THE IMPACT OF VIRTUAL REALITY SIMULATION TRAINING ON NURSES' COMPETENCY IN DISASTER MANAGEMENT: A SCOPING REVIEW

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ABSTRACT

Nurses are pivotal in disaster management. Suboptimal preparedness impairs response, communication, and patient safety. Virtual Reality-based training can enhance clinical skills, readiness, and decision-making, yet logistical and cost challenges persist. This scoping review aims to map evidence on the impact of Virtual Reality Simulation (VRS) in enhancing nurses' competency in disaster management. The methodology framework utilized in this scoping review followed Arksey and O'Malley's approach. Literature was systematically searched across PubMed, Scopus, and EBSCO using keywords: nurses, Virtual Reality Simulation Training, nurses' competency, and disaster management. Inclusion criteria required English-language publications. All extracted data were systematically tabulated to facilitate comparative analysis and thematic synthesis. A total of 164 articles were identified, nine studies met the inclusion criteria and were selected for this scoping review. VR training consistently improved nurses' disaster preparedness, response capabilities, knowledge, and satisfaction compared to traditional methods. Immersive VR enhances practical skills, decision-making, and engagement, despite challenges related to resources, infrastructure, and standardization. VR-based training enhances nurses' disaster preparedness more effectively than conventional methods. Despite its benefits, the widespread adoption of this approach is hindered by infrastructure, resource demands, and technical limitations in developing realistic simulation environments.

Keywords: Disaster Management, Disaster Preparedness, Nurse's Competency, Simulation Training, Virtual Reality.

INTRODUCTION

Nursing plays a pivotal role in disaster management by facilitating medical care, enabling rapid decision-making, and stabilizing patients in diverse healthcare and community settings (C. J. Wakefield et al., 2021). Suboptimal preparedness can compromise response times, undermine interprofessional communication, and reduce the overall efficacy of nursing interventions (Jung, 2022). Comprehensive training that addresses mitigation, preparedness, response, and recovery is imperative, yet traditional educational methods often lack realism and fail to replicate the

complexities of actual disaster scenarios (World Health Organization(WHO), 2019) Workshops, seminars, and theoretical lectures offer limited emotional engagement, which can hinder knowledge retention and application in high-pressure environments (Feng et al., 2020). High-fidelity simulations partially resolve these issues but often require substantial logistical resources and do not always permit individualized feedback (Wiese et al., 2021).

Evidence on VR-based interventions in disaster training for nurses reveals both advantages and barriers, emphasizing the need for systematic scrutiny to understand how VR might optimize skill acquisition and emotional preparedness (Wiese et al., 2021). Shortcomings in standard simulations, coupled with the potential benefits of realistic technological immersion, underscore a significant opportunity to advance nursing competencies in disaster settings (M. K. Wakefield et al., 2021). A scoping review is essential to map current evidence, synthesize findings, and illuminate gaps related to VR's impact on nurses' disaster management proficiency (Jung, 2022). Insights into leadership development, critical decision-making, and collaborative competencies are especially pertinent, as these elements are often critical determinants of success in disaster management (Jung, 2022; M. K. Wakefield et al., 2021). This scoping review aims to map evidence on the impact of Virtual Reality Simulation (VRS) in enhancing nurses' competency in disaster management.

LITERATURE REVIEW

Virtual Reality (VR) presents an alternative by creating immersive learning experiences that mirror real-life emergencies without subjecting participants to actual harm (Feng et al., 2020). Studies indicate that VR can improve nurses' confidence, clinical decision-making, and familiarity with rapid responses essential in disaster management (Zhang et al., 2021). Game-based VR training has demonstrated heightened engagement and better decision-making performance in emergency nursing contexts (Hu et al., 2024). Fire evacuation training conducted through VR environments has been shown to enhance readiness and motivation among learners, though technological costs and accessibility challenges persist (Wong & So, 2024). Research highlights concerns around infrastructure, such as the need for high-end hardware, stable network connections, and specialized software that can be difficult to implement across all healthcare institutions (Padilha et al., 2019). Heterogeneity in VR platforms, research designs, and outcome measures further complicates definitive conclusions regarding VR's overall effectiveness (Feng et al., 2020).

RESEARCH METHODS

This scoping review aimed to map evidence on the effectiveness of Virtual Reality Simulation (VRS) in enhancing nurses' competency in disaster management. The methodology framework utilized in this scoping review followed Arksey and O'Malley's approach, encompassing five essential stages: (1) identifying the research question, (2) identifying relevant studies, (3) selecting studies based on clearly defined inclusion and

exclusion criteria, (4) systematically extracting data, and (5) analyzing and reporting the results. This approach was chosen due to its capability to broadly explore the research area, identify existing gaps in the literature, and provide guidance for future research needs (Westphaln et al., 2021). This Study guided by the Research Question: What is the impact of VR-based simulation training on nurses' disaster preparedness and management skills?

Search Strategy

The article search was conducted across three electronic databases: PubMed, Scopus, and EBSCO, which are recognized for their comprehensiveness and credibility in the fields of healthcare and nursing education. The search strategy was formulated using the Population, Concept, and Context (PCC) framework to ensure a structured and systematic approach. The Population included nurses or registered nurses, the Concept focused on Virtual Reality Simulation Training and Nurses' Competency, and the Context pertained to disaster management and disaster preparedness. The search strategy employed Boolean operators to refine the query and ensure the retrieval of relevant studies. The following search strings were used for the database:

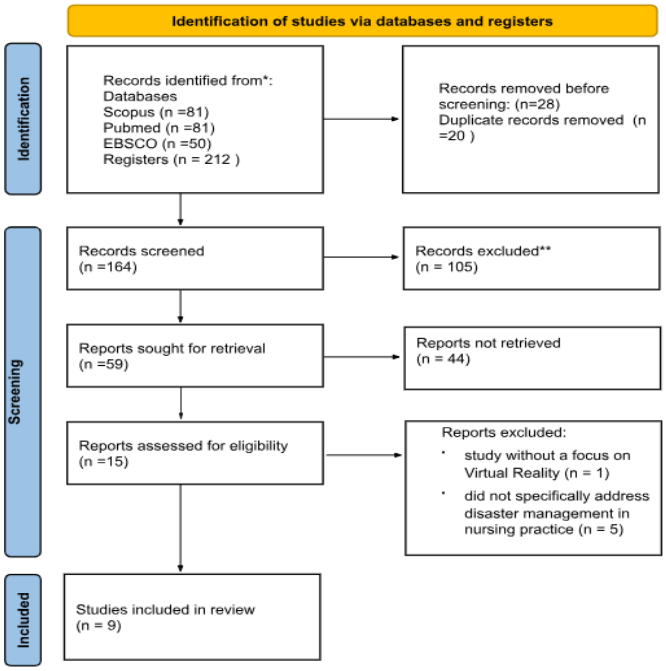
("Nurses" OR "Registered Nurses" OR "Nursing Personnel") AND ("Virtual Reality" OR "Simulation Training" OR "Educational Virtual Reality") AND ("Nurses Competency" OR "Clinical Competency" OR "Clinical Skill") AND ("Disaster Management" OR "Disaster Response" OR "Disaster Planning" OR "Emergency Preparedness" OR "Disaster Relief Planning").

The search results were systematically documented and reported using the Preferred Reporting Items for Systematic Reviews and Meta-Analyses extension for Scoping Review (PRISMA-ScR) flow diagram. This framework facilitated the visualization of the article selection process, from the identification stage to the final inclusion of eligible studies, ensuring transparency and methodological rigor in study selection.

Inclusion and Exclusion Criteria

This study established specific inclusion and exclusion criteria to ensure the relevance and methodological rigor of the selected articles. The inclusion criteria were as follows: (a) the population consisted of registered nurses working in hospitals or other healthcare facilities; (b) the intervention involved simulation-based training using Virtual Reality (VR) technology and simulation training methods; (c) the study outcomes assessed the impact of training on nursing competencies, including knowledge, technical and non-technical skills, communication, triage, and decision-making abilities; (d) the study context focused on natural disasters, human-made disasters, pandemics, or other medical emergencies; and (e) the article was published in English Conversely, the exclusion criteria included: (a) studies that did not utilize VR-based and simulation training interventions; (b) studies where the research subjects were not nurses (e.g., nursing students, physicians, or other healthcare professionals); (c) articles that were not directly related to nursing competencies in disaster management or emergencies; (d) publications classified as opinions, editorials, letters to the editor, or

conference abstracts without full-text availability; and (e) studies that did not provide clear results or data regarding the impact of VR training on nursing competencies



Picture 1. Prisma Flow Diagram

Data Extraction

VData extraction was conducted systematically to ensure consistency and accuracy in capturing relevant study characteristics. A standardized extraction form was developed to collect essential information from the included studies. The extracted data encompassed the following elements: author(s), year of publication, study objective, country of study, study design, sample characteristics, and key findings related to the impact of Virtual Reality (VR) simulation training on nurses' competency in disaster management.

Each study was independently reviewed by seventh researchers to extract data, minimizing bias and enhancing reliability. In cases of discrepancies, an eighth researcher was consulted to reach a consensus. The study objectives were analyzed to determine how each research aimed to assess VR-based simulation training for disaster preparedness. The country of study provided insights into the geographical distribution of research on this topic. The study design categorized the methodological approach, including randomized controlled trials, quasi-experimental studies, and observational research. The sample characteristics detailed the number of participants and their backgrounds. The key findings synthesized the major outcomes, including statistical results, improvements in knowledge, technical and non-technical skills, decision-making abilities, and disaster preparedness. All extracted data were systematically tabulated to facilitate comparative analysis and thematic synthesis.

Data Analysis

In line with the methodological framework for scoping reviews, this analysis exclusively examined the impact of Virtual Reality (VR) simulation training on nurses' competency in disaster management. The findings were presented in two stages. First, a descriptive numerical analysis provided an overview of the included studies, categorizing them based on study design and geographical distribution. Second, a thematic content analysis synthesized the extent to which VR simulation training enhances nurses' cognitive skills, technical proficiency, triage capabilities, decision-making, and overall disaster preparedness.

Each study was assessed for improvements in these competencies post-VR training, with particular attention to variability in effectiveness across different VR methodologies. The synthesis offers a structured perspective on VR's contribution to disaster management training for nurses, while also identifying critical research gaps regarding long-term knowledge retention, real-world applicability, and standardization of VR-based training protocols.

RESEARCH RESULTS

Characteristic of the Included Study

The systematic search for studies on the impact of virtual reality (VR) simulation training on nurses' competency in disaster management identified a total of 212 records from various databases, including Scopus (n = 81), PubMed (n = 81), and EBSCO (n = 50). Twenty-eight records were removed before screening, including 20 duplicate entries. A total of 164 articles underwent title and abstract screening, with 105 studies excluded due to irrelevance to the research focus. Fifty-nine studies were sought for full-text retrieval, but 44 reports did not align with the objectives of this scoping review. Fifteen full-text articles were assessed for eligibility, with six excluded—one study did not focus on virtual reality, and five did not specifically address disaster management in nursing practice. Nine studies met the inclusion criteria and were selected for this scoping review

Table 1. Data Extraction

Author (Year)	Objective	Country	Study Design	Sample	Key Findings
Zhang et al. (2025)	To assess the feasibility and effectiveness of a nonimmersive VR (NIVR) training program for nurses in isolation wards.	China	Randomized Controlled Trial	90 nurses (45 in intervention, 45 in control)	No significant difference in theoretical knowledge scores between groups (p=0.75). Intervention group completed tasks faster (p<0.001). NIVR group completed patient reception and exit tasks significantly quicker (p=0.002, p=0.003).
Wiese et al.	To compare the effectiveness	USA	Randomized	BSN students	Students retained more knowledge after virtual

(2021)	of live and virtual disaster simulations on nursing students' learning outcomes.		quasi-experimental, crossover design	(number not specified)	simulation, except for triage-related items. Self-assessed learning was similar in both groups. Live simulations caused emotional distress, highlighting the need for debriefing.
Hu et al. (2024)	To evaluate the effectiveness of a serious game in training nurses for international emergency medical teams.	China	Retrospective comparative analysis	209 nurses (103 lecture group, 106 game group)	Game group had higher test scores than lecture group (p=0.010, OR=1.363). Game group had higher motivation and lower cognitive load.'Serious gaming enhanced decision-making and knowledge retention.
Wong et al. (2024)	To develop and evaluate an immersive VR hospital fire evacuation training program for nursing students.	Hong Kong	Pilot study	65 final-year nursing students	Overall satisfaction with training was 4.6/5.Highest-rated aspects were knowledge gained (4.7/5) and facilitation skills (4.7/5). Students valued immersive 3D experience and ward in-charge role-play.
Chang et al. (2022)	To evaluate the effectiveness of a 360° VR chemical disaster training program on disaster preparedness and self-efficacy in ER nurses.	Taiwan	Quasi-experimental, two-group repeated measures	77 ER nurses (32 VR group, 35 tabletop drills group)	VR group showed significantly higher preparedness scores one week after intervention (p<0.05). No significant difference between groups after three weeks. Tabletop drills were more effective for nurses with prior disaster response experience.
Genç et al. (2025)	To assess the impact of structured digital-based education on disaster literacy and preparedness belief levels in nursing students.	Türkiye	Randomized controlled trial (pre-test post-test design)	74 senior nursing students	Structured digital education improved disaster literacy and preparedness belief levels. Participants with access to a mobile app, disaster volunteerism, and family disaster plans had stronger preparedness scores. Significant improvement in disaster literacy post-intervention (p<0.01).

Zhang et al. (2021)	To develop and assess the impact of VR training on emergency response capabilities among reserve nurses.	China	Prospective quasi-experimental study	120 nurses (intervention and control groups)	VR group had significantly higher scores in knowledge, emergency response capacity, and disaster preparedness ($p<0.01$). Technical skills improved more in the control group. No difference in post-disaster management scores between groups.
Lowe et al. (2020)	To evaluate the feasibility and effectiveness of a 360° VR platform for training triage and out-of-hospital interventions in pediatric mass casualty incidents.	USA	Cross-sectional observational study	207 participants (physicians, residents, medical students, EMTs)	Residents performed better than attending physicians ($p=0.005$). Participants under 40 years old scored higher ($p<0.001$). VR training was rated highly immersive and engaging.
Farra et al. (2013)	To examine the effects of VR simulation on learning outcomes and retention in disaster training.	USA	Longitudinal experimental design	Associate degree nursing students	VR simulation significantly improved knowledge retention over time ($p<0.0001$). VR group had better long-term retention than traditional methods. VR training stabilized learning effects over two months.

Impact of Virtual Reality Simulation Training on Nurses' Competency in Disaster Management

The impact of VR in enhancing nursing competency for disaster management was consistently demonstrated across all selected studies. Several studies reported significant improvements in disaster preparedness and response capabilities among nurses following VR-based training. VR training significantly improved disaster preparedness scores in emergency nurses one week post-intervention ($p < 0.05$) (Chang et al., 2022). A study on public health emergency nurses indicated significantly higher scores in knowledge and emergency response capacity compared to traditional training methods ($p < 0.01$) (Zhang et al., 2021). Game-based VR training for emergency medical team nurses was associated with significantly better post-test performance compared to lecture-based training (odds ratio = 1.363, $p = 0.010$) (Hu et al., 2024). These findings highlight VR's potential to enhance disaster-related competencies by providing an immersive, experiential learning environment that strengthens

knowledge retention and decision-making skills.

Comparative analyses between VR and conventional training methods showed that VR offers superior real-time disaster response simulation. Virtual simulations led to better knowledge retention among participants, although triage-related skills were more effectively acquired through direct simulation (Wiese et al., 2021). One study on 360° VR mass casualty incident (MCI) training demonstrated immersive and engaging learning experiences, significantly enhancing performance among younger healthcare professionals compared to senior attending physicians ($p = 0.005$) (Lowe et al., 2020). Structured digital-based disaster education that integrated VR elements raised disaster literacy and preparedness beliefs ($p < 0.05$) (Genç et al., 2025). A hospital fire evacuation training study recorded high satisfaction (4.6/5), particularly regarding knowledge gained (4.7/5) and facilitation skills (4.7/5) (Wong & So, 2024). These findings suggest that VR-based disaster training is more engaging and effective than traditional lectures or classroom-based methods, because it provides a high-fidelity, risk-free setting for clinical nurses to refine emergency responses.

Different types of VR technologies produced varied impacts on nurses' learning experiences. Non-immersive VR, such as 2D screen-based VR simulations, improved task efficiency in isolation ward nursing but did not significantly elevate theoretical knowledge acquisition ($p = 0.75$) (Zhang et al., 2025). Immersive VR, including 360° simulations or three-dimensional virtual environments, was more effective at promoting practical skill development and decision-making abilities. A hospital fire evacuation training reported that nurses appreciated the realism and interactive nature of immersive VR (Wong & So, 2024). A serious gaming approach employed in disaster training for emergency nurses enhanced learning motivation and lowered cognitive load in comparison to lecture-based approaches (Hu et al., 2024). Studies comparing 360° VR and traditional tabletop drills indicated that both methods improved preparedness, yet VR offered particular advantages for nurses who had limited or no prior experience in disaster response (Chang et al., 2022). These outcomes suggest that a higher degree of immersion can improve skill acquisition and engagement in disaster management contexts.

Several challenges were identified in implementing VR-based disaster training for nurses. Infrastructure and resource requirements for VR hardware, software development, and maintenance pose barriers to widespread adoption (Wiese et al., 2021). Limited technological infrastructure hinders scalability, since not all healthcare institutions possess adequate resources for VR training (Zhang et al., 2025). Variations in research design and evaluation metrics impede direct comparisons of VR training outcomes; some studies relied on standardized instruments to measure disaster preparedness, while others employed subjective evaluations such as satisfaction surveys or knowledge tests (Genç et al., 2025; Wong & So, 2024). A lack of instructor expertise in delivering VR-based training was noted as an additional barrier, underlining the need for professional development programs to facilitate the integration of VR into clinical nursing practice (Hu et al., 2024).

DISCUSSION

Virtual Reality (VR)-based training has emerged as a significant educational method for improving nurses' competencies in disaster management. Its implementation in health education has proven effective in developing technical skills, clinical preparedness, and critical decision-making compared to conventional training methods. Several studies have documented the effectiveness of VR in enhancing knowledge of Personal Protective Equipment (PPE), self-efficacy, and infection control measures among healthcare professionals, particularly nurses (Yu & Yang, 2022). Research findings indicate that VR-based training provides authentic, realistic, and in-depth learning experiences that directly support the development of participants' critical thinking and clinical reasoning skills beyond what is achievable through traditional simulation methods (Kiegaldie & Shaw, 2023; Qiao et al., 2023).

The effectiveness of VR simulation in enhancing nurses' disaster preparedness is supported by research demonstrating significant increases in disaster preparedness scores following VR-based training (Kiegaldie & Shaw, 2023; Yu & Yang, 2022). VR technology creates interactive and immersive three-dimensional learning environments, enabling training scenarios that closely approximate real emergency conditions in a safe manner, while allowing scenario repetition without physical risks (Luo et al., 2021). Interaction within these VR environments offers participants a unique opportunity to experience crisis dynamics realistically, thereby strengthening emotional readiness and adaptability in actual disaster situations (Ma et al., 2024).

VR training exhibits several advantages over traditional simulation methods, such as tabletop drills or interactive lectures. Previous studies show that Immersive Virtual Reality (IVR), which utilizes devices like Head-Mounted Displays (HMD) or Cave Automatic Virtual Environments (CAVE), yields more favorable outcomes than Non-Immersive Virtual Reality (NVR). IVR is considered more effective in improving participant engagement, establishing realistic simulation environments, and fostering rapid and accurate clinical decision-making during disasters (Feng et al., 2020; Qiao et al., 2023). VR training consistently demonstrates increases in self-efficacy and confidence among healthcare professionals, which are crucial factors in disaster management (Feng et al., 2020).

VR proves superior in visually and interactively depicting crisis conditions compared to conventional simulations such as tabletop drills. VR-based simulations present scenarios in a realistic and immersive manner, incorporating visual and sensory elements that are difficult to replicate in traditional simulations, thereby enabling participants to experience psychological pressures akin to real emergencies (Alshowair et al., 2024). Research findings confirm that VR's ability to accurately simulate urgent situations enhances clinical responses and team coordination in disaster contexts, encompassing both technical skills and communication among team members (Farra et al., 2019; Ingrassia et al., 2012; Rahouti et al., 2021).

The implications of VR use in clinical training suggest a need to integrate VR into nursing curricula and training within healthcare

facilities. VR-based simulations provide added value by boosting learning retention, improving clinical preparedness, and accelerating decision-making capacity in critical situations (S. Farra et al., 2013; Jung, 2022). These findings support the view that VR training is no longer merely an adjunct but should be regarded as a core component of healthcare professionals' competency development, especially for disaster management. Educational institutions and healthcare facilities should consider adopting VR as a new standard in routine training to reinforce effective disaster response (Shalahuddin et al., 2021).

The implementation of VR in disaster training faces various significant practical and technical challenges. Major obstacles include the relatively high cost of hardware procurement and software development. Initial VR implementation expenses can pose barriers, although VR simulation is deemed more economical in the long term than direct simulation that requires extensive human and logistical resources (Andreatta et al., 2010). Another challenge involves limited technological infrastructure, such as stable internet access and uneven VR device availability across healthcare institutions, especially in resource-constrained regions.

Limitations of simulation realism also represent a significant issue beyond economic and infrastructural challenges. Physical realism, including tactile sensations and pressure, remains difficult to replicate fully with available VR technology, potentially preventing trainees from developing muscle memory and adapting to genuine high-pressure settings (Bryant et al., 2015). This constraint underscores the need for additional innovations, such as haptic feedback and Artificial Intelligence (AI), to elevate the realism of future VR simulations (Kiruthika & Khaddaj, 2017).

Further research on VR effectiveness is essential, particularly to examine the long-term impact of VR-based training on clinical skills and disaster preparedness. Most existing studies focus on short-term outcomes, highlighting the need to investigate participants' skill retention post-training and assess effectiveness in actual disaster scenarios (Alshowair et al., 2024). Comparative investigations between VR and other training methods, such as mannequin-based simulations or field exercises, also require expansion to offer a more holistic perspective of each method's overall effectiveness. Analysis of cost-effectiveness for VR training relative to conventional methods is another critical aspect for institutions to consider when determining optimal future training strategies (Alshowair et al., 2024; Keating et al., 2018).

CONCLUSION

Virtual Reality (VR)-based training has been demonstrated to be more effective than conventional training methods in enhancing nurses' preparedness for disaster response. Currently, VR technology is implemented in two forms Immersive Virtual Reality (IVR) and Non-Immersive Virtual Reality (NVR), each possessing distinct advantages and limitations.

However, the adoption of VR for training presents several challenges, particularly regarding limitations in simulation environments due to infrastructural and resource requirements for VR hardware, software development, and maintenance pose barriers to widespread adoption. This

technology necessitates a stable internet connection for optimal functionality, and the development of virtual environments and interactive elements remains a significant challenge for training institutions due to the substantial resources required.

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