REVIEW ARTICLE

Understanding Lightning as a Public Health Hazard: A Comprehensive Narrative Review

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ABSTRACT

Introduction: Lightning is a sudden natural electrical discharge that causes significant mortality and injury worldwide. In India, lightning has emerged as a major cause of weather-related deaths, especially among rural and agricultural communities. Climate change, deforestation, and urbanisation have further increased the frequency and intensity of lightning events. **Methods:** This narrative review was conducted using information collected from online databases such as PubMed, Google Scholar, and ScienceDirect, along with reports from the National Disaster Management Authority (NDMA) and the India Meteorological Department (IMD). Studies published between 2000 and 2025 were included. The keywords used were "lightning injuries," "lightning fatalities," "thunderstorms," "climate change," "India," and "public health." The data were analysed qualitatively and organised into key themes: mechanism of injury, epidemiology, impacts, and mitigation measures. **Results:** Lightning remains one of the leading causes of natural disaster-related deaths in India, accounting for a large share of rural fatalities. Most victims are outdoor workers such as farmers and labourers, and incidents are concentrated during the monsoon months. Environmental and socio-economic factors, including unsafe housing and limited awareness, contribute to high vulnerability. However, early warning systems, mobile applications like *Damini* and *SACHET*, and improved disaster preparedness have led to a noticeable decline in fatalities in recent years. **Discussion:** Despite growing awareness and technological interventions, lightning continues to pose a serious public health challenge. Strengthening community-based preparedness, promoting safe shelter practices, and integrating lightning safety into disaster management policies are essential to reduce future risks. Continued public education and coordinated policy action are key to building a lightning-resilient society.

KEYWORDS

Lightning Injuries; Thunderstorms; Climate Change; Public Health; Disaster Preparedness

INTRODUCTION

Lightning is a naturally occurring electrical discharge that takes place between clouds and the ground or within the atmosphere. Its global and regional variability across multiple timescales makes lightning activity highly unpredictable. This unpredictability arises primarily from fluctuations in the flash rate per thunderstorm and variations in the number of thunderstorms that occur. Lightning remains one of the most intense and destructive atmospheric phenomena worldwide (1).

Globally, lightning occurs frequently approximately 50 flashes every second of which nearly 20% strike the ground. Although precise figures are difficult to obtain, estimates suggest that lightning causes around 24,000 deaths and roughly ten times as many injuries annually (2). The highest lightning strike densities are reported in parts of Africa, where certain areas experience over 50 lightning strikes per square kilometre each year. In the United States, the estimated lifetime risk of being struck by lightning is about 1 in 3,000, with a fatality risk of approximately 1 in 35,000 (3). On a global scale, available data indicate that 4,000 to 5,000 deaths occur each year due to lightning; however, this figure may significantly underestimate the true burden, particularly in regions with high lightning activity and limited reporting systems (4).

According to the National Crime Records Bureau (NCRB) of India, lightning accounted for 9.86% of all deaths from natural causes between 2001 and 2014 (5). The state of Jharkhand, for instance, recorded an average of 52,350 lightning flashes annually, underscoring its persistent vulnerability to lightning hazards (6).

Lightning injuries represent a major global public health concern and are among the leading causes of weather-related mortality, following tornadoes, flash floods, and hurricanes. The majority of lightning-related deaths and injuries occur among individuals engaged in outdoor occupations or recreational activities. Such incidents are associated with high mortality rates and can result in long-term physical and neurological impairments (7).

The increasing incidence of lightning and thunderstorms is primarily linked to global warming and climate change. Research conducted by Columbia University indicates that for every 1°C rise in temperature, the frequency of lightning strikes in the United States may increase by approximately 12%. Correspondingly, studies undertaken in India by the Climate Resilient Observing Systems Promotion Council (CROPC) and the India Meteorological Department (IMD) reported a 57% increase in lightning occurrences between April 2019 and March 2024. In the Indian context, a 1°C rise in temperature has been associated with a 7-18% increase in lightning activity.

Beyond temperature rise, several anthropogenic and environmental factors contribute to this escalation, including environmental degradation, excessive emissions, increased atmospheric aerosol concentrations, depletion of water bodies, deforestation, rapid urbanisation, industrial expansion, and the formation of urban heat islands (8).

Material & Methods

This paper is based on a narrative review of existing literature on lightning, its effects on humans, and related public health concerns. The main objective was to gather and summarise available information on the causes, patterns, and impacts of lightning, as well as the strategies used to prevent and manage lightning-related injuries and deaths. Information was collected from various online databases such as PubMed, Google Scholar, ScienceDirect, and official government websites. The keywords used for the search included "lightning injuries," "lightning deaths," "thunderstorms," "climate change," "India," "public health," and "lightning safety." Reports and documents published by national and international agencies, including the National Disaster Management Authority (NDMA) and the India Meteorological Department (IMD), were also reviewed to provide a broader understanding of the topic. Only studies and reports published in English between 2000 and 2025 were included in this review. The selected materials focused on lightning-related injuries, fatalities, health effects, and preventive or policy measures. Studies that dealt only with meteorological data or lightning patterns without reference to human impacts were excluded. Relevant information from each source was carefully noted, including the year of publication, study location, main findings, and key conclusions. The data were then organised into major themes such as the mechanism of injury, epidemiology, health and social impacts, and mitigation or policy responses. The findings from the reviewed sources were compared and summarised to highlight important trends and patterns. Because the materials varied in type and approach, a qualitative method of analysis was used rather than statistical analysis. As this review is based entirely on published and publicly available information, no ethical approval was required. All sources have been properly cited to maintain academic integrity.

Results

Mechanism of Injury: Lightning can cause injury and death through several distinct mechanisms. A direct strike occurs when lightning directly hits an individual, transmitting a large electrical current through the body. Touch voltage injuries are particularly common in rural areas, where awareness about lightning safety is limited. During rainfall, individuals often seek shelter under trees or inside small huts or sheds. When lightning strikes a tree, anyone in contact with it or in physical contact with another person touching the tree may be electrocuted due to the transfer of current through the body. Similarly, when individuals take refuge in small, thatched, or metal-roofed structures, the confined space often results in multiple points of contact with conductive surfaces, increasing the risk of electrocution via touch voltage (9).

Another mechanism, step voltage, arises from the potential difference between two points on the ground during a lightning strike. In agricultural settings, for instance, individuals working barefoot or with feet apart in open fields are at risk when lightning strikes nearby objects such as trees or poles. The current entering the ground can create a voltage gradient between the feet, leading to severe injuries or death (10).

Orifice entry occurs when lightning strikes near the head, allowing the electrical current to enter through natural openings such as the ears, eyes, or mouth, potentially causing internal injuries. Blunt trauma associated with lightning may result either from the forceful muscle contractions induced by the electrical current or from being physically thrown due to the explosive energy of the strike (11).

Physiologically, lightning acts as a sudden and massive direct current shock, depolarising the entire myocardium simultaneously. In some cases, intrinsic cardiac automaticity may restore cardiac rhythm spontaneously; however, respiratory arrest due to thoracic muscle spasm or suppression of the respiratory centre may persist even after circulation returns. Without prompt respiratory support, secondary hypoxic (asphyxial) cardiac arrest can occur. Lightning-related injuries present a wide spectrum of clinical manifestations, including brain injury, sensorineural hearing loss, oesophageal perforation, and polyradiculoneuritis. Although various complications may follow, cardiac arrest and fatal arrhythmias are the predominant causes of immediate death, while renal failure, septicemia, and secondary infections can contribute to delayed mortality (12).

Epidemiology of lightning: Between 1967 and 2020, lightning strikes resulted in approximately 101,309 deaths across India, corresponding to an average fatality rate of 46 per state and union territory. A marked gender disparity exists, with 73% of deaths occurring among males compared to 27% among females (13).

The vast majority of lightning-related deaths (99.5%) and injuries (97.5%) have been reported from rural areas. Among male victims, fatalities were most common in the 11–20-year age group, followed by those aged 41–50 years (14). Population density plays a significant role in determining mortality patterns—states with larger populations, such as Madhya Pradesh (313 deaths annually), Maharashtra (281), and Odisha (255), report far higher death tolls compared to sparsely populated or hilly regions like Jammu and Kashmir, Assam, and Himachal Pradesh (15).

In terms of occupation, farmers account for the highest proportion of lightning-related fatalities (73.66%),

followed by labourers (15.78%) and students (7.89%). Approximately 96% of lightning-related losses occur in rural India, where nearly 70% of the population depends on agriculture as the primary source of livelihood. These high fatality rates are largely attributed to unsafe housing, occupational exposure, and inadequate protective infrastructure. Casualties are predominantly reported among farmers, cattle herders, tribal communities, fishermen, and daily-wage labourers. Lightning incidents exhibit a distinct seasonal trend, with 94.73% of cases occurring during the monsoon months (June–September), and only 5.26% reported in May (16,17).

Impact: Lightning is responsible for the highest number of fatalities among all natural disasters, accounting for 39% of total disaster-related deaths, followed by floods (18%), landslides (15%), heat strokes (15%), and cold waves (13%) (18). Although lightning strikes are frequently fatal, among survivors, 66–75% experience permanent disabilities, 20% sustain second-degree burns, and approximately 69% exhibit symptoms of lower-limb paralysis (19).

The repercussions of lightning extend beyond the individual to the entire family unit. Survivors with disabilities often face significant socioeconomic challenges, including loss of employment, financial strain due to inadequate compensation, and increased caregiving burdens. These stressors can disrupt family dynamics, occasionally resulting in marital breakdowns or even suicides (20).

In developing countries, lightning-related property damage has both direct and indirect economic consequences. Beyond the destruction of infrastructure, power outages caused by lightning can lead to food spoilage, disruption of hospital operations, and damage to critical data and electronic systems. The costs of repair or replacement are often prohibitive, particularly in contexts already burdened by poverty, drought, underemployment, civil unrest, or epidemics such as HIV. Furthermore, for many rural households, the loss of livestock—a primary asset and indicator of wealth—represents a severe economic setback (21).

Despite its devastating impact, lightning-related mortality often remains underrepresented in official and media reports. Studies indicate that injuries may be underreported by up to 50%, while fatalities may be underestimated by about 11%. This underreporting distorts public perception of risk and reduces policy attention toward lightning safety (22).

Professor Yuval Noah Harari conceptualises the "dramatization of death" as the human tendency to exaggerate and emotionally magnify certain kinds of deaths while overlooking others that occur on a much larger scale. He argues that societies react more strongly to intentional and dramatic deaths than to natural or statistical ones. For example, terrorist attacks, though they kill relatively few people, evoke global fear, dominate media discourse, and influence political decisions. In contrast, far greater numbers of people die daily from tuberculosis, malaria, or road accidents, yet these deaths receive minimal attention. We extend this idea by observing that the same pattern is evident in deaths caused by lightning, which claim more lives annually than terrorism but seldom provoke fear or public outcry. This reflects a deep psychological bias: humans dramatize deaths involving agency, intent, and narrative while disregarding those that appear random or routine. Consequently, the modern perception of danger is often shaped not by factual reality but by emotional and media-driven storytelling. Consequently, public perception of danger is often shaped more by emotion and media framing than by objective reality (22,23).

Response and mitigation: India's strategy for addressing lightning-related hazards follows a two-pronged approach: first, the adoption and implementation of scientific solutions within communities, and second, climate action measures aimed at mitigating the frequency and intensity of extreme weather events.

The National Disaster Management Authority (NDMA) has issued comprehensive guidelines for the preparation of action plans focused on the prevention and management of lightning and thunderstorms. These guidelines serve as the foundational framework for the formulation of State and local-level Lightning Action Plans. NDMA has also developed a protocol for the dissemination of early warnings (EWs), and the Common Alert Protocol (CAP) was officially implemented in 2023 to streamline multi-agency coordination. To enhance real-time public safety communication, the SACHET mobile application was launched, providing alerts about imminent lightning strikes and integrating with India's Single Emergency Response Number (112) for prompt emergency assistance.

Public awareness initiatives play a critical role in lightning risk reduction, particularly before the onset of the lightning season. Educational campaigns emphasising basic lightning safety practices ("Do's and Don'ts") are disseminated among rural populations through various media channels. Additionally, Gram Panchayats have been mobilised to raise awareness and promote community preparedness. To systematically address lightning vulnerability, India has introduced a Lightning Resilient Framework, designed to be adaptable to local environmental and seasonal conditions.

According to the Annual Lightning Report 2023–2024, jointly published by the India Meteorological Department (IMD) and the Climate Resilience Observation Systems Promotion Council (CROPC) under the Lightning Resilient India Campaign, the country recorded a 57% increase in lightning occurrences between 2019 and 2024, yet fatalities declined by over 22% during the same period. This reflects the effectiveness of integrated early warning systems, public education, and resilience-building initiatives (24).

Furthermore, NDMA's 2018 guidelines on the "Preparation of Action Plan – Prevention and Management of Thunderstorm, Lightning, Squall, Dust, Hailstorm, and Strong Winds" provide detailed operational measures for disaster preparedness and response (25). Complementing these efforts, the Ministry of Health and Family Welfare (MoHFW) has incorporated lightning injury prevention into its National Strategy for the Prevention of Unintentional Injuries, which adopts a comprehensive, systems-level approach (26). In addition to national frameworks, the Government of India launched the Damini smartphone application, which

provides localised alerts about lightning activity and educates users on safety measures (27).

Policy reforms introduced in 2015 further empowered state governments to allocate up to 10% of the State Disaster Response Fund (SDRF) toward state-specific natural disasters, including lightning (6). Most recently, the Parliament of India introduced "The Victims of Natural Lightning Disaster (Compensation) Bill, 2024," proposing structured financial compensation for lightning victims and their families (28).

Conclusion

Lightning is a major yet underrecognized public health and disaster burden in India, disproportionately affecting rural and agricultural populations and causing significant mortality, disability, and socioeconomic loss.

Recommendation

To reduce lightning-related deaths in rural and high-risk areas, innovative approaches beyond conventional awareness campaigns are needed. Community-level "Lightning Safe Zones" with low-cost lightning protection towers can be installed in agricultural fields and open working areas to provide immediate safe shelter for farmers and outdoor workers. Lightning early-warning systems should be integrated with mobile networks to deliver automatic voice alerts in local languages and trigger community sirens during high-risk periods. Additionally, governments may consider introducing lightning risk insurance and conditional cash incentives for farmers, fishermen, and outdoor workers who complete certified lightning safety training programs, thereby linking disaster risk reduction with social protection and behavioural change strategies.

Limitation of the Study

This study has several limitations. First, lightning-related mortality and injury data are likely affected by underreporting and inconsistencies in surveillance systems, particularly in rural and remote areas. Second, much of the available evidence is based on secondary data sources and descriptive reports, which limits causal interpretation and detailed risk factor analysis. Third, regional variations in reporting practices, infrastructure, and disaster response systems may limit the generalizability of the findings across different states and settings.

Relevance of the Study

This study is relevant because it highlights lightning as a major yet underrecognized public health and disaster risk in India, emphasizing the need for improved surveillance, early warning systems, community awareness, and policy-level interventions to reduce preventable deaths and disabilities.

Authors Contribution

All authors have contributed equally.

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Conflict of Interest

There are no conflicts of interest.

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Declaration of Generative AI and AI Assisted Technologies in the Writing Process

The authors acknowledge that artificial intelligence was used only for language editing and grammar refinement, and the authors take full responsibility for the content and interpretation of the manuscript.

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