

Review Paper

Exploring the Forensic Implications of Death Cases Resulting from Airsoft Gun and Air Gun Shots: A Systematic Review of Case Reports

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Abstract

Airsoft guns and air guns are replica weapons resembling real firearms that use the force of a spring or air to fire bullets; these weapons are often considered toys and can cause fatal injury if not used properly. This study aims to highlight the forensic implications of deaths caused by airsoft guns and air guns. A systematic review was conducted by the PRISMA guidelines. Study searches were conducted on PubMed, ScienceDirect, Scopus, and Wiley databases in February 2024 to collect all published case reports. The study search and selection process resulted in 15 articles that met the inclusion criteria for qualitative synthesis. Case reports were published from 1972 to 2023 and reported from 9 countries. Victims ranged in age from 11 months to 73 years; 10 of the 15 victims were male. All deaths were caused by air gun shooting; most used a bullet size of 5.5 mm. The most common mode of death was accidental death, caused by brain injury and cardiac tamponade. In conclusion, identifying the weapon's characteristics and the injury's dynamics are essential to determine the cause of death. The most common causes are brain injury and hemorrhagic shock resulting from cardiac tamponade.

Keywords: airsoft gun; air rifle; death cases; forensic implications; systematic review.

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1. Introduction

An *airsoft gun* is a replica weapon that looks and feels like a real firearm that uses the direct force of a spring or air as power to fire plastic bullets. There are three main types of airsoft guns: spring-powered, gas-powered, and electric-powered single-shot. The muzzle velocity of airsoft gunshots can reach over 120 m/s, but most commercially available airsoft guns have a muzzle velocity of around 70 to 90 m/s. In contrast, air guns (BB guns) using lead bullets or 4.5 mm iron bullets have a velocity of about 140 m/s, with a shooting range of up to 300 m, which can cause eye- and life-threatening injuries[1]. In general, both airsoft guns and air guns are widely used worldwide for sporting purposes, bird hunting, and firearms training. In Indonesia, the use of air guns is legal but still strictly regulated by laws and government regulations [2,3].

Regulation of the National Police of the Republic of Indonesia Number 1 of 2022 concerning Licensing, Supervision, and Control of Standard Firearms of the National Police of the Republic of Indonesia, Non-Organic Firearms of the National Police of the Republic of Indonesia/Indonesian National Army, and Security Equipment Classified as Firearms states that air pistols and air rifles may only be used for target shooting sports. Airsoft guns are only used for reaction shooting sports and require a license to use [4]. Despite the strict regulations, these air guns can be dangerous when not used properly. Serious and fatal injuries can occur accidentally or intentionally by irresponsible or unattended parties. In Indonesia, there have been many cases of air gun shootings. There were 25 reported cases of air gun shootings from January 2023 to December 2023, both intentional and unintentional, with victims aged 12 to 62. A total

of 8 victims sustained gunshot wounds and required hospitalization, while fatal gunshot wounds occurred in 17 other victims. Injury sites included the head, neck, chest, and extremities. Most deaths occurred in cases of gunshot wounds to the head, with ten cases, followed by the chest with six cases, and one was not described.

To date, no study has systematically summarized the findings on fatal airsoft gun and air gun shootings. This systematic review aims to detail and organize the existing literature related to airsoft gun and air gun fatalities and provide a deeper understanding of clinical findings, post-mortem findings, and causes of death, both intentional and unintentional.

2. Method

We conducted the systematic review according to the procedures outlined in the Cochrane Handbook for Systematic Reviews of Interventions and Preferred Reporting Items for Systematic Reviews and Meta-Analyses (PRISMA) 2020 to report the review results [5,6].

2.1. Search Strategy

A literature search was conducted on four electronic databases, namely PubMed, ScienceDirect, Scopus, and Wiley, until February 2024, with keywords such as (airsoft gun OR air gun OR air weapon OR air rifle OR air pellet) AND (death OR fatal OR lethal) AND (Case Report OR Case Study OR Case Studies OR Case Histories), combined with known synonyms and

Medical Subject Headings (MeSH) terms. Details of the search keywords can be seen in **Attachment 1**.

2.2. Study Selection

All citations obtained from the database were then aggregated in Mendeley Desktop and Rayyan.ai to remove duplicates [7]. The remaining articles were then screened by two independent reviewers based on title and abstract, with any discrepancies resolved by consensus or by a third reviewer.

2.3. Eligibility Criteria

Eligibility of articles was determined using the Population, Intervention, Comparison/Control, Outcome, and Study Design (PICOS) framework. Details of the eligibility criteria can be seen in **Table 1**.

2.4. Assessment of Study Quality

The Joanna Briggs Institute (JBI) critical appraisal tools for case reports were used to assess the quality of the included studies [8]. The instrument consists of 8 questions, each answered in four ways: Yes, No, Unclear, and Not Applicable. Furthermore, the assessment results are classified into Poor, Fair, and Good. In this review, study quality was assessed by two independent reviewers, and any disagreement was resolved through discussion or by a third reviewer.

Table 1. PICOS framework

Frame	Inclusion Criteria	Exclusion Criteria
Population	Cases of death in humans due to the use of air guns or airsoft guns	Live cases, animal casualties
Intervention	Penetration of air gun or airsoft gun projectiles	Firearms
Comparison/Control	Not applied	Not applied
Outcome	Mode of death, post-mortem findings, cause of death	Not applied
Study Design	Case reports	Review articles, expert commentaries, letters to the editor, and conference abstracts, research conducted on non-humans, not in English or Indonesian, and not accessible in full-text

2.5. Data Extraction

Two independent reviewers used Google Sheets to extract data. Then, each extraction result was submitted to a fourth reviewer to make the final decision. Specific details extracted from the included studies were the author and year of publication, study location, study design, sex and age of the victim, description of weapon used, manner of death, post-mortem findings, and cause of death.

3. Result

3.1. Characteristics and Selection Results of Included Studies

The initial literature search on the four databases yielded 342 articles, totaling 289 after removing duplicates. Next, screening by title and abstract yielded 21 articles for full-text review. We excluded six articles and left 15 that met the inclusion criteria for qualitative analysis. The flowchart of the study search can be seen in **Figure 1**. This systematic review included 15 case reports (age range of victims: 11 months to 78 years, and ten victims were male) published from 1972 to 2023. Five cases occurred in the United States, two in India, two in Croatia, and one in the United Kingdom, Japan, Macedonia, Montenegro, Hungary, and Poland. A synthesized summary of the included studies is presented in **Table 2**.

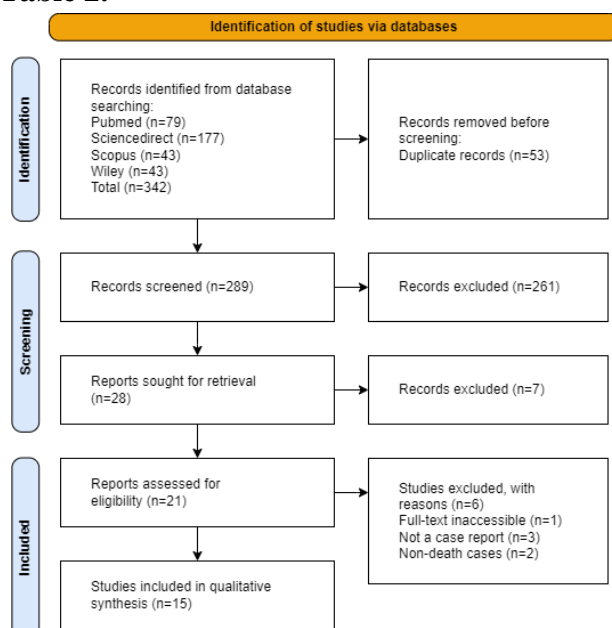


Figure 1. PRISMA flow diagram of study search

3.2. Study Quality Assessment Result

Study quality was assessed using the JBI critical appraisal tools for case reports. Overall, 13 studies were rated as 'good,' 2 were rated as 'fair,' and no studies were rated as 'poor.' **Table 3** summarizes the study quality assessment results.

4. Discussion

To the best of our knowledge, this is the first systematic review to address the forensic implications of airsoft gun and air rifle death cases. Our findings show that all deaths occurred from air gun use, while no deaths from airsoft guns were reported. Most cases occurred in the United States (5 out of 15) [9–13]. Most cases also reported that the bullet size used was 5.5 mm or .22 caliber (6 out of 15 cases) [9–14]. In addition, victims generally died by 'accidental death,' 7 out of 15 cases [14–20] with the most common causes of death being brain injury [9,10,13,16,17,19,20] and cardiac tamponade [11,12,18,21].

Our synthesis shows that the majority of air gun deaths occur in the United States. This may be related to the looser regulation of the possession of these weapons in the United States compared to other countries. In general, the use of airsoft guns and air guns is legalized without a permit in the United States, although the legality may differ based on state and local laws [19]. Most states have enacted laws allowing individuals of a certain age to own and use airsoft guns and air guns for shooting practice, hunting, and pest control. Age requirements for individuals may vary, as many governments set a minimum age of 18, while others set the age at 16. Certain states may also impose additional prerequisites, such as using an orange-colored tip on the gun's barrel to distinguish it from a real firearm [22,23]. Meanwhile, in Indonesia, permits related to the ownership and use of airsoft guns, air pistols, or air rifles are regulated in the Regulation of the Indonesian National Police Number 1 of 2022 concerning Licensing, Supervision, and Control of Standard Firearms of the Indonesian National Police, Non-Organic Firearms of the Indonesian National Police / Indonesian National Army, and

Security Equipment Classified as Firearms. The conditions required include: 1) have a membership card of a shooting group under Persatuan Menembak Sasaran dan Berburu Indonesia (PERBAKIN); 2) be at least 15 (fifteen) years old and at most 65 (sixty-five) years old; 3) be physically and mentally healthy as evidenced by a certificate from a doctor and a psychologist from the National Police; and 4) have shooting skills as evidenced by a certificate issued by PERBAKIN. In addition, the types and calibers of air pistols and air rifles permitted for target shooting purposes are 4.5 mm caliber air pistols and 4.5 mm caliber air rifles [4].

An air rifle is considered a form of firearm, as it is a barreled weapon, and the shot ejects pellets. The only difference from other firearms is that they propel the projectile through compressed air. Injuries from air rifles are relatively rare in Indonesia as they are not commonly used. However, they are relatively common in countries like the United States (US). According to US Consumer Products, two million air rifles are sold annually in the US. In Indonesia, although the use of air rifles is rare, it is still being promoted. No laws are related to air rifles; anyone can purchase them for hunting purposes, and no license is required. Furthermore, newspaper articles are published to sell air guns. In Indonesia, the legalized use is 4.5 mm caliber. The use of air rifles is also allowed for sporting purposes of reaction shooting [4,24].

Most cases mentioned that the air rifle used was 5.5 mm caliber (6 out of 15 cases). The most common mode of death was accidental death. The regulation of the use of air rifles is still accessible, causing many people to use them as toys. Air rifles should not be considered toys as they can cause fatal injuries and even death [17].

In this systematic review, we found that the most common causes of death were brain injury (7 out of 15 cases) and cardiac tamponade (4 out of 15 cases). Gunshot trauma to the chest wall is associated with high morbidity and mortality due to the presence of various vital organs in the area.

The slightest force generated by a bullet penetrating the chest wall can injure the heart, lungs, ascending and descending aorta, superior and inferior vena cava, vertebrae, and spinal cord. As the bullet has a forward and rotational motion, it has a much higher amount of kinetic energy, causing more damage to vital organs. The energy is dissipated when the bullet slows down inside the soft tissue. High-velocity injuries also cause secondary damage due to bone fragmentation, which is destroyed on impact and can aggravate the injury. Complications associated with the injury include cardiac tamponade, pneumothorax, and haemothorax, loss of sensory and motor function due to severe damage to the spinal cord, and spinal fractures [27].

Gunshot wounds to the head are an emergency with a high mortality rate. The extent of brain damage will depend on the energy of the bullet, so low-velocity shots always have a better prognosis than high-velocity shots. Low-velocity bullets cause penetrating brain injury, not perforation [28]. Aggressive management is essential to improve prognosis and patient outcomes [29].

There are several limitations to note from this review. We only included case reports that included a single patient, so it is impossible to analyze and generalize to a larger population, nor is it possible to determine causal relationships. Not all case reports reported detailed characteristics of the weapon used. Also, this review only included case reports that mainly occurred in European and American countries, as no studies from other countries met the inclusion criteria.

Table 2. Summary of inclusion study characteristics

No.	Authors	Year of Publication	Study Location	Age/Gender of Victim	Characteristics of Gun Used	Manner of Death	Post-Mortem Findings	Cause of Death
1.	Lal & Subrahmanyam[15]	1972	India	25 yrs/Male	Air rifle	Accidental	<p>Blood clots were found in both nostrils, and blood in the trachea, esophagus, and stomach.</p> <p>The right eye was swollen, and there was ecchymosis on the lower eyelid.</p> <p>An entry gunshot wound was found 1 cm below the edge of the lower eyelid and 2 cm right of the bridge of the nose, circular in shape, 0.5 cm in diameter, with irregular bruised edges.</p> <p>A bell-shaped pellet bullet with a diameter of 0.5 cm and a length of 0.7 cm was found lodged in the left cavernous sinus.</p> <p>On the bullet trajectory, a fracture of the right clinoid process was found; the direction of the wound was inward, backward, and from right to left.</p> <p>The brain and right eyeball were normal and intact.</p>	Hemorrhagic shock
2.	DiMaio[10]	1975	United States	17 yrs/Male	Sheridan air rifle with 5.5 mm bullet size	Homicide	<p>An entry wound in the right upper eyelid measuring 6 mm in diameter with a central perforation of 4 mm and sloughed edges.</p> <p>The bullet entered the skull cavity through the right orbital plate adjacent to the lamina cribiformis, creating a 2.2 x 2 cm oval defect. The bullet crossed the ventral aspect of the fitting straight gyrus, crossed the midline, penetrated the left straight gyrus, continued upward, posteriorly, and laterally along the anterior limb of the left internal capsule, stopping subcortically in the left posterior middle gyrus 5 cm to the left of the midline.</p>	Penetrating brain injury
3.	Green & Good[13]	1982	United States	47 yrs/Male	Sheridan air rifle with 5.5 mm bullet size	Homicide	<p>X-ray examination revealed projectiles on the right cheek, right temporal scalp, and midline of the occipital lobe. Projectile fragments were also seen on the pons and left temporal scalp.</p> <p>There were gunshot entry wounds to the right ear, left ala nasi, and left frontal-temporal scalp with a diameter of 4.5 mm.</p> <p>The wound to the right ear consisted of a short pathway passing through the scalp with an upward and forward deflection towards the temporalis muscle. The wound to the left ala nasi fractured the maxillary bone below the anterior spina nasalis. Exploration of the frontal-temporal region revealed projectile fragments in the temporalis muscle. A single wound track was</p>	Penetrating brain injury

							found passing through the brain's left hemisphere and ending at the pons. There was a subdural blood clot in the left hemisphere as well as a subarachnoid hemorrhage on the entire surface of the left hemisphere.	
4.	Buchanan[16]	1982	English	61 yrs/Male	Air gun with 4.5 mm bullet size	Accidental	<p>A 5 mm entry wound was found on the anteromedial wall of the orbital.</p> <p>The bullet entered through the ethmoid orbital plate, crossed the ethmoid air sinus, and entered the anterior fossa of the skull through the left cribriform plate. The bullet tore through the dura and meninges, and penetrated the lower surface of the frontal lobe, entered above and penetrated the left brain, tore the basal ganglia, crossed the left lateral ventricle before re-entering the left parieto-occipital cortex.</p> <p>There was extensive hemorrhage in and around the bullet path, and the hemorrhage had extended to the left hemispheric surface at the medial fossa and compressed the underlying structures.</p> <p>At the skull base, there was tentorial grooving of the uncus gyrus and herniation of the left cingulate gyrus below the falx with flame hemorrhage.</p>	Brain herniation
5.	Pottker et al.[9]	1997	United States	14 yrs/Male	Air rifle	Suicide	<p>Entry gunshot wounds were found in the bilateral temporal region with a diameter of 5 mm, consisting of circular perforation wounds with surrounding abrasion.</p> <p>The bullet perforated the lateral wall of the orbit and passed through the soft tissue behind the eyeball, disrupting the optic nerve and stopping at the superior orbital fissure.</p> <p>On the left, the bullet perforated the base of the skull, passed through the anterior and lateral aspects of the floor of the middle cranial fossa, entered the left temporal lobe, penetrated the brain in a straight path from left to right in a superior and posterior direction, and was recovered from the right occipital lobe.</p> <p>The brain showed diffuse edema, with bilateral subdural and subarachnoid hemorrhages. Mechanical disruption was limited to the BB pathway, with hemorrhage occurring.</p>	Brain death
6.	Ng'walali et al.[21]	2001	Japan	78 yrs/Female	Air gun with 5.5 mm bullet size	Homicide	Two entry gunshot wounds were found on the left chest wall and right back. Penetrations were found in the anterior pericardial sac, right ventricular infundibulum and left atrial anterior wall.	Cardiac tamponade

							Pellets migrated with blood flow to the left ventricle and aortic arch and lodged at the tip of the left subclavian artery Found a fatal pellet weighing 0.9 g and 5.5 mm in diameter and out of shape.	
7.	Kuligod et al.[17]	2006	India	12 yrs/Male	Air gun	Accidental	An entry wound, 7 mm in diameter, with a 4 mm central perforation and brown wound edges, was found 0.5 cm above the right eye brow and 4 cm right of the bridge of the nose. The bullet penetrated the skull cavity through the roof of the right orbit near the lamina cribiformis, entered the right frontal part of the brain, and lodged in the left occipital lobe. Diffuse subdural and subarachnoid hemorrhage was found, and both lateral ventricles were filled with blood clots. The recovered bullet weighed 0.78 grams.	Cerebral edema
8.	Stankov et al.[18]	2013	Macedonia	6 yrs/Male	Air gun with a bullet size of 4.5 mm and bullet weight of 0.5 grams	Accidental	It was found that the gunshot wound was 7 cm above and to the left of the right nipple and 90 cm above the heel; the diameter of the wound was 3 mm, accompanied by eccentric abrasion 2 mm wide. The bullet travels down through the right second intercostal muscle in the parasternal line, through the superior lobe of the lung, leaving a star-shaped footprint in the aortic wall and lodging at the base of the pericardial sac full of blood.	Cardiac tamponade
9.	Bakovic et al.[25]	2014	Croatia	26 yrs/Female	Diana Panther 31 with 4.5 mm bullet size	Suicide	During surgery, some blood is removed from the left chest cavity, and a defect found in the right ventricle is sutured. A metal object was found in the left chest cavity. Post-mortem findings showed surgical wounds that were sutured on the left chest wall and abdomen. Internal examination showed the front side of the pericardial sac that was surgically opened with no apparent wound on the dorsal side and two suture wounds in the heart.	Cardiac arrest
10.	Radojevic et al.[26]	2015	Montenegro	48 yrs/Female	Diana 350 Magnum air rifle with 4.5 mm bullet size	Homicide	An oval-shaped entrance wound, 4.0-3.5 mm in diameter, with a 2 mm wide skin abrasion ring, was found. The bullet passes through the right sternohyoid muscle above the thyroid gland, then through the right thyroid cartilage into the larynx, just below the vocal cords, and finally through the left thyroid cartilage to the left omohyoid muscle, where the two ruptured bullets are found.	Asphyxia due to laryngeal edema and hemorrhage

11.	Simon et al.[19]	2019	Hungary	11 months/Male	Tytan B2-4 air rifle with 5.5 mm bullet size	Accidental	Frontal bone defects with a diameter of 1.5-2 cm were found. Macroscopic examination of the lungs shows signs of acute bronchitis, and an embolus is found in the main artery of the lower right lobe. A sagittal brain laceration started from the frontal lobe and reached the occipital lobe. The thalamus is destroyed and unrecognizable, and the laceration is surrounded by focal macroscopic hemorrhage.	Brain death
12.	Mogni & Maines[12]	2019	United States	31 yrs/Male	GAMO Big Cat 1200 air rifle with 4.5 mm bullet size	Homicide	The pellet penetrates the anterior pericardial sac and penetrates the right ventricle of the heart, where it eventually enters the left pulmonary vein and is found around the left pulmonary artery. Non-cardiac injuries include emphysema mediastinum, mediastinal hemorrhage of the left hilus and soft tissues, and hemoaspiration. In addition, 500 milliliters (mL) of hemopericardium and 250 mL of left hemothorax were found.	Cardiac tamponade
13.	Guenther et al.[11]	2020	United States	21 yrs/Male	Pellet gun	Unknown	Pellets penetrate from the anterior crest of the left ventricle, the posterior aspect of the base of the left ventricle, the posterior pericardium, and the anterior esophagus. No defects were found in the posterior esophagus, and bullets were found in the abdomen.	Cardiac tamponade
14.	Dumenčić et al.[14]	2020	Croatia	7 yrs/Male	Air gun with 5.5 mm bullet size	Accidental	A gunshot wound was found on the left side of the chest, below the fifth rib, with a diameter of 4 mm. The wound path passes through the left lung and the diaphragm, and pointed lead pellets (4.5 mm caliber) are found in the liver.	Multiple organ injury
15.	Glowinski et al.[20]	2023	Poland	36 yrs/Female	KANDAR B3 3 airgun with 5.5 mm bullet size	Accidental	A gunshot wound was found in the left temporal region with a diameter of 5 mm; the wound path stretched the temporal bone, penetrating the dura mater and pia mater in the temporal lobe and left frontal (where diffuse subarachnoid hemorrhage was found) to the left lateral wall of the sphenoid sinus (with hematomas in the lumen and massive aspiration of blood to the lower airway). The bullet channel in the wound in the head has a total length of 6 cm.	Intracranial injury and asphyxia

The autopsy revealed that after turning the victim's body to the side, the bullet came out along with the blood, flowing out of his body through the nasal cavity.

On the right leg, a 6 x 3 mm gunshot wound was found surrounded by abrasions 1 mm wide. The path of the gunshot wound is 60 mm long and runs under the skin above the dorsal side of the second metatarsal bone towards the base of the second toe.

The results of toxicology tests also revealed the presence of 0.34% ethyl alcohol in the blood and 0.46% in the urine.

Table 3. Study quality assessment results

No.	Authors	Years	Q1	Q2	Q3	Q4	Q5	Q6	Q7	Q8	Total Scores (Out of 8)	Quality
1.	Lal & Subrahmanyam[15]	1972	Y	Y	Y	Y	Y	N	Y	Y	7	Good
2.	DiMaio[10]	1975	Y	Y	Y	Y	N	N	Y	Y	6	Good
3.	Green & Good[13]	1982	Y	N	Y	N	Y	Y	N	Y	5	Fair
4.	Buchanan[16]	1982	Y	Y	Y	Y	Y	U	Y	Y	7	Good
5.	Pottker et al.[9]	1997	Y	Y	Y	Y	N	N	Y	Y	6	Good
6.	Ng'walali et al.[21]	2001	Y	Y	N	Y	Y	Y	Y	Y	7	Good
7.	Kuligod et al.[17]	2006	Y	Y	Y	Y	Y	Y	Y	Y	8	Good
8.	Stankov et al.[18]	2013	Y	Y	U	Y	Y	Y	Y	Y	7	Good
9.	Bakovic et al.[25]	2014	Y	N	Y	Y	Y	Y	Y	Y	7	Good
10.	Radojevic et al.[26]	2015	Y	Y	Y	Y	Y	N	Y	Y	7	Good
11.	Simon et al.[19]	2019	Y	U	Y	Y	Y	Y	Y	Y	8	Good
12.	Mogni & Maines[12]	2019	Y	N	Y	N	Y	N	Y	Y	5	Fair
13.	Guenther et al.[11]	2020	Y	U	Y	Y	Y	Y	Y	Y	7	Good
14.	Dumenčić et al.[14]	2020	Y	Y	Y	Y	Y	Y	Y	Y	8	Good
15.	Glowinski et al.[20]	2023	Y	N	Y	Y	Y	N	Y	Y	6	Good

The quality of the included studies was assessed with: Poor 0-2; Fair 3-5; Good 6-8

Abbreviations: Y: Yes; N: No; U: Unclear

5. Conclusion

In conclusion, the death rate in cases of air rifle gunshot wounds is highest when the bullet hits a vital organ. The most common causes of death were brain injury and hemorrhagic shock due to cardiac tamponade, which were found in the post-mortem findings. There were no reported cases of death related to the use of airsoft guns; all reported cases were deaths that occurred due to the use of air rifles. In addition, there are many cases of accidental shooting with airsoft guns by friends, relatives, or self-harm. While airsoft guns can be used in beneficial ways, they are dangerous when used by children without adult supervision.

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8. Attachment

Attachment 1. study search keywords

Database	Keywords	Search Results
Pubmed	(airsoft gun OR air gun OR air weapon OR air rifle OR air pellet) AND (death OR fatal OR lethal) AND (Case Report OR Case Study OR Case Studies OR Case Histories)	79
ScienceDirect	("airsoft gun" OR "air gun" OR "air pellet") AND ("death" OR "fatal" OR "lethal") AND ("case report" OR "case study")	177
Scopus	("airsoft gun" OR "air gun" OR "air pellet") AND ("death" OR "fatal" OR "lethal") AND ("case report" OR "case study")	43
Wiley	("airsoft gun" OR "air gun" OR "air pellet") AND ("death" OR "fatal" OR "lethal") AND ("case report" OR "case study")	43