**Title:** Training Healthcare Personnel in Bioterrorism in Iran: A Scoping Review

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## Abstract

**Background:** Bioterrorism, with a high fatality rate, poses a serious threat to public health. This scoping review examined the types of bioterrorism training for healthcare personnel in Iran, assessed their level of awareness and preparedness, and identified educational gaps to inform strategies for strengthening national preparedness.

**Materials and Methods:** A scoping review was conducted through a search of national and international databases in both Persian and English, including SID, Magiran, IranDoc, PubMed, ScienceDirect, and Web of Science, as well as Google Scholar, covering 2014–2025. The five-stage framework developed by Arksey & O'Malley (2005) guided the process.

**Results:** Twenty-one relevant articles were identified and categorized into three groups: (a) Experimental and Quasi-experimental Studies (n=10), (b) Descriptive and Cross-sectional Studies (n=7), and (c) Review Studies (n=4). Experimental studies highlighted three training approaches: Experiential Learning, Traditional Learning, and E-learning. Descriptive studies showed low awareness and preparedness among healthcare personnel, while review studies emphasized the role of training in enhancing readiness.

**Discussion:** Findings indicated that experiential learning, including simulations and workshops, improved knowledge, attitudes, and performance among healthcare personnel, whereas traditional lectures had a limited impact. E-learning showed positive outcomes, but standardized curricula and sustainable programs were lacking in Iran. Therefore, practical, context-specific, and interdisciplinary training was essential to close knowledge gaps and enhance preparedness for bioterrorism incidents.

**Conclusion:** Simulated training, practical exercises, and scenario-based workshops effectively improved preparedness. Policymakers should integrate training, enhance collaboration, and develop monitoring systems. Overall, strengthening bioterrorism training and preparedness supports healthcare resilience and contributes to national security.

**Keywords:** Bioterrorism, Training, Education, Health Care Personnel

## Highlights

- Simulation-based training significantly improved preparedness in nurses.
- Most Iranian healthcare workers showed low bioterrorism awareness.
- E-learning outperformed traditional lecture methods in knowledge retention.
- Scenario-based workshops were the most effective training strategy.
- Few studies assessed training outcomes using standardized evaluation tools.

## Plain Language Summary

Bioterrorism refers to the intentional release of harmful biological agents like bacteria or viruses to cause illness and fear among people. Due to the increasing risk of such attacks, especially in sensitive regions like Iran, healthcare workers play a critical role in recognizing and managing these threats. However, many healthcare professionals in Iran are not adequately trained for such situations. This study reviewed 21 research articles published between 2014 and 2025 to assess how healthcare workers in Iran are being trained to deal with bioterrorism. The review found that most healthcare workers, including nurses and emergency staff, had low levels of awareness and preparedness. Among various teaching methods, practical training techniques like simulations and escape room activities were the most effective. Traditional methods such as lectures and booklets were less impactful, while online learning showed promising results in boosting knowledge and confidence. These findings highlight the urgent need to include bioterrorism training in medical and nursing curricula across the country. Better education and regular drills can help healthcare workers respond more effectively during biological emergencies, potentially saving many lives. Policymakers should support the development of accessible, interactive, and up-to-date training programs to strengthen the country's preparedness against bioterrorist threats.

## Introduction

Modern weapons are widely used in contemporary warfare. Among these, biological weapons have gained increased attention due to their ease of production, high replication capability, simple storage, ability to protect friendly forces, and difficulties in tracing the perpetrator. Moreover, their effectiveness extends beyond humans to animals and agricultural products, making them a significant threat [1, 2].The use of such weapons to harm humans and animals is referred to as bioterrorism. In other words, bioterrorism involves the misuse of biological agents, including viruses, bacteria, fungi, and other microorganisms, to destroy, harm, or endanger human life and other living organisms [3]. The primary goal of bioterrorism is to utilize these organisms and their byproducts to cause death, illness, and widespread fear. The use of biological agents as weapons dates back to 600 BC when corpses and animal carcasses were used to spread disease among enemies [4].

For example, in 1346 AD, during the siege of Caffa (present-day Ukraine), the Tatars catapulted the bodies of plague victims into the city, leading to a deadly outbreak [5]. A biological warfare simulation conducted in the United States demonstrated that if a biological agent such as the plague is released in a densely populated city, it could result in 3,700 infections and 2,000 deaths within the first week [6].Iran, due to its strategic geopolitical position, is also vulnerable to such threats posed by other countries [7]. Healthcare personnel, including physicians, nurses, and emergency responders, are the first to encounter casualties resulting from such attacks. Therefore, training healthcare personnel in this area is of utmost importance and plays a significant role in mitigating the consequences of biological weapons [8]. Numerous studies have been conducted on training healthcare personnel in bioterrorism preparedness. For instance, Gorji et al. conducted a study among nurses in Sari, Mazandaran Province, and found that 91.7% of nurses had poor knowledge of bioterrorism, while 93.3% had no opinion on the matter [9]. Similarly, Bahraini Moghadam et al., in a study aimed at assessing the awareness and attitudes of volunteers and rescuers of the Iranian Red Crescent Society during a bioterrorism attack in Mahabad, West Azerbaijan Province, reported that 78.3% of volunteers had no knowledge of how to respond to bioterrorism incidents, and only 7.1% had adequate awareness [10].

Since the nursing curriculum in Iran does not include specific training on bioterrorism, addressing this educational gap could enhance the knowledge and preparedness of nurses [11]. Most studies on hospital preparedness in Iran have focused solely on evaluating the functional, structural, and non-structural readiness of healthcare centers for natural disasters, with little attention given to preparedness for biological incidents. Additionally, the lack of implementation of standards and preparedness guidelines in healthcare centers hinders effective planning for biological emergencies [12].

Studies have also shown that interventions such as education can increase nurses' awareness, knowledge, and willingness to respond to biological attacks, although the level of preparedness among Iranian nurses remains low [13]. Traditional teaching methods have not sufficiently met the educational needs of learners and often fail due to the inability to apply theoretical knowledge in real-life situations and the tendency to forget training when needed. Therefore, educational experts have introduced a problem-based learning system that has been widely adopted by universities worldwide in recent years [14]. One of the most effective modern teaching methods in bioterrorism is simulation-based training, which offers higher efficiency compared to traditional lecture-based approaches while eliminating the risks associated with real-world scenarios. However, despite its effectiveness, simulation-based training remains costly [15].

Given Iran's strategic geopolitical location and its exposure to regional threats, bioterrorism preparedness is not only a public health concern but also a matter of national security. Ensuring that healthcare personnel are well-prepared is essential for effective emergency response and minimizing casualties in potential biological attacks [16, 17]. Although several international systematic reviews have addressed bioterrorism preparedness (e.g., Kim & Lee, 2023; Li et al., 2023), there is no comprehensive scoping review focused on the Iranian healthcare system [18, 19]. This study is necessary to identify the specific educational gaps, assess current training practices in Iran, and support the development of context-specific strategies to improve national readiness. Therefore, the aim of this study was to conduct a scoping review of the training provided to healthcare personnel in Iran regarding bioterrorism, in order to identify existing gaps and support the development of practical training strategies to improve national preparedness.

**Materials and Methods**

This study was conducted as a scoping review aimed at examining the status of bioterrorism training provided to healthcare personnel in Iran. The review followed the five-stage framework proposed by Arksey and O'Malley, which includes the following steps:

1. Identifying the Research Question:

   The main research questions were:

   - "What types of bioterrorism training have been provided to healthcare personnel in Iran?"
   - "What is the level of awareness and preparedness of healthcare personnel regarding bioterrorism in Iran?"

2. Identifying Relevant Studies: A comprehensive search was conducted across credible national and international databases, including SID, Magiran, IranDoc, PubMed, ScienceDirect, and Web of Science, as well as Google Scholar as a scientific search engine. The keywords used for the search included: "Bioterrorism", "Training", "Education", "Health Care Providers", "Teaching", "Healthcare Personnel and Biological Threats", "Biological Warfare Agents". Boolean operators AND, OR, and NOT were applied to develop the search strategy. The detailed search strategies used for the databases and the scientific search engine are available in Appendix 1.
3. Study Selection: Articles published between April 2014 and January 2025 were reviewed. This period was selected to include the most recent research on bioterrorism training for healthcare personnel in Iran. Inclusion criteria included studies focused on bioterrorism training for healthcare personnel in Iran, with no time restrictions applied. Due to the limited number of Iranian studies, review articles were included as supplementary sources and analyzed as a separate category. Studies focusing on bioterrorism education in non-healthcare fields or lacking full text were excluded. The Google Scholar search initially found 16,800 records; for feasibility, the first 400 results were screened for eligibility. An initial search yielded 17,750 articles. After removing duplicates and applying inclusion and exclusion criteria, a total of 21 studies were selected for final analysis (Figure 1). Screening was conducted by two independent reviewers. Titles and abstracts were screened first, followed by full-text review of potentially eligible studies. Any disagreements were resolved through discussion, and if

consensus could not be reached, a third reviewer adjudicated. As this was conducted as a scoping review, no formal quality appraisal or risk of bias assessment of the included studies was performed, in accordance with PRISMA-ScR guidelines.

4. Data Extraction and Analysis: Key information such as the type of training, target groups, educational methods, and reported outcomes were extracted and categorized.
5. Collating, Summarizing, and Reporting Results: The findings were categorized and analyzed based on main themes to identify knowledge gaps and educational needs. This scoping review provides a comprehensive overview of the status of bioterrorism training for healthcare personnel in Iran and can serve as a basis for future planning in this area.

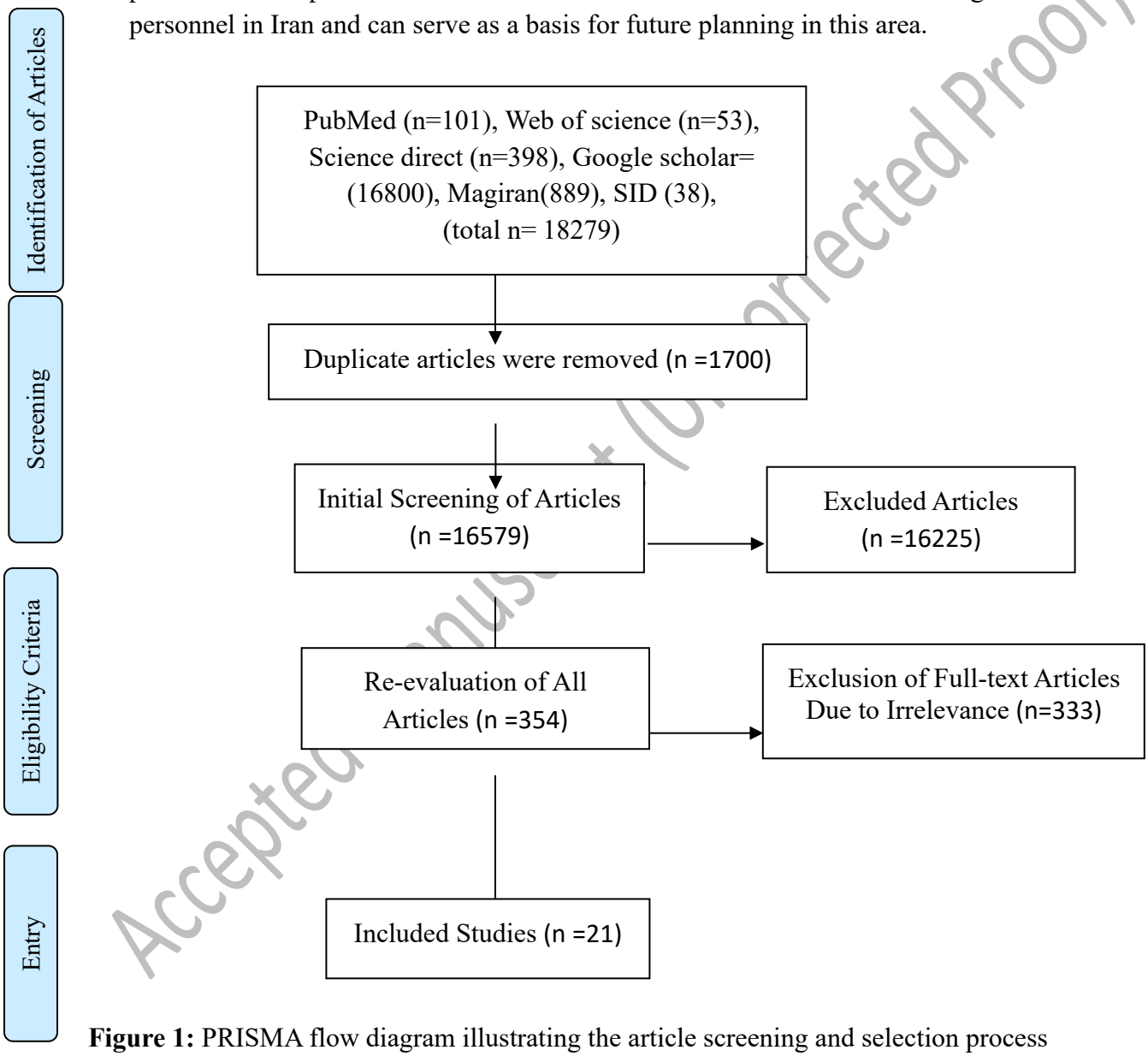


**Figure 1:** PRISMA flow diagram illustrating the article screening and selection process

**Results**

The findings of the review study are summarized in Table 1. Out of 354 full-text articles, 21 studies met the inclusion criteria and were selected. The articles were categorized into three groups: (a) Experimental and Quasi-experimental Studies (12 studies), (b) Descriptive and Cross-sectional Studies (Needs Assessment) (9 studies), and (c) Review Studies (4 studies) (Table 1).

a) Experimental Studies:

In the content analysis of the interventions in experimental studies, the training methods for healthcare personnel in bioterrorism were categorized as follows:

Active and Experiential Learning Methods (Experiential Learning): These included studies with simulation-based interventions (Simulation-based Training) aimed at using simulation for role-playing exercises for students [15], game-based learning (Game-based Learning), such as the "escape room" method for enhancing preparedness[20], and workshops & hands-on training: through slides, videos, Q&A, and group work [11], as well as conducting workshops accompanied by lectures[15].

Traditional and Theoretical Learning Methods (Traditional & Theoretical Learning): These studies involved methods such as lecture-based training [16], with or without PowerPoint presentations and Q&A sessions [21], and comparisons of lectures with instructional packages (greater effectiveness of lectures) [22] in bioterrorism education. Additionally, manual and booklet-based learning, along with the provision of booklets in combination with workshops [11], and comparisons of lectures with book-based learning [16], were other traditional methods used in training healthcare personnel on bioterrorism.

Electronic and Distance Learning Methods (E-learning & Online Education): This category included virtual learning (Online Learning & E-learning) as a modern method of non-face-to-face training for healthcare personnel. Studies comparing e-learning with in-person classes (greater effectiveness of online education)[14] and online education combined with videos, slides, and escape room games [20] were placed in this category.

b) Descriptive and Needs Assessment Studies (Descriptive & Survey-based Studies):

This group of studies assessed the awareness and preparedness levels of various healthcare personnel in response to bioterrorism. These studies showed a low level of awareness and preparedness among healthcare workers [6, 9, 10, 12, 23].

c) Review Studies:

These studies examined the importance of educational programs and provided recommendations for improving bioterrorism education[18, 24-26].

**Table 1:** Results of a review of studies related to the role of military medicine in casualty evacuation and transport during crises in Iran

| No. | Authors | Year | Title | Study Type and Method | Findings | Sample Size |
|---|---|---|---|---|---|---|
| **A) Experimental and Semi-experimental Studies** | | | | | | |
| **1** | Mahsa Ghahremani, Zahra Rooddehghan, Shokouh Varaei, Shima Haghani | 2022 | Knowledge and practice of nursing students regarding bioterrorism and emergency preparedness: comparison of the effects of simulations and workshops | Experimental | -Knowledge and practice improved significantly after intervention<br>- Workshop: lecture-based, topics included triage, incident command, disaster communication, decontamination, quarantine, mental health, epidemiology, decision-making, reporting, access to resources, identification of biological agents<br>- Simulation: students performed roles under supervision; no recording allowed | 40 participants (20 for workshop group, 20 participants for the simulation group) |
| **2** | Masoud Khoshnudi, Fahime Ghadamgahi, Gholamreza Najjarzade, Farzane Habibi Mud1, Nahid Aghaei, No'man Arab, Seyyed-Javad Hosseini-Shokouh, Atabak Nikbakht | 2022 | Comparison of the effect of bioterrorism education through two methods of lecture and booklet on the knowledge and attitude of nurses at Shams Al Shomus Nezaja Hospital | Semi-experimental | - Significant increase in knowledge in both groups<br>- Lecture: two 3-hour classes on consecutive day | 77 participants (divided into two groups) |
| **3** | Maryam Aghamohammadi, Marzieh Barzegar, Fariba Tayebi Arasteh, Mehdi Molavi Vardanjani | 2017 | The effect of bioterrorism education through holding a workshop and offering a manual | Semi-experimental | - Education significantly increased knowledge-One-day 6-hour workshop and manual provided | 90 participants |

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| | | | on the knowledge of nursing students | | | |
| **4** | Majid Hashempoor, Simin Tahmasbi | 2021 | The Effect of Educational Intervention on Health Rescue and Treatment Employees' Knowledge, Attitude, and Preparedness of Isfahan Police Force about Bioterrorism | Semi-experimental | - Improved knowledge, attitude, and preparedness - Up-to-date bioterrorism info essential for law enforcement healthcare staff | 60 participants |
| **5** | Maryam Beheshtifar, Seyyed Amir Hossin Pishgooie, Simin Taj Sharififar, Amir Khoshvaghti | 2021 | Evaluation of the Effect of Gaming-Based Education in the Escape Room Theme on Preparedness of Aja Undergraduate Nursing Students in Dealing with Bioterrorism | Semi-experimental (intervention) | - Escape room method led to higher preparedness than lecture method | 61 participants |
| **6** | Mahnaz Aghabeigi, Hamid Taghinejad, Mosayeb Mozafari, Ali Khorshidi | 2020 | Effect of Bioterrorism Management Education on Nurses' Knowledge | Semi-experimental | - Education increased knowledge- Lectures, Q&A, and educational materials used | 92 participants |
| **7** | Nahid Aghaei, Masoumeh Bagheri Nesami | 2013 | Bioterrorism Education Effect on Knowledge and Attitudes of Nurses | Experimental | - Positive impact on knowledge and attitudes- Two 2-hour lectures, slides, Q&A, handouts | 65 participants |
| **8** | Mostafa Alavi-Moghaddam, Gheysar Molavi, Ali Shahrami, Hamidreza Hatamabadi, Majid Shojaei, Kamran Heidari | 2015 | Effectiveness of E-learning Compared to Classroom Learning in the Diagnostic Approach to Bioterrorism and Chemical Terrorism for Emergency Physicians | Semi-experimental | - E-learning more effective- 75-min educational video on CME website | 160 participants |

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| **9** | Maryam Ramezani Vishki, Marjan Seyedmazhari, Seyed Amir Hossein Pishgooie | 2022 | The Comparison Effect of Lecture-Based Education and Education Package in Biologic Attack Crisis Management on Nurses' Knowledge and Attitude in Hospitals Affiliated to Aja University of Medical Science | Semi-experimental | - Increased knowledge and attitude<br><br>- Lecture-based method more effective than package | 60 participants |
| **10** | Siavash Hamzehpour, Nazli Khajehnasiri | 2017 | Effect of Education on Knowledge and Attitude Regarding Bioterrorism | Experimental | - Education improved knowledge on nature of bioterrorism, causative agents, diagnostic methods, and management | 100 participants |
| **B) Descriptive and Cross-Sectional Studies** | | | | | | |
| **11** | Surveying Knowledge and Performance of Basij Medical Community Members of West Azerbaijan in Response to Biological Events in 2016-2017: A Short Report | 2016 | Siavash Hamzeh Pour | Descriptive | -Knowledge level regarding bioterrorism threats was low- Greatest gaps in:<br>- Familiarity with clinical syndromes in biological events<br>- Knowledge of chemical and biological decontamination agents<br>- Use of personal and collective protective equipment<br>- Knowledge of CBRN protective systems<br>- Awareness of contamination radius of biological agents<br>- Familiarity with procedures for transferring casualties | 142 participants |

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| **12** | Methods of Acquiring Insight, Knowledge, and Skills of Self-Protection in Incidents and Chemical Warfare for New Nursing Students of the Army | 2016 | Monireh Ebadi, Simintaj Sharififar, Armin Zareiyan | Descriptive-Survey | - Increasing knowledge and skills of military nurses in disaster response is essential<br>- Lack of preparedness or belief it is unnecessary is catastrophic<br>- Relevant training programs should be provided by healthcare centers and organizations<br>- Course delivered via lectures and Q&A sessions | 78 participants |
| **13** | Preparedness Assessment of Teaching Hospitals Affiliated With Shahid Beheshti University of Medical Sciences in Response to Biological Incidents | 2024 | Saeed Younesi, Zohreh Ghomian, Hossein Hatami, Simintaj Sharififar | Cross-sectional | - Preparedness of hospitals was satisfactory overall<br>- Highest level of readiness required for biological incidents<br>- Focus on all dimensions, especially lower<br>-scoring areas, is essential to reach optimal conditions | 14 hospitals |
| **14** | Attitude, Knowledge, and Practice Response of Nurses during COVID-19 Outbreak in Military Hospital, 2021 | 2022 | Mahdiye Nejadshafiee | Cross-sectional | - Participants were knowledgeable and had positive attitudes<br>- Effective actions were taken during COVID-19 outbreak<br>- Highlights need to enhance nurses' knowledge and skills for pandemics and emerging diseases | 122 participants |
| **15** | An Assessment of Knowledge and Attitude of Iranian Nurses Towards Bioterrorism | 2017 | Hasan Abolghasem Gorji, Noureddin Niknam, Nahid Aghaei, Tahereh Yaghoubi | Cross-sectional | - Large number of participants had low knowledge regarding bioterrorism management | 240 participants |
| **16** | Knowledge and Attitude of Iranian Red Crescent Society Volunteers in Dealing with | 2016 | Seyed Ali Bahreini Moghadam, Siavash Hamzeh Pour, Mahmoud Toorchi, Youssof Sefidi Heris | Cross-sectional | - Majority male participants<br>- Knowledge and readiness to deal with bioterrorism were inadequate | 120 participants |

| | Bioterrorist Attacks | | | | | |
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| **No.** | **Authors** | **Year** | **Title** | **Study Type and Method** | **Findings** | **Sample Size** |
| **C) Review Studies** | | | | | | |
| **18** | The Importance of Self-Care in Bioterrorism Attacks | 2022 | Fatemeh Habibi, Leila Lotfian, Hojjat Niknam Sarabi, Mohammad Nobakht | Review | - Education in self-care programs is effective against bioterrorism agents<br>- Recommended inclusion in all university curricula and public broadcasting<br>- Public education reduces exposure to microbial attacks | 34 articles |
| **19** | Hospital Management Preparedness Tools in Biological Events: A Scoping Review | 2019 | Mohsen Aminizadeh, Mehrdad Farrokhi, Abbas Ebadi, Gholam Reza Masoumi, Pirhossein Kolivand, Hamid Reza Khankeh | Review | - Findings can guide development and management of hospital facilities for bioterrorism threats | 20 articles |
| **20** | Bioterrorism-Related Training Programs for Healthcare Workers: A Systematic Review | 2023 | Yujeong Kim, Haeyoung Lee | Review | - Interventions enhance healthcare workers' capabilities- Regular and accessible bioterrorism training improves preparedness against terrorism | 12 articles |
| **21** | Best Practices of Hospitals in Management of Epidemic Conditions: A Scoping Review | 2023 | Ali Tahmasebi, Iravan Masoudi Asl, Aryankhesal, Soudabeh Vatankhah, Gholamreza Masoumi | Review | - Majority conducted in the US, focused on COVID-19- Findings categorized into:<br>• Intra-hospital operational preparedness (11 main categories: physical structure, resource management, exposure reduction, patient/caregiver management, corpse management, | 24 articles |

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| | | | | | disinfection, staff support, patient admission, protocols, telecommunication, training; 26 subcategories)<br>• Logistical preparedness (3 main categories: leadership/team building, communication, capability utilization; 5 subcategories) | |

**Discussion**

The present study demonstrated that various research methodologies have been employed to assess the knowledge, performance, and attitudes of healthcare personnel, as well as their impact of bioterrorism training. This categorization highlights existing gaps in knowledge and identifies areas where further research is needed to improve bioterrorism training for healthcare personnel. Based on these findings, the studies were divided into three groups: experimental and quasi-experimental studies, descriptive and cross-sectional studies, and review studies, as discussed below:

A) Experimental and Quasi-Experimental Studies

The present study revealed that experiential learning methods, including simulation, escape room games, and workshops, effectively increased knowledge, attitudes, and performance scores among healthcare personnel in Iran.

These findings align with the study by Ghahremani et al., titled "Awareness and Performance of Nursing Students on Bioterrorism and Emergency Preparedness: Comparison of the Effects of Simulation and Workshops" (2022), which indicated that simulation-based training significantly increased knowledge and performance among healthcare staff before and after the educational intervention [15]. Similarly, Beheshtifar et al., in their study titled "The Effect of Escape Room-Based Training on the Preparedness of Undergraduate Nursing Students of AJA University in Dealing with Bioterrorism" [17], concluded that simulation-based interventions such as escape rooms were more effective than traditional methods such as lectures. Additionally, in the study by Heba Ghazi et al., titled "The Impact of an Educational Program on Nurses' Knowledge of Bioterrorism Preparedness" (2022), it was shown that the nurses' knowledge level was low before the simulation-based (practical workshop) intervention, but this knowledge improved significantly after the intervention, reaching a desirable level [27].

These findings are in line with Kim & Lee (2023), who also emphasized the superiority of simulation-based training in improving practical preparedness among healthcare workers[18].

However, unlike many global settings where bioterrorism preparedness is a core part of emergency education, the Iranian healthcare curriculum still lacks standardized training in this area.

Traditional and theoretical learning methods were another type of intervention used in the experimental studies. The study by Ramazani et al., titled "Comparison of the Effect of Lecture-Based Training and Crisis Management Educational Packages in Biological Attacks on the Knowledge and Attitudes of Nurses Working in Hospitals Affiliated with AJA University of Medical Sciences" (2022), conducted in military hospitals, demonstrated that lecture-based intervention was more effective than an educational package that included booklets and CDs with

instructional videos. This difference was attributed to variations in the teaching approach and the study environment [18].
E-learning and online education were also among the interventions used. The study by Alavi et al., titled “Effectiveness of E-Learning Compared to Classroom Learning in Diagnostic Approaches to Bioterrorism and Chemical Terrorism for Emergency Physicians” (2015), revealed that the E-learning intervention, which included uploading educational videos on the Shahid Beheshti University of Medical Sciences website, had a higher efficacy compared to traditional classroom-based methods [14].
Similarly, Li et al. (2023) found that online learning methods showed promising results globally, which is consistent with the effectiveness of e-learning observed in several Iranian studies included in this review[19]. These studies suggested that both active experiential methods and well-structured e-learning enhanced knowledge and preparedness, whereas traditional methods had limited but context-dependent effectiveness, highlighting the need to adapt teaching strategies to specific educational settings.B) Cross-sectional Descriptive Studies
The present study showed that most healthcare workers in Iran have limited awareness about bioterrorism. These findings are similar to those of Siavash Hamzehpour’s study titled "Assessment of the Awareness and Skills of Members of the Medical Basij Organization of West Azerbaijan Province in Dealing with Biological Incidents and Biological Emergencies" conducted in 2016, in which none of the participants had the necessary awareness regarding the types of biological agents, bioterrorism, and the harmful biological effects and medical syndromes resulting from them. Additionally, the study by Saeed Younesi and colleagues, titled "Evaluation of the Preparedness of Educational Hospitals Affiliated with Shahid Beheshti University of Medical Sciences in Dealing with Biological Incidents" conducted in 2024, indicated that the preparedness level of their hospitals was satisfactory, but the environment of their study was different, which contradicts the current findings. The study by Abdul Karim and colleagues, titled "Knowledge and Attitudes Towards Biological Warfare Among Health-related Students" in 2023, conducted in Ghanaian hospitals and Jazan University, found that the participants had satisfactory awareness regarding biological warfare, which was different from the situation in Iran, possibly due to the differences in the foundational education system of the two countries[28]. Collectively, the cross-sectional evidence indicated that Iranian healthcare workers lacked sufficient awareness compared to their international counterparts, who demonstrated greater preparedness.

C) Review Studies
The present study showed that educational programs aimed at improving bioterrorism education for healthcare workers are essential, and both healthcare workers and the public need to be educated on bioterrorism-related harms. According to the findings, the study by Kim & Lee titled "Educational Programs Related to Bioterrorism for Healthcare Workers" in 2023, conducted in South Korea, demonstrated that bioterrorism educational programs could be developed to enhance healthcare personnel’s capacity to respond to bioterrorism threats, and easier access to these educational programs should be provided[29]. In contrast to these findings, in Iran, such bioterrorism educational programs were limited in availability and lacked long-term sustainability, which highlighted gaps in accessibility and the continuity of training for healthcare personnel.

Limitations: This study focused exclusively on bioterrorism training for healthcare personnel in Iran, and only English and Persian publications were included, which may have led to the omission of relevant studies in other languages or contexts. Additionally, review articles were included as supplementary sources due to the limited number of primary studies. Future research should

expand the scope to multiple countries, include diverse healthcare settings, and consider multilingual literature searches to enhance the generalizability and applicability of findings.

## Conclusion

This review contributed by mapping current gaps in bioterrorism education among Iranian healthcare personnel and identifying effective training methods such as simulation-based exercises and scenario-based workshops. It was observed that the knowledge and awareness of healthcare workers in Iran regarding bioterrorism are insufficient, and in the event of a bioterrorism attack, they might not perform effectively. Given the absence of bioterrorism-related education in the curriculum approved by the Ministry of Health, Treatment, and Medical Education, it is recommended that this critical issue be included in the formal educational program. Additionally, the effectiveness of modern educational methods, such as escape rooms and simulation techniques, was found to be higher than traditional methods like lectures and booklets.

Overall, healthcare workers' education plays a crucial role in disaster management and in dealing with biological threats. The findings suggest that countries with structured educational programs for healthcare personnel perform better when facing crises.

Studies indicate that insufficient awareness among healthcare workers leads to delays in identifying and controlling biological threats, such as bioterrorism attacks and epidemics. Continuous education and the standardization of educational programs, along with strategic planning, can enhance the resilience of health systems and reduce casualties and damages. Furthermore, the use of modern technologies, such as artificial intelligence and early warning systems, has been introduced as an effective solution in some studies.

Finally, policymakers should prioritize integrating specialized training, increasing interdepartmental collaboration, and developing advanced monitoring systems to improve preparedness against biological threats. It is also recommended to establish a national certification or periodic competency assessment for healthcare personnel in bioterrorism preparedness to ensure consistent readiness across all regions.Future research should explore the structure, content, and delivery quality of existing bioterrorism educational programs,assess the long-term effectiveness and cost-efficiency of simulation-based and e-learning interventions, and design standardized training modules tailored to the Iranian healthcare context.

## Ethical Considerations

## Authors'contributions

Conceptualization, methodology and supervision: Maryam Shabany. Searching, screening and selecting article: Javad Zahedi Asl; Data analysis: Maryam Shabany, Searching and data extraction: Sanaz Tavana, Hamidreza Zohrabi; Manuscript drafting and editing: Maryam Shabany, Javad ZahediAsl; Final approval of the manuscript: All authors

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**Appendix 1:** Search strategy in the database and scientific search engine

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|---|
| **Google scholar:**<br><br>**"Teaching" OR "education" OR "training"**<br>**AND "Health Personnel"**<br>**AND "Bioterrorism" OR "Biological Warfare Agents"**<br>**AND "Iran"**<br>**Magiran and SID**<br>**("Teaching" OR "education" OR "training")**<br>**AND "Health Personnel"**<br>**AND ("Bioterrorism" OR "Biological Warfare Agents")**<br>**AND "Iran"** |
| **Web of science:**<br><br>**TS=("Teaching" OR "education" OR "training")**<br>**AND TS=("Health Personnel")**<br>**AND TS=("Bioterrorism" OR "Biological Warfare Agents")**<br>**AND TS=("Iran")**<br>**TS= Topic( title , abstract, keywords)** |
| **ScienceDirect:**<br><br>**(TITLE-ABSTR-KEY("Teaching") OR TITLE-ABSTR-KEY("education") OR TITLE-ABSTR-KEY("training"))**<br>**AND TITLE-ABSTR-KEY("Health Personnel")**<br>**AND (TITLE-ABSTR-KEY("Bioterrorism") OR TITLE-ABSTR-KEY("Biological Warfare Agents"))**<br>**AND TITLE-ABSTR-KEY("Iran")** |
| **SID and Magiran**<br>**آموزش و پرسنل سلامت و بیوتروریسم و ایران**<br>**(آموزش یا تعلیم یا یادگیری) و (پرسنل سلامت یا کارکنان بهداشت) و (بیوتروریسم یا تروریسم زیستی یا جنگ بیولوژیک) و ایران**<br>**("Teaching" یا "Education" یا "Training" یا "آموزش" یا "یادگیری" یا "توانمندسازی" یا")**<br>**("Health Personnel" کارکنان سلامت" یا "پرسنل درمانی" یا") و**<br>**("Biological Warfare Agents" یا "Bioterrorism" بیوتروریسم" یا "عوامل جنگ‌افزار زیستی" یا") و**<br>**("Iran" ایران" یا") و** |

**Pubmed:**

| Search | Query | Results |
|---|---|---|
| #13 | Search: **((((("Teaching"[Mesh]) OR ("Teaching"[tiab])) OR ("education" [Subheading]) OR ("training" [Subheading]) AND (("Health Personnel"[Mesh]) OR ("Health Personnel"[tiab]))) AND ((("Bioterrorism"[tiab] OR "Biological Warfare Agents"[tiab])) OR ("Bioterrorism"[Mesh] OR "Biological Warfare Agents"[Mesh])) AND "Iran"** | 0 |
| #12 | Search: **((((("Teaching"[Mesh]) OR ("Teaching"[tiab])) OR ("education" [Subheading]) OR ("training" [Subheading])) AND (("Health Personnel"[Mesh]) OR ("Health Personnel"[tiab]))) AND ((("Bioterrorism"[tiab] OR "Biological Warfare Agents"[tiab])) OR ("Bioterrorism"[Mesh] OR "Biological Warfare Agents"[Mesh])) AND "Iran" - Schema: all** | 0 |
| #11 | Search: **((((("Teaching"[Mesh]) OR ("Teaching"[tiab])) OR ("education" [Subheading]) OR ("training" [Subheading])) AND (("Health Personnel"[Mesh]) OR ("Health Personnel"[tiab]))) AND ((("Bioterrorism"[tiab] OR "Biological Warfare Agents"[tiab])) OR ("Bioterrorism"[Mesh] OR "Biological Warfare Agents"[Mesh]))** | 101 |
| #10 | Search: **(("Bioterrorism"[tiab] OR "Biological Warfare Agents"[tiab])) OR ("Bioterrorism"[Mesh] OR "Biological Warfare Agents"[Mesh])** | 7,013 |
| #9 | Search: **("Health Personnel"[Mesh]) OR ("Health Personnel"[tiab])** | 646,113 |
| #8 | Search: **"Bioterrorism"[tiab] OR "Biological Warfare Agents"[tiab]** | 3,911 |
| #7 | Search: **"Bioterrorism"[Mesh] OR "Biological Warfare Agents"[Mesh]** Sort by: **Most Recent** | 4,998 |
| #6 | Search: **"Health Personnel"[tiab]** | 10,045 |
| #5 | Search: **"Health Personnel"[Mesh]** Sort by: **Most Recent** | 639,903 |
| #4 | Search: **(("Teaching"[Mesh]) OR ("Teaching"[tiab])) OR ("education" [Subheading])** | 492,336 |
| #3 | Search: **"education" [Subheading]** Sort by: **Most Recent** | 307,939 |
| #2 | Search: **"Teaching"[tiab]** | 183,654 |
| #1 | Search: **"Teaching"[Mesh]** Sort by: **Most Recent** | 95,119 |