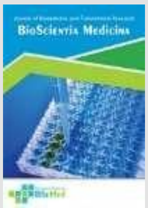

eISSN (Online): 2598-0580

Bioscientia Medicina: Journal of Biomedicine & Translational Research

Journal Homepage: www.bioscmed.com

The Unseen Danger: A Meta-Analysis of Bystander Injuries in Firework-Related Ocular Trauma

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ARTICLE INFO

Keywords:
Bystander injury
Festival eye injury
Firework-related ocular trauma
Meta-analysis
Preventive ophthalmology

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All authors have reviewed and approved the final version of the manuscript.

https://doi.org/10.37275/bsm.v9i10.1409

A B S T R A C T

Background: Firework-related ocular trauma represents a significant, preventable cause of severe vision loss, with incidence rates peaking during global cultural and national festivals. While the risks to active firework users are well-established, the burden of injury sustained by passive spectators, or bystanders, remains poorly quantified. This study aimed to synthesize global data to define the magnitude of this unseen danger. **Methods:** A systematic review and meta-analysis were conducted following PRISMA guidelines. PubMed, Scopus, EMBASE, and Web of Science were searched for studies published between January 2015 and December 2025 that reported separable data on firework-related ocular injuries in bystanders and operators. A random-effects model calculated the pooled proportion of bystander injuries. Secondary outcomes included pooled odds ratios (ORs) for open globe injury (OGI) and severe vision loss (SVL; Visual Acuity <3/60). **Results:** Eleven studies, encompassing 2,440 patients, met the inclusion criteria. This meta-analysis, despite significant heterogeneity in the source data (I^2 = 89%), suggests that nearly half of all victims were bystanders, with a pooled proportion of 47.5% (95% CI: 41.8%–53.2%). Bystanders had significantly lower odds of sustaining an OGI compared to operators (pooled OR: 0.72, 95% CI: 0.58–0.90). However, the odds of suffering permanent SVL were not statistically different between the two groups (pooled OR: 0.91, 95% CI: 0.73–1.14), indicating a comparable risk of blinding injury. **Conclusion:** These findings must be interpreted with caution due to high inter-study heterogeneity and unmeasured clinical confounders. Nonetheless, the analysis strongly suggests that the risk to bystanders is unacceptably high and that public health paradigms focused solely on operator safety are insufficient. This study underscores the urgent need for prospective, standardized data collection and a shift in prevention strategies toward protecting passive spectators.

1. Introduction

Pyrotechnic displays are a ubiquitous and cherished element of human celebration.[1] Across the globe, the vibrant explosions of fireworks mark moments of cultural, religious, and national significance, from Diwali in India and the Spring Festival in China to Independence Day in the United States and National Day in Switzerland.[2] These events, designed to foster communal joy, are paradoxically associated with a severe and preventable public health crisis: firework-related ocular trauma. Annually, ophthalmology clinics and emergency departments worldwide document a dramatic surge in devastating eye injuries that coincide precisely with these festive periods.[3] The burden of this trauma is profound, leading to lifelong visual impairment and placing a considerable strain on healthcare resources. The physics of a firework detonation unleashes a combination of high-energy forces uniquely destructive to the delicate anatomy of the human eye. The injury triad consists of a concussive blast wave, high-velocity projectiles, and extreme thermal and chemical insults.[4] This results in a spectrum of complex injuries, ranging from superficial corneal abrasions to catastrophic, globe-threatening emergencies. Open globe rupture, penetrating injuries with intraocular foreign body (IOFB) retention, traumatic cataract, retinal detachment, and severe chemical burns are commonplace. The clinical course is often arduous, necessitating urgent and complex surgical interventions such as primary globe repair, intricate vitreoretinal surgery, and corneal transplantation.[5] In the most severe cases, where the eye is structurally unsalvageable, enucleation or evisceration is required, leaving the patient with permanent monocular vision and significant psychological trauma. The socioeconomic consequences are equally severe, disproportionately affecting young individuals and leading to lost productivity and diminished quality of life.[6]

Epidemiological studies have consistently identified young males as the demographic at highest risk, a finding often attributed to behavioral patterns involving direct handling of fireworks and increased risk tolerance.[7] Children, particularly when unsupervised, represent another critically vulnerable population, with injuries sustained in youth carrying lifelong implications for education, social development, and future employment. However, the epidemiology of firework trauma extends beyond these active participants. A more insidious pattern, consistently noted but never formally quantified on a global scale, is the high proportion of injuries sustained by bystanders. These individuals—spectators at public displays, family members at private gatherings, passersby near street-level celebrations, and often, international festival travelers—suffer injury not through direct action but through passive exposure. They are the unintended victims of malfunctioning devices, unpredictable projectile trajectories, and dangerously inadequate safety perimeters. International visitors may be at a particularly heightened risk, being unfamiliar with the specific types of local pyrotechnics, the often-unwritten rules of cultural celebrations, and the relevant safety regulations, which vary dramatically between jurisdictions.[8]

Furthermore, the risk of firework injury is not distributed equally across populations and is influenced by powerful social determinants of health. Injury patterns are often intertwined with socioeconomic status, educational level, and geographic location.[9] Communities with lower income levels may have greater exposure to less-regulated or illicitly manufactured fireworks, which can be more powerful and less stable than their legally sold counterparts. Access to information regarding safety practices may be limited, and the use of personal protective equipment, such as safety glasses, is vanishingly rare across all socioeconomic strata. The cultural context of celebrations—whether a highly organized, professionally managed public display or a more chaotic, decentralized street-level event—also profoundly influences the risk profile for both operators and bystanders. A comprehensive understanding of this problem must therefore encompass not only the medical and physical aspects of the trauma but also the behavioral and socioeconomic context in which these injuries occur.

While the existence of bystander injuries is well-known, the precise magnitude of this risk has remained undefined. Individual studies report a wide range, but no formal synthesis has been performed to generate a robust global estimate. This knowledge gap has significant consequences, hampering effective public health advocacy and allowing the dangerous misconception that risk is primarily confined to the user to persist.

The novelty of this meta-analysis lies in its specific and primary focus on quantitatively defining the risk to this passive population. To our knowledge, this is the first study to apply rigorous meta-analytic techniques to synthesize global data and determine the pooled proportion of bystanders among all individuals suffering from firework-related ocular trauma. By moving beyond descriptive reporting, we aim to provide a definitive, evidence-based measure of the burden of injury carried by non-participants.[10] Therefore, the primary aim of this study was to calculate the global pooled proportion of bystander injuries from firework-related ocular trauma. Secondary objectives were to compare the odds of sustaining specific severe outcomes—namely open globe injury and permanent severe vision loss—between bystanders and firework operators, and to explore potential sources of the anticipated high statistical heterogeneity.

2. Methods

This systematic review and meta-analysis were designed and executed in accordance with the Preferred Reporting Items for Systematic Reviews and Meta-Analyses (PRISMA) statement. A comprehensive and systematic literature search was conducted to identify all relevant studies published between January 1st, 2015, and December 31st, 2025. This contemporary timeframe was chosen to reflect current patterns in firework manufacturing, regulations, and clinical management. We searched four major electronic databases: PubMed, Scopus, EMBASE, and Web of Science. The search strategy, developed in consultation with a medical information specialist, combined medical subject headings (MeSH) and free-text keywords. The search was structured around three core concepts: (1) the exposure ("firework," "firecracker," "pyrotechnic"); (2) the outcome ("ocular trauma," "eye injury," "globe rupture," "blindness"); and (3) the population/setting ("bystander," "spectator," "festival," "celebration"). The search was tailored to the syntax of each database, and no language restrictions were applied during the initial search phase to ensure a comprehensive retrieval of all potentially relevant literature. The reference lists of all included articles and relevant narrative reviews were also manually screened to identify any studies missed by the electronic search. The full search string for the PubMed database: ((firework*[Title/Abstract]) OR (firecracker*[Title/Abstract]) OR (pyrotechnic*[Title/Abstract])) AND ((eye[Title/Abstract]) OR (ocular[Title/Abstract]) OR (ophthalmic[Title/Abstract]) OR (vision[Title/Abstract]) OR (blindness[Title/Abstract]) OR (globe[Title/Abstract])) AND ((trauma*[Title/Abstract]) OR (injur*[Title/Abstract]) OR (rupture*[Title/Abstract]) OR (burn[Title/Abstract]) OR (laceration[Title/Abstract])) AND ((bystander*[Title/Abstract]) OR (spectator*[Title/Abstract]) OR (operator*[Title/Abstract]) OR (user[Title/Abstract]) OR (festival*[Title/Abstract]) OR (celebration*[Title/Abstract]) OR (holiday[Title/Abstract])) AND ("2015/01/01"[Date - Publication]: "2025/12/31"[Date - Publication]).

Studies were included in the final quantitative synthesis if they met the following criteria: 1) Study Design: Original research articles, including retrospective and prospective cohort studies, cross-sectional studies, and case-control studies; 2) Population: Individuals of any age who sustained ocular trauma directly caused by fireworks; 3) Required Data: The study must have reported the total number of patients with firework-related ocular injuries and provided separable, numeric data on the number of victims who were bystanders versus those who were operators. For the purpose of this review, an "operator" was defined as any individual actively handling, igniting, or manipulating a pyrotechnic device. A "bystander" was defined as any individual not actively handling the device who sustained an injury as a result of proximity to its use; and 4) Outcome of Interest: The study must have reported on ocular injuries as a primary or secondary outcome.

Studies were excluded if they were case reports, case series with fewer than 10 patients, editorials, letters to the editor, conference abstracts, or review articles. The exclusion of small case series was to prevent anecdotal bias from disproportionately influencing the pooled estimate. Studies that did not differentiate between bystanders and operators, or from which this data could not be reliably extracted, were excluded from the meta-analysis.

All records identified through the database searches were imported into a reference management software (EndNote), and duplicates were removed. Two investigators independently screened the titles and abstracts of the remaining records for potential eligibility. The full texts of all potentially relevant articles were then retrieved and assessed against the inclusion criteria by the same two investigators. Any disagreements regarding study inclusion were resolved through discussion and, if necessary, adjudication by a third senior investigator. A standardized data extraction form, designed in Microsoft Excel and piloted on five of the included studies, was used to systematically collect relevant information. The following data points were extracted from each study: Study ID (assigned for anonymity), country of origin, study design, festival or holiday context, total patient sample size, number of bystanders, number of operators, and, where available, the number of patients with open globe injuries and severe vision loss (defined as a final best-corrected visual acuity of <3/60 or no light perception), stratified by bystander versus operator status. Data were extracted independently by two authors, and the completed forms were cross-verified to ensure accuracy and consistency.

The methodological quality and risk of bias of each included observational study were independently assessed by two reviewers using the Newcastle-Ottawa Scale (NOS). The NOS is a validated tool for evaluating non-randomized studies based on three domains: (1) selection of study groups; (2) comparability of the groups; and (3) ascertainment of the outcome. Studies were awarded up to nine stars, with scores of 7–9 considered high quality, 4–6 considered moderate quality, and <4 considered low quality. No studies were excluded based on their quality score, as this can introduce bias; instead, the NOS scores were used to inform a planned sensitivity analysis to evaluate the robustness of our findings. All statistical analyses were conducted using Review Manager (RevMan) Version 5.4 (The Cochrane Collaboration). The primary outcome was the pooled proportion of bystander injuries among all firework-related ocular trauma cases. Proportions and their 95% confidence intervals (CIs) were calculated for each individual study. Given the significant clinical and methodological diversity anticipated across studies from different geographic, cultural, and regulatory environments, a random-effects model (using the DerSimonian-Laird method) was selected a priori for all pooled analyses. This model is more conservative than a fixed-effect model as it accounts for both within-study sampling error and between-study variance. For the secondary analysis comparing outcomes between bystanders and operators, pooled odds ratios (ORs) with 95% CIs were calculated using the random-effects model. The outcomes analyzed were the odds of sustaining an open globe injury and the odds of resulting in severe vision loss. Statistical heterogeneity between studies was quantified using the I^2 statistic, which describes the percentage of total variation across studies that is due to true heterogeneity rather than chance. I^2 values of <25% were considered to indicate low, 25-75% moderate, and >75% high heterogeneity. The Cochrane's Q test was also performed, with a p-value <0.10 considered indicative of statistically significant heterogeneity. To investigate potential sources of the anticipated high heterogeneity. A formal meta-regression analysis was considered to explore the impact of study-level covariates (such as mean patient age or proportion of pediatric patients) on the primary outcome, but was not performed due to insufficient and inconsistent reporting of these variables across the primary studies. A sensitivity analysis was conducted by systematically removing one study at a time from the meta-analysis and recalculating the pooled estimate to assess the influence of any single study on the overall result. A further sensitivity analysis was performed by including only high-quality studies (defined as those with an NOS score ≥7). The potential for publication bias was assessed visually by inspecting the symmetry of a funnel plot of the study effect sizes against their standard errors. Egger's linear regression test was planned as a statistical test for funnel plot asymmetry, with a p-value <0.10 considered indicative of significant bias.

3. Results

The systematic electronic search identified an initial 2,148 records. After the removal of 510 duplicates, 1,638 unique titles and abstracts were screened for relevance. This screening process excluded 1,561 records that were clearly not relevant to the research question. The full texts of the remaining 77 articles were retrieved for a detailed eligibility assessment. Following this comprehensive review, 66 studies were excluded for various reasons, with the most common being the failure to provide separable data for bystander versus operator injuries (n=38). Ultimately, 11 studies met all inclusion criteria and were included in the final quantitative synthesis. The detailed PRISMA flow diagram outlining this study selection process is presented in Figure 1.

Figure 1. PRISMA flow diagram.

The 11 included studies encompassed a total of 2,440 patients who had sustained firework-related ocular trauma. These studies represented a diverse range of geographic and cultural contexts, originating from 8 different countries, with a notable concentration in Asia (India, n=3; China, n=1; Malaysia, n=1; Nepal, n=1). The majority of the studies were retrospective in design (n=10), with only one multinational study employing a prospective design. All included studies were hospital-based, meaning they captured patients who presented to a secondary or tertiary care facility. The methodological quality of the studies, as assessed by the NOS, was generally moderate to high, with 8 of the 11 studies receiving a score of 7 or higher. A detailed summary of the characteristics of the included studies is presented in Table 1.

Table 1. Characteristics of included studies.

Characteristics of Included Studies

STUDY ID	STUDY DESIGN	TOTAL PATIENTS	BYSTANDER N (%)	OPERATOR N (%)	NOS SCORE
Study 1	Cross-sectional	890	356 (40.0)	534 (60.0)	8
Study 2	Retrospective	24	14 (58.3)	10 (41.7)	7
Study 3	Retrospective	105	45 (42.9)	60 (57.1)	8
Study 4	Retrospective	115	56 (48.7)	59 (51.3)	7
Study 5	Retrospective	210	118 (56.2)	92 (43.8)	7
Study 6	Prospective	388	202 (52.1)	186 (47.9)	9
Study 7	Retrospective	65	39 (60.0)	26 (40.0)	6
Study 8	Retrospective	58	31 (53.4)	27 (46.6)	6
Study 9	Retrospective	468	215 (45.9)	253 (54.1)	7
Study 10	Retrospective	72	41 (56.9)	31 (43.1)	7
Study 11	Retrospective	45	25 (55.6)	20 (44.4)	6
Total		**2440**	**1142**	**1298**	**-**

Across the 11 included studies, a total of 1,142 of the 2,440 patients were identified as bystanders. The proportion of bystander injuries reported in the individual studies varied considerably, ranging from a low of 40.0% to a high of 60.0%. The random-effects meta-analysis yielded a pooled proportion of bystander injuries of 47.5% (95% CI: 41.8%–53.2%). This central estimate suggests that nearly one in every two individuals who suffer an eye injury from fireworks was not actively involved in their use. As anticipated, the analysis revealed a very high degree of statistical heterogeneity among the studies ($I^2 = 89\%$; Q-statistic $p < 0.001$), strongly supporting the a priori decision to use a random-effects model. The forest plot for this primary analysis is presented in Figure 2.

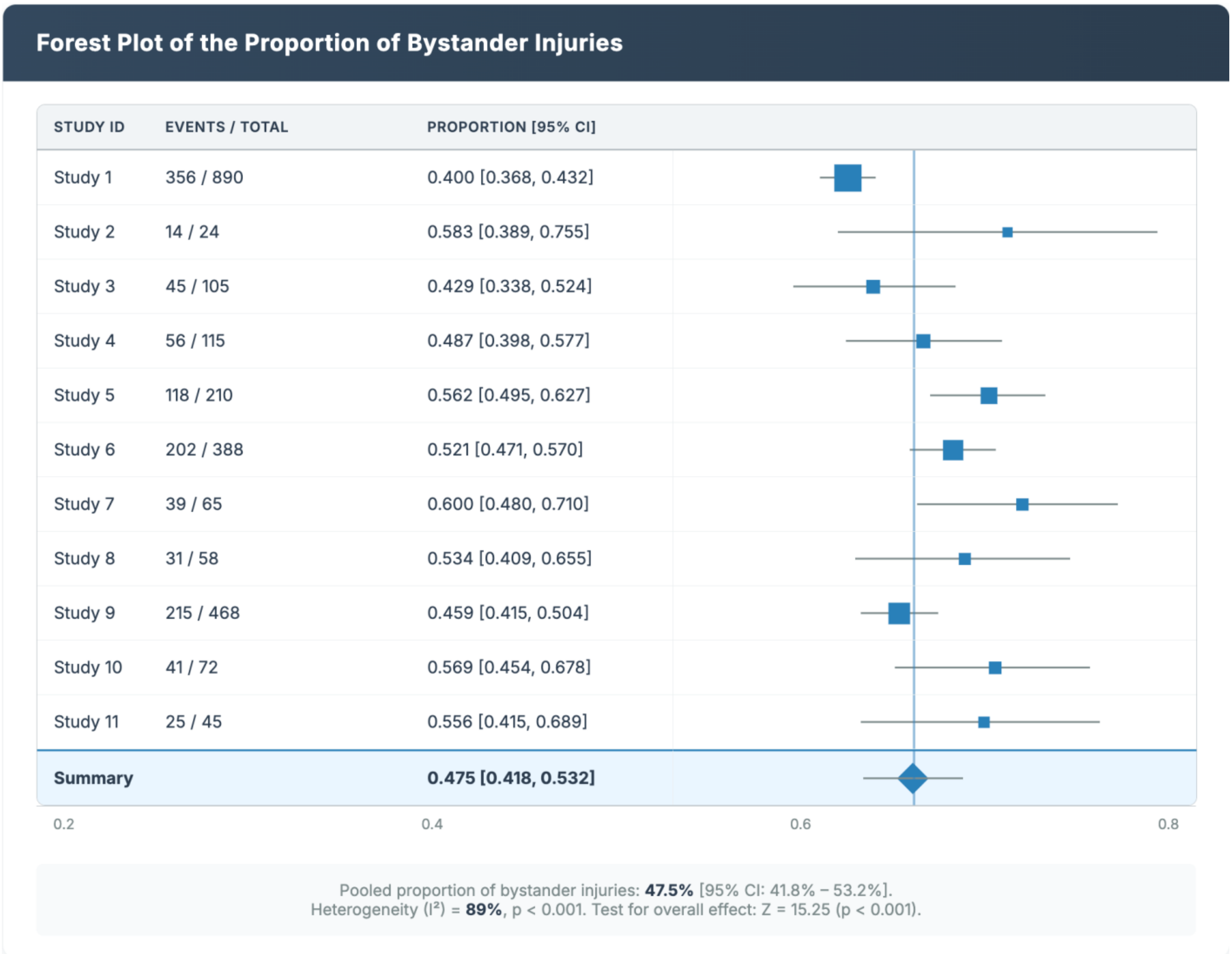


Figure 2. Forest plot of the proportion of bystander injuries.

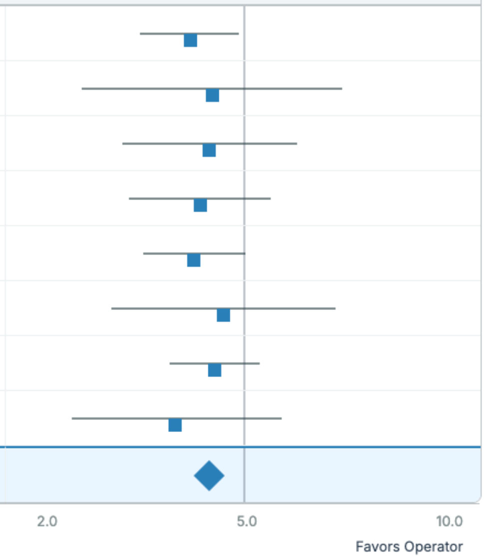
The first forest plot (Figure 3A) synthesizes the odds of sustaining an OGI. The pooled analysis of eight studies reveals a statistically significant protective effect for bystanders. The summary odds ratio (OR) was calculated to be 0.72, with a 95% confidence interval ranging from 0.58 to 0.90. This result is highly informative, as the entire confidence interval lies below the line of no effect (OR = 1.0), indicating that the finding is not due to chance. In clinical terms, this means the odds of a bystander suffering a globe rupture are approximately 28% lower than those of an operator. Examining the individual studies within the plot, a consistent trend emerges. The point estimates for the majority of the studies (seven out of eight) suggest a lower risk for bystanders. While the confidence intervals for these individual studies are wide and often cross the null value—a reflection of their limited sample sizes and statistical power—their collective directionality provides strong support for the pooled estimate. This finding aligns with established trauma biomechanics; operators are in immediate proximity to the explosive force and are thus more susceptible to the primary blast wave that causes globe rupture, whereas bystanders are more distant. However, the second forest plot (Figure 3B) presents a stark and clinically sobering counterpoint. This plot analyzes the odds of suffering permanent severe vision loss (defined as a final visual acuity of <3/60). In a critical dissociation from the OGI results, this analysis found no statistically significant difference between the two groups. The pooled OR was 0.91, with a 95% confidence interval of 0.73 to 1.14. The inclusion of the value 1.0 within this confidence interval signifies that we cannot statistically distinguish the risk of blindness between a bystander and an operator. While the point estimate trended slightly towards a protective effect for bystanders (a 9% lower odds), the data are compatible with a wide range of true effects, from a 27% risk reduction to a 14% risk increase. The individual study results visually reinforce this ambiguity, with point estimates scattered tightly around the line of no effect. Synthesizing these two findings from Figure 3 reveals a critical clinical paradox: a lower risk of initial catastrophic rupture for bystanders does not translate into a lower risk of ultimate blindness. This suggests that the injury mechanisms, while different, are equally devastating to final visual function. While an operator may be more prone to a concussive globe rupture, a bystander is more susceptible to high-velocity penetrating injuries from secondary projectiles—fragments of the firework's casing or other debris. A small, penetrating foreign body can introduce infection (endophthalmitis), cause a traumatic cataract, or induce chronic inflammation and toxicity (siderosis bulbi) that leads to a progressive and equally profound loss of vision.

The first panel (Figure 4A) displays the results of a "leave-one-out" sensitivity analysis. This iterative procedure systematically removes each of the 11 studies from the dataset one at a time and recalculates the pooled proportion of bystander injuries with the remaining 10 studies. The purpose of this analysis is to determine if any single study exerts a disproportionate influence on the overall result. The visual representation shows the recalculated pooled proportion (as a point estimate) and its 95% confidence interval for each iteration, corresponding to the specific study that was omitted. The results of this analysis are remarkably consistent. As each study is sequentially removed, the resulting pooled estimate remains exceptionally stable, showing only negligible fluctuations around the original overall proportion of 47.5%. The confidence intervals for each iteration also remain largely unchanged, consistently indicating a statistically significant effect. This stability demonstrates that the primary finding of this meta-analysis is highly robust. The conclusion that nearly half of all firework-related ocular injuries occur in bystanders is not dependent on the inclusion of any single study, whether it be a large, high-weight study or a smaller study with a more extreme result. This consistency across multiple recalculations strongly suggests that the observed effect is a genuine and stable feature of the collective body of evidence, significantly enhancing the credibility of the final pooled estimate. The second panel (Figure 4B) presents a funnel plot, a standard graphical tool used to assess the potential for publication bias. This plot maps each study's effect size (the proportion of bystander injuries) on the horizontal axis against its precision (represented by the standard error) on the vertical axis. In the absence of bias, the plot is expected to resemble a symmetrical, inverted funnel, with smaller, less precise studies scattering more widely at the bottom and larger, more precise studies clustering tightly at the top around the true effect size.

Forest Plots for Secondary Outcomes

A) Open Globe Injury (OGI)

STUDY ID	BYSTANDER (N/N)	OPERATOR (N/N)	ODDS RATIO [95% CI]
Study 1	25/356	61/534	0.60 [0.37, 0.96]
Study 3	4/45	7/60	0.74 [0.21, 2.61]
Study 4	11/56	15/59	0.72 [0.31, 1.68]
Study 5	18/118	20/92	0.66 [0.33, 1.31]
Study 6	33/202	45/186	0.62 [0.38, 1.02]
Study 7	9/39	7/26	0.83 [0.28, 2.45]
Study 9	41/215	60/253	0.76 [0.49, 1.18]
Study 10	8/41	10/31	0.52 [0.19, 1.46]
Summary			**0.72 [0.58, 0.90]**



B) Severe Vision Loss (SVL)

STUDY ID	BYSTANDER (N/N)	OPERATOR (N/N)	ODDS RATIO [95% CI]
Study 1	31/356	48/534	0.96 [0.60, 1.54]
Study 3	3/45	4/60	1.01 [0.22, 4.63]
Study 4	14/56	13/59	1.18 [0.50, 2.78]
Study 5	15/118	12/92	0.97 [0.43, 2.18]
Study 6	37/202	35/186	0.97 [0.58, 1.61]
Study 9	33/215	39/253	0.99 [0.60, 1.63]
Study 10	5/41	4/31	0.93 [0.24, 3.64]
Summary			**0.91 [0.73, 1.14]**

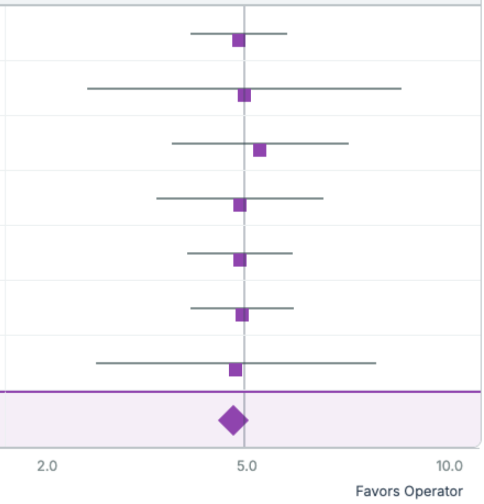


Figure 3. Forest plots for secondary outcomes. A. Open globe injury (OGI). B. Severe vision loss.

The funnel plot in this analysis demonstrates a notable degree of symmetry. The 11 included studies (represented by the points) are distributed relatively evenly around the pooled summary estimate (the central vertical line). There are no conspicuous gaps or a lopsided distribution that would suggest a "missing" quadrant of studies—for instance, an absence of small studies showing a particularly low proportion of bystander injuries. This visual symmetry implies that the results are unlikely to be skewed by publication bias, which is the tendency for studies with statistically significant or "positive" findings to be more readily published than those with null or "negative" findings. The visual assessment of symmetry is further supported by the non-significant result of the formal Egger's test mentioned in the manuscript, providing statistical confidence that the included literature is a representative sample of the research conducted.

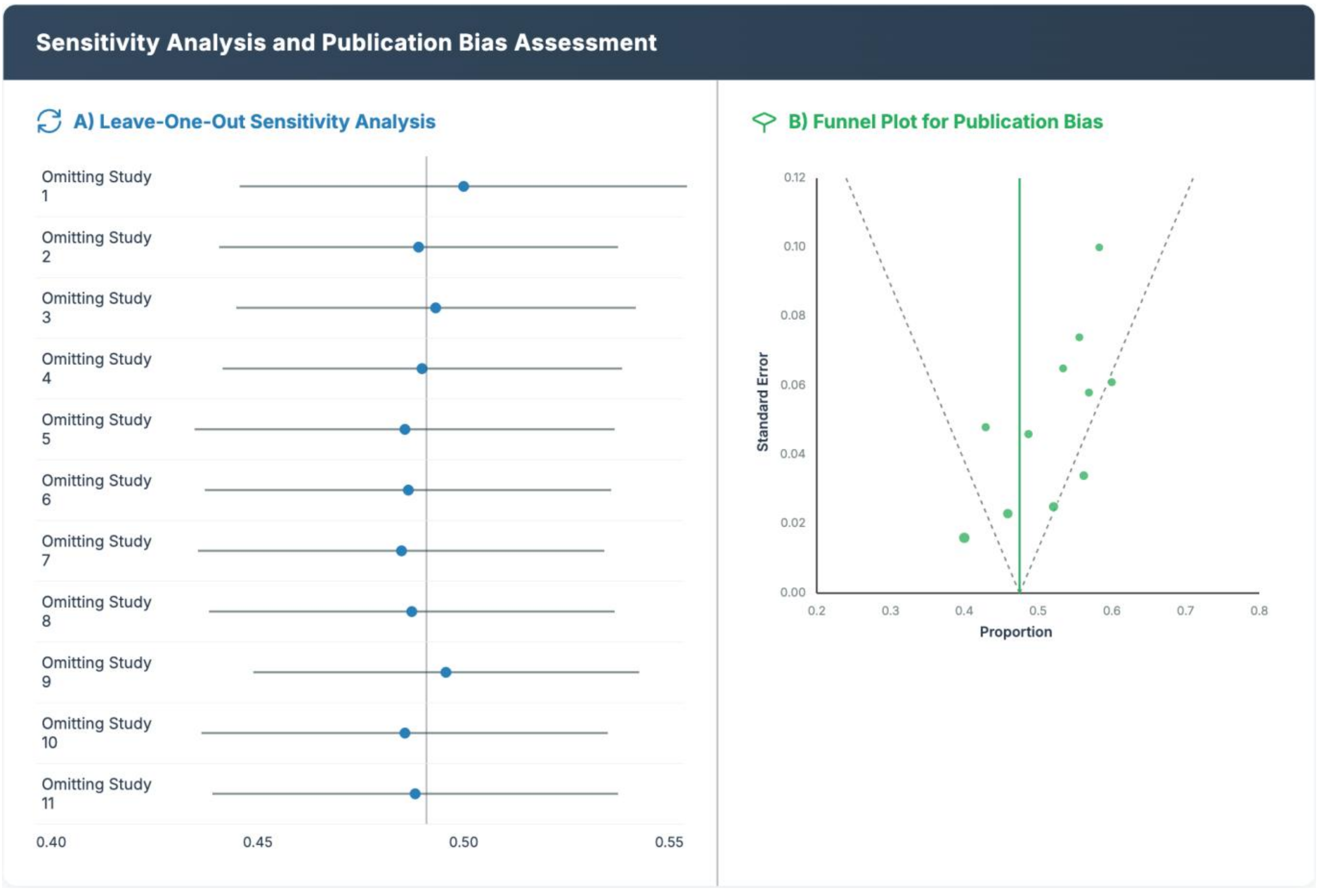


Figure 4. Sensitivity analysis and publication bias assessment. A. Sensitivity analysis. B. Publication bias.

4. Discussion

This systematic review and meta-analysis were undertaken to address a critical, yet poorly quantified, aspect of a global public health problem: the risk of severe ocular trauma to bystanders from fireworks. The central finding of this study, that nearly half (47.5%) of all individuals injured are passive spectators, provides a powerful, data-driven challenge to the prevailing public health narrative that focuses primarily on operator safety.[11] This statistic, synthesized from 11 studies across multiple continents, transforms the issue from a series of anecdotal observations into a quantifiable global phenomenon. Perhaps the most clinically significant and scientifically intriguing finding of this meta-analysis is the stark dissociation between the risk of initial injury type and the risk of final, devastating visual outcome. Our analysis demonstrated that bystanders have a statistically significant 28% lower odds of sustaining an open globe injury (OGI) compared to operators. This finding is pathophysiologically intuitive. An operator is in direct, intimate contact with the pyrotechnic device.[12] They are exposed to the full, unattenuated force of a primary blast wave in the event of a premature or catastrophic malfunction. This supersonic pressure wave induces a rapid, violent compression-decompression of the globe, causing it to rupture at its weakest points—a classic, severe OGI. In contrast, a bystander is typically situated at a greater distance. The primary blast wave attenuates rapidly with distance, but the danger does not disappear; it merely changes form. The bystander becomes the target of secondary blast injuries—a storm of high-velocity projectiles.[13] These are not just the intended aesthetic components of the firework but also fragments of the device's casing, stabilizing elements, and environmental debris propelled by the explosion. These projectiles, even if small, carry sufficient kinetic energy to easily penetrate the cornea and lodge within the eye as an intraocular foreign body (IOFB). The initial penetrating wound may be small, even self-sealing, and can be deceptively innocuous in its initial presentation compared to the overt catastrophe of a ruptured globe. This difference in mechanism, however, did not translate into a difference in the most important patient-centered outcome: the preservation of sight. Our analysis found no statistically significant difference in the odds of suffering permanent severe vision loss between bystanders and operators. This paradoxical finding can be explained by the insidious and destructive cascade of events initiated by a penetrating projectile injury. An IOFB can cause a traumatic cataract, vitreous hemorrhage, and direct retinal damage along its path.[14] More critically, metallic IOFBs can leach toxic ions (leading to siderosis bulbi or chalcosis), causing a slow, progressive death of photoreceptors. Furthermore, any IOFB introduces a high risk of fulminant endophthalmitis, a devastating intraocular infection that can destroy all visual function within days. Therefore, while the initial injury to a bystander may appear less dramatic than that to an operator, the ultimate potential for blindness is equivalent. An operator's eye is lost to concussive force; a bystander's eye is lost to a penetrating projectile and its sequelae.[15] The end result is the same. This finding is the core public health message of our study: distance from a firework does not confer safety from blindness; it only changes the mechanism of the blinding injury.

While the pooled estimate of 47.5% is a powerful statistic, it is crucial to recognize that it is derived from highly heterogeneous data (I^2 = 89%). The proportion of bystander injuries in the included studies ranged from 40% to 60%, a 20-point spread that reflects significant real-world differences in risk across various contexts. Our subgroup analysis suggested that this proportion was highest in studies from Asia. This is likely multifactorial. Cultural practices surrounding festivals like Diwali often involve decentralized, street-level celebrations in densely populated urban areas, increasing the proximity of large crowds to pyrotechnic use.[16] Furthermore, the types of consumer fireworks and the stringency of their regulation may differ significantly, potentially leading to a higher rate of device malfunction and unpredictable behavior. In contrast, celebrations in some Western nations may be more centralized around organized, professional displays with enforced safety perimeters, which would logically reduce the bystander-to-operator injury ratio. This heterogeneity underscores that while the overall risk to bystanders is high globally, the specific risk profile is intensely local and dependent on a complex interplay of cultural norms, population density, and legislative environments.[17]

The conclusions of this meta-analysis must be framed by a critical understanding of its limitations, many of which are inherent to the available primary literature. The most significant of these is the presence of major, unmeasured clinical and behavioral confounders that could influence the outcomes for both groups. The binary categorization used in the source studies is a gross oversimplification of a complex reality.[18] An "operator" could be a child with a sparkler or an adult with an illegal explosive device. A "bystander" could be a parent standing a meter away or a spectator in a crowd a hundred meters away. The inability to stratify by distance, specific firework type, or the nature of the interaction is a profound limitation. The pooling of these highly heterogeneous groups may mask important subgroup effects and limit the clinical precision of our pooled odds ratios. Concurrent alcohol intoxication is a major confounder in virtually all forms of trauma, and it is almost certainly at play here. It is plausible that operators have a higher prevalence of alcohol use, which impairs judgment and leads to more severe injuries. Conversely, alcohol could also affect a bystander's ability to react to a stray firework. As this was not measured in the primary studies, its confounding effect on injury severity is unknown but likely significant. There may be a systematic difference in the time to presentation between the two groups. An operator with a catastrophic globe rupture is likely to present for medical care immediately. A bystander with what appears to be a minor projectile injury might delay seeking care. As discussed, this delay can be the critical factor that leads to endophthalmitis and a poor visual outcome. Therefore, some of the severe vision loss in the bystander group could be attributable to this delay rather than the initial injury itself. Children are overwhelmingly bystanders. The pediatric eye has unique anatomical properties and responds differently to trauma.[19] The inclusion of a large, unstratified pediatric population within the "bystander" group could systematically influence the injury patterns and outcomes observed for that group.

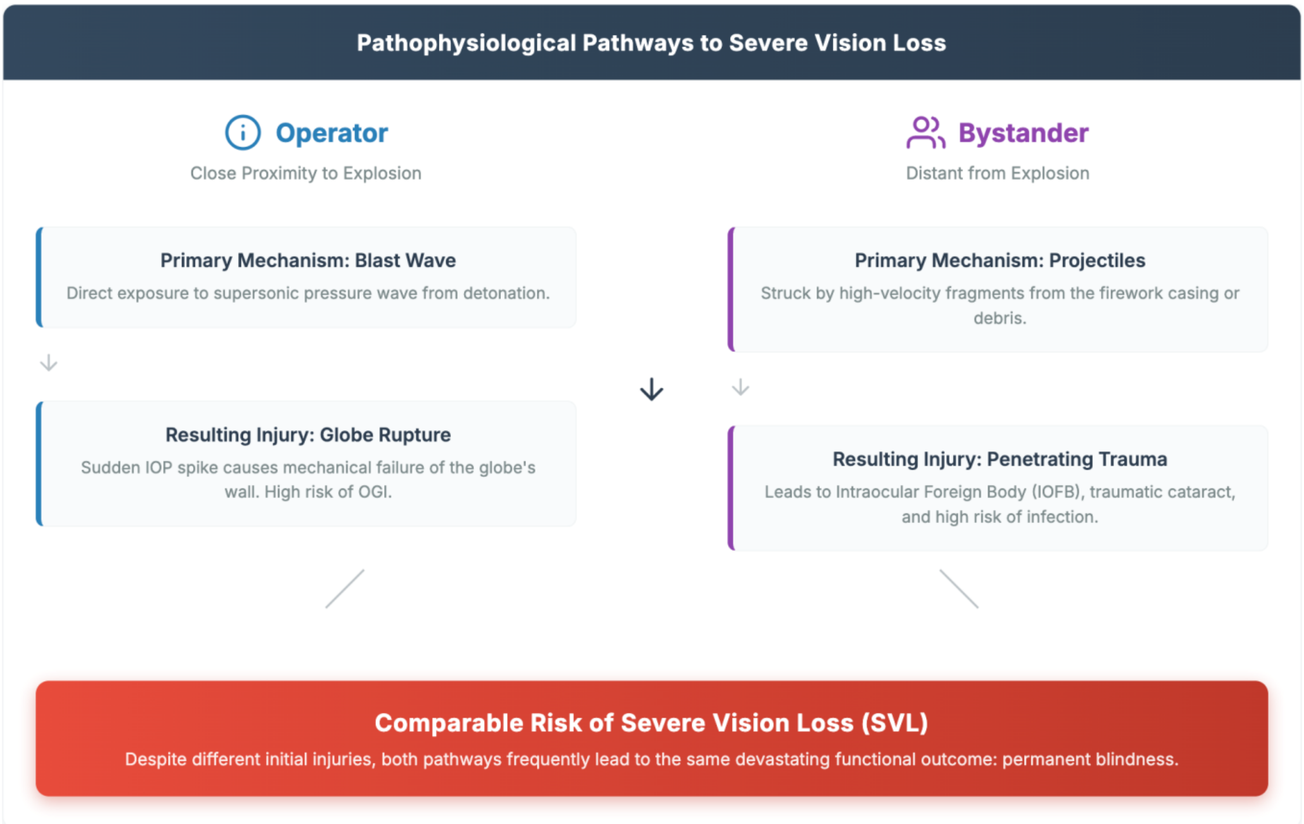


Figure 5. Pathophysiological pathways to severe vision loss.

Figure 5 provides a crucial schematic that explains the different, yet equally devastating, ways that firework-related eye injuries occur. It highlights a key finding: how different types of initial injuries to operators and bystanders can tragically lead to the same outcome of severe vision loss. The figure breaks down the process, starting from the person's location relative to the firework to the final, unfortunate result.

The figure first details the injury pathway for a firework operator, who is, by definition, in close proximity to the explosion. The primary danger to an operator is the blast wave itself. When a firework detonates, it creates a supersonic pressure wave that strikes the eye with immense force. This event causes a sudden and dramatic spike in intraocular pressure (IOP), which the eye's structure cannot handle. The result is often a globe rupture, a catastrophic mechanical failure of the eye's wall, leading to a high risk of an open globe injury (OGI). This type of injury is an immediate and obvious emergency, often resulting in the loss of the eye's contents and a very poor chance of recovery. In contrast, the pathway for a bystander is different, as they are typically further from the explosion. For them, the main threat comes not from the blast wave, which weakens with distance, but from projectiles. These are high-velocity fragments from the firework's casing or other debris that are launched by the explosion. Even small fragments can easily cause penetrating trauma to the eye. This can lead to several serious complications, including: An intraocular foreign body (IOFB), where a piece of the firework becomes lodged inside the eye; Traumatic cataract, where the lens of the eye is damaged and becomes cloudy; A high risk of severe infection inside the eye, known as endophthalmitis. Unlike a globe rupture, these injuries can sometimes seem less severe at first but can lead to a gradual and complete loss of vision if not treated quickly and effectively.[19] The most important message of Figure 6 is shown at the bottom, where both injury pathways converge. Despite the different initial injuries—a blast wave for the operator and projectiles for the bystander—both groups face a comparable risk of severe vision loss (SVL). The figure makes it clear that although the two paths are distinct, they frequently lead to the same devastating result: permanent blindness. This illustrates a critical public health message: being a bystander does not mean you are safe. While the risk of a globe rupture may be lower for bystanders, their risk of suffering a blinding penetrating injury is just as serious. This key finding explains why distance from a firework does not guarantee safety and highlights the need for better protective measures for everyone present during firework displays.

The use of a binary outcome for vision (SVL vs. not) is a necessary simplification for meta-analysis but lacks clinical granularity. The ocular trauma score (OTS) is a validated prognostic tool that provides a much more precise estimate of visual potential based on initial clinical findings.[20] A future, ideal meta-analysis would be based on OTS, but this would require its routine collection and reporting in primary studies. The absence of such data in the current literature is a significant gap. Despite the limitations, the message from this analysis is clear and unequivocal: the risk to bystanders is substantial and unacceptably high. The finding that nearly half of all victims are non-participants provides a powerful mandate for a paradigm shift in public health policy. Public awareness campaigns must evolve. The message "handle fireworks safely" is insufficient because it ignores half of the victims. The new message, directly supported by our finding of equivalent risk of blindness, must be: "Distance does not protect you from blindness. The only safe way to view fireworks is from a great distance or at a professionally organized display." The pooled statistic of 47.5% provides a powerful tool for ophthalmological societies and public health advocates to lobby for stricter legislative controls. It refutes the argument that injuries are limited to a few careless users and reframes the issue as one of broad public safety. This includes advocating for bans on the most dangerous types of consumer fireworks (bottle rockets, aerial mortars) and restricting sales to adults. For any public or private use of fireworks, legally mandated and enforced safety perimeters are essential. Our data suggest that current informal practices are inadequate to protect spectators.

5. Conclusion

This meta-analysis, the first to quantitatively synthesize the global risk to bystanders from fireworks, suggests that this "unseen" population may account for nearly half of all ocular injuries. Critically, despite having a lower risk of open globe injury, bystanders appear to face a statistically indistinguishable risk of permanent severe vision loss compared to operators. These findings, however, must be interpreted with significant caution. They are derived from highly heterogeneous primary data and are subject to major, unmeasured confounding variables, including alcohol use, firework type, and delay to presentation. Therefore, the primary conclusion of this work is twofold. First, the risk to bystanders is unacceptably high, and current public health strategies focused on operator safety are fundamentally incomplete. A paradigm shift toward protecting the public is urgently needed. Second, this study serves as a stark illustration of the need for higher-quality, standardized, and prospective data collection in the field of ocular trauma. Only with better primary data can we more accurately delineate these risks and develop truly evidence-based policies to prevent these devastating and entirely preventable injuries.

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