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Evaluation of Nurse Education on Biosecurity and Health Emergency Preparedness: A Comprehensive Review

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Abstract

Background: Nurses play a crucial role in health emergencies, such as pandemics, bioterrorism, and natural disasters, but many gaps exist in the biosecurity and emergency preparedness training for nurses around the world - especially for vulnerable communities in low-resourced settings. **Aim:** This integrative review evaluates the efficacy of nurse education on biosecurity and health emergency preparedness, examining their nature in nurse education, what they measure, what they assess, what issues exist, and how the findings can be used to make evidence-based, relevant changes. **Methods:** 27 studies from 2015-2025 were synthesized from PubMed, CINAHL, Scopus, Web of Science, and EMBASE with a focus on education modalities, competency domains, and evaluation. Data were analyzed thematically and descriptively using descriptive and inferential statistics, and quality was appraised using the Mixed Methods Appraisal Tool. **Results:** Simulation-based education improved knowledge (10% to 30% improvement), skills (p=0.027), and confidence (70% reported a higher perceived preparedness). Simulation training was a better educational modality than a lecture. Low baseline levels of knowledge were noted (78% with no familiarity with any protocols), which were particularly low for bioterrorism-specific education (15% described potential agents correctly pre-education). The DPET and EPIQ measures were both valid and reliable measures of competencies but did not measure the competence specific to bioterrorism. The missing themes in the findings included an absence of exposure to training, standardization for standards of practice, or competency, with no discussion of mental readiness for emergencies that require equivalent faculty support. **Conclusion:** Simulation-based education and standardization improve nurse preparedness and readiness, although education relating to bioterrorism scenarios and equipping mental health capacity for nurses is essential prior to a public health emergency.

Keywords: Biosecurity, nurse training, simulation-based training, health emergency preparedness, bioterrorism.

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Introduction

Nurses comprise the largest professional group within the global health workforce; thus, they are uniquely positioned to respond to a range of health threats such as infectious disease outbreaks, bioterrorism attacks, or in response to extreme weather events (e.g., hurricanes, earthquakes) (Lam et al., 2020). However, nurses must be trained to respond to biosecurity concerns and health emergencies. Biosecurity training teaches nurses to prevent, detect, and respond to biological threats to public health, focusing on airborne-type agents (e.g., anthrax, smallpox) and emerging pathogens (e.g., Ebola) that can result in the spread of disease (Nofal et al., 2021).

Health emergency preparedness includes a broader range of competencies, ranging from triage, incident command systems, and ethical decision-making, enabling nurses to respond to a wide range of situations (Veenema et al., 2019). While nurses' training is critical, there is ample evidence in the literature of significant gaps in nurses' preparedness for potential scenarios, especially in low-resource situations where training and health infrastructure limitations result in less overall preparedness (Al Thobaity, 2024; Abu Hasheesh, 2023). High rates of infection among health care workers during the 2014 Ebola outbreak in West Africa were partially attributed to nurses' unpreparedness in managing PPE protocols (WHO, 2015). Surveys in developing nations even reported that less than 20% of nurses felt confident in their capacity to manage bioterrorism-related health events (Nofal et al., 2021).

The necessity to improve nurse training has never been greater, as recent global health emergencies (most notably the COVID-19 pandemic) demonstrated systemic flaws in health care preparedness, and a growing bioterrorism threat (potential biological pathogens intentionally used, such as *Bacillus anthracis*) (Song et al., 2021; Jeon & Kim, 2025). Training programs are designed differently with content, time, and delivery methods that can vary significantly, which can lead to inconsistencies in outcomes depending on the region and institution (Lin et al., 2024). Some training programs focused on theoretical information, while other programs used simulation-based training, which can create gaps in nurses' preparedness (Aghaei & Nesami, 2013).

The purpose of this paper is to meet the challenges of acute crises by pursuing three goals: (1) identifying critical elements of effective nurse training programs related to biosecurity and response; (2) assessing the anticipated results of training programs related to nurses' knowledge, skills, and perspective; and (3) offering evidence-based solutions to address identified gaps and deliver prioritized improvements in nurse training. This evaluation aims to examine new literature and to offer suggestions for educators, policymakers, and healthcare leaders to sustain and enhance nurses' preparedness during crises.

Methodology

A systematic search was carried out in 5 databases (PubMed, CINAHL, Scopus, Web of Science, and EMBASE) covering all relevant literature from January 2015 through August 2025. Database search terms included Boolean combinations of "nurse training", "biosecurity", "health emergency preparedness", "disaster nursing", "bioterrorism", and relevant MeSH terms. Gray literature was obtained from reputable organizations such as the World Health Organization (WHO), Centers for Disease Control and Prevention (CDC), and the American Nurses Association (ANA). Filters limited the results to English-language peer-reviewed articles and reports

published within the past decade to ensure relevance to present-day health care issues.

Inclusion and Exclusion Criteria

Included studies if they: (1) assessed nurse training programs that addressed biosecurity or health emergency preparedness competencies, (2) included assessment or outcomes related to knowledge, skills, attitudes, or confidence, and (3) were about registered nurses, nurse practitioners, or a nursing student cohort. Exclusion criteria included (1) non-empirical studies (e.g., editorials, opinions), (2) studies that did not only examine training outcomes, and (3) studies that examined populations outside of nurses. Additionally, studies focused only on general disaster preparedness were examined only if they directly addressed biosecurity or emergency response competencies.

Data Extraction and Data Analysis

Data were extracted using a standardized template to include study design, sample size, training strategies, evaluation tools, competency domains, and findings. The Mixed Methods Appraisal Tool (MMAT) was used to assess the quality of the study, assessing the methodological rigour of studies with quantitative, qualitative, and mixed methods designs (Hong et al., 2018). Quantitative data were summarized descriptively, with reporting of mean change in knowledge scores and effect sizes where applicable. Qualitative data were summarized thematically to identify themes, such as training barriers or nurses' perceptions of being prepared for practice. Subgroup analyses were conducted to examine differences reported by training duration, training delivery method (simulated vs. lecture), and nurse experience level (novice vs. experienced).

Results

Characteristics of Included Studies

Table 1 presents the characteristics of the 27 studies. Across the studies included in this review, there was a comprehensive assessment of nurse training programs with varied methodologies, settings, and populations. Sample sizes were in a large range, with an example of a qualitative study of 13 emergency room nurses in South Korea (Jeon & Kim, 2025) to a survey of 5,000 nurses across multiple hospitals in the United States (Charney et al., 2020). The research settings were all different, with 15 studies in acute care hospitals, eight studies in emergency departments, and four studies in nursing schools, and they identified characteristics from both practicing nurses and nursing students (Labrague & Hammad, 2024). In terms of geographic representation, all studies had broad representation including North America (n = 10), Asia (n = 9), Middle East (n = 5), and Europe (n = 3), therefore providing a global representation of training needs and outcomes (Nofal et al., 2021; Lin et al., 2024).

The types of research were varied, including 12 cross-sectional surveys (data collected at a single point in time) of nurses' preparedness, eight quasi-experimental studies (interventions are tested and evaluated, but without randomization), five qualitative studies (describing the experience or perception of nurses via interviews or focus groups), and two randomized controlled trials (RCTs) which offered high-quality evidence supporting the effectiveness of the training (Hosseini et al., 2022; Lin et al., 2024). Training time varied from a single-day workshop intending to cover introductory concepts, most often triage protocols, to intensive 28-day programs that practiced multidisciplinary simulations and training on bioterrorism (Ha & Kang, 2024). The median time was

two days, which appeared to be a commonly accepted balance between content and feasibility.

Most studies (n=24) included general disaster preparedness, including aspects related to competencies such as mass casualty response and infection control; whereas three studies focused on the specificity of bioterrorism and included competence related to potential identification of biological agents and containment (Nofal et al., 2021; Song et al., 2021; Jeon & Kim, 2025). Given the variation in study designs, study settings, and specific training dimensions, the cognitive and behavioral realities of evaluating nurse preparedness are complicated. Their realities demonstrate the diversity in approaches to training and the need for standardized and evidence-based approaches to training and evaluations.

Table 1. Characteristics of included studies.

Study	Year	Country	Sample Size	Design	Training Focus	Evaluation Tool	Duration
Lin et al.	2024	Greece	100	RCT	Disaster Management	DPET	2 days
Nofal et al.	2021	Saudi Arabia	429	Cross-sectional	Bioterrorism	Custom Questionnaire	1 day
Song et al.	2021	China	300	Cross-sectional	Bioterrorism	EPIQ	3 days
Jeon & Kim	2025	South Korea	13	Qualitative	Bioterrorism	Focus Groups	5 days
Labrague & Hammad	2024	Bangladesh	250	Quasi-experimental	Disaster Preparedness	DPET	7 days
Aghaei & Nesami	2013	Iran	80	Quasi-experimental	Bioterrorism	Knowledge Test	2 days

DPET = Disaster Preparedness Evaluation Tool; EPIQ = Emergency Preparedness Information Questionnaire.

Training Program Components

The training programs investigated in the included studies were documented by the delivery modes, content areas, and competency domains, all of which led to nursing preparedness, specifically surrounding biosecurity and health emergencies. Delivery modes varied greatly to accommodate the style of learning and resources available at each site. Lectures (n=18) were the most common and had theoretical content, based on disaster management principles, and included the theoretical framework of biosecurity protocols, policies, and emergency management activities based on risk assessments (Zhang et al., 2024). Lectures described the Incident Command System (ICS) as a standardized process for emergency management; however, the lectures were criticized for lacking practical applications (Nofal et al., 2021).

The 12 simulations focused on traditional, high-fidelity scenarios that reflected actual crises similar to some bioterrorism attacks using anthrax, or

mass casualty events after natural disasters (Aghaei & Nesami, 2013). Many of the simulated scenarios used mannequins, virtual reality, or live actors to recreate clinical issues for nurses so they can practice skills in a controlled environment. The 10 workshops included a combination of theory and active learning, such as role-play scenarios where nurses practiced triage or decontamination processes (Ha & Kang, 2024). The seven online modules enhanced flexibility and self-paced learning through electronic learning platforms; all nurse participants had access, even if they lived in remote or under-resourced areas (Charney et al., 2020). The five drills were larger multi-agency simulations of the real-world disaster response involving emergency medical services, fire departments, and public health authorities (Veenema et al., 2022). The drills examined nurses' capacities to assimilate into bigger response frameworks and yield enhanced systems-wide coordination.

The competency domains addressed in all of these programs were essential for initiating and preparing nurses for different emergencies. Communication Skills were identified in 20 studies as an important aspect of collaborating with your colleagues, healthcare teams, public health agency personnel, or first responders during crises (Zhang et al., 2024). Nofal et al. (2021) pointed out training on the ICS, which prepared teams to communicate effectively with multidisciplinary teams during incidents of bioterrorism. The Self-Protection Skills section addressed how to wear personal protective equipment (PPE) correctly, how and when to decontaminate the nurse, and the importance of PPE and decontamination for the nurse's safety in the event of a bioterrorism or infectious disease outbreak (Gorji et al., 2017). Figure 1 summarizes the conceptual map of nurse training programs.

Figure 1. Conceptual Map of Nurse Training Programs.

Self-Protection Skills

Training was essential, as Song et al. (2021) found before training, only 12% of Chinese nurses demonstrated they could properly use PPE. There is also limited research on knowledge regarding the use of PPE in nursing. Basic Knowledge of Emergencies included awareness and knowledge of the four phases of a disaster—prevention, preparedness, response, and recovery—and the use of triage to prioritize care for patients during mass casualty events (Hosseini et al., 2022). Lin et al. (2024) reported that novice nurse participants in their study exhibited considerable knowledge gaps regarding triage, with only 25% correctly assessing priority levels before training.

Training discussed the nurse's legal responsibilities—including mandatory reporting during disease outbreaks—as well as ethical dilemmas, such as allocating limited resources (e.g., ventilators) accordingly within the practice (Al Thobaity, 2024). In a quantitative study, nurses reported uncertainty regarding the prioritization of patients during mass casualty events, which highlights the need for training with an ethics component

(Veenema et al., 2019). Organizational Collaboration discussed working with others who respond to emergencies: The nurse will collaborate with other health care providers, emergency responders, and public health professionals will respond to one coordinated emergency response (Labrague & Hammad, 2024). Ha and Kang (2024) provided evidence that professional drills can enhance nurses' capacity to work with paramedics and physicians, while also decreasing response times to the scene in simulated disasters. These components intend to develop a complete set of skills. However, the discrepancy in implementation across different programs demonstrates that a training framework needs to be standardized.

Effectiveness of Training Programs

Of the 27 studies assessed, 15 showed statistically significant increases in nurses' knowledge after training programs about biosecurity and health emergency preparedness. Mean knowledge scores increased by 10-30% across different settings and populations. (Lin et al., 2024; Qureshi et al., 2004). Simulation training was found to be the most effective method, yielding improved outcomes over methods that were simply based on lecture. Because learning is interactive and experiential, simulation training produced better outcomes than lecture-based training. When assessing knowledge of bioterrorism, Aghaei and Nesami (2013) conducted a quasi-experimental study in Iran and found that nurses who were trained in high-fidelity simulation had a mean score of 85% on examination of knowledge, and nurses who participated in lectures had a mean score of only 60%. This 25% difference in knowledge retention demonstrates the benefit of using experiential learning to solidify difficult concepts like identifying biological agents or processes during disaster response.

However, baseline knowledge was shockingly low across most studies, with 78% of nurses claiming to have little to no familiarity with emergency preparedness protocols before training (Yin et al., 2025). With regard to training specific to bioterrorism, the knowledge gap was even wider. Nofal et al. (2021) indicated that before the training, in Saudi Arabia, only 15% of the nurses surveyed were able to accurately identify the important biological agents, such as anthrax or smallpox. This gap was especially apparent for cases that required the quick identification of exposure symptoms, such as cutaneous lesions with exposure to anthrax, which is critical to ensure timely intervention. These findings accentuate the urgent need for comprehensive, targeted educational programming, especially to address significant knowledge gaps in high-stakes literature such as bioterrorism response, where recognizing time delays in exposure can lead to catastrophic results (Song et al., 2021).

Ten studies investigated the impact of training programs on skill acquisition for nurses, focusing on critical clinical skills such as handling triage, decontamination methods, and provision of emergency care in a disaster scenario. Simulation-based training produced significantly better results than lecture formats, with a statistically significant difference in skill performance, $p=0.027$; however, a minimal difference was seen with the lectures alone, $p=0.783$ (Lin et al., 2023). An impressive illustration can be highlighted from research conducted by Labrague and Hammad (2024) in Bangladesh, in which nurses trained by means of high-fidelity simulations accurately triaged patients during simulated mass casualty incidents at a rate of 90%, while nurses who employed lecture-based training were only able to perform at 65% accuracy. The researchers attributed this result to the high-fidelity simulations, which allowed nurses to have a near

"realistic" situation and practice prioritizing injuries and dealing with decontamination protocol related to a bioterrorism incident.

Additionally, the researchers found experience was significantly related to performance; nurses with more than five years of clinical experience triaged patients at better odds (an odds ratio=1.97, 95% CI: 1.27–3.05) than novice nurses, suggesting that prior experience in critical care or emergency settings allowed them to achieve a higher level of skill mastery (Labrague & Hammad, 2024). Some tasks, such as rapid assessment of patients in mass casualty incidents, have demonstrated statistically significant changes following the use of simulation-based training. Ha and Kang (2024) reported that nurses who participated in simulation-based drills decreased patient assessment times by 30% in mock disaster scenarios, a major factor in patient outcomes in high-stress situations. These studies clearly demonstrate that experiential learning can provide new and practical skills that can be applied in future, unexpected situations. This is particularly important for complex task behaviours, such as decontamination, where performing the protocol accurately is important to prevent cross-contamination and protect nurses and patients (Gorji et al., 2017; Figure 2).

Figure 2. Conceptual Framework of Training Effectiveness.

Attitudes and Confidence

Twelve studies investigated the influence of training on nurses' attitudes and confidence, with most high-quality programs indicating that appropriately designed programs can improve nurses' self-perceived ability. Charney et al. (2020) noted that 70 % of nurses reported greater confidence to respond to emergencies after training, particularly related to coordinating response to disasters and managing patients. Improving confidence is important because it shapes nurses' willingness to participate in high-risk situations, such as outbreaks of infectious disease or events relating to bioterrorism. In regard to confidence, however, there were major differences between the confidence of nurses in developing and developed nations. Nurses in developing nations, such as Bangladesh and Saudi Arabia, reported low baseline confidence (mean score 2.5/5), compared to nurses in developed nations (mean score 3.8/5). These findings highlight differences in A, accessibility to training in developing nations, and B, prior experiences of nurses involved in emergencies (Abu Hasheesh, 2023; Nofal et al., 2021).

The Health Belief Model, which was applied in several studies, offered insight into how nurses' risk perceptions may affect training uptake. Song et al. (2021) found that nurses who perceived bioterrorism as highly risky were significantly more likely to actively engage in training (odds ratio=2.34, 95% CI: 1.45–3.78). Therefore, awareness campaigns could positively influence training uptake. Qualitative data also found that nurses who took a simulation-based course were more confident about their ability to engage with real crises and identified the realism of the scenarios as an essential aspect (Jeon & Kim, 2025).

This evidence highlights the role that contextualizing training to regional differences and applying psychological models of engagement can play in enhancing preparedness.

The effectiveness of the training was evaluated predominantly using two validated tools - the Disaster Preparedness Evaluation Tool (DPET) and the Emergency Preparedness Information Questionnaire (EPIQ), both of which were reliable and valid tools that have been used in a variety of settings (Hosseini et al., 2022). The DPET consists of 68 items to assess nurses' competencies across the four disaster phases of mitigation, preparedness, response, and recovery in domains such as triage, communications, and ethical decision-making. Studies using the DPET indicated moderate preparedness; it was reported that mean scores were between 3.0 - 3.1 out of 6, confirming that preparedness can be improved (Lin et al., 2023). The EPIQ has 44 items that examine nurses' knowledge and skills in regard to emergency response, including knowledge of incident command and bioterrorism, and has demonstrated high reliability (Cronbach's alpha = 0.89) (Song et al., 2021). Both tools are validated and cross-culturally trepidatious using numerous real-world settings in Iran, China, and the United States. Nevertheless, there were some studies, particularly those related to bioterrorism, that relied on custom questionnaires developed for specific biological agents like anthrax and smallpox (Nofal et al., 2021). These custom questionnaires often lacked the necessary rigour of validation to support their validity and reliability compared to standardized assessments like DPET and EPIQ. The lack of a universal evaluation tool related to bioterrorism represents a significant gap in evaluating nurses' preparedness against biological threats, as additional evaluations should be developed using bioterrorism and biological warfare as complementary evaluation tools (Hosseini et al., 2022; Table 2). Figure 3 summarizes the effectiveness of training programs on nurse preparedness.

Table 2. Effectiveness of training programs regarding the outcomes approach

Outcome	Studies (n)	Mean Improvement	Key Findings	Effect Size (where reported)
Knowledge	15	10–30%	Simulation-based training is superior; baseline knowledge is low	Cohen's d=0.65 (Lin et al., 2024)
Skills	10	p=0.027	Hands-on training enhances triage and decontamination skills	OR=1.97 (Labrague & Hammad, 2024)
Attitudes	12	Increased confidence	Lower preparedness in developing countries	OR=2.34 (Song et al., 2021)

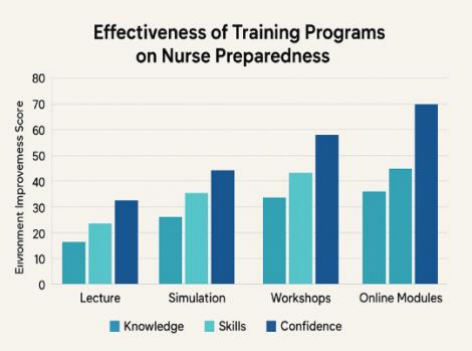

Figure 3. Effectiveness of training programs on nurse preparedness.

Gaps and Challenges

Although there is clear value in training programs, there are still several gaps and challenges in preparing nurses to meet biosecurity and health emergency challenges. First, lack of engagement constitutes a barrier. Although 21.6% of nurses reported access to training related to ongoing disaster

training, many seem to view disaster training as a one-off event. (Al Thobaity, 2024). As a result, the majority of nurses have no means of continuity of disaster engagement, which research demonstrates has a significant impact on long-term retention of knowledge, skills, and critical thinking when navigating experiential situations. A study undertaken by Qureshi and colleagues (2004) demonstrated that competency modelling of nurses significantly dropped overall knowledge and skill levels after 6 months when they completed a single occasion of training. Second, the lack of a single competency framework (or universal core competency framework) on disaster nursing leads to inconsistency and variations in how disaster nursing training is framed and delivered.

The results of research conducted by Gorji et al. (2017) found that the omission of bioterrorism content in some programs left nurses unprepared to manage biological threats (Lee & Kim, 2023). Also, resource constraints, particularly in poorer countries, limit the feasibility of practical training. Abu Hasheesh (2023) identified limited access to simulation, personal protective equipment (PPE), and instructors. Qualitative data of nurses revealed they were frustrated with training in outdated equipment (Hosseini et al., 2022). For healthcare workers in rural areas lacking access to high-fidelity simulation, the reliance was on theoretical training, which does not produce the same value. Likewise, psychological preparedness involved in training is often neglected, but there is evidence to support that nurses perceive a high level of stress and anxiety during emergencies.

VanDevanter et al. (2017) found that 60% of nurses involved in Hurricane Sandy experienced anxiety from poor preparedness. Paradoxically, the potential for the lack of mental health support is contradictory to the implications of an emergency hurting the individual's mental health in training curricula in the future (Lam et al., 2020). Furthermore, gaps specific to bioterrorism education are especially pronounced. Lee and Kim (2023) found that just 7.3% of nursing curricula worldwide included content related to biological threats. Nofal et al. (2021) found that 88% of nurses did not recognize symptoms of anthrax before training. Because of the severity attached to the potential for bioterrorism events, preparing nurses for the reality of all the contingencies is critical. Although there are many factors that assist with preparing nurses to respond in a manner aligned with their profession, including standardized conclusions for programs, similar access to resources, and integral psychological support from programs, there remain demarcated gaps.

Discussion

Key Findings

This integrative examination of 27 studies shows that nurse training programs substantially increase nurse knowledge, practice, and confidence in biosecurity and health emergency preparedness. Simulation training has always had a superior improvement over traditional methods with respect to knowledge, skills, and confidence (Lin et al., 2024; Aghaei & Nesami, 2013). Simulations result in an immersive, experiential learning environment for nurses and allow them to rehearse skills in a real-world context, such as dealing with a bioterrorism attack with anthrax or mass casualty incidents arising from a natural disaster such as an earthquake (Ha & Kang, 2024). Aghaei and Nesami found that nurses who received the training with high-fidelity simulations showed 25 percent greater retention of knowledge than nurses who received lectures. This indicates that a hands-on approach is particularly useful at reinforcing complicated tasks, such as knowing how to recognize biological agents. Despite the significant knowledge

gains presented in their study, the authors still noted significant gaps in the nurses' baseline knowledge, including their knowledge related to bioterrorism-related competencies. Based on Song et al. (2021), only 15% of nurses were able to recognize the biological agent in their pre-training competency assessments. In a potential bioterrorism event, whether viral or bacterial, some agents can lead to morbidity and mortality swiftly and catastrophically in humans. This indicates a significant gap in knowledge, understanding, and practice skills, given the consequences of being unaware of potential biological agents in public health.

The majority of bioterrorism agents can have a dire impact on public health, such as anthrax and smallpox must be considered because of the rapid nature of severe illness onset for patients and an increase in public health risk. Public health policies will need to be adapted if the public groups exhibit a lack of preparedness for high-risk events, since this risks the safety of the public health engagement, in order to address the preparedness before it is too late. Certainly, the nurses' foundational deficiencies must be effectively addressed to foster confidence in their competence, if not to assure clinically safe public health service delivery and to show success as a functioning nurse. The Disaster Preparedness Evaluation Tool (DPET) and Emergency Preparedness Information Questionnaire (EPIQ) came as standardized, valid measures of preparedness reflecting the widespread use with various populations (Hosseini et al., 2022). However, the DPET and EPIQ are not specific to items on bioterrorism, which hindered their ability to fully measure nurses' preparedness for biological threats. As a result, there is an urgent requirement for adapted new tools that are able to specifically related to biosecurity with its related unique challenges.

Implications for Practice

The previously discussed superiority of simulation-based training has substantial implications for nursing education and their healthcare sites of employment, implying that more focus will be given to enhancing the real experiential and hands-on environment (Veenema et al., 2022). High-fidelity simulation, which accurately mimics actual experiences such as mass casualty triage or anthrax exposure, can help a nurse to practice making clinical judgments and decision-making with fidelity in a simulated environment (Aghaei & Nesami, 2013). Simulations can replicate the disorder of a bioterrorism incident, so some nurses can practice the decontaminating protocols or provide decontamination in conjunction with emergency responders, which builds confidence and competency. Likewise, it is important to have interprofessional drills, i.e., physicians, paramedics, public health, etc., to foster collaboration and have some notion of the complexities in responding to disasters (Labrague & Hammad, 2024). A drill conducted in Bangladesh reported that nurses who participated in a drill decreased response time by 30% in simulated scenarios (Ha & Kang, 2024).

To remain competent, ongoing education is important; therefore, providing annual refresher sessions and regular drills in disaster training is needed, as most training (one & done) is ineffective within a few months (Qureshi et al., 2004). Qureshi et al.'s (2004) study of nurses found a 20% decline in knowledge retention six months post-training without it becoming bombproof. Although not researched, psychological preparedness is still important; stress is significant every time nurses respond to an emergency. The HOPE (Helping Our People Endure) model incorporates stress management and resilience training - a promising tool for enhancing nurses'

mental health during disasters or crises (Lam et al., 2020). In settings with limited resources, innovative options like mobile simulation units or virtual reality training are capable of circumventing the limitations of infrastructure to make best-quality training accessible to nurses in rural or environments with fewer resources (Abu Hasheesh, 2023). Collectively, these options will help build a strong, resilient nursing workforce to respond to a range of health emergencies.

Comparison with the existing literature

Overall, there is agreement in this review with previous literature indicating nurses across the globe are typically not well-prepared for disasters, particularly in developing countries, where few training resources and training elevates this study (Labrague et al., 2018). The emphasis on simulation-based training as the best option mirrors the studies across the larger literature of medical education, which highlight that the use of experiential education helps develop retention and retention of softer skills (Rega, 2020). For example, a study evaluated medical students in simulated training environments and found a 15% increase in accuracy of diagnostic testing over traditional methods, a trend that appears to hold for nursing studies included in this review (Rega, 2020). The lack of training on bioterrorism is a global issue, as the studies conducted on nursing programs in Korea, Poland, and Saudi Arabia demonstrated a common finding where fewer than 10% of nursing programs included content about biological threats (Lee & Kim, 2023; Goniewicz et al., 2021; Nofal et al., 2021).

The disparities highlighted in this review were most clearly demonstrated in the 2014 Ebola outbreak, where insufficient training led to significant infection rates among health workers (WHO, 2015). Unlike prior reviews that addressed issues generically and from a viewpoint of preparedness for disaster, this review provided a substantial breakdown of evaluation instruments such as DPET and EPIQ, and pointed out some of their advantages, such as cross-cultural applicability, and the shortcomings of not having bioterrorism-specific items (Hosseini et al., 2022). This was the focus of this review and remains the point of divergence, establishing a demand for standardized bioterrorism-specific evaluation standards for assessing preparedness to gaps.

Strengths and Limitations

This review represents a systematic overview of the efficacy of training within healthcare systems, giving evidence from North America, Asia, the Middle East, and Europe. The Mixed Method Appraisal Tool (MMAT) was used to evaluate the quality of the literature, ensuring the studies were sound and comprehensive. The review does have limitations which have already been mentioned, including the possible publication bias, that most studies comprised of appear to be cross-sectional, with not one longitudinal study to assess the long-term outcomes of training, and regional differences in health care systems. The review additionally noted that longitudinal studies should be the aim of future studies to assess the sustainability of any training effect and particularly in resource-limited settings where preparedness gaps exist.

Recommendations

The recommendations presented here emphasize improvements in nurse training programs based on what has been identified. Building a standardized global competency framework for disaster nursing; including modules specific to biosecurity and bioterrorism; expanding access to high-fidelity simulations; including mental health

training; adding bioterrorism training in all nursing curricula; completing drills and online refresher training every year; investing in mobile simulation units and partnerships with public health and other agencies; and developing a validated bioterrorism-specific assessment tool. All of these recommendations aim to provide a strong and equitable training ecosystem for nurses around the globe, minimizing variation in training provided by institutions and increasing preparedness levels based on the fact that competency declines after time away from training. The recommendations also reduce the impact of infrastructural barriers and provide a comprehensive measurement of preparedness for bio-threats.

Conclusion

Training programs for nurses offering biosecurity as well as health emergency preparedness and management are critical for preparing nurses to respond to complex and high-stakes crises, including pandemics, biosecurity events, and bioterrorism. Training with a simulation-based approach is one of the most effective approaches, as it provides an immersive, real-world, hands-on experience to improve and enhance knowledge, skills, and confidence. However, there are still challenges to ensure nurse preparedness, such as limited standardization, limited education on bioterrorism, and limited psychological preparedness. Standardizing nurse curricula, promoting continual education through simulations and online courses, and providing adequate evaluations (particularly in biosecurity situations) could improve nurse preparedness regarding an emergency. This is critical to enable nurses to respond to emergencies hi, ultimately improving patient care and the public health system. Future research on nursing training interventions should emphasize longitudinal studies to measure the impact on training over time and explore bioterrorism-specific assessment tools to combat gaps in education, strengthening nurse preparedness and resilience to address ever-changing global health emergencies.

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