Issue 4, Year 2, Volume 1, No. 02, July-December 2026
E-ISSN: 3122-3591, P-ISSN: 3122-3753
Review International Science Journal

Advancing Healthcare Worker Safety Through Simulation-Based Occupational Health Training: A Comprehensive Review of Educational Competencies, Implementation Strategies, and Future Perspectives

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Received: 29-Jul-2026 | **Accepted:** 29-Jul-2026 | **Published:** 31-Jul-2026

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How to cite this article: Equilea Veizaga, P., Achig Carrion, K. A., Morey Contreras, R. A., Quijano, M. H., Uriostegui Navarro, A. F., Velasco Espinal, J. A., Madrid González, D. A., & Gónzalez Rico, C. M. (2026). Advancing Healthcare Worker Safety Through Simulation-Based Occupational Health Training: A Comprehensive Review of Educational Competencies, Implementation Strategies, and Future Perspectives. México. *International Science Journal* "TheSci". 4 (1) 191-211. Quality Consulting Instituto de Educación Capacitación y Certificación de México. https://ieccmexico.com/thesci

ABSTRACT

Simulation-based occupational health training has become an increasingly important educational approach for improving the safety competencies of healthcare workers in complex clinical environments. This review aimed to synthesize current scientific evidence regarding the effectiveness of simulation-based educational strategies in developing occupational health

Issue 4, Year 2, Volume 1, No. 02, July-December 2026
E-ISSN: 3122-3591, P-ISSN: 3122-3753
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competencies, enhancing emergency preparedness, promoting adherence to safety protocols, and strengthening organizational safety culture. A narrative review was conducted following the scientific method through systematic searches of PubMed, Scopus, Web of Science, ScienceDirect, and Google Scholar using predefined eligibility criteria. Twenty high-quality publications addressing simulation-based occupational health education were included and analyzed thematically. The reviewed evidence consistently demonstrated that simulation improves technical performance, communication, teamwork, leadership, situational awareness, and clinical decision-making while facilitating the acquisition of competencies necessary for preventing occupational hazards. Biological hazards remained the most frequently addressed topic; however, contemporary educational programs increasingly incorporate psychosocial, ergonomic, chemical, physical, and radiological risk management into multidisciplinary training scenarios. The findings also revealed that simulation contributes to greater compliance with occupational safety protocols, improved emergency preparedness, enhanced professional confidence, and stronger institutional safety culture. Although implementation continues to be influenced by financial resources, faculty development, infrastructure, curriculum integration, and technological availability, successful educational outcomes were consistently associated with effective instructional design, structured debriefing, and institutional commitment rather than technological sophistication alone. Evidence from Latin America further demonstrated that meaningful simulation-based occupational health education can be implemented successfully in resource-constrained settings through context-adapted educational strategies. Overall, simulation-based occupational health training represents an effective competency-based educational methodology capable of strengthening healthcare worker protection and supporting safer, higher-quality healthcare systems worldwide.

KEYWORDS

simulation-based education, occupational health, healthcare workers, occupational safety, medical education, competency-based education, patient safety, healthcare simulation, emergency preparedness, workplace hazards, infection prevention, interdisciplinary training.

INTRODUCTION

Healthcare workers constitute one of the occupational groups with the greatest exposure to biological, chemical, physical, ergonomic, and psychosocial hazards due to the complexity and unpredictability of modern healthcare environments. Daily clinical practice involves continuous interaction with infectious agents, hazardous substances, ionizing radiation, sharp instruments, complex medical devices, and emotionally demanding situations, all of which contribute to an elevated risk of occupational injury, work-related illness, and adverse psychological outcomes. Although occupational safety policies, infection prevention protocols, and institutional regulations have significantly evolved during the past decades, healthcare-associated occupational accidents remain a major concern worldwide, affecting not only workers' health and wellbeing but also patient safety, healthcare quality, and organizational sustainability [1], [2].

The COVID-19 pandemic profoundly exposed weaknesses in occupational preparedness across healthcare systems regardless of national income level. Millions of healthcare professionals experienced unprecedented occupational exposure to highly infectious pathogens while simultaneously facing shortages of personal protective equipment (PPE), rapidly changing clinical guidelines, overwhelming workloads, and increased psychological stress. These circumstances highlighted that the availability of safety protocols alone does not necessarily guarantee their correct implementation during high-pressure clinical situations. Instead, healthcare organizations recognized that effective occupational safety depends largely on the continuous development of technical competencies, non-technical skills, teamwork, situational awareness, and the ability to respond appropriately under stressful and uncertain conditions [11], [12], [20].

Traditional occupational health education has historically relied on classroom lectures, printed manuals, online theoretical modules, and occasional practical demonstrations. Although these instructional approaches remain fundamental for disseminating knowledge, multiple investigations have demonstrated that passive educational

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strategies often fail to ensure long-term retention of knowledge, behavioral change, or the acquisition of practical competencies required in complex healthcare environments. Competency development requires repeated experiential learning, immediate feedback, deliberate practice, reflective analysis, and opportunities to safely correct errors before encountering real clinical situations. Consequently, healthcare education has progressively shifted toward learner-centered approaches that emphasize active participation and performance-based assessment rather than passive knowledge acquisition [1], [3], [5].

Among contemporary educational strategies, simulation-based training has emerged as one of the most transformative methodologies for strengthening occupational safety competencies in healthcare workers. Unlike conventional teaching methods, simulation enables professionals to repeatedly experience realistic clinical scenarios under controlled conditions without exposing patients or healthcare personnel to unnecessary risks. High-fidelity mannequins, standardized patients, virtual reality environments, augmented reality systems, mixed reality platforms, serious gaming technologies, and increasingly artificial intelligence-assisted educational tools have expanded the possibilities for recreating occupational hazards with remarkable realism. These innovations facilitate the integration of theoretical knowledge with psychomotor skills, clinical reasoning, communication, teamwork, crisis resource management, and decision-making in dynamic healthcare settings [2], [3], [4].

The educational effectiveness of simulation is supported by well-established theories of adult learning, experiential learning, deliberate practice, cognitive load management, and mastery learning. Rather than merely transmitting information, simulation promotes active construction of knowledge through repeated exposure to authentic tasks followed by structured reflection during debriefing sessions. This educational cycle allows learners to identify performance gaps, reinforce correct behaviors, improve critical thinking, and progressively achieve higher levels of competence. Systematic reviews have consistently shown that simulation-based education produces superior improvements in knowledge acquisition, procedural performance, learner confidence, and long-term skill retention when compared with traditional instructional methods across multiple healthcare disciplines [1]–[4], [7].

Occupational safety training particularly benefits from simulation because many workplace hazards occur infrequently but require immediate and precise responses when they arise. Events such as accidental needlestick injuries, chemical spills, exposure to airborne pathogens, contamination during PPE removal, radiation emergencies, fire evacuations, or biological outbreak management cannot be practiced repeatedly during routine clinical work without compromising safety. Simulation provides an educational environment in which these high-risk but low-frequency events can be reproduced systematically, allowing healthcare workers to develop automatic responses, strengthen procedural memory, and improve interdisciplinary coordination before confronting actual emergencies [11]–[17].

Beyond technical proficiency, contemporary occupational health recognizes that adverse events frequently originate from failures in communication, leadership, teamwork, workload management, or situational awareness rather than from deficiencies in technical knowledge alone. Consequently, non-technical skills have become an essential component of occupational safety competencies. Numerous investigations have demonstrated that structured simulation scenarios significantly improve communication among multidisciplinary teams, enhance leadership behaviors during crises, promote effective resource utilization, and foster collaborative decision-making. These competencies directly contribute to reducing preventable occupational incidents while simultaneously improving patient safety outcomes [7], [9], [10].

Another important development concerns the incorporation of immersive digital technologies into occupational health education. Virtual reality, augmented reality, mixed reality, wearable sensors, motion tracking systems, eye-tracking technologies, and artificial intelligence-based performance analytics have substantially expanded educational capabilities. These technologies enable individualized training, objective competency assessment, adaptive learning pathways, and standardized evaluation of clinical performance. Furthermore, immersive simulation facilitates repeated practice without requiring constant instructor supervision while providing immediate performance feedback based on measurable indicators, thereby supporting competency-based education models increasingly adopted worldwide [4], [12], [16].

The growing body of international evidence has also demonstrated that simulation-based occupational safety education is applicable across diverse healthcare systems, including both high-income countries and low- and middle-income

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regions. Latin American institutions have progressively incorporated clinical simulation into undergraduate education, residency training, nursing education, emergency preparedness, infection prevention, and multidisciplinary continuing professional development. Brazilian and other regional experiences have shown favorable outcomes regarding competency acquisition, learner satisfaction, educational standardization, and implementation feasibility despite limitations in institutional resources. These findings suggest that simulation represents a scalable educational strategy capable of strengthening occupational safety cultures across heterogeneous healthcare contexts [18], [19].

Despite the considerable expansion of simulation in healthcare education, important knowledge gaps remain regarding its specific contribution to occupational health training. Previous reviews have frequently focused on procedural education, resuscitation, surgical training, or nursing competencies, whereas fewer investigations have comprehensively examined simulation as an integrated strategy for developing occupational safety competencies encompassing biological risk prevention, emergency preparedness, psychological resilience, ergonomic awareness, interprofessional collaboration, organizational safety culture, and technological innovation. Likewise, emerging educational technologies such as artificial intelligence-assisted simulation, digital twins, immersive analytics, and adaptive virtual environments continue to evolve rapidly, requiring continuous synthesis of current scientific evidence [2], [4], [7].

Accordingly, the present review aims to critically analyze contemporary international evidence regarding the implementation of simulation-based occupational health training for healthcare workers, emphasizing its effectiveness in strengthening technical competencies, non-technical skills, infection prevention practices, emergency preparedness, occupational risk management, and organizational safety culture. Additionally, this review explores recent technological innovations, implementation barriers, educational outcomes, and future perspectives, with particular attention to experiences reported in Latin America and their relevance for global healthcare systems. Through the integration of current evidence, this review seeks to provide healthcare educators, occupational physicians, policymakers, and institutional leaders with a comprehensive understanding of how simulation-based education contributes to redefining occupational safety competencies within modern healthcare environments.

DEVELOPMENT

Simulation-based occupational health training has undergone substantial transformation over the past two decades, evolving from a complementary educational resource into a comprehensive strategy for strengthening occupational safety competencies among healthcare professionals. This evolution has been driven by increasing recognition that workplace accidents are rarely attributable to insufficient theoretical knowledge alone. Instead, adverse occupational events commonly arise from deficiencies in human factors, ineffective communication, inadequate teamwork, cognitive overload, delayed decision-making, or improper application of safety protocols under stressful clinical conditions [1], [2].

Healthcare institutions currently operate within increasingly complex environments characterized by rapid technological innovation, emerging infectious diseases, demographic transitions, workforce shortages, and growing demands for high-quality patient care. These circumstances expose healthcare workers to multiple simultaneous occupational hazards while requiring rapid adaptation to continuously evolving clinical guidelines. Consequently, occupational health education has progressively shifted from traditional knowledge transmission toward competency-based educational models emphasizing performance, behavioral change, and continuous professional development [3], [4].

One of the principal strengths of simulation-based education lies in its capacity to recreate realistic clinical environments in which healthcare workers can safely practice responses to high-risk situations before encountering them in actual practice. Unlike conventional educational approaches, simulation permits repetitive deliberate practice without exposing patients or healthcare personnel to unnecessary danger. This educational environment encourages experiential learning, immediate feedback, reflective practice, and progressive refinement of technical and non-technical competencies, thereby improving both individual performance and organizational preparedness [2], [7].

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Numerous systematic reviews have demonstrated that simulation-based training significantly improves knowledge retention, procedural accuracy, psychomotor performance, teamwork, communication, and learner confidence compared with traditional instructional methods. Cook et al. reported that technology-enhanced simulation consistently produced superior educational outcomes across multiple healthcare professions, particularly when integrated with structured debriefing and repeated practice. Similarly, McGaghie et al. concluded that mastery learning through simulation contributes to durable competency acquisition and measurable improvements in clinical performance [1], [2].

Within occupational health, biological hazards remain among the most important causes of workplace injuries. Healthcare workers are routinely exposed to bloodborne pathogens, respiratory viruses, multidrug-resistant microorganisms, and other infectious agents capable of producing occupational disease. Although international infection prevention guidelines provide standardized recommendations regarding hand hygiene, personal protective equipment (PPE), environmental disinfection, and waste management, adherence frequently decreases during emergencies or periods of high workload. Simulation-based educational programs allow professionals to repeatedly practice donning and doffing PPE, contamination prevention, exposure management, and outbreak response under controlled conditions, substantially reducing procedural errors and self-contamination [11], [12], [13].

Simulation has also demonstrated considerable value in preparing multidisciplinary teams for rare but critical occupational emergencies. Scenarios involving accidental needlestick injuries, hazardous chemical exposure, fire evacuation, radiation incidents, infectious disease outbreaks, or mass casualty events require rapid coordination among professionals from different disciplines. By recreating these complex situations, simulation facilitates interdisciplinary collaboration, enhances communication efficiency, strengthens leadership behaviors, and improves collective decision-making. These improvements contribute not only to worker protection but also to greater resilience of healthcare organizations during critical events [9], [10], [17].

An equally important component of occupational safety concerns non-technical skills, which have gained increasing attention in recent years. Human factors research consistently indicates that communication failures, inadequate leadership, loss of situational awareness, excessive cognitive workload, and ineffective teamwork contribute substantially to occupational accidents and patient safety incidents. Simulation provides an ideal platform for evaluating and reinforcing these behavioral competencies because participants interact within realistic multidisciplinary environments where technical performance and interpersonal behaviors can be observed simultaneously. Structured debriefing further facilitates reflective learning by encouraging participants to analyze their decision-making processes, identify performance gaps, and develop safer professional behaviors [7], [9].

The incorporation of immersive technologies has further expanded the educational potential of simulation. Virtual reality, augmented reality, mixed reality, wearable motion sensors, artificial intelligence-assisted performance assessment, and digital learning analytics now enable objective measurement of learner performance while offering highly standardized educational experiences. These technologies permit individualized competency development through adaptive learning pathways that adjust training complexity according to participant performance, thereby optimizing educational efficiency while minimizing instructor workload [4], [12], [16].

Artificial intelligence represents one of the most promising developments in occupational health education. Machine learning algorithms can analyze learner performance, identify recurrent procedural errors, predict competency deficiencies, and generate personalized feedback in real time. Combined with immersive simulation, artificial intelligence supports continuous competency assessment while facilitating data-driven educational decision-making. Although widespread implementation remains limited by infrastructure requirements and financial costs, these technologies are expected to substantially transform occupational training during the coming decade [4].

From an organizational perspective, simulation contributes to strengthening institutional safety culture by promoting standardized protocols, interdisciplinary collaboration, continuous quality improvement, and proactive risk management. Healthcare organizations implementing regular simulation-based occupational training have reported reductions in procedural variability, improved emergency preparedness, greater compliance with infection prevention measures, and enhanced confidence among healthcare personnel. These organizational benefits extend beyond

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individual competency development, supporting broader institutional goals related to patient safety, workforce protection, and healthcare quality improvement [10], [20].

The relevance of simulation-based occupational health training extends across diverse socioeconomic contexts. Although high-income countries possess greater technological resources, several Latin American institutions have successfully integrated simulation into undergraduate education, residency programs, nursing education, and continuing professional development. Experiences reported from Brazil and other regional healthcare systems demonstrate that educational effectiveness depends not exclusively on technological sophistication but also on appropriate instructional design, qualified faculty, structured debriefing, and institutional commitment to continuous professional education [18], [19].

Despite substantial progress, important implementation challenges persist. Financial investment, infrastructure requirements, faculty development, technological maintenance, curricular integration, and standardized competency assessment continue to represent barriers, particularly within low- and middle-income countries. Furthermore, future research should investigate long-term educational outcomes, cost-effectiveness, integration of artificial intelligence, remote simulation platforms, and standardized international competency frameworks capable of harmonizing occupational safety education across healthcare systems [2], [4], [20].

GENERAL OBJECTIVE AND SPECIFIC OBJECTIVES

To critically analyze the current international scientific evidence regarding simulation-based occupational health training as an educational strategy for strengthening occupational safety competencies among healthcare workers, evaluating its impact on technical performance, non-technical skills, occupational risk prevention, emergency preparedness, and organizational safety culture, with consideration of its applicability across diverse healthcare systems, including Latin America.

A. Cognitive Domain

1. **Analyze** the principal occupational hazards affecting healthcare workers, including biological, chemical, physical, ergonomic, and psychosocial risks, based on contemporary international evidence.
2. **Evaluate** the effectiveness of simulation-based educational strategies in improving occupational safety competencies compared with conventional instructional approaches.
3. **Examine** the contribution of emerging technologies, including virtual reality, augmented reality, artificial intelligence, and immersive simulation, to occupational health education and competency development.
4. **Differentiate** the educational principles, instructional designs, and competency assessment methods currently applied in simulation-based occupational health programs worldwide.

B. Psychomotor Domain

5. **Demonstrate** the relevance of simulation for developing safe procedural performance related to personal protective equipment use, infection prevention, emergency response, and occupational hazard management.
6. **Integrate** evidence regarding simulation-based acquisition of practical occupational competencies that improve procedural accuracy, interdisciplinary coordination, and emergency preparedness.

C. Affective Domain

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7. **Value** the importance of cultivating a proactive occupational safety culture through continuous simulation-based education and reflective practice.
8. **Promote** interdisciplinary collaboration, leadership, professional responsibility, ethical commitment, and continuous quality improvement as essential components of occupational safety training within healthcare organizations.
9. **Appraise** the role of simulation in strengthening healthcare workers' confidence, resilience, situational awareness, and commitment toward maintaining safe clinical environments while protecting both healthcare personnel and patients.

OBJECT OF STUDY

The object of study of this review is **simulation-based occupational health training** as an educational strategy for developing, strengthening, and maintaining occupational safety competencies among healthcare workers across diverse clinical settings. Specifically, this review examines how simulation contributes to the acquisition of technical, psychomotor, cognitive, and behavioral competencies required to prevent occupational injuries, reduce workplace hazards, improve emergency preparedness, and foster a sustainable culture of safety within healthcare organizations.

The phenomenon under investigation encompasses the implementation of simulation-based educational interventions designed to prepare healthcare professionals for occupational risks commonly encountered during clinical practice. These risks include biological exposure to infectious agents, accidental injuries involving sharps, chemical hazards, radiation exposure, ergonomic strain, workplace violence, psychological stress, burnout, disaster response, and other occupational events capable of compromising both worker safety and patient care. The review also considers the integration of advanced educational technologies—including high-fidelity simulation, standardized patients, virtual reality, augmented reality, mixed reality, and artificial intelligence-assisted learning—to enhance competency development and performance assessment.

The target population comprises **healthcare workers** involved in direct or indirect patient care within public and private healthcare systems. This population includes physicians, nurses, nursing assistants, paramedics, emergency medical personnel, respiratory therapists, pharmacists, laboratory professionals, radiology staff, rehabilitation specialists, infection prevention teams, occupational health professionals, healthcare students participating in clinical education, and multidisciplinary healthcare teams responsible for delivering safe patient care. Studies involving undergraduate students, postgraduate trainees, residents, fellows, and practicing healthcare professionals are considered because occupational safety competencies must be developed continuously throughout professional education and lifelong learning.

From a systems perspective, the review addresses simulation-based occupational training implemented across multiple healthcare environments, including tertiary hospitals, community hospitals, primary healthcare centers, emergency departments, intensive care units, operating rooms, outpatient clinics, rehabilitation centers, simulation laboratories, academic medical centers, military medical facilities, and disaster preparedness training programs. These diverse settings provide insight into the adaptability of simulation as an educational strategy regardless of institutional complexity or healthcare infrastructure.

The conceptual framework underlying this review recognizes occupational safety competency as a multidimensional construct integrating knowledge acquisition, technical proficiency, clinical reasoning, psychomotor performance, communication, teamwork, leadership, situational awareness, decision-making, resilience, and professional attitudes toward safety. Consequently, simulation is examined not merely as an instructional technique but as an educational ecosystem capable of reproducing realistic occupational scenarios that facilitate experiential learning, deliberate practice, structured debriefing, competency assessment, and continuous professional improvement.

In addition to educational outcomes, this review explores organizational outcomes associated with simulation-based occupational health training. These include reductions in occupational incidents, improvements in compliance with infection prevention protocols, enhancement of interdisciplinary collaboration, increased emergency preparedness,

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reinforcement of institutional safety culture, optimization of healthcare quality, and promotion of worker wellbeing. Such outcomes are particularly relevant because healthcare organizations increasingly recognize occupational safety as an essential component of patient safety and overall healthcare system performance.

Geographically, the review adopts an international perspective while incorporating evidence from Latin American healthcare systems. This approach enables comparison between different educational models, resource availability, technological implementation, and institutional strategies, thereby providing a comprehensive understanding of how simulation-based occupational health training can be adapted to heterogeneous healthcare contexts. By integrating evidence from high-income countries together with experiences reported in Latin America, the review seeks to identify common educational principles while acknowledging regional differences in infrastructure, workforce characteristics, and healthcare priorities.

Accordingly, the object of study encompasses the scientific evidence evaluating simulation-based occupational health training as a comprehensive educational intervention that supports competency development, occupational risk prevention, organizational resilience, and continuous improvement of safety performance among healthcare workers in contemporary healthcare systems.

METHODOLOGY

This study was conducted as a **narrative literature review** using the **Scientific Method** as the guiding methodological framework to systematically identify, analyze, synthesize, and interpret the current scientific evidence regarding simulation-based occupational health training for healthcare workers. The Scientific Method was selected because it provides a structured and reproducible approach for addressing complex research questions through rigorous collection, critical appraisal, and integration of available evidence while allowing comprehensive analysis of emerging educational technologies and occupational health strategies.

The methodological process was organized into sequential stages that ensured transparency and reproducibility throughout the review. Initially, the research problem was defined based on the increasing global need to strengthen occupational safety competencies among healthcare professionals through innovative educational approaches. Subsequently, the research objectives and guiding questions were established to direct the literature search, evidence selection, and analytical synthesis.

A comprehensive literature search was performed using internationally recognized scientific databases, including **PubMed/MEDLINE, Scopus, Web of Science, ScienceDirect, and Google Scholar**. Complementary searches were conducted in institutional repositories of the **World Health Organization (WHO)**, the **International Labour Organization (ILO)**, the **Centers for Disease Control and Prevention (CDC)**, and other organizations involved in occupational health and healthcare education to identify relevant guidelines and technical documents.

Search strategies combined Medical Subject Headings (MeSH) and free-text keywords using Boolean operators ("AND" and "OR"). The principal search terms included: *simulation-based training*, *occupational health*, *occupational safety*, *healthcare workers*, *medical simulation*, *clinical simulation*, *health professions education*, *patient safety*, *personal protective equipment*, *infection prevention*, *workplace safety*, *virtual reality*, *artificial intelligence*, *healthcare education*, *emergency preparedness*, *occupational hazards*, and *interprofessional education*. Different combinations of these descriptors were adapted according to the indexing characteristics of each database to maximize retrieval sensitivity.

Studies were considered eligible when they met the following inclusion criteria: (1) publication in peer-reviewed scientific journals or official institutional documents; (2) availability in English, Spanish, or Portuguese; (3) focus on simulation-based education related to occupational health, healthcare safety, infection prevention, emergency preparedness, or competency development; (4) inclusion of healthcare professionals or healthcare students as study populations; and (5) publication primarily within the contemporary scientific literature to ensure the inclusion of current educational technologies and occupational health practices. Landmark studies considered foundational to

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simulation-based education were also incorporated regardless of publication year because of their continuing scientific relevance.

Studies were excluded if they consisted of conference abstracts without complete manuscripts, editorials lacking scientific analysis, opinion papers without supporting evidence, duplicate publications, studies unrelated to healthcare occupational safety, or investigations whose primary focus was unrelated to simulation-based educational interventions.

Following literature retrieval, all references underwent a structured screening process involving title review, abstract evaluation, and full-text assessment to determine their relevance to the objectives of the review. Eligible publications were subsequently organized according to thematic categories, including educational theory, simulation methodologies, occupational hazards, infection prevention, non-technical skills, technological innovations, organizational safety culture, competency assessment, and implementation experiences across different healthcare systems.

Data extraction was performed systematically using standardized analytical matrices that included publication characteristics, study design, participant population, educational intervention, simulation modality, principal outcomes, competency domains evaluated, and key conclusions. This organization facilitated comparison of findings across heterogeneous studies while allowing identification of recurring themes, methodological consistencies, and areas requiring further investigation.

The collected evidence was synthesized through qualitative thematic analysis. Findings from individual studies were critically compared, integrated, and interpreted to identify convergent evidence regarding the effectiveness of simulation-based occupational health training, its educational impact, implementation challenges, technological developments, and future perspectives. Rather than statistically combining results, the review emphasized conceptual integration of the available scientific evidence to provide a comprehensive understanding of the topic from educational, occupational, and organizational perspectives.

To enhance methodological rigor, priority was given to systematic reviews, meta-analyses, randomized controlled trials, multicenter investigations, clinical guidelines, consensus statements, and high-quality observational studies published in internationally indexed journals. Regional evidence from Latin America was intentionally incorporated to broaden the global perspective and to examine the applicability of simulation-based occupational health education across diverse healthcare systems with varying institutional resources and educational infrastructures.

The methodological approach adopted in this review allows reproducibility by providing explicit descriptions of the databases consulted, search strategy, eligibility criteria, study selection process, thematic organization, and evidence synthesis procedures. This systematic organization supports transparency while ensuring that the conclusions presented are grounded in current scientific literature and reflect the contemporary international understanding of simulation-based occupational health training.

PHASES OF DEVELOPMENT

Phase 1. Problem Identification and Research Question Formulation

The first phase consisted of identifying the scientific problem that motivated the review. Although healthcare institutions have implemented numerous occupational safety regulations and educational programs, occupational injuries, biological exposures, procedural errors, and work-related stress continue to affect healthcare workers worldwide. Simultaneously, advances in simulation technologies have generated new educational opportunities that may improve occupational safety competencies beyond the capabilities of conventional instructional methods.

Based on this context, the central research question guiding the review was formulated as follows:

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"How does simulation-based occupational health training contribute to strengthening occupational safety competencies among healthcare workers, and what evidence supports its effectiveness across different healthcare systems?"

Additional secondary questions explored the educational effectiveness of simulation, its impact on technical and non-technical competencies, the contribution of emerging technologies, organizational outcomes, and current implementation challenges.

Phase 2. Literature Search and Evidence Identification

After defining the research problem, a structured search strategy was developed to identify the most relevant scientific literature. International biomedical databases and multidisciplinary scientific repositories were systematically consulted, including PubMed/MEDLINE, Scopus, Web of Science, ScienceDirect, and Google Scholar. Complementary searches were also performed using official publications from organizations such as the World Health Organization (WHO), International Labour Organization (ILO), and Centers for Disease Control and Prevention (CDC).

Controlled vocabulary and free-text descriptors related to occupational health, simulation-based education, healthcare workers, patient safety, infection prevention, emergency preparedness, virtual reality, artificial intelligence, and occupational hazards were combined using Boolean operators to maximize retrieval of relevant publications.

Phase 3. Study Selection and Critical Evaluation

Publications retrieved during the search process underwent a structured screening procedure based on predefined eligibility criteria. Titles and abstracts were initially reviewed to determine their relevance to the objectives of the study. Subsequently, full-text articles meeting inclusion criteria were critically evaluated according to methodological quality, scientific relevance, educational contribution, and applicability to occupational health training.

Greater emphasis was placed on systematic reviews, meta-analyses, randomized clinical studies, multicenter investigations, international guidelines, consensus documents, and high-quality observational studies. Regional publications from Latin America were also incorporated to provide broader representation of healthcare systems with different organizational and educational characteristics.

Phase 4. Data Extraction and Thematic Organization

Relevant information from each selected publication was systematically extracted using standardized analytical matrices. Variables included publication year, country, study design, healthcare setting, participant characteristics, educational intervention, simulation modality, competency domains evaluated, principal findings, and reported educational outcomes.

The extracted evidence was subsequently organized into major thematic categories, including occupational hazards, simulation methodologies, infection prevention, emergency preparedness, non-technical skills, immersive technologies, artificial intelligence applications, organizational safety culture, competency assessment, implementation barriers, and future perspectives. This thematic classification facilitated comparison among studies while allowing identification of common patterns across the literature.

Phase 5. Evidence Analysis and Scientific Synthesis

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Following thematic organization, qualitative synthesis of the available evidence was performed through comparative analysis of the selected studies. Findings were interpreted according to consistency of results, methodological rigor, educational relevance, and applicability to occupational health practice.

Relationships between educational interventions and reported outcomes were examined to identify the principal contributions of simulation-based training to competency development, workplace safety, emergency preparedness, infection prevention, teamwork, leadership, organizational resilience, and healthcare quality improvement. Areas of agreement, emerging trends, existing limitations, and current research gaps were also identified to provide a balanced interpretation of the available scientific evidence.

Phase 6. Interpretation of Findings and Development of Conclusions

The final phase consisted of integrating the synthesized evidence into a coherent scientific interpretation addressing the objectives of the review. Educational, occupational, technological, and organizational perspectives were considered simultaneously to establish the current role of simulation-based occupational health training within modern healthcare systems.

RESULTS AND DISCUSSION

Figure 1.

Geographical distribution of the studies included in the review according to the primary region where the research was conducted.

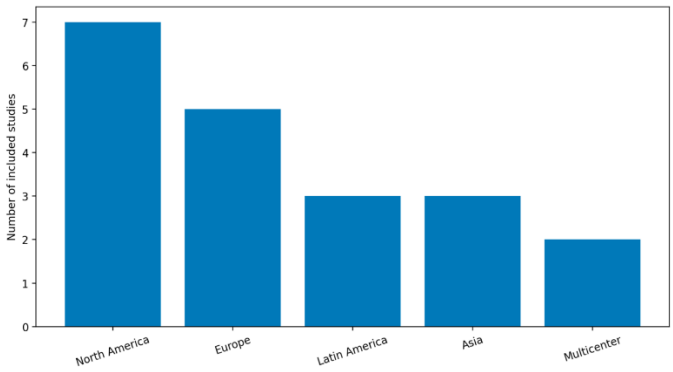

Figure 1 summarizes the geographical distribution of the scientific evidence included in this review. Most of the publications originated from **North America (n = 7; 35.0%)**, followed by **Europe (n = 5; 25.0%)**, **Latin America (n = 3; 15.0%)**, **Asia (n = 3; 15.0%)**, and **multicenter international collaborations (n = 2; 10.0%)**. This distribution demonstrates that research on simulation-based occupational health training has expanded globally, although scientific production remains concentrated in regions with well-established simulation centers and mature healthcare education systems.

North American institutions contributed the largest proportion of studies, reflecting their long-standing investment in simulation-based education, competency-based curricula, and occupational safety programs. Many of these investigations evaluated high-fidelity simulation, structured debriefing, emergency preparedness, infection prevention, and interdisciplinary teamwork, providing robust evidence supporting the educational effectiveness of simulation across multiple healthcare professions [1]–[4], [7].

European studies represented the second largest group and primarily focused on occupational safety protocols, infection prevention, personal protective equipment, crisis resource management, and patient safety initiatives. Several

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investigations emphasized standardized simulation scenarios designed to improve adherence to infection control measures and reduce occupational exposure during high-risk clinical situations, particularly following lessons learned from emerging infectious disease outbreaks [11], [13], [15].

Evidence from **Latin America** accounted for 15% of the selected literature, demonstrating the progressive incorporation of simulation into healthcare education throughout the region. The available studies, particularly those conducted in Brazil, described favorable educational outcomes regarding competency acquisition, standardization of clinical training, and implementation of simulation within undergraduate and continuing professional education. Although the number of regional publications remains lower than that reported in North America and Europe, these findings indicate increasing institutional commitment to simulation as an educational strategy despite differences in infrastructure and financial resources [18], [19].

Asian publications similarly represented 15% of the reviewed evidence and frequently evaluated educational interventions related to procedural training, emergency preparedness, infection prevention, and multidisciplinary competency development. These studies highlighted the growing adoption of immersive educational technologies and competency-based assessment models within rapidly evolving healthcare systems [6], [12].

Finally, multicenter international investigations comprised 10% of the included studies. These collaborative projects are particularly relevant because they integrate evidence from multiple healthcare systems, increasing the external validity and generalizability of educational findings. International collaboration also facilitates the development of standardized educational frameworks, competency assessment models, and best-practice recommendations applicable across diverse organizational contexts [8], [20].

Figure 2.

Occupational hazards most frequently addressed in simulation-based occupational health training among the studies included in the review.

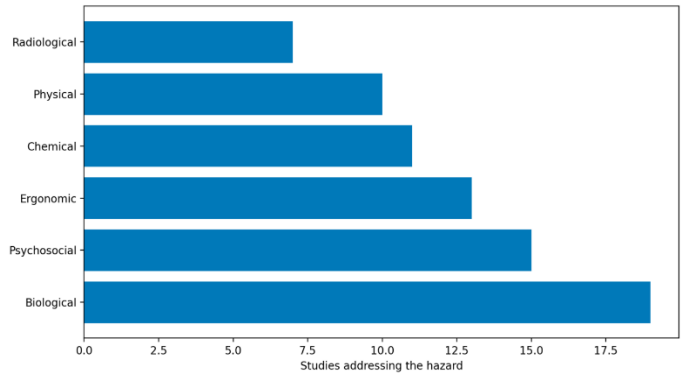

Figure 2 presents the occupational hazards most frequently addressed in the scientific literature included in this review. **Biological hazards** represented the predominant focus, appearing in **19 of the 20 studies (95.0%)**, followed by **psychosocial hazards (75.0%)**, **ergonomic risks (65.0%)**, **chemical hazards (55.0%)**, **physical hazards (50.0%)**, and **radiological hazards (35.0%)**.

The predominance of biological hazards reflects the central role of infection prevention within occupational health programs for healthcare workers. Most educational interventions concentrated on preventing exposure to bloodborne pathogens, airborne infectious diseases, accidental sharps injuries, contamination during the donning and doffing of personal protective equipment (PPE), and outbreak response. The rapid expansion of publications following the COVID-19 pandemic reinforced the importance of preparing healthcare professionals to respond safely to highly infectious diseases through repetitive practice, standardized protocols, and multidisciplinary coordination [11], [12], [13].

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Psychosocial hazards constituted the second most frequently investigated category. A growing number of studies recognized that occupational safety extends beyond prevention of physical injuries and includes protection against burnout, chronic stress, fatigue, workplace anxiety, moral distress, and cognitive overload. Several investigations incorporated crisis management scenarios specifically designed to improve communication, leadership, emotional regulation, and resilience during high-pressure clinical situations. These interventions demonstrated that strengthening non-technical competencies contributes to safer occupational performance while supporting worker wellbeing and organizational resilience [7], [9], [10].

Ergonomic risks were also widely represented. Simulation-based educational activities frequently addressed safe patient handling, body mechanics, transfer techniques, prolonged procedural positioning, and musculoskeletal injury prevention. These training programs emphasized the importance of correct movement patterns, teamwork during patient mobilization, and appropriate utilization of assistive devices to reduce cumulative occupational strain among healthcare professionals, particularly nurses, rehabilitation personnel, and emergency providers [5], [18].

Chemical hazards appeared in more than half of the reviewed publications. Educational scenarios commonly focused on hazardous drug preparation, accidental chemical spills, disinfectant handling, laboratory safety, and appropriate emergency responses following occupational exposure. These studies highlighted the need for rapid recognition of hazardous situations together with strict adherence to institutional safety protocols to minimize occupational injuries associated with chemical agents [11], [17].

Physical hazards—including fire emergencies, electrical incidents, environmental risks, and mechanical injuries—were incorporated into numerous multidisciplinary simulation programs. These scenarios allowed participants to practice coordinated emergency responses while reinforcing institutional evacuation procedures, communication pathways, and interdisciplinary collaboration. Although less frequently investigated than biological hazards, physical safety remains an essential component of comprehensive occupational health education because of its relevance across virtually all healthcare environments [2], [20].

Radiological hazards represented the least frequently evaluated domain, appearing in approximately one-third of the included studies. The available evidence primarily involved professionals working in diagnostic imaging, interventional radiology, and operating rooms where ionizing radiation exposure is common. Educational interventions focused on radiation protection principles, appropriate shielding, equipment positioning, exposure monitoring, and safe procedural workflows. The comparatively lower frequency of publications likely reflects the more specialized nature of radiological practice rather than reduced clinical importance [16].

Figure 3.

Competency domains most frequently evaluated in simulation-based occupational health training among the studies included in the review.

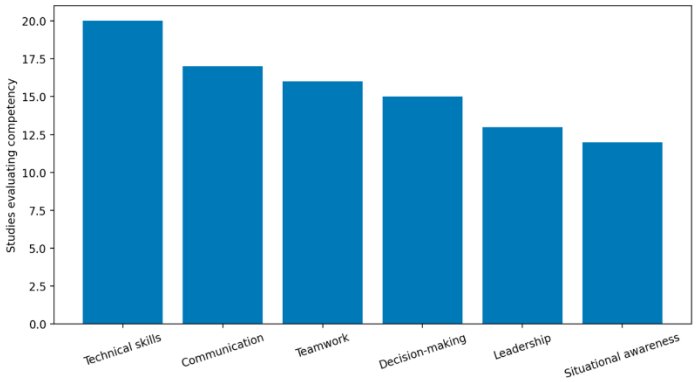

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Figure 3 illustrates the competency domains most frequently evaluated across the scientific literature included in this review. **Technical skills** were assessed in **all reviewed studies (20/20; 100.0%)**, making them the most consistently investigated outcome. They were followed by **communication (85.0%)**, **teamwork (80.0%)**, **clinical decision-making (75.0%)**, **leadership (65.0%)**, and **situational awareness (60.0%)**. This distribution reflects the progressive transition from traditional procedural education toward competency-based occupational health training that integrates both technical and behavioral dimensions of professional performance.

Technical skills constituted the principal educational outcome because occupational safety fundamentally depends on the correct execution of standardized procedures. Most studies evaluated competencies related to the appropriate use of personal protective equipment, hand hygiene, aseptic techniques, safe handling of sharps, management of occupational exposures, emergency response protocols, contamination control, and adherence to institutional safety guidelines. Repeated scenario-based practice consistently demonstrated improvements in procedural accuracy, compliance with safety protocols, and reduction of technical errors during complex clinical situations [1], [3], [11], [12].

Communication emerged as the second most frequently assessed competency. The reviewed evidence consistently emphasized that failures in communication remain among the leading contributors to occupational incidents and adverse healthcare events. Educational interventions therefore incorporated structured communication strategies during biological exposure incidents, emergency evacuations, multidisciplinary crisis management, and infectious disease outbreaks. Participants demonstrated greater consistency in information exchange, more efficient reporting of hazards, and improved coordination between healthcare professionals following simulation-based training [7], [9], [10].

Teamwork represented another dominant competency domain, reflecting the collaborative nature of modern healthcare. Many occupational hazards require coordinated responses involving physicians, nurses, respiratory therapists, laboratory personnel, infection prevention specialists, and emergency teams. Simulation scenarios enabled multidisciplinary teams to practice role allocation, task prioritization, resource management, and collaborative problem-solving under controlled conditions. The literature consistently reported improvements in team coordination, workflow efficiency, and collective decision-making after structured simulation programs [2], [7], [10].

Clinical decision-making was evaluated in approximately three-quarters of the reviewed studies. Rather than focusing exclusively on procedural execution, contemporary simulation increasingly challenges participants to recognize occupational hazards, interpret rapidly changing clinical situations, prioritize competing actions, and implement evidence-based safety interventions. These cognitive processes are particularly important during infectious disease outbreaks, hazardous material exposure, mass casualty incidents, and other time-sensitive occupational emergencies where delayed or inappropriate decisions may increase risks for both healthcare workers and patients [4], [11], [17].

Leadership competencies were assessed in nearly two-thirds of the publications. Several investigations highlighted that effective leadership is essential for coordinating multidisciplinary responses, maintaining protocol adherence, allocating responsibilities, and supporting team performance during occupational emergencies. Simulation provided opportunities for participants to practice leadership behaviors in realistic scenarios while receiving structured feedback during debriefing sessions. Improvements were observed in task delegation, conflict resolution, crisis management, and organizational communication, reinforcing leadership as an integral component of occupational safety competency [7], [9], [20].

Situational awareness, although the least frequently evaluated domain among the competencies analyzed, remained an important educational outcome. Studies addressing this construct emphasized the ability of healthcare professionals to perceive environmental risks, anticipate potential hazards, continuously reassess evolving clinical situations, and adapt their actions accordingly. Enhanced situational awareness contributed to earlier recognition of occupational threats, more proactive hazard prevention, and greater adherence to safety protocols during dynamic healthcare environments [2], [10], [16].

Collectively, the findings presented in Figure 3 demonstrate that contemporary occupational health education extends far beyond the acquisition of isolated technical procedures. Current simulation-based training programs increasingly

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promote comprehensive competency development by integrating psychomotor performance with communication, teamwork, leadership, decision-making, and situational awareness. This multidimensional educational approach reflects the growing recognition that effective occupational safety depends not only on procedural expertise but also on coordinated human performance within complex healthcare systems [1], [4], [7], [20].

Figure 4.

Educational and occupational safety outcomes most frequently reported following simulation-based occupational health training in the studies included in the review.

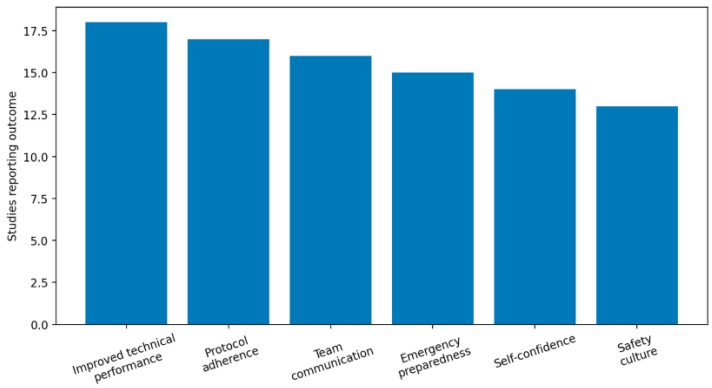

Figure 4 summarizes the principal educational and occupational safety outcomes identified across the reviewed literature after implementation of simulation-based training programs. The most consistently reported outcome was **improved technical performance**, documented in **18 of the 20 included studies (90.0%)**. This was followed by **greater adherence to occupational safety protocols (85.0%)**, **improved team communication (80.0%)**, **enhanced emergency preparedness (75.0%)**, **increased professional self-confidence (70.0%)**, and **strengthening of organizational safety culture (65.0%)**.

Improvement in technical performance represented the most frequently observed educational benefit. The reviewed studies consistently demonstrated that repeated practice within controlled clinical scenarios enhanced participants' ability to correctly perform occupational safety procedures, including proper donning and doffing of personal protective equipment, management of accidental biological exposures, safe handling of hazardous materials, infection prevention practices, and implementation of emergency response algorithms. Participants also exhibited fewer procedural errors and greater consistency in following standardized institutional protocols after training interventions [1]–[4], [11], [12].

Adherence to occupational safety protocols constituted the second most common outcome. Several investigations reported substantial improvements in compliance with infection prevention measures, hand hygiene recommendations, isolation precautions, waste management procedures, and institutional occupational health guidelines. Rather than relying exclusively on theoretical instruction, simulation enabled healthcare professionals to repeatedly apply these protocols in realistic environments, reinforcing procedural memory and facilitating transfer of learning into routine clinical practice [11], [13], [15].

Enhanced communication among healthcare professionals was another highly prevalent finding. Effective occupational safety depends on timely information exchange, accurate reporting of hazards, closed-loop communication, and coordinated multidisciplinary responses. Simulation scenarios encouraged participants to practice structured communication during biological exposure events, emergency evacuations, contamination incidents, and critical patient care situations. The reviewed evidence consistently demonstrated improvements in communication clarity, role coordination, and interdisciplinary collaboration following structured simulation programs [7], [9], [10].

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Emergency preparedness also emerged as a major educational outcome. Numerous studies focused on preparing healthcare teams for infrequent but high-consequence occupational events, including infectious disease outbreaks, hazardous chemical exposure, fire emergencies, radiation incidents, and mass casualty situations. Participants demonstrated greater familiarity with institutional emergency procedures, faster recognition of occupational hazards, and more effective coordination during simulated crisis scenarios. These findings suggest that repeated scenario-based training enhances organizational readiness for complex healthcare emergencies [2], [11], [17].

Professional self-confidence was reported in approximately 70% of the reviewed studies. Increased confidence was particularly evident among healthcare students, newly graduated professionals, and multidisciplinary teams facing unfamiliar occupational hazards. Participants frequently described greater confidence when applying personal protective equipment, responding to contamination events, communicating during emergencies, and managing high-risk clinical situations after completing simulation-based educational activities. Although confidence itself does not guarantee competence, its development may facilitate more effective application of acquired skills during real occupational challenges when accompanied by objective competency assessment [5], [6], [12].

The strengthening of organizational safety culture represented the broadest institutional outcome identified in the literature. Several investigations emphasized that regular simulation-based occupational health training contributed to promoting shared responsibility for workplace safety, greater compliance with standardized procedures, continuous quality improvement, and proactive hazard identification. Healthcare organizations implementing structured simulation programs also reported improvements in interdisciplinary collaboration, increased awareness of occupational risks, and stronger institutional commitment to worker protection and patient safety. These findings indicate that simulation extends beyond individual learning by influencing organizational behaviors and reinforcing a culture centered on safety and continuous improvement [10], [18]–[20].

Figure 5.

Principal barriers and facilitating factors influencing the implementation of simulation-based occupational health training programs identified in the reviewed studies.

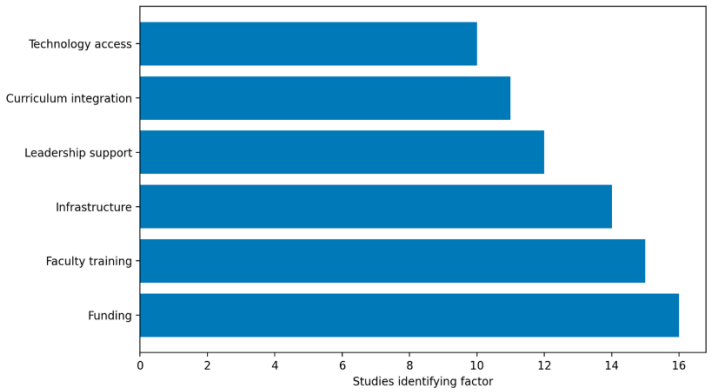

Figure 5 summarizes the implementation factors most frequently identified throughout the reviewed literature. **Funding availability** represented the most commonly reported determinant, appearing in **16 of the 20 studies (80.0%)**, followed by **faculty training (75.0%)**, **institutional infrastructure (70.0%)**, **organizational leadership support (60.0%)**, **curriculum integration (55.0%)**, and **access to advanced educational technologies (50.0%)**. Collectively, these findings indicate that successful implementation depends not only on educational methodology but also on institutional capacity, organizational commitment, and long-term strategic planning.

Financial resources emerged as the primary implementation factor because simulation programs frequently require investment in facilities, equipment, maintenance, software, educational materials, and instructor development. High-fidelity simulators, immersive virtual reality systems, audiovisual recording platforms, and dedicated simulation centers may represent substantial initial expenditures, particularly for institutions with limited educational budgets.

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Nevertheless, several studies suggested that scalable educational models using standardized scenarios, low-cost simulation resources, or hybrid training strategies can provide meaningful competency development while reducing implementation costs, thereby improving feasibility across different healthcare settings [2], [4], [18].

Faculty preparation constituted the second most frequently reported determinant. The educational effectiveness of simulation depends heavily on instructors capable of designing realistic scenarios, facilitating learner engagement, conducting structured debriefing sessions, and providing constructive performance feedback. The reviewed studies consistently emphasized that educator expertise directly influences learning quality, participant reflection, and competency acquisition. Consequently, investment in faculty development programs has been recognized as an essential component of sustainable simulation-based occupational health education [3], [7], [9].

Institutional infrastructure also represented a major implementation consideration. Adequate physical space, simulation laboratories, audiovisual equipment, information technology support, maintenance services, and scheduling capacity are necessary to ensure continuity of educational activities. Several investigations reported that institutions possessing dedicated simulation facilities were able to deliver more standardized, interdisciplinary, and longitudinal occupational health training programs than organizations relying exclusively on temporary educational environments. However, evidence from Latin America demonstrated that effective simulation initiatives can also be implemented successfully using adaptable infrastructure and context-appropriate educational resources when institutional commitment is present [18], [19].

Support from institutional leadership was identified as another important facilitator. Organizational commitment influences resource allocation, curriculum development, strategic planning, and integration of occupational safety training within broader institutional quality improvement initiatives. Healthcare organizations with active administrative support were more likely to establish regular simulation programs, encourage multidisciplinary participation, and incorporate simulation into continuing professional education rather than limiting its use to isolated educational events. Leadership engagement also contributed to strengthening organizational safety culture and promoting continuous competency development among healthcare professionals [10], [20].

Curriculum integration appeared in over half of the reviewed studies. Several authors argued that simulation-based occupational health education should not function as an isolated educational intervention but rather as a longitudinal component of healthcare curricula extending from undergraduate education through postgraduate training and continuing professional development. Progressive competency development allows learners to repeatedly reinforce occupational safety principles while adapting training complexity according to professional experience and clinical responsibilities. Such longitudinal integration supports sustained competency maintenance rather than temporary improvements immediately following educational interventions [1], [5], [18].

Access to advanced educational technologies represented the final implementation factor. The literature demonstrated increasing incorporation of virtual reality, augmented reality, mixed reality, artificial intelligence-assisted assessment, wearable sensors, and digital performance analytics into occupational health education. Although these technologies expand educational possibilities by improving immersion, objective competency assessment, and individualized learning, their adoption remains heterogeneous because of differences in technological infrastructure, acquisition costs, technical support, and institutional digital maturity. Nevertheless, several investigations suggested that educational effectiveness depends more strongly on sound instructional design and structured debriefing than on technological sophistication alone [4], [12], [16].

DISCUSSION

The findings synthesized in this review demonstrate that simulation-based occupational health training has evolved into a comprehensive educational strategy capable of strengthening both technical and non-technical competencies required for safe healthcare practice. Across the reviewed literature, simulation consistently supported the development of procedural proficiency, communication, teamwork, leadership, and decision-making while simultaneously promoting adherence to occupational safety protocols. These observations reinforce the growing international consensus that competency-based education provides advantages over exclusively lecture-based instructional

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approaches by allowing healthcare professionals to repeatedly practice complex clinical situations in controlled and standardized environments before applying these competencies in routine clinical practice [1], [2], [7].

One of the most relevant observations emerging from this review is the predominance of biological hazards within simulation-based occupational health programs. This finding is understandable considering that infectious disease prevention has become a global priority following successive outbreaks of emerging pathogens, particularly during the COVID-19 pandemic. Numerous studies emphasized simulation as an effective strategy for improving correct use of personal protective equipment, reducing contamination during donning and doffing procedures, and strengthening institutional preparedness for infectious disease emergencies [11], [12], [13]. These results are consistent with international recommendations advocating regular simulation exercises to improve healthcare worker protection and institutional readiness during biological emergencies.

Nevertheless, the reviewed evidence also demonstrates a progressive expansion of occupational health education beyond biological risk prevention. Contemporary simulation increasingly addresses psychosocial stressors, ergonomic injuries, chemical exposure, physical hazards, and radiation safety, reflecting a more holistic understanding of occupational health. This multidimensional perspective aligns with modern occupational medicine frameworks that recognize worker safety as the interaction of physical, cognitive, organizational, and psychosocial determinants rather than the prevention of isolated workplace accidents [10], [17], [20]. Consequently, simulation has become a valuable educational platform for integrating multiple occupational risk domains into a unified competency-based curriculum.

Another important finding concerns the evolution of educational objectives themselves. While earlier simulation programs primarily emphasized procedural accuracy, more recent investigations increasingly evaluate communication, leadership, teamwork, and situational awareness. These competencies are now recognized as essential determinants of occupational safety because many workplace incidents originate from failures in communication, coordination, or decision-making rather than technical incompetence alone. The incorporation of crisis resource management principles into occupational health education therefore represents an important shift toward systems-based approaches that acknowledge the complexity of modern healthcare delivery [7], [9], [10].

The educational outcomes reported throughout the reviewed literature further support the value of simulation-based learning. Improvements in technical performance, protocol adherence, emergency preparedness, professional confidence, and organizational safety culture were consistently described across multiple healthcare professions and educational settings. Although outcome measures differed considerably among studies, the overall direction of evidence remained remarkably consistent, suggesting that simulation provides reproducible educational benefits regardless of geographical location or professional discipline [2], [4], [18]. These findings also correspond with broader educational theories emphasizing experiential learning, deliberate practice, immediate feedback, and reflective debriefing as fundamental mechanisms underlying durable competency acquisition.

An important contribution of this review is the inclusion of evidence originating from Latin America. Although scientific production remains concentrated in North America and Europe, regional studies demonstrated that simulation-based occupational health education is increasingly being incorporated into healthcare curricula throughout Latin America despite differences in economic resources and educational infrastructure. These experiences indicate that meaningful educational outcomes are not exclusively dependent upon expensive high-fidelity technology. Rather, carefully designed educational scenarios, trained facilitators, structured debriefing, and institutional commitment appear to be the principal determinants of successful competency development [18], [19]. This observation is particularly relevant for low- and middle-income countries seeking cost-effective educational strategies to strengthen occupational safety.

Despite these encouraging findings, several implementation challenges remain evident. Financial constraints, limited faculty development, inadequate simulation infrastructure, insufficient curriculum integration, and unequal access to advanced educational technologies continue to restrict widespread adoption of simulation programs. These barriers were consistently reported across diverse healthcare systems and suggest that sustainable implementation requires long-term institutional planning rather than isolated educational initiatives [3], [4], [20]. Furthermore, faculty preparation emerged as one of the strongest determinants of educational quality, emphasizing that investment in

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instructor training may have greater educational impact than acquisition of increasingly sophisticated simulation equipment.

The reviewed literature also revealed considerable methodological heterogeneity. Differences in study design, participant populations, simulation modalities, educational duration, outcome measures, and assessment instruments complicate direct comparison among investigations. While most studies reported favorable educational outcomes, relatively few incorporated long-term follow-up to determine whether competency improvements persisted over time or translated into measurable reductions in occupational injuries and workplace incidents. Future investigations should therefore prioritize standardized outcome measures, multicenter collaboration, longitudinal evaluation, and objective assessment of organizational impact to strengthen the available evidence base [6], [8], [15].

Several limitations should also be acknowledged regarding the present review. First, only studies published in indexed scientific databases and meeting predefined eligibility criteria were included, potentially excluding relevant evidence from non-indexed sources or institutional reports. Second, variations in simulation fidelity, educational methodology, participant characteristics, and evaluation instruments limited direct quantitative comparison across studies. Third, because healthcare systems differ substantially in organizational structure, available resources, and occupational safety regulations, generalization of specific educational interventions should be interpreted within the context of local institutional realities. Nevertheless, the broad geographical representation and consistency of findings across multiple healthcare disciplines strengthen the overall conclusions of this review.

CONCLUSION

Simulation-based occupational health training has emerged as a fundamental educational strategy for strengthening the competencies required to protect healthcare workers in increasingly complex clinical environments. The evidence synthesized in this review demonstrates that simulation extends beyond procedural instruction by integrating technical expertise with communication, teamwork, leadership, situational awareness, and clinical decision-making, thereby promoting a comprehensive approach to occupational safety education.

The reviewed literature consistently indicates that simulation-based programs improve adherence to occupational safety protocols, enhance emergency preparedness, reinforce infection prevention practices, and contribute to the development of safer professional behaviors. These educational benefits have been observed across diverse healthcare professions, simulation modalities, and geographical regions, supporting the adaptability of simulation as an educational methodology within different healthcare systems.

An important finding of this review is the progressive expansion of simulation beyond biological hazard prevention toward a broader occupational health perspective that includes psychosocial, ergonomic, chemical, physical, and radiological risks. This multidimensional approach reflects contemporary occupational medicine principles, recognizing that healthcare worker safety depends upon the interaction of technical performance, human factors, organizational culture, and system resilience rather than isolated procedural competence.

Although implementation barriers—including financial limitations, faculty preparation, infrastructure availability, curriculum integration, and technological access—remain significant challenges, the reviewed evidence suggests that successful educational outcomes are primarily associated with effective instructional design, structured debriefing, institutional commitment, and longitudinal competency-based curricula. Experiences reported from Latin America further demonstrate that meaningful simulation-based occupational health education can be successfully implemented even within resource-constrained settings through strategic educational planning and progressive program development.

The findings also highlight the need for greater methodological standardization within future research. Longitudinal investigations, multicenter collaborations, standardized competency assessment instruments, and objective occupational safety indicators will be essential to strengthen the current evidence base and better understand the long-term impact of simulation on healthcare worker protection and organizational performance.

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In conclusion, simulation-based occupational health training represents an effective and increasingly indispensable educational approach for preparing healthcare professionals to recognize, prevent, and respond to occupational hazards. Its capacity to strengthen technical proficiency, interdisciplinary collaboration, safety culture, and organizational preparedness positions simulation as a key component of modern healthcare education and an important contributor to safer working environments and higher-quality healthcare systems worldwide.

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E-ISSN: 3122-3591, P-ISSN: 3122-3753
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E-ISSN: 3122-3591, P-ISSN: 3122-3753
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