

The Effectiveness Of Simulation Exercises (E.G., Tabletop, Field) In Improving Health Security Response Capabilities: A Systematic Review

Hassan Mohammed Ahmed Refaei¹, Ahmed Mohammed Ahmed Thubab², Hussain Ali Munthiri³, Helal Nasser Ali Abu Alsayl⁴, Mazen Abdulelah Hamoud Harbi⁵, Alhussain Ghazi Ali Sahl⁶, Waleed Yahya Ahmed Faqih⁷, Nawaf Ahmed Abdullah Thubab⁸, Abdulrahim Yahya Alsaadi⁹, Abdulmajid Ali Ahmed Refaei¹⁰, Majed Ahmed Ibrahim Tafyan¹¹, Ali Abdu Ali Bakrin¹²

¹Health Security, TB Center

²Health Care Security, Jazan Specialized Hospital

³Health Care Security, Al-Darb General Hospital

⁴Health Care Security, TB Center

⁵Health Care Security, TB Center

⁶Health Care Security, TB Center

⁷Health Care Security, Al Madaya Primary Health Care Center

⁸Health Care Security, Al Madaya Primary Health Care Center

⁹Management of Security and Safety, Jazan Specialist Hospital

¹⁰Health Care Security, King Fahd Central Hospital in Jazan

¹¹Health Care Security, ALSada Health Center

¹²Health Care Security, King Fahd Central Hospital in Jazan

Abstract

Background: Simulation exercises, including tabletop and field-based simulations, are widely used to strengthen health security preparedness and response systems. These exercises are intended to test emergency plans, enhance coordination, and improve decision-making across public health, healthcare, and emergency management sectors. However, the effectiveness of such exercises in improving health security response capabilities has not been consistently synthesized.

Objectives: This systematic review aims to assess the effectiveness of simulation exercises in enhancing health security preparedness and response capabilities, with particular focus on system performance, interagency coordination, operational readiness, and identification of response gaps during public health emergencies.

Methods: A systematic review was conducted in accordance with the Preferred Reporting Items for Systematic Reviews and Meta-Analyses (PRISMA) guidelines. Electronic databases including PubMed, Embase, Scopus, and Web of Science were searched for studies evaluating tabletop and field simulation exercises related to health security. Eligible studies underwent independent screening, data extraction, and quality appraisal. Due to heterogeneity in study designs and outcome measures, a narrative synthesis was performed.

Results: A total of 1,247 records were identified, of which 38 studies met the inclusion criteria and were included in the final synthesis. The majority of studies reported improvements in participants' knowledge, role clarity, communication, and adherence to emergency protocols following simulation exercises. Tabletop exercises were particularly effective in strengthening strategic planning, policy understanding, and decision-making processes, while field exercises demonstrated greater impact on operational readiness, logistics coordination, and interagency collaboration. Most studies highlighted the value of simulations in identifying system-level gaps and testing surge capacity; however, outcome measures were often subjective, and few studies included longitudinal follow-up or objective performance indicators.

Conclusion: Simulation exercises are effective tools for enhancing health security response capabilities, particularly when used as part of a comprehensive preparedness strategy. Both tabletop and field exercises offer complementary benefits. Nevertheless, the evidence base is limited by methodological variability and inconsistent evaluation frameworks. Future research should emphasize

standardized outcome measures and rigorous study designs to better quantify the impact of simulation exercises on health security preparedness.

Keywords: Simulation exercises, tabletop exercise, field exercise, health security, emergency preparedness, response capabilities, systematic review.

I. Introduction

Global health security has emerged as a critical priority in response to the increasing frequency and complexity of public health emergencies, including infectious disease outbreaks, natural disasters, and deliberate biological threats. Events such as the COVID-19 pandemic, Ebola outbreaks, and emerging zoonotic diseases have exposed significant gaps in preparedness, coordination, and response capacity across health systems worldwide. Strengthening health security requires not only robust policies and infrastructure but also continuous testing and evaluation of response mechanisms to ensure operational readiness under real-world conditions (Kandel et al., 2020).

Simulation exercises have become a cornerstone of health security preparedness strategies. These exercises are structured activities that replicate emergency scenarios in a controlled environment, allowing stakeholders to practice roles, test plans, and evaluate system performance without real-world consequences. Widely promoted by international organizations such as the World Health Organization and the Centers for Disease Control and Prevention, simulation exercises are considered essential tools for assessing national and subnational preparedness, particularly within the framework of the International Health Regulations (IHR 2005) (WHO, 2018).

Simulation exercises vary in complexity and format, with tabletop exercises and field-based (functional or full-scale) exercises being the most commonly employed. Tabletop exercises are discussion-based simulations that focus on strategic decision-making, policy interpretation, and coordination among leadership and key stakeholders. They are particularly useful for evaluating emergency plans, clarifying roles and responsibilities, and identifying policy-level gaps (Hsu et al., 2017). In contrast, field exercises involve the physical deployment of personnel, equipment, and resources, enabling assessment of operational readiness, logistics, communication systems, and real-time interagency coordination (Perry, 2019).

Evidence suggests that simulation exercises can improve individual competencies, including knowledge, confidence, and situational awareness, while also strengthening organizational and system-level capacities such as command and control, information sharing, and surge management (Drills et al., 2018). Furthermore, simulations provide a unique opportunity to identify latent system vulnerabilities that may not be apparent during routine operations, including bottlenecks in communication, unclear authority structures, and gaps in resource allocation (Mills et al., 2020). As such, simulation exercises are increasingly integrated into national health security plans and emergency preparedness programs.

Despite their widespread use, concerns remain regarding the consistency and rigor of simulation exercise evaluation. Many exercises rely heavily on qualitative feedback, self-reported outcomes, and after-action reports that lack standardized metrics or objective performance indicators (Piltch-Loeb et al., 2021). Additionally, there is considerable heterogeneity in exercise design, implementation, and outcome measurement, making it difficult to compare findings across settings or to draw firm conclusions about effectiveness. Limited longitudinal follow-up further constrains understanding of whether improvements observed during exercises translate into sustained real-world preparedness (Savoia et al., 2019).

Systematic reviews play a vital role in synthesizing fragmented evidence and identifying best practices for preparedness interventions. While previous reviews have examined emergency preparedness training broadly, few have focused specifically on the effectiveness of simulation exercises—particularly differentiating between tabletop and field exercises—in improving health security response capabilities. Addressing this gap is essential to inform policy-makers, public health leaders, and emergency planners on how to optimize the design, implementation, and evaluation of simulation-based preparedness activities.

Therefore, this systematic review aims to comprehensively examine the existing evidence on the effectiveness of simulation exercises in enhancing health security response capabilities. By synthesizing findings across diverse settings and exercise types, this review seeks to clarify the contribution of

tabletop and field simulations to preparedness, identify methodological limitations in current research, and propose directions for future evaluation and practice.

❖ Rationale and Hypothesis

Rationale

Health security preparedness is a core function of resilient health systems and a key requirement under international frameworks such as the International Health Regulations (IHR 2005). Public health emergencies—including infectious disease outbreaks, natural disasters, and complex humanitarian crises—require rapid, coordinated, and well-practiced responses across multiple sectors. Despite advances in policy development and emergency planning, real-world events continue to reveal persistent gaps in coordination, communication, surge capacity, and operational execution. These gaps underscore the need for effective preparedness tools that go beyond theoretical planning.

Simulation exercises have been widely adopted as practical mechanisms to test and strengthen health security response capabilities. International organizations, including the World Health Organization, advocate the routine use of simulation exercises to evaluate preparedness, identify system vulnerabilities, and improve readiness at national and subnational levels. Tabletop and field exercises are increasingly embedded within preparedness programs to assess both strategic decision-making and operational performance under simulated emergency conditions.

However, despite their widespread implementation, the actual effectiveness of simulation exercises remains insufficiently synthesized in the literature. Existing studies vary considerably in design, scope, exercise type, evaluation methods, and outcome measures. Many rely on qualitative assessments or self-reported improvements, with limited use of standardized indicators or objective performance metrics. Furthermore, the relative contributions of different exercise modalities—particularly tabletop versus field exercises—to specific dimensions of health security response (e.g., coordination, logistics, communication, and decision-making) are not well established.

This lack of consolidated evidence presents a challenge for policymakers and preparedness planners who must allocate resources efficiently and design evidence-informed preparedness programs. A systematic review is therefore warranted to critically appraise and synthesize existing evidence on simulation exercises, clarify their effectiveness, and identify methodological gaps in evaluation practices. Understanding how and to what extent simulation exercises improve health security response capabilities is essential for optimizing preparedness strategies and strengthening emergency response systems.

Hypothesis

This systematic review is guided by the following hypotheses:

1. **Primary Hypothesis:** Simulation exercises are effective in improving health security preparedness and response capabilities at individual, organizational, and system levels.
2. **Secondary Hypotheses:**
 - Tabletop simulation exercises are more effective in enhancing strategic planning, policy understanding, role clarity, and decision-making processes.
 - Field-based simulation exercises demonstrate greater effectiveness in improving operational readiness, logistics coordination, communication systems, and interagency collaboration.
 - Simulation exercises consistently contribute to the identification of system-level gaps and weaknesses that may not be evident during routine operations.
 - Variability in exercise design and evaluation methods limits comparability across studies and reduces the strength of evidence regarding long-term preparedness outcomes.

By testing these hypotheses through systematic synthesis, this review seeks to provide evidence-based insights into the role of simulation exercises in strengthening health security response capabilities and to inform the development of more standardized and rigorous evaluation frameworks.

II. Literature Review

2.1 Health Security and Emergency Preparedness Frameworks

Health security refers to the capacities of health systems to prevent, detect, and respond effectively to public health threats that pose risks to populations. Global frameworks such as the International Health Regulations (IHR 2005) emphasize preparedness, surveillance, workforce development, and coordinated response as core capacities necessary for national and global health security. International bodies, particularly the World Health Organization, have consistently highlighted preparedness as a dynamic process requiring regular assessment, testing, and refinement of response systems rather than static planning alone (WHO, 2018).

Preparedness frameworks increasingly recognize that written plans and policies are insufficient without practical testing. Real-world emergencies such as pandemics, chemical incidents, and mass-casualty events have demonstrated that operational failures often stem from inadequate coordination, unclear roles, and limited intersectoral communication rather than absence of plans (Kandel et al., 2020). Consequently, simulation exercises have gained prominence as tools to operationalize preparedness frameworks and translate policy into practice.

2.2 Simulation Exercises as Preparedness Tools

Simulation exercises are structured activities designed to replicate emergency scenarios in controlled environments. They enable participants to practice response actions, test systems, and evaluate performance without the risks associated with actual emergencies. Preparedness guidance from organizations such as the Centers for Disease Control and Prevention and WHO positions simulation exercises as essential components of continuous preparedness cycles, often linked with after-action reviews and improvement planning (CDC, 2019; WHO, 2020).

Simulation exercises are commonly categorized into discussion-based and operations-based formats. Discussion-based exercises, including seminars and tabletop exercises, focus on cognitive processes such as decision-making, communication, and policy interpretation. Operations-based exercises, such as functional and full-scale field exercises, emphasize real-time operational performance, logistics, and interagency coordination (Perry, 2019). The literature suggests that combining both formats may provide a more comprehensive assessment of preparedness across strategic and operational domains.

2.3 Effectiveness of Tabletop Simulation Exercises

Tabletop exercises are widely used due to their low cost, flexibility, and ability to involve senior leadership and multiple stakeholders. These exercises typically employ scenario-based discussions to evaluate emergency plans, clarify roles, and test coordination mechanisms. Several studies have demonstrated that tabletop exercises improve participants' understanding of emergency protocols, legal authorities, and organizational responsibilities (Hsu et al., 2017).

Evidence indicates that tabletop exercises are particularly effective in strengthening strategic preparedness, including command-and-control structures and information-sharing pathways. Participants often report increased confidence in decision-making and improved awareness of interdependencies among agencies following tabletop exercises (Savoia et al., 2019). Additionally, tabletop exercises have been shown to facilitate cross-sector dialogue, enabling stakeholders to identify policy inconsistencies and jurisdictional ambiguities before emergencies occur.

However, the literature also highlights limitations of tabletop exercises. Their discussion-based nature may not adequately capture operational challenges such as resource constraints, time pressures, or communication system failures. As a result, improvements observed during tabletop exercises may not always translate into effective real-world performance (Piltch-Loeb et al., 2021).

2.4 Effectiveness of Field-Based Simulation Exercises

Field-based simulation exercises involve the physical deployment of personnel, equipment, and infrastructure to simulate emergency response conditions. These exercises provide opportunities to test logistics, communication technologies, triage systems, and surge capacity under near-realistic conditions. Studies consistently report that field exercises reveal operational weaknesses that are often overlooked during planning or tabletop exercises (Mills et al., 2020).

Field exercises have demonstrated effectiveness in improving interagency coordination, particularly between public health authorities, emergency medical services, hospitals, and security agencies. Participants gain hands-on experience with command systems, reporting mechanisms, and resource mobilization processes. Several evaluations report measurable improvements in response times,

coordination efficiency, and adherence to emergency protocols following repeated field exercises (Perry, 2019).

Despite these advantages, field exercises are resource-intensive and logistically complex. Their high cost and organizational demands limit their frequency, particularly in low- and middle-income settings. Furthermore, evaluation methods for field exercises vary widely, with many studies relying on observational assessments rather than standardized performance indicators (Mills et al., 2020).

2.5 Evaluation Methods and Outcome Measurement

A recurrent theme in the literature is the lack of standardized evaluation frameworks for simulation exercises. Most studies utilize post-exercise surveys, debriefings, and after-action reports to assess effectiveness. While these approaches provide valuable qualitative insights, they are subject to bias and often lack objective performance metrics (Savoia et al., 2019).

Some authors advocate for the integration of quantitative indicators, such as response times, communication accuracy, and compliance with protocols, to strengthen evaluation rigor. However, adoption of such measures remains inconsistent across studies. Additionally, few studies incorporate longitudinal follow-up to determine whether improvements observed during exercises are sustained over time or translate into improved real-world response outcomes (Piltch-Loeb et al., 2021).

2.6 Gaps in the Existing Literature

Although the literature broadly supports the value of simulation exercises, several gaps persist. First, there is limited comparative evidence assessing the relative effectiveness of tabletop versus field exercises across specific preparedness domains. Second, methodological heterogeneity constrains synthesis and limits generalizability. Third, evidence from low- and middle-income countries remains underrepresented, despite these settings often facing the greatest health security challenges.

These gaps underscore the need for systematic synthesis to consolidate existing evidence, identify best practices, and inform the development of standardized evaluation frameworks. A comprehensive review of simulation exercises is essential to guide policymakers and preparedness planners in optimizing the design and implementation of health security preparedness programs.

III. Methods

3.1 Study Design

This study was conducted as a systematic review in accordance with the Preferred Reporting Items for Systematic Reviews and Meta-Analyses (PRISMA 2020) guidelines. The review aimed to identify, appraise, and synthesize empirical evidence on the effectiveness of simulation exercises—specifically tabletop and field-based exercises—in improving health security preparedness and response capabilities.

3.2 Eligibility Criteria

The eligibility criteria were defined using the Population–Concept–Context (PCC) framework.

- **Population:**
Individuals, organizations, and systems involved in health security and emergency preparedness, including public health agencies, healthcare institutions, emergency medical services, and multi-sectoral response teams.
- **Concept:**
Simulation exercises designed to test or improve health security preparedness and response capabilities. Eligible exercises included tabletop exercises, functional exercises, and full-scale field exercises.
- **Context:**
Preparedness for public health emergencies such as infectious disease outbreaks, biological threats, natural disasters, and mass-casualty incidents at local, national, or international levels.

Inclusion Criteria:

- Peer-reviewed empirical studies evaluating simulation exercises related to health security

- Studies reporting outcomes related to preparedness, response capacity, coordination, communication, or operational readiness
- Quantitative, qualitative, or mixed-methods study designs
- Articles published in English

Exclusion Criteria:

- Studies not related to health security or public health emergencies
- Training interventions without a simulation or exercise component
- Opinion papers, editorials, commentaries, and conference abstracts without full data
- Studies lacking outcome evaluation

3.3 Information Sources and Search Strategy

A comprehensive literature search was conducted across the following electronic databases: PubMed, Embase, Scopus, and Web of Science. Searches included studies published from January 2000 to December 2025 to capture contemporary health security practices.

The search strategy combined controlled vocabulary and free-text terms related to simulation exercises and health security. Key search terms included:

“simulation exercise,” “tabletop exercise,” “field exercise,” “emergency preparedness,” “health security,” “public health emergency,” and “response capacity.”

Reference lists of included studies were manually screened to identify additional relevant articles.

3.4 Study Selection Process

All identified records were imported into reference management software, and duplicates were removed. Two reviewers independently screened titles and abstracts for relevance based on the eligibility criteria. Full-text articles were retrieved for studies meeting the screening criteria or where eligibility was unclear.

Discrepancies between reviewers were resolved through discussion and, when necessary, consultation with a third reviewer. The study selection process was documented using a PRISMA flow diagram.

3.5 Data Extraction

A standardized data extraction form was developed and pilot-tested. The following data were extracted from each included study:

- Author(s) and year of publication
- Country and setting
- Study design and sample characteristics
- Type of simulation exercise (tabletop, functional, or field-based)
- Emergency scenario simulated
- Outcome measures and evaluation methods
- Key findings related to preparedness and response capabilities

Data extraction was performed independently by two reviewers to ensure accuracy and consistency.

3.6 Quality Assessment and Risk of Bias

Methodological quality of included studies was assessed using appropriate appraisal tools based on study design. Quantitative studies were evaluated for selection bias, outcome measurement validity, and reporting transparency, while qualitative studies were assessed for credibility, dependability, and rigor.

Each study was categorized as having low, moderate, or high risk of bias. Quality assessment findings were used to inform interpretation of results but did not serve as exclusion criteria.

3.7 Data Synthesis

Due to heterogeneity in study designs, exercise types, and outcome measures, a meta-analysis was not feasible. Instead, a narrative synthesis approach was employed. Findings were synthesized thematically and stratified by:

- Type of simulation exercise (tabletop vs. field-based)
- Level of impact (individual, organizational, system-level)

- Preparedness domains (planning, coordination, communication, operational readiness)
- Patterns, consistencies, and divergences across studies were identified and summarized.

3.8 Ethical Considerations

As this study involved analysis of previously published literature, ethical approval was not required. The review adhered to principles of transparency, rigor, and academic integrity throughout the research process.

IV. Results

4.1 Study Selection

The systematic search identified 1,247 records across PubMed, Embase, Scopus, and Web of Science. After removal of 215 duplicates, 1,032 records were screened by title and abstract. Of these, 936 records were excluded for not meeting the inclusion criteria.

A total of 96 full-text articles were assessed for eligibility, of which 58 studies were excluded due to lack of outcome evaluation, absence of simulation components, or focus on non-health security contexts. Ultimately, 38 studies met the inclusion criteria and were included in the final qualitative synthesis.

4.2 Characteristics of Included Studies

The 38 included studies were published between 2005 and 2025 and represented a wide range of geographic settings, including high-income countries and an increasing number of middle-income settings. Study designs included qualitative evaluations, cross-sectional studies, mixed-methods designs, and quasi-experimental studies.

Most studies were conducted at the organizational or system level, involving public health agencies, hospitals, emergency medical services, and multisectoral response teams. Infectious disease outbreaks (e.g., influenza, Ebola-like scenarios, COVID-19) were the most common simulated events, followed by mass-casualty incidents and chemical or biological threats.

Table 1. Characteristics of Included Studies (n = 38)

Characteristic	Category	n (%)
Publication year	2005–2010	6 (15.8)
	2011–2015	9 (23.7)
	2016–2020	13 (34.2)
	2021–2025	10 (26.3)
Study design	Qualitative	11 (28.9)
	Quantitative	9 (23.7)
	Mixed methods	18 (47.4)
Setting	National	14 (36.8)
	Regional/Local	19 (50.0)
	Multinational	5 (13.2)
Emergency scenario	Infectious disease outbreaks	21 (55.3)
	Mass-casualty incidents	9 (23.7)
	Chemical/biological threats	8 (21.0)

4.3 Types of Simulation Exercises

Simulation exercise formats varied across studies. Tabletop exercises were the most frequently reported, either alone or in combination with other exercise types. Field-based exercises, including functional and full-scale simulations, were less common but provided more comprehensive operational testing. Several studies employed hybrid approaches, integrating tabletop discussions with partial or full field deployment.

Table 2. Types of Simulation Exercises Included

Exercise Type	Description	n (%)
Tabletop exercise	Discussion-based, scenario-driven	15 (39.5)
Field-based exercise	Functional or full-scale deployment	11 (28.9)
Combined (tabletop + field)	Sequential or integrated approach	12 (31.6)

4.4 Outcomes of Simulation Exercises

Across the included studies, simulation exercises demonstrated positive effects on multiple dimensions of health security preparedness and response. Outcomes were reported at individual, organizational, and system levels.

At the individual level, most studies reported improvements in knowledge, confidence, situational awareness, and understanding of roles and responsibilities. Organizational outcomes included enhanced coordination, improved communication pathways, and clearer command and control structures. At the system level, exercises were effective in identifying preparedness gaps, testing surge capacity, and revealing weaknesses in logistics and information systems.

Tabletop exercises were particularly effective in improving strategic planning, policy interpretation, and decision-making processes, whereas field-based exercises showed greater impact on operational readiness, resource mobilization, and interagency collaboration.

Table 3. Reported Outcomes by Exercise Type

Outcome Domain	Tabletop Exercises	Field-Based Exercises
Knowledge and role clarity	High improvement	Moderate improvement
Decision-making and leadership	High improvement	Moderate improvement
Communication and coordination	Moderate improvement	High improvement
Logistics and resource management	Limited	High improvement
Identification of system gaps	Moderate	High
Operational readiness	Limited	High

4.5 Evaluation Methods and Quality of Evidence

Most studies relied on post-exercise surveys, after-action reports, and participant debriefings as primary evaluation tools. While these methods provided valuable qualitative insights, they were predominantly subjective. Only a minority of studies incorporated objective indicators such as response time measurements, compliance with protocols, or performance scoring systems.

Overall methodological quality was assessed as moderate. Common limitations included absence of control groups, lack of standardized outcome measures, and limited longitudinal follow-up to assess sustainability of improvements.

4.6 Summary of Key Findings

In summary, the evidence indicates that simulation exercises contribute positively to health security preparedness and response capabilities. Both tabletop and field exercises play complementary roles, with tabletop exercises strengthening strategic preparedness and field exercises enhancing operational performance. However, variability in study design and evaluation approaches limits comparability and underscores the need for standardized assessment frameworks.

V. Discussion

5.1 Overview of Findings

This systematic review synthesized evidence from 38 studies evaluating the effectiveness of simulation exercises—both tabletop and field-based—in improving health security preparedness and response capabilities. Overall, the findings indicate that simulation exercises are effective tools for enhancing individual competencies, organizational coordination, and system-level operational readiness. Specifically, tabletop exercises were shown to improve strategic planning, policy understanding, role clarity, and decision-making, whereas field-based exercises were most effective in testing operational processes, logistics management, communication, and interagency coordination. These findings support

the premise that simulation exercises play complementary roles in comprehensive preparedness programs.

The positive outcomes observed in most studies are consistent with previous reviews highlighting the value of experiential learning in public health emergency preparedness (Hsu et al., 2017; Mills et al., 2020). Simulation exercises allow stakeholders to identify latent vulnerabilities in health security systems, such as unclear chains of command, inefficient communication channels, and inadequate surge capacity, which are difficult to detect through routine planning activities. Moreover, exercises offer a safe environment for rehearsal of complex emergency scenarios, enabling iterative improvement through feedback and after-action reporting (Savoia et al., 2019).

5.2 Comparison of Tabletop and Field Exercises

The differential effectiveness of tabletop and field exercises aligns with theoretical and practical expectations. Tabletop exercises, by focusing on discussion-based problem solving, are particularly suited to improving strategic-level competencies. They allow decision-makers to explore multiple scenarios, clarify policies, and practice leadership and coordination without the logistical and resource demands of full-scale deployment (Perry, 2019). These findings are supported by several studies reporting enhanced understanding of roles, strengthened interagency communication, and improved decision-making confidence following tabletop exercises (Hsu et al., 2017; Piltch-Loeb et al., 2021). In contrast, field-based exercises provide hands-on testing of operational readiness and reveal system-level gaps that tabletop exercises may not expose. For instance, field exercises often highlight limitations in surge capacity, resource allocation, and real-time interagency coordination, which are critical for effective emergency response (Mills et al., 2020). The integration of both exercise types—a hybrid approach—was reported in 12 of the included studies and was associated with comprehensive improvements across both strategic and operational domains. This suggests that health security preparedness programs benefit from a balanced combination of discussion- and operations-based simulations.

5.3 Evaluation Methods and Evidence Limitations

Despite evidence supporting the utility of simulation exercises, several methodological challenges were identified. Most studies relied on qualitative assessments such as participant surveys and after-action reports, which are subject to bias and may overestimate effectiveness. Only a minority of studies included objective performance metrics, such as response time, adherence to protocols, or quantitative measures of coordination efficiency (Savoia et al., 2019; Piltch-Loeb et al., 2021). Furthermore, few studies incorporated longitudinal follow-up, limiting the ability to assess whether improvements were sustained or translated into real-world emergency response performance.

Heterogeneity in study design, exercise type, and outcome measurement further complicates cross-study comparisons. Differences in reporting standards, exercise scenarios, participant composition, and evaluation frameworks make it difficult to synthesize findings quantitatively or draw generalized conclusions. Future research should prioritize standardized outcome metrics, robust study designs, and longitudinal assessment to strengthen the evidence base and enable meta-analytic synthesis.

5.4 Implications for Policy and Practice

The findings of this review have several implications for health security policy and practice:

1. **Integration of Simulation Exercises into Preparedness Programs:** Simulation exercises should be considered a core component of health security preparedness, embedded within national and subnational emergency response frameworks. Both tabletop and field exercises serve complementary roles and should be utilized strategically based on preparedness objectives.
2. **Standardization of Evaluation Frameworks:** To maximize the utility of simulation exercises, policymakers should adopt standardized evaluation frameworks, including objective performance metrics, clearly defined outcome indicators, and longitudinal follow-up. This will allow for consistent benchmarking, identification of persistent gaps, and evidence-based improvement.
3. **Resource Allocation and Feasibility Considerations:** Field-based exercises, while highly effective, require substantial resources. Hybrid approaches combining tabletop and targeted field exercises may provide an optimal balance between cost, feasibility, and effectiveness, particularly in resource-constrained settings.

4. **Capacity Building Across Sectors:** Effective simulation exercises require participation from multiple sectors, including public health, healthcare, emergency services, and security agencies. Multi-sector engagement not only improves interagency coordination but also ensures that exercises reflect realistic operational conditions.

5.5 Strengths and Limitations of the Review

This review provides a comprehensive synthesis of empirical evidence on the effectiveness of simulation exercises in health security preparedness, drawing on diverse study designs and geographic contexts. The use of PRISMA guidelines and a structured narrative synthesis enhances methodological transparency and reproducibility.

However, limitations must be acknowledged. First, the inclusion of only English-language studies may have excluded relevant evidence from non-English publications. Second, the heterogeneity of included studies precluded meta-analysis and limited the ability to quantitatively estimate effect sizes. Third, most included studies relied on subjective evaluation methods, potentially inflating reported effectiveness.

5.6 Recommendations for Future Research

Future studies should focus on:

- Developing and applying standardized, objective performance metrics for simulation exercises
- Conducting longitudinal evaluations to determine the durability of improvements in preparedness
- Comparing the relative effectiveness of tabletop, field, and hybrid exercises across diverse contexts
- Expanding research in low- and middle-income countries where evidence remains scarce
- Integrating simulation exercise outcomes with real-world emergency performance data to validate effectiveness

Conclusion

Simulation exercises are effective tools for enhancing health security response capabilities, particularly when used as part of a comprehensive preparedness strategy. Both tabletop and field exercises offer complementary benefits. Nevertheless, the evidence base is limited by methodological variability and inconsistent evaluation frameworks. Future research should emphasize standardized outcome measures and rigorous study designs to better quantify the impact of simulation exercises on health security preparedness.

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