Abstract:
Firearm violence is a serious threat to the safety of children and adolescents. Older adolescents, minorities, and boys are at increased risk, as are children who have been victims of firearm violence or violent crime in the past. Meaningful change to prevent firearm violence must incorporate principles of public health. Emergency physicians are uniquely poised to advocate for and participate in preventive efforts. This article discusses the state of firearm violence among adolescents as well as primary, secondary, and tertiary prevention efforts that have demonstrated effectiveness. This includes hospital-based programs that take a multi-disciplinary, comprehensive approach to the care of at-risk patients.

Keywords:
firearms; adolescent health; emergency medicine; public health

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1522-8401

Firearm Violence and the Path to Prevention: What We Know, What We Need

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The epidemic of firearm violence poses a continual threat to the safety and security of children. The challenge of confronting this threat necessitates a strategic and creative use of the tools of preventive medicine and advocacy. A comprehensive approach to violence prevention has to be rooted in the principles of public health. This approach has proven successful in other areas, including the prevention of poisonings and in the reduction of injury and death due to motor vehicle collisions.

Firearms are a particularly dangerous source of major injury with significant lethality when compared to other means of interpersonal violence. Firearm violence, compared to other mechanisms of injury, is associated with higher mortality rates, more serious injuries and major surgeries, which lead to higher healthcare costs.[1] The case fatality rate for firearm injuries is 74% for suicidal injuries and 14% for firearm-related assaults.[2] Additionally, the consequences of firearm injury go far beyond the immediate physical effects. Exposure to mass shooting events has been shown to have an adverse effect on perceptions of safety and psychological well-being in affected communities.[3] Exposure to violence in multiple forms, from television portrayals to direct victimization, has been shown to have adverse effects on child development, school performance, behavioral challenges, substance use, and mental illness. Equally concerning is the relationship between exposure to violence and the likelihood of perpetrating violence.[4] In addition to significant costs to the individual and to the community, an estimated $21 billion a year

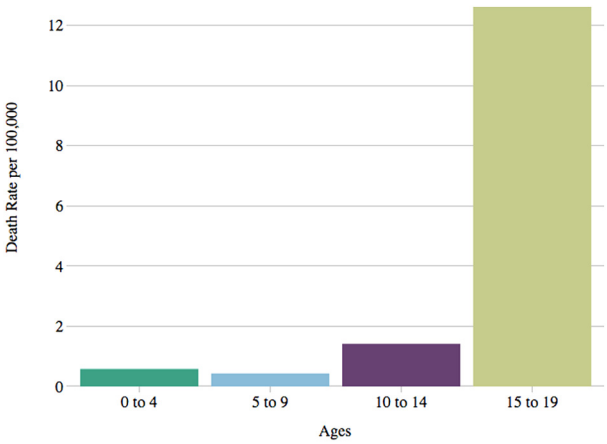

Figure 1. Firearm injury rate in children by age, all intents, 2016.[12]

in the US are spent on health care and lost productivity due to firearm violence.[5]

Pediatric emergency physicians have a unique opportunity to encounter youth at multiple key points of intervention. Adolescents seen in the emergency department (ED) for assault-related injuries are at increased risk for future victimization and injury due to violence.[6,7] At the initial entry point for injured youth, emergency physicians should be key stakeholders in the work of violence prevention. The body of knowledge around firearm violence and its devastating effect on youth is growing, which provides a greater foundation for prevention strategies. This knowledge must translate into a clear articulation of what is needed: a robust, effective public health effort to end the onslaught of violence in the lives of youth.

EPIDEMIOLOGY

When compared to other high-income nations, the United States ranks first in firearm-related deaths. The firearm assault-related death rate in the US is greater than ten times the combined number of deaths for the four nations with the next highest gross domestic product.[8] Adolescents bear a significant burden of this disease. Children 13 to 17 years of age have a rate of firearm death that is 12 times higher than children under 12 years.[2] The most recent data from the Centers for Disease Control and Prevention demonstrates a consistent pattern of higher rates in older adolescents (Figure 1). This is in part due to the high-risk characteristics of this developmental stage, including a quest for autonomy, a belief in one's own invincibility, impulsive behaviors, and peer group influence.[9]

The World Health Organization (WHO) references a larger group (children aged 10-19 years) when defining adolescents.[10] In 2016, there were 2954 firearm related deaths in this age group. About

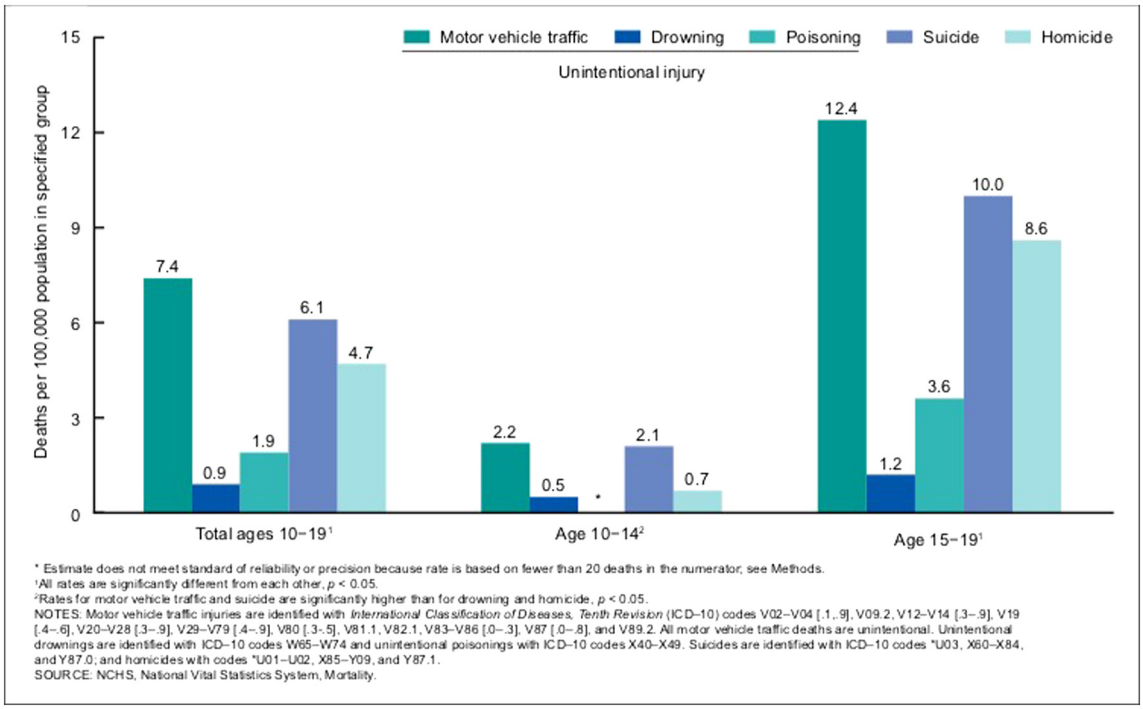

Figure 2. Selected injury death rates by intent and leading methods of unintentional injury for children and adolescents aged 10 to 19 years, by age group: United States, 1999-2016.[11]

57% of these were homicides, 37% were suicides, 2.5% were unintentional injuries, and approximately 1.5% had a designation of unknown intent. Deaths in the same age group due to motor vehicle collisions (MVC), still a major cause of mortality in adolescents, numbered 3230 (Figure 2).[11] Public health policy measures, such as restraint use and traffic light camera policies, resulted in a decrease in MVC deaths by 44% over the previous decade. By comparison, firearm-related deaths dropped only 4%, as efforts to reduce firearm violence were challenged by funding deficits, political barriers, and inadequate research and reporting systems for violent deaths.[12,13]

Firearm violence-related deaths vary significantly by state. Recent studies have demonstrated the highest rates of firearm-related mortality in the District of Columbia and Louisiana from 2010 to 2014. Homicide-related deaths have been concentrated in the South and Midwest, as well as a few key states in the West and Northeast.[2] The most recent available data from 2016 shows similar patterns (Figure 3).

Males bear the brunt of firearm-related deaths, particularly in the adolescent age group, with rates of firearm death six times higher for 13 to17 year old boys than for girls of the same age (Figure 4).[2,12] This trend persists as adolescents enter adulthood. Overall, males carry an adjusted rate of firearm death that is six times that of females.[12] In a sample of children 0 to 14 years of age, studied in the year following the shooting at Sandy Hook Elementary School, 77% of victims and 82% of perpetrators in unintentional firearm deaths were male. A number of factors may contribute to this phenomenon, including higher rates of gun ownership and carriage in males, as well as complex social dynamics around gender roles and expectations, with a "hypermasculinized culture of firearm use."[14]

Firearm violence also differentially affects black children. The rate of firearm violence resulting in homicide showed a marked disparity between black and white children. From 2012 to 2014, the gun homicide rate among black children 0 to 17 years of age was approximately 10 times higher than that of white children. Unintentional firearm deaths are also more prevalent in black children, with a rate twice that seen in white children and four times that seen in Hispanic children.[2] In 2016, black children 0 to19 years of age had an adjusted rate of firearm-related death nearly four times that of their white

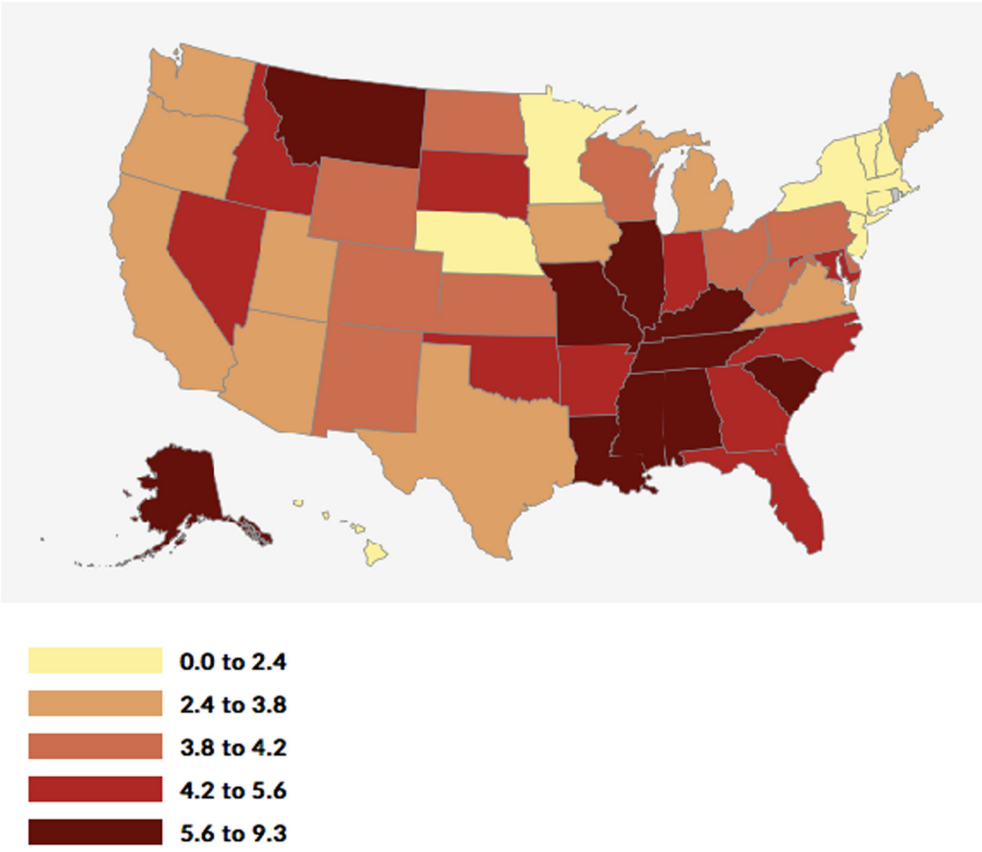

Figure 3. United States 2016 map of firearm injury-related death rates per 100 000, 0 to 19 years of age.[12]

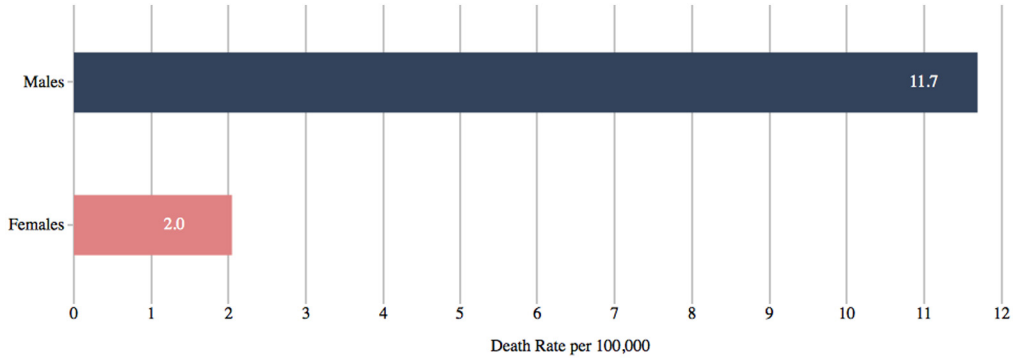

Figure 4. Breakdown of firearm injury rate by sex, 10 to 19 years old, all intents, 2016.[12]

counterparts.[12] In contrast, the rates of firearm suicide was almost 4 times higher in white children than in black children.[2] In review of adolescent data, these trends are similar.[12]

Urban areas also see more firearm injury hospitalizations in children than rural areas. Assaults in 15- to 19-year-olds account for the highest rates of hospitalization.[15] Non-fatal firearm injuries have been shown to have similar demographic breakdowns as fatal injuries. In 2016, there were over 16 000 firearm-related injuries in children 10 to 19 years of age. The vast majority of these injuries (over 15 000) were in the 15- to 19-year-old group. Similarly, nearly 15 000 of these injuries were in males.[12] The available data suggests that black children saw more than twice as many firearm-related injuries than white non-Hispanic children. A large number of cases had an unknown ethnicity, making it difficult to draw conclusions, highlighting the importance of more effective monitoring systems to accurately track firearm injuries in children.

Although data on firearm-related injury is limited, recent studies have attempted to quantify the number of pediatric patients seen for these injuries using available databases. A recent study utilized the Nationwide Emergency Department Sample (NEDS) database, which reported approximately 75 000 ED visits a year from firearm injuries in children under 18 years of age. Similar trends to previous data were noted, including higher rates in males (fivefold higher than in females) and higher

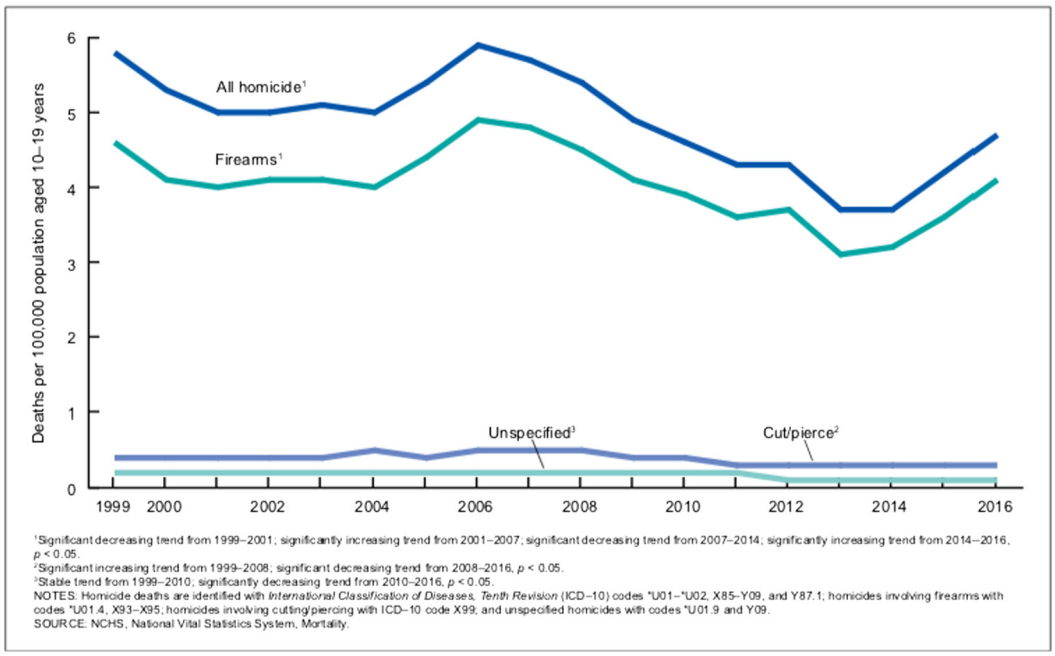

Figure 5. Homicide death rates for children and adolescents aged 10 to 19 years for leading methods: United States 1999-2016.[11]

rates in older adolescents. This study reported a 6% mortality rate for firearm-related injuries and a mean cost of $270 million per year.[16]

Homicide

Firearms were the primary method of homicide deaths in both male and female adolescents 10 to 19 years of age from 1999 to 2016. They accounted for 87% of homicide related deaths in 2016 (Figure 5).[11] The year 2016 saw 1706 deaths that were attributable to homicide by firearm in adolescents. The vast majority (over 1600) were children 15 to 19 years of age, with the number increasing steadily with each year of age. Over 1100 were in black children, with an age-adjusted death rate almost 16 times that of white children. Males in this age group had a rate almost six times that of females.

Suicide

A significant number of suicide deaths among children 10 to 19 years of age were secondary to firearm use (1102, as compared to 1103 for suffocation, the leading cause of suicide death in 2016). Firearms remained the primary method of suicide for males in this age group (Figure 6).[11] The rate of suicides in older adolescents aged 15 to 19 years was over five times the rate seen in younger adolescents. As with homicides, the rate increased steadily with each year of age. However, in the category of suicide, white children had approximately double the rate seen in their black counterparts. Of note, the total number of suicide-related deaths in American Indians and Alaskan Natives was low, but the adjusted rate was almost identical to that seen in white children. Suicides by firearm, similar to homicide rates, were about five times more common in males compared to females.

Of great concern is the trend of firearm-related suicides over time. The past 5 years have a seen a 30% increase in the number of firearm-related suicides in both younger and older adolescents.[12] Studies have linked suicides in children to periods of acute crisis, as well unmet mental health needs. The presence of a lethal means of suicide in moments of acute stress is a major factor in the fatality of suicide attempts.[2]

Unintentional Deaths

Unintentional deaths make up a minority of firearm-related deaths in adolescents. Rates are higher in boys than girls, with a ratio of approximately 4.5 to 1.[2] Although firearm deaths of all intents are higher in older children, the degree of difference is greater with suicides and homicides than in the category of unintentional deaths. Prior studies have described a downward trend in children overall, though recent numbers have shown more fluctuation.[2,12] Unintentional deaths are often in the context of a child "playing" with a gun, assuming it was unloaded or unable to fire.

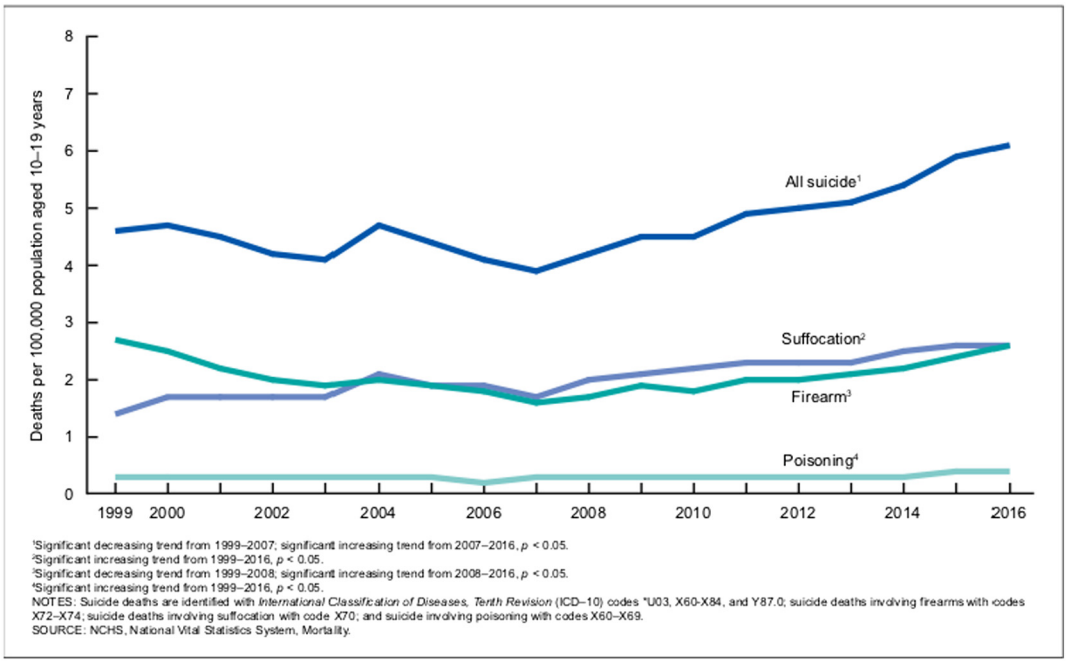

Figure 6. Suicide death rates for children and adolescents aged 10–19 years for leading methods: United States, 1999-2016.[11]

These frequently occur in the home, and the vast majority involve a handgun.[2]

Death by Legal Intervention

Though adolescent deaths by legal intervention do not account for a large portion of overall firearm deaths, they are a highly controversial source of firearm mortality that has merited a significant media attention. These occur more frequently in young men in their 20s and 30s, with the highest rate in the 30 to 34 age group. However, 63% are in those 15 to 34 years of age.[12] Of note, is the death-rate ratio for black men to white consistently 2.5 (or greater) to 1. Thus, the racial disparity for firearm-related deaths remains consistent among categories, with the exception of suicide deaths.[17]

AN APPROACH TO PREVENTION

The American Academy of Pediatrics maintains that the absence of guns from all locations where children work and play is the most reliable form of prevention. The presence of firearms in these settings has been directly linked to greater numbers of suicides, conflict-related deaths, and unintentional injury. Healthcare providers have an obligation to counsel families about effective ways to protect their children from firearm-related injury and death. From the point of manufacture, the design of guns should have the safety of children in mind, decreasing their ease of use and lethality. Gun violence prevention in children deserves quality research and thoughtful implementation.[9]

An approach to injury prevention using Haddon's matrix focuses on the host, the agent, and the physical and social environment. For firearm injury prevention, this translates to an understanding of the shooter (host), the gun (agent) with its specific lethality and ease of access, and the environment, a complex interaction of physical and social factors. These include the physical setting and presence of barriers, regional violence prevalence, media/internet depictions of violence, local and national legal practices, societal standards, social norms, and others. Host, agent, and physical/social environment are evaluated at three major time points – pre-event, during the event, and post-event. This is similar to the language of primary, secondary, and tertiary prevention.

A third dimension to Haddon's matrix is the most recent addition, a systematic review of values that guide decision-making in planning prevention. These values may include cost, feasibility, effectiveness, stigmatization, and others, all essential to the process of choosing among viable intervention strategies. This approach has been successfully applied to multiple areas of violence prevention.[18]

Primary Prevention

Primary prevention is reduction in the occurrence of a disease in a population not yet affected but at high risk, recognizing that prevention is more cost-effective and preferable to treatment. Study of, and making changes to, the environment in which firearm injuries occur is likely to be more effective than attempting to change individual behaviors.[19] The interconnection among the many factors contributing to violence cannot be overstated. Determining how gun access translates to violent death must address these factors, which include the exposures to violence, substance use and abuse, limits on access to quality education, poverty, and the resultant behavioral risk factors that predispose to violence. Failing to account for the social determinants of gun violence exposure and victimization lead to policies that are not sustainable.[20]

The ideal allocation of resources is a concentrated effort toward primary prevention, beginning with firearm access. The National Youth Risk Behavior Surveillance report for 2017 indicates that gun carrying remains relatively common among adolescents. Approximately 5% of students endorsed carrying a gun at least one day in the preceding year, not including those who used a gun for sport. The rates of carriage, however, vary greatly by age and sex. Males in the 12th grade had a carriage rate of almost 10%.[21] We know that several risk factors predispose adolescents to firearm carriage, including drug and alcohol use, gang membership, and exposure to violence.[9] Adolescents who have been injured due to assault in the past have a higher risk of subsequent firearm violence, and youth who report firearm violence are at increased risk of victimization due to firearms.[6]

A significant portion of child access to guns is in the home. About a third of children in the US live in homes with guns, and approximately 43% of these guns are unlocked and accessible. Thirteen percent of firearms in homes are both unlocked and either loaded or stored with ammunition.[22] Many caregivers do not recognize that their children are aware of the presence and location of firearms in the home. In one study, 73% of children less than 10 years of age had knowledge of a firearm in the home, and 36% of them endorsed having handled the firearm.[23] Older patients (10 to 14 years) were even more likely to know the location of the firearm (79%). Of note was the significant contrast between parental

assessment of their child's awareness of guns in the home, and what children reported: 39% of parents misjudged their children's knowledge about the firearm location in the home, and 22% misjudged whether their children had handled the firearm. Alarmingly, these discrepancies were present whether or not the firearms were locked or children received parental education on firearm safety.[23]

Many parents may not recognize developmental limitations in safe gun handling. One study found that three-fourths of parents who owned guns felt confident that their children 4 to 12 years of age could distinguish a real gun from a toy gun, and 23% trusted their child with a loaded gun.[24] Parents may attempt to teach their children about safe storage using common programs such as the Eddie Eagle GunSafe Program, developed by the National Rifle Association to instruct young children regarding appropriate behavior with an unsecured firearm. However, studies with in-situ observation of young children who have received "Eddie Eagle" training demonstrate infrequent compliance with safety instructions, especially when compared to active behavioral skills training.[25]

Studies have also identified inconsistencies and knowledge gaps among members of the same household regarding guns in the home. Women who live in homes with guns, but who are not the gun owners, have reported a lack of awareness of firearms stored loaded and unlocked – even when identified as the primary caregiver of children in the home.[26]

Safe storage has significant implications for both intentional and unintentional firearm-related deaths in children. Safe practices, including storage of firearms locked, unloaded, and separate from ammunition, have been protective measures for both intentional and unintentional injuries.[27] Storing guns locked and unloaded were found to have a 74% and 70% protective effect, respectively.[27]

Child access prevention (CAP) laws place the onus of protecting the health and safety of the children in proximity to a firearm on the gun owner. These laws establish liability for those who negligently store firearms in locations that provide easy access to minors. One study found that adolescents with mental health risk factors were just as likely to report unsafe storage practices as those without these risks.[28] The most successful CAP laws are those that can be enforced regardless of whether the unsecured firearm results in harm or injury.[29] The effectiveness of these laws has been demonstrated over time, with reductions in unintentional shootings, homicides, and suicides, particularly in youth.[30,31]

Studies on interventions that combine community-based counseling on safe gun storage with the provision of storage devices have demonstrated improved firearm practices. Interventions that advocate for safe storage without provision of a device were found to be less effective, but options for safe storage devices gave families some autonomy in achieving safe practices.[32,33]

Mandating safe storage is only part of effective primary prevention. A growing body of literature supports various screening tools that serve to identify youth at risk for violence. As many as 1 in 5 high school students reported being bullied in the past year. Aggression in multiple forms, including bullying and physical fights, can serve as an antecedent to firearm violence.[5] With screening and identification of at-risk youth comes the opportunity to provide services that teach alternatives to gun violence (or any aggression) as they confront the challenges of their environment.[34,35]

Hospital-based violence intervention programs provide those youth identified as high risk, due to prior exposures or by risk-assessment tools, with critical services. These include psychosocial supports, substance abuse referrals, and family-based therapy, in addition to standard medical treatment. This comprehensive approach has proven a cost-effective way to mitigate the risk of future violence, and empower physicians, other healthcare providers, and hospital systems to promote patient health and safety beyond the scope of a limited hospital interaction. Participation in violence intervention programs has also proven a cost-effective way to decrease repeat violent criminal activity.[36-38]

Primary prevention requires knowledge of the factors that contribute to the problem, especially with an epidemic as complex as firearm violence. This highlights the need for a national database that describes the frequency and nature of firearm violence in a systematic, structured way. Recent attempts to describe the circumstances around child firearm violence have been limited to databases that have an inadequate number of participating states. Incidents reported to the National Violent Death Reporting System (NVDRS) represent data from only 17 participating states.

The data from the NVDRS, though limited in scope, provides compelling information. Homicides of younger children were frequently part of multi-victim incidents of domestic violence, whereas older children were just as likely to be killed at home as on the streets. Firearm suicides in children were often preceded by personal crises or interpersonal conflicts, with frequent concurrent mental health issues. Unintentional deaths in both older and younger children were commonly associated with "playing" with a gun.[2]

While this limited data gives us a glimpse into the complex environments in which childhood firearm injuries occur, it leaves us with more questions than answers. The loss of years of robust firearm research due to funding limitations in a charged political climate has left us striving for solutions with a paucity of data to inform recommendations and prevention strategies.[39] A registry that tracks both fatal and non-fatal firearm injuries in all ages can only strengthen primary prevention efforts. There have been regional efforts to establish research consortia to address these needs, such as the "States for Gun Safety" coalition, which includes Connecticut, New Jersey, New York, and Rhode Island.[39]

Secondary Prevention

Secondary prevention focuses prevention efforts on at-risk individuals or communities. It assumes that the condition, in this case firearm violence, is at an early stage, amenable to interventions that can either slow the rate of progression or reverse the condition all together. There have been several violence prevention initiatives that have borrowed from this philosophy, targeting communities that see endemic firearm violence where youth are at risk to be victims or perpetrators of violence. Many programs use deterrence methods at the scene of potentially violent altercations to re-direct youth to different behaviors that lead to improved outcomes.[40]

Programs like Cure Violence, founded by epidemiologist Dr Gary Slutkin, a former WHO infectious disease control specialist, focus prevention efforts first on high-risk individuals to limit the spread of the violence. Dr Slutkin's model is based on the recognition of violence as contagious within a community. This violence prevention model requires: (1) vector control to interrupt transmission of disease, (2) intervention with those at highest risk for disease, and (3) change within the community. Cure Violence targets high-risk youth, which is defined by gang involvement, activity in drug organizations, history of violent crime or recent incarceration, a reputation for gun carrying, being a victim of a prior shooting, and/or the age 16 to 25 years. A number of trained personnel, including "violence interrupters" with prior experience, establish relationships with high-risk youth to prevent violent crime before it occurs, especially in the setting of known or ongoing altercations. These youth are provided alternate means of conflict resolution modeled in the moment. Cure Violence was designed as a comprehensive care model, involving outreach workers who connect youth to resources and opportunities in the community. Finally, acknowledging the impact of social norms on high-risk youth, the programs support anti-violence messaging and events, building relationships with existing organizations, from faith-based institutions to law enforcement, to impact the local culture.

This approach, used in a number of programs throughout the country (including Safe Streets in Baltimore, Save our Streets in New York City, the TRUCE program in Phoenix, One Vision One Life in Pittsburgh, and Philadelphia CeaseFire) has showed some success in the reduction of violent crime. Several features, such as consistent and reliable staffing, and greater fidelity to the model, could improve outcomes.[40] It is worth noting that community-based programs have the potential to serve as primary, secondary, and tertiary prevention efforts, and are strengthened by the fact that they draw from community experts to design effective solutions.

Tertiary Prevention

Tertiary prevention attempts to ameliorate the effects after a condition has occurred. In the realm of firearm violence, this includes trauma resuscitation, post-resuscitation care, and treatment of the profound psychological effects of trauma victimization for both the patient and their family. ED trauma care provides an opportunity to address a particularly high-risk group of adolescents, including those who do not receive routine primary care and may only present in the context of acute injury.[35]

One element of tertiary prevention in firearm violence is addressing recidivism. Exposure to violence by firearms doubles the risk of perpetrating violence in the subsequent 2 years.[35] Violence intervention programs that employ a multidisciplinary team can provide support in the patient's home environment to mitigate this risk. These programs span the continuum from primary to tertiary prevention, as they reach youth at risk for firearm violence, as well as youth who have been victimized or witnessed firearm violence. In one study assessing the effectiveness of this approach, a team that included trauma and critical care physicians, members of law enforcement, and social workers, studied patients hospitalized for violent injury and designed a comprehensive service plan. They noted significant impact with reduction in both the number and magnitude of subsequent violent crimes in the cohort assigned to intervention.[36] These programs are costly to implement, but several cost-effectiveness analyses purport an overall cost reduction in health-care expenditures.[35,37]

Research Funding

In 1996, the World Health Organization acknowledged firearm violence as a priority in public health. The same year, federal appropriations in the US restricted funding for firearm-related research by the Centers for Disease Control and Prevention, characterized by select policymakers as projects that "advocate or promote gun control." This had a significant impact on firearm injury research. In contrast to the increase in peer-reviewed journal articles on gun violence from 1960 to 1996, what followed was a notable reversal of this trend, with fewer publications by established researchers from 1996 to 2014.[41] Of note, gun violence research funding in the US is significantly less than funding for diseases of similar mortality,[42] impeding effective prevention and intervention strategies. Quality research informs both the development of new programs, as well as efficacy studies of existing interventions. Adequate funding is necessary to find and implement lasting solutions.

SUMMARY

Firearm violence remains a substantial threat to the health and safety of youth. Older adolescents, boys, and minorities see a significant portion of the morbidity and mortality associated with firearm violence. This epidemic is amenable to the tools of public health science, and resources should be dedicated to the work of primary prevention. Hospital-based programs have shown promising results for the screening and identification of high-risk youth, and the implementation of comprehensive intervention to reduce the effects of violence. Emergency physicians have a key role to play as the front-line providers for injured youth due to violence.

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