet safety, and substance abuse, but discussion of firearm safety remains nonexistent, a surprising finding given the magnitude of the public health threat posed by gun violence. In addition to education about safe storage, several advocacy groups, including the AAP,<sup>37</sup> recommend encouraging parents to ask about guns in the homes of others when their children spend time in someone else's home. Encouraging parents not only helps ensure the safety of their own child but also promotes community dialogue surrounding gun safety.

The AAP also recommends that physicians screen for access to firearms in all patients with mood disorders, substance abuse, or history of suicide attempts.<sup>37</sup> Several states, including Florida, Montana, Missouri, and Minnesota, enacted legislation limiting how and when patients can be asked about gun ownership or limiting how much they are to document in the medical record. However, they do allow physicians to ask if medically necessary and if a patient is at risk.<sup>42</sup> Access to firearms is an obvious risk factor for suicide completion.<sup>43</sup> Legislation that restricts a physician's ability to counsel could prevent a physician from obtaining life-saving information from a depressed adolescent who has access to firearms in his or her home. Restrictive legislation has been challenged in several state courts, and in Florida it has also involved the federal courts. The issue remains dynamic, and federal involvement may affect future legislation in other states. It is important to consider the context from which this legislation and cases evolved. In Florida, in a well-publicized case, a pediatrician discharged a family from his practice after the mother refused to answer questions about access to firearms. This case along with other complaints led to the passage of Florida's physician gag law.<sup>19,44,45</sup> The Florida chapters of the AAP, the American Academy of Family Physicians, and the American College of Physicians challenged the law. As this issue continues to evolve, pediatricians must remain involved and aware of any legislation that restricts their ability to keep children safe.

## Leading Research Efforts to Study Firearm-Related Injury Prevention

Progress in firearm injury prevention has been limited in the United States by a lack of scientific inquiry, knowledge, and publications on this topic, primarily because of lack of funding. According to a 2013 report published by the Institute of Medicine, "the scarcity of research on firearm-related violence limits policymakers' ability to propose evidence-based policies that reduce injuries and death and maximize safety."<sup>46</sup> In the 1980s, the CDC launched efforts to promote scientific inquiries about firearm-related injuries; however, in 1996 Congress restricted the agency from funding work "to advocate or promote gun control."<sup>46</sup> An executive order in 2013 by President Obama sought to increase firearm-related funding to the CDC, but Congress did not give full support. Journal publications are the cornerstone of dissemination of scientific knowledge and can provide evidence for intervention development and policymaking. However, given the dearth of funding in this area, publications on this topic have plateaued. Between 1985 and 1999, the annual number of publications about gun violence increased markedly, but then they plateaued through 2012 at about 90 articles annually.<sup>46</sup> When researchers accounted for the growth of scientific literature as a whole over the time period, publications on firearm-related injury prevention declined 64% in 2012, compared with an increase in firearm-related publications between 1985 and 1999; in addition, there are few active career researchers in this area.<sup>46</sup> Adding scientific inquiry and evidence in this area can help promote change at the local level, with more interventions or program development, and at the national level, providing policymakers with evidence. A more nuanced understanding of pediatric firearm-related injury through rigorous, well-conducted research will inform the work of public health agencies, policymakers, and pediatricians to effectively intervene legislate and counsel.

## FIREARM LEGISLATION

There are >300 federal gun laws in the United States that regulate the sale and

possession of firearms and ammunition. However, because of different state and local laws, there is tremendous variation in the implementation of these federal laws at the local level.<sup>47,48</sup> A 2016 study evaluating individual laws (through 2009) compared their effectiveness in reducing firearm-related mortality.<sup>49</sup> Only 3 laws were found to be strongly associated with reduced deaths from firearms in this study: universal background checks before the purchase of guns, universal background checks before the purchase of ammunition, and firearm identification (microstamping or ballistic fingerprinting) requirements.<sup>49</sup> More recently, in a 2017 systematic review focusing on firearm homicide, US firearm laws were divided into 5 categories: those that curb gun trafficking, strengthen background checks, improve child safety, ban military-style assault weapons, and restrict firearms in public places.<sup>50</sup> These researchers found that laws that strengthen background checks and that require a permit to purchase a firearm are associated with decreased firearm homicide rates across all ages. However, specific laws directed to improve child safety were not associated with decreases in firearm homicide rates.<sup>50</sup> These findings are in contrast to other studies that focus on unintentional shooting deaths or suicide deaths (not only firearm homicides), which show a reduction in firearm-related death in children when laws aimed to improve child safety are associated with felony prosecution or broader firearm legislation to promote responsible ownership.<sup>51-53</sup>

The Brady Handgun Violence Prevention Act of 1993 (Brady Act) is one of the most significant pieces of legislation that exists to control firearm access by strengthening background checks. The Brady Act mandates that federally licensed firearm dealers perform federal background checks. The original legislation instituted a 5-day waiting period for all people purchasing a handgun; however, this requirement ended in 1998, and currently there is no federally mandated waiting period. Once the background check is complete, the gun can be transferred to the purchaser. Although a federally licensed firearm dealer is required to wait

3 business days to complete the background check, a gap in the law allows unlicensed sellers, perhaps online or at gun trade shows, to sell firearms without background checks. Background checks blocked almost 2.8 million prohibited people from purchasing or receiving a permit to purchase or carry a firearm between 1994 and 2014.<sup>54</sup> It is important to note that unless local or state laws exist to regulate private sales, only federally licensed firearm dealers are required to conduct background checks before sales. This variability in firearm regulation at the state and local level makes evaluating the effectiveness of different categories of firearm legislation difficult.

Child safety laws include requiring the sale of guns with mechanical trigger locks and mandating age restrictions for gun purchases. Child access prevention laws regulate the safe storage of firearms to prevent access by minors and impose criminal liability on adults who allow children unsupervised access to firearms.<sup>50,51,55</sup> No federal child access prevention law exists, and as of 2013, only 27 states and the District of Columbia have enacted child access prevention laws.<sup>56</sup> Whereas Lee et al<sup>50</sup> concluded in their systematic review that the overall evidence from the 9 studies related to laws improving child safety does not support the effectiveness of child protection laws in reducing firearm homicide deaths, other studies have shown that stronger firearm legislation and child safety laws are associated with safer firearm storage in families with preschool-aged children<sup>57</sup> and that child safety laws are effective in reducing unintentional firearm and suicide deaths among children.<sup>51-53</sup> For example, 1 study evaluated the impact of the child access prevention laws in 12 states and found that unintentional firearm deaths fell by 23% from 1990 to 1994 for children <15 years of age, but only in the subgroup of 3 states in which violation of the law was a felony.<sup>51</sup> Other studies noted that child access prevention laws were associated with an 8.3% decrease in suicide among 14- to 17-year-olds<sup>52</sup> and a decrease in unintentional pediatric firearm-related injuries in states with very aggressive,

felony prosecution for violators (eg, Florida and California).<sup>53</sup> Overall, child safety laws have shown reductions in unintentional firearm deaths and suicide deaths in youth, and their role in overall firearm homicide by age group may warrant more study.

Other available research examines the overall strictness of firearm regulation based on state-based legislation in relation to firearm-related injury or mortality. The Brady Campaign to Prevent Gun Violence and the Law Center to Prevent Gun Violence annually assess and compare each state's legislation on gun laws and assign a score based on various policy points including strength of background checks, limitation of military-style assault weapons, and limitation on firearms in public places.<sup>47</sup> Although it is not a validated score, studies have used the Brady score to account for variability in state-based firearm legislation when studying firearm-related injuries. A study that examined gun laws and firearm-related injuries across 18 states revealed that states with the strictest gun laws had the lowest numbers of hospital visits for nonfatal firearm-related injuries.<sup>58</sup> In particular, among children, stricter states also had lower rates of hospital admissions and visits for firearm-related injuries than states with less strict firearm legislation.<sup>58</sup> Additionally, in a national sample, mean firearm-related injury rates among trauma patients were higher in states with less strict firearm legislation than in states with strict firearm legislation.<sup>48</sup> Stricter firearm laws have also been associated with fewer high school students reporting firearm carriage in the past 30 days.<sup>59</sup>

Although the data suggest that individual review of gun laws is sufficient to evaluate their effectiveness, important interactions between laws must not be overlooked. There are hundreds of state-level laws that regulate firearms. Attention should be focused on supporting the laws, or combination of laws, that have been shown to be effective.

## CONCLUSIONS

Firearm-related injuries are a pediatric public health crisis with significant morbidity and mortality in the United States. Of 20 000 firearm-related pediatric

injuries every year, injury in younger children is generally caused by accidental access, whereas adolescent injury is most often intentional, from suicide attempts and violence. Legislation to combat firearm-related injuries has existed since the signing of the Brady Act in 1993. Since then, research has emerged clearly demonstrating that universal background checks and firearm identification are the most effective pieces of legislation to prevent firearm injuries.<sup>49,50</sup> Child access prevention laws with felony prosecution of violators may also play an important role in the legislative environment.

Rigorous investigations, with the use of validated scoring systems, large comprehensive databases, and accurate detailed reporting and surveillance of firearm access and related injury, are urgently needed. Firearm research by the CDC has been limited by constant threats by Congress to reduce funding, and recent efforts to increase funding have been unsuccessful.<sup>60</sup> A collective, data-driven public health approach is crucial to halt the epidemic of pediatric firearm-related injury.

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