

Danielle Laraque, MD, and the Committee on Injury, Violence, and Poison Prevention

Injury Risk of Nonpowder Guns

ABSTRACT. Nonpowder guns (ball-bearing [BB] guns, pellet guns, air rifles, paintball guns) continue to cause serious injuries to children and adolescents. The muzzle velocity of these guns can range from approximately 150 ft/second to 1200 ft/second (the muzzle velocities of traditional firearm pistols are 750 ft/second to 1450 ft/second). Both low- and high-velocity nonpowder guns are associated with serious injuries, and fatalities can result from high-velocity guns. A persisting problem is the lack of medical recognition of the severity of injuries that can result from these guns, including penetration of the eye, skin, internal organs, and bone. Nationally, in 2000, there were an estimated 21840 (coefficient of variation: 0.0821) injuries related to nonpowder guns, with approximately 4% resulting in hospitalization. Between 1990 and 2000, the US Consumer Product Safety Commission reported 39 nonpowder gun-related deaths, of which 32 were children younger than 15 years. The introduction of high-powered air rifles in the 1970s has been associated with approximately 4 deaths per year. The advent of war games and the use of paintball guns have resulted in a number of reports of injuries, especially to the eye. Injuries associated with nonpowder guns should receive prompt medical management similar to the management of firearm-related injuries, and nonpowder guns should never be characterized as toys. *Pediatrics* 2004;114:1357–1361; nonpowder guns, BB guns, pellet guns, air rifles, paintball guns.

ABBREVIATIONS. BB, ball bearing; CPSC, US Consumer Product Safety Commission; NEISS, National Electronic Injury Surveillance System; EPD, eye-protective device; ASTM, American Society for Testing and Materials.

BACKGROUND

A traditional firearm gun is one that launches a projectile (ie, a bullet) by using the energy generated by burning of gunpowder. Nonpowder guns utilize the power of compressed air to launch a projectile. Nonpowder guns can be classified by the type of projectile they fire, the propulsion mechanism, or the type of barrel.^{1–4} The type of projectile can be lead, brass, steel, copper, or, most recently, a paintball. Paintballs are small gelatin projectiles that are 17 mm in diameter, filled with nontoxic, water-soluble paint, and intended to explode on contact with an object.^{5,6} This type of projectile is

used in war games designed to mark the player with paint when he or she is hit. Air guns have been used since the 16th century^{7,8} in warfare and to kill game as large as deer.

The caliber of a projectile refers to its diameter and is measured in hundredths of an inch or millimeters. The caliber affects how much energy the projectile acquires before leaving the muzzle, or the end of the barrel. Tight-fitting missiles, those with little discrepancy between the diameter of the projectile and that of the muzzle, lead to higher velocities. In older nonpowder guns, the projectile was smaller than the barrel size, leading to dissipating of compressed air and an inefficient, low-velocity gun. Technical modifications of these guns have resulted in higher-velocity weapons.⁹ Standard pellet guns fire a pellet or spherical ball bearing (BB) with a diameter of less than 0.18 in (4.57 mm). Pellets have several designs, such as wad cutter, sharp pointed, round nosed, and hollow point. Each is suited for a different purpose. Hollow points are used for hunting, and the pellet's diameter increases on impact to cause maximum damage. Ballistic studies have shown that a larger caliber pellet will penetrate the body (eg, skin, bone) at lower velocities because of its increased mass. Skin penetration can be achieved, for example, at a velocity of approximately 331 ft/second with a 0.177-caliber pellet but at 245 ft/second with a 0.22-caliber pellet. Ocular penetration can occur at velocities as low as 130 ft/second.^{7,10} Polishing steel pellets with a plastic skirt increases velocity, accuracy, and range and is designed to increase penetration. Typically, high-velocity guns are classified as those with muzzle velocities higher than 350 ft/second (D. Tinsworth, MS, US Consumer Product Safety Commission [CPSC], written communication, November 26, 2001).^{7,9,11–13}

Projectiles can be fired by 3 propulsion mechanisms. The spring-piston type is a powerful spring that is cocked manually and released, driving the piston that shoots a stream of air. Use of the spring-piston can result in muzzle velocities between 250 and 350 ft/second. The carbon dioxide-powered gun uses a gas cartridge to generate a propulsive force that can produce muzzle velocities of 350 to 450 ft/second. Muzzle velocities ranging, on average, from 300 to 950 ft/second can be generated depending on the number of times the weapon is pumped, although velocities in excess of 1200 ft/second have been reported in the literature. This range of velocity

The guidance in this report does not indicate an exclusive course of treatment or serve as a standard of medical care. Variations, taking into account individual circumstances, may be appropriate.

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overlaps velocities reached by traditional firearm pistols that have muzzle velocities from 750 ft/second to 1450 ft/second.^{1,3,9}

The longer the gun barrel is, the higher the velocity. Gun barrels can be smooth or rifled. Rifled weapons produce a spin in the projectile, giving it more stability in flight. Dieseling of the barrel is achieved when oil placed in the barrel is combusted by the heat generated from friction, leading to an explosion. This is used to increase the speed of the projectile. Piggybacking entails simultaneously loading 2 pellets into the firing chamber, increasing the momentum and energy of the missile.⁹ A "zip gun" is a modified gun using homemade powder ammunition.⁸ These modifications of nonpowder guns can result in increased ability of these guns to cause serious injury, not unlike traditional powder guns.

EXPOSURE AND INJURY PROFILE

The CPSC estimates that there are approximately 3.2 million nonpowder guns sold yearly.¹²⁻¹⁴ Nonpowder guns are sold in many department stores, including toy stores.⁹ Eighty percent have muzzle velocities over 350 ft/second, and 50% have muzzle velocities between 500 and 930 ft/second. In 2000, the National Electronic Injury Surveillance System (NEISS), operated by the CPSC, collected information from a nationally representative sample of 100 US hospital emergency departments that included information on nonpowder gun injuries.

According to data from the Centers for Disease Control and Prevention (<http://webapp.cdc.gov/sasweb/ncipc/nfirates.html> and www.cdc.gov/ncipc/wisqars/nonfatal/datasources.htm) and the CPSC,¹² in 2000 the overall nonfatal age-adjusted rate of injury from BB or pellet guns was 7.71 per 100000 population. In 2000, there were an estimated 21840 (coefficient of variation: 0.0821) nonpowder gun-related injuries treated in emergency departments (D. Tinsworth, MS, CPSC, written communication, November 26, 2001). Of these, 2% occurred in children 0 to 4 years of age; 49% occurred in children 5 to 14 years of age; 33% occurred in those 15 to 24 years of age; and the balance occurred in adults 25 years and older. Approximately 12% of injuries were to the eye; 24% were to the head and neck, excluding the eye; 63% were to extremities; and 1% were to other body areas. With the exception of the age group of 0 to 4 years, most victims were males. Sixty-six percent of injuries were diagnosed as either foreign-body lodgments or puncture wounds. There were no clear seasonal variations in the injury incidence. Nguyen et al¹⁵ provided a review of trends in BB or pellet gun injuries in children and adolescents in the United States from 1985 to 1999 derived from a special study using the NEISS, which focused specifically on injuries associated with penetrating gunshot wounds. On the basis of data from this study, in 1999 an estimated 14313 (95% confidence interval: 12025-16601) children and adolescents had BB or pellet gun-related injuries.

Many articles have been written detailing the clinical manifestations of children injured by nonpowder guns.^{3-10,16-31} Some striking observations have been

made. Lawrence³ reported on a series of 10 fatalities, 1 of which was a shot through the medial canthus of the eye in a 6-year-old. The weapon was a carbon dioxide-powered BB pistol. Bond et al¹⁰ described 16 children, 57% of whom required intraoperative treatment, and 19% of whom required other invasive procedures such as arteriogram or ventriculostomy. Thoracic injuries were associated with high morbidity and mortality when penetration of the chest wall occurred. Abdominal wounds were frequently associated with visceral injury and multiple perforations, usually of the small bowel. Peritoneal penetration was associated with a more than 80% chance of visceral injury. Transtracheal and brain injuries were also reported. These authors warn that the wound itself may seem trivial, but if not appreciated for their potential for tissue disruption, nonpowder gun injuries to the head, chest, and abdomen may have catastrophic results. They also note that the pellets from air guns have a propensity to embolize if the missile enters a blood vessel or the heart. The light weight of air gun pellets allows the missile to be swept by the blood flow more readily than heavier, higher-energy projectiles. Friedman et al⁷ report that the potential seriousness of pneumatic weapon injury is frequently underestimated. These authors concluded that injuries from air guns should be treated in a manner similar to those from low-velocity powder firearms. Bratton et al⁴ reviewed the clinical course of 101 children injured by nonpowder guns between 1988 and 1996 from Cincinnati, Ohio; Kansas City, Missouri; and Seattle, Washington. The case fatality rate for intracranial injuries was 30%, and 56% of patients required at least 1 surgical procedure. Amirjamshidi et al¹⁶ noted that air-gun pellet injuries are rare but catastrophic, with entrance usually through the orbit or the neck and the entry wound being so small that it may be disregarded on physical examination in the emergency department. They concluded that early recognition and correct management of possible complications is important to improve outcomes. Bhattacharyya et al¹⁷ reported on 42 children admitted to a level I pediatric trauma center for air-gun injuries over a 7-year period (1988-1995). They had a mean hospital stay of 7 days (range: 1-136 days) and a mean injury severity score of 8.3. Half of the children underwent operative procedures, and 38% had serious long-term disability. They concluded that these guns are not toys but are weapons, and injuries related to their use should be evaluated and managed in a similar fashion to powder-weapon injuries. These findings were similar to those of Walsh et al.¹⁸ In 1 study, the predominant risk factors for ocular injury from an air gun were lack of adult supervision, use of the gun for a purpose other than target practice, and being at a friend's home or yard.²⁰ Hearing loss has been reported from nonpowder gun use,²³ and suicides from the use of air guns have been documented.^{8,28} Concurrent use of alcohol has been noted also and probably contributes to misuse.

Paintballs used in war games are a relatively new phenomenon.^{5,6,21,25} Semiautomatic and fully automatic paintball pistols are available for purchase. The

sport typically involves a team, designated fields, and referees used to ensure fair and "safe" play. Players should be 18 years and older, but younger adolescents are allowed to play with the consent of their parent(s). Private games also occur. The players often wear camouflage, and start-up costs for the weapon, goggles, and paintballs total \$100 to \$150. The paintballs consist of spherical shells filled with sorbitol, glycol, and food dye. The propulsion mechanism is usually a carbon dioxide canister, and muzzle velocities between 60 and 250 ft/second can be achieved. Given the size of the projectile, the resulting injuries are nonpenetrating. Locally manufactured paintballs are harder than the more expensive imported varieties and may be responsible for the severity of injuries reported in the United States. Importantly, the increasing popularity of war games has been associated with a number of reports in the literature of ocular injuries. These injuries have included but are not limited to hyphemas, commotio retinae, glaucoma, cataracts, choroidal rupture, corneal abrasion, conjunctival laceration, dislocation of the crystalline lens, macular hole, and retinal detachments.^{5,6,25,32,33} The visual outcome for many of these injuries is poor. Injuries have occurred even with eye-protective devices (EPDs), but no case of a player injured while properly wearing an EPD meeting the current American Society for Testing and Materials (ASTM) standards has been reported.⁶ Some players have sustained injuries to the eye when they have removed their goggles because of fogging. Current antifog inserts with a polycarbonate lens with a urethane-based hydroscopic coating can help prevent fogging. The current ASTM specifications do not involve testing EPDs for their ability to resist fogging but do require manufacturers to attach a warning to EPDs without antifog treatment noting that fogging may occur and recommending the use of an antifog solution. There have been no reported deaths directly related to paintballs, but the CPSC issued a warning on March 24, 2004, because of its investigation of 2 deaths caused by carbon dioxide canisters flying off paintball guns (www.cpsc.gov/CPSC/PUB/PREREL/prhtml04/04105.html).

Before 1972, only 2 nonpowder gun-related fatalities were reported in the literature. However, between 1972 and 1982, the decade after the introduction of high-powered air rifles, 10 more fatalities were recorded by the CPSC.¹⁰ The number of deaths per year has increased since then. From 1990 to 2000, the CPSC reported 39 nonpowder gun-related deaths, of which 32 were children younger than 15 years, with an average of 4 deaths per year.¹¹ The highest number of deaths occurred in 1989, 1990, and 1991.¹⁵ The trends in nonpowder gun fatalities and nonfatal injuries parallel the epidemic of firearm-related injuries and deaths of the past 2 decades.³⁴

SAFETY STANDARDS

An ASTM voluntary safety standard was originally published in 1978. The current edition was published in December 1992 (ASTM F589, Standard Consumer Safety Specification for Non-Powder Guns).³⁵ This standard contains performance re-

quirements to ensure the proper functioning of these products as well as provisions to address instructions, labeling, and marketing. The guns are general-purpose guns not classified as precision, adult, or training guns. For higher-power guns, the minimum labeled age is 16 years, and the potential for serious injury or death is indicated. For lower-power guns, the minimum labeled age is 10 years, and the risk of serious injury, particularly to the eye, is indicated, but not the risk of death. In the pediatric literature as early as 1984, Christoffel et al^{36,37} pointed to the dangers of nonpowder guns, noting that they were loosely regulated and could be legally purchased by young adolescents in most jurisdictions. They also emphasized the inadequacy of voluntary standards and proposed stricter regulations.

From June 1 through July 31, 1994, the CPSC conducted a limited study using follow-up telephone investigation of the circumstances of 55 cases of nonpowder gun-related injuries reported to the NEISS. Percentages provided in the analysis were based on national estimates projected from the 55 cases for the 2 months of the survey. Additionally, information on deaths was obtained from the CPSC Death Certificate, In-Depth Investigation, and Injury or Potential Injury Incident files for the period of January 1, 1985, through September 1, 1994. Information on 37 deaths was included (D. Tinsworth, MS, CPSC, written communication, November 26, 2001). Respondents were victims or parents or guardians of victims. The injury epidemiology mirrored that described for the 2000 data, with most injuries occurring in males younger than 16 years. Individuals who fired the guns ranged in age from 8 to 32 years, with most reported to be younger than 16 years. When the gun operator was younger than 16 years, there was no one 18 years or older present at the time of the incident in more than two thirds of the cases. The gun was most often reported to be a rifle and received as a gift, and two thirds were high-powered guns. As reported by the respondents, 51% of the hazard patterns were unintentional shootings, with victims coming into the line of fire during practice, discharges during loading of the gun, or incidents in which the gun "accidentally fired." Fourteen percent were of unknown intent, 7% were intentional shootings, and 28% involved a gun thought to be unloaded, guns that discharged unexpectedly, ammunition that ricocheted, or fingers that became pinched in gun components. Ninety percent of those who died were younger than 16 years. Most fatalities resulted from wounds to the head or chest.

The CPSC report concluded that the effectiveness of age-specific warnings on packaging and instructions needed additional study and that adult supervision was often lacking. It was unclear from the data whether product modification to reduce hazards would be effective.

LEGISLATIVE EFFORTS

Almost 30 states have regulations, ordinances, or laws covering nonpowder guns.^{9,38} Two of the strongest are in New York City and New York State. In New York City, air rifles and BB guns are prohibited, and licenses are not available. In New York State, no

purchase or unsupervised use by someone younger than 16 years is permitted, and adult supervision is required at a shooting range or when hunting for someone of this age. Florida also has a strong law similar to the New York State law. In Florida, it is a second-degree misdemeanor for a minor younger than 16 years to use a BB gun, air gun, or gas-operated gun unless an adult is supervising the possession and the minor's parent has consented to such possession.

However, much variability exists, with some states regarding nonpowder guns as firearms and others not.¹⁵ Some state laws do not address nonpowder guns at all. Many authors have called for restrictions in sales and use of nonpowder guns, especially in light of the technologic advances that have resulted in much more powerful and dangerous weapons that are capable of killing and maiming.^{9,19,31,39}

SUMMARY/CONCLUSIONS

This technical report is focused mainly on the potential for injury and death associated with the use of nonpowder guns. Although some comments have been made on risk factors for injury, this report is not meant to be an exhaustive review of the behavioral risk factors for injury, nor does the report summarize the literature regarding the psychological implications or effects of the use of these weapons. The data presented do allow the following conclusions:

- Nonpowder guns pose a serious risk of injury, permanent disability, and even death.
- Since the 1980s, the use of high-powered air rifles has been associated with approximately 4 deaths per year.
- The range of muzzle velocities for nonpowder guns overlaps velocities reached by traditional firearms.
- Data suggest that lack of supervision and unstructured use may be risk factors contributing to the incidence of injury from nonpowder guns.
- EPDs can be useful in decreasing, but not fully eliminating, the incidence of ocular injuries associated with paintball use.
- Injuries associated with nonpowder guns should receive prompt medical management similar to the management of firearm-related injuries.
- Nonpowder guns (BB guns, pellet guns, air rifles, paintball guns) are weapons and should never be characterized as toys.

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