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# A direct qualitative content analysis on the design, implementation, and evaluation of prehospital earthquake exercises aligned with the HSEEP framework

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## Abstract

**Introduction** Disaster exercises are a vital strategy for enhancing Emergency Medical Services (EMS) operational preparedness. This study aimed to extract “Golden Keys” for Design, Implementation and Evaluation of earthquake exercises aligning these key components with the internationally recognized Homeland Security Exercise and Evaluation Program (HSEEP) Framework from the perspective of experienced Iranian prehospital technicians.

**Method** A qualitative study was conducted using a directed content analysis. Data were systematically gathered through in-depth semi-structured interviews with 11 prehospital technician that purposefully selected based on their demonstrated expertise in prehospital exercise management. Data analysis was conducted in five steps following Granheim and Lundman’s approach and the study used Lincoln and Guba’s recommendations to assess data trustworthiness.

**Result** After multiple rounds of data analysis and summarization 386 initial codes, 13 subcategories, and five main categories were identified. These main categories included “Exercise Foundation and Program Governance”, “Exercise Design, Coordination, and Control”, “Operational Implementation of the Exercise”, “Performance Evaluation and Capability Assessment” and “Learning, Workforce Empowerment”, and “System Improvement”.

**Conclusion** Earthquake preparedness exercises must be sustained as an ongoing effort to enhance prehospital system resilience. The indicators identified in this study provide an actionable, evidence-based framework for EMS managers and policymakers to design, implement, and evaluate exercises aligned with system priorities. Translating exercise outcomes into actionable evidence facilitates informed decision-making targeted resource allocation and evidence-based policy formulation. Future research should focus on contextualizing this framework within localized programs and conducting quantitative validation of the proposed indicators.

**Keywords** Preparedness, Prehospital, Earthquake, Exercise

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## Introduction

Earthquakes stand as one of nature's most imposing geological phenomena consistently remaining at the forefront of catastrophic natural hazards due to their acute unpredictability and destructive potential upon human populations and built environments [1, 2]. Statistical overview confirms this severity and over the last two decades 552 seismic events have occurred globally and constituting 8% of all recorded disasters and ranking third in overall frequency [3]. Iran is located in one of the most seismically active regions of the world with approximately 93% of its territory exposed to significant seismic risk placing a substantial proportion of the population and critical infrastructure at risk during major earthquakes [4, 5]. The earthquake hazards have seriously impacted health care system. They have damaged hospitals and Prehospital emergency bases in the areas hit and which has led to fewer medical services for those hurt and without homes [6]. Additionally, the earthquakes hazards have also put a lot of pressure on doctors and nurses as they have been required to work many hours to care for those injured and deal with the emergency [7].

Prehospital emergency services which involve providing immediate help and moving patients are essential during earthquake rescues and quick medical help can greatly increase the chances of survival for those injured [8]. However, these services often face major challenges due to the destruction caused by earthquakes to buildings and health systems [9]. The absence of prehospital emergency services after an earthquake quickly closes the survival window for severely injured patients and leads to an increase in preventable mortality. This situation simultaneously causes immediate saturation of hospital capacity and disruption of vital care chains [10]. In developed countries most health care system is required to maintain an up-to-date preparedness and skills development plan for disaster response. One way to increase and maintain preparedness of prehospital systems in world is the implementation of disaster exercise [11].

Regular disaster discussion and operational based exercises constitute a cornerstone of preparedness, enabling EMS organizations to translate written plans into operational capability and adaptive response capacity [12]. Disaster exercises serve as simulations of potential incidents thereby improving planning and raising awareness. These exercises provide a valuable training opportunity to assess the integration and performance of various components of the health system in responding to disasters [13].

Chou et al. used a three-dimensional tabletop exercise (3D-TTX) model, showing significant improvement in knowledge. Post-exercise assessment scores were notably higher than pre-exercise scores. Each of the five Disaster Medical Coordination Centers (DMCCs) also showed

consistent score increases. Additionally, 96.9% of students reported a positive change in their understanding of disaster medicine after the 3D-TTX [2]. A study comparing full-scale exercises and tabletop exercises found high learning in both with TTX participants reporting slightly higher scores, likely due to the low-stress discussion format [14].

Nevertheless, the absence of standardized, evidence-based indicators for the design, implementation, and evaluation of disaster drills limits their effectiveness and hinders systematic performance improvement in pre-hospital emergency services [12, 15]. The HSEEP serves as a comprehensive framework for planning, conducting, and evaluating emergency preparedness exercises. This protocol integrates exercise design with clearly defined objectives, realistic operational scenarios, and systematic performance assessment [16]. By prioritizing measurable capabilities and rigorous review processes, the program facilitates the precise identification of institutional strengths and vulnerabilities. Addressing operational gaps and translating empirical findings into actionable improvement plans effectively enhances response efficacy within the realm of emergency management [17].

Qualitative research serves as a critical tool for gaining an in-depth understanding of complex phenomena. It provides a methodology to explore the nuanced perspectives of prehospital emergency specialists, enabling the identification of key components and the development of indicators tailored to the nation's specific cultural, organizational, and social context. The insights gained from such studies can subsequently inform the creation of targeted training programs, the refinement of policies, and the enhancement of inter-organizational coordination [18].

So far, no study has extracted indicators of the design, implementation, and evaluation of prehospital exercise for earthquake hazard from the perspective of prehospital operational personnel. Therefore, this study aimed to extract "Golden Keys" for Design, Implementation and Evaluation of earthquake exercises aligning these key components with the internationally recognized Homeland Security Exercise and Evaluation Program (HSEEP) Framework from the perspective of experienced Iranian prehospital technicians. The indicators and components highlighted in this study are anticipated to enhance the effectiveness of prehospital exercises, improve team coordination, reduce performance errors, and elevate the quality of prehospital emergency care during emergencies and disasters.

## Methodology

### Study design and setting, and participants

This qualitative study employed a directed content analysis approach to extract "Golden Keys" for design,

implementation and evaluation of earthquake hazard exercises based of HSEEP framework from the perspective of experienced Iranian prehospital technicians in 2025. Directed Content Analysis is a qualitative research method used to analyze textual or visual data with pre-defined categories or themes [19]. This study was conducted through interviews with key informants using purposive sampling with 11 prehospital technicians who were selected from 5 provinces of Iran, including Tehran, Alborz, Kerman, Zahedan and Shiraz.

#### **Study inclusion and exclusion criteria**

The inclusion criteria consisted of substantial experience in designing, implementing, and evaluating prehospital preparedness exercises for earthquake hazard. Individuals who were unwilling to participate or unable to continue participation throughout the study were excluded.

#### **Data collection instruments**

To collect data in-depth and individual semi-structured interviews were conducted from March 5, 2025, to June 7, 2025. The interview began with general questions designed as an interview guide and the answers were open-ended and explanatory. The main interview questions were designed based on the framework of HSEEP and include: In your opinion, what are the essential components and characteristics of operations-based and discussion-based prehospital exercises for an earthquake hazard? What requirements and functions do you believe should be considered and incorporated into the design, implementation process, and immediate post-exercise phase of discussion-based and operations-based prehospital exercises for an earthquake hazard? In your experience, what are the primary challenges and problems encountered during the implementation of prehospital exercises for an earthquake hazard? Exploratory questions such as "Can you provide an example?" or "Could you elaborate further on this topic?" were utilized to gain deeper insights for identify of indicators and components that can be utilized in the management and assessment of prehospital preparedness exercises in earthquake hazards. The approximate duration of the interviews was between 60 and 130 min. Although there are no universally agreed-upon definition of data saturation and no standardized method for applying it, data saturation is the process of adding participants until new data no longer provides fresh insights [31]. In this study, data saturation was determined after the ninth interview. To ensure saturation, two additional interviews were conducted, and no new codes were identified.

#### **Ethical considerations**

Ethical considerations in this study included providing clear information to participants regarding the aim's

significance and methods of the study as well as emphasizing the voluntary nature of participation and their right to withdraw at any stage without consequences. Written informed consent was obtained from all participants included in the study, including consent to audio-record the interviews. To ensure confidentiality all recorded interviews were transcribed verbatim and anonymized by removing personal identifiers and assigning unique codes to each participant. The privacy and anonymity of the participants were ensured by coding the questionnaires and only the research team had access to the audio recordings of the interviews. The time and location of the interviews were determined by the participants' preferences and their comfort level.

#### **Data analysis**

Data analysis was done in five steps based on Granheim and Lundman's approach [32]. In the first step, the entire interview was written verbatim immediately after each interview and compared with the original file to ensure accuracy. In the second step, the whole text was reviewed to have a general understanding of its content. In the next step, appropriate labels were given to semantic units, and initial coding was performed. Semantic units were words, sentences, or paragraphs that had related aspects in terms of content and context. In the fourth step, by making a continuous comparison and considering the similarities and differences, similar primary codes were classified into more general classes, and in the last step, by comparing the sub-classes with each other and through deep and detailed reflection, the hidden content in the data as the main classes was introduced. Qualitative data analysis was performed using MAXQDA version 20 software.

#### **Reliability and validity**

To ensure the rigor and validity of the findings, the trustworthiness criteria for qualitative research established by Guba and Lincoln credibility, dependability, confirmability, and transferability were employed [20]. To enhance credibility, strategies such as prolonged engagement in the field and persistent observation were utilized. Furthermore, the extracted codes and categories were reviewed and verified by the research team through peer debriefing sessions. The conceptual validity of the findings was also confirmed by seeking feedback from some participants on the developed categories and interpretations (member checking). To promote confirmability, an audit trail was maintained, ensuring that the research process and findings were traceable and that researcher bias was minimized. Regarding transferability, the study's findings along with supporting quotations were presented to three professionals with expert health in emergencies and disasters who had not been involved in the

**Table 1** Demographic information of participants

Demographic Characteristics	Subcategory	Number (%)
Gender	Male	8 (73%)
	Female	3 (27%)
Age (Years)	40–50	5 (45.5%)
	≥ 50	6 (54.5%)
Work Experience (Years)	11–20	3(27%)
	21–30	8(73%)
Organizational positions	Prehospital	9 (82%)
	University medical sciences	2 (18%)
Educational Status	Bachelor’s degree	5 (45/5%)
	Master’s degree	6 (54/5%)
Field of Study	Emergency Medical Services	8 (73%)
	Nurse	3 (27%)

research, and whose experiences aligned with the study’s context. All phases of data collection, analysis, and interpretation were systematically reviewed and approved by the entire research team.

**Results**

**Demographic information of participants**

The study included 11 participants, all of whom had direct experience in conducting prehospital exercises. The majority of participants were male ( $n = 8, 73\%$ ) and had Work Experience of 21–30 years ( $n = 8, 73\%$ ). All 11 participants (100%) reported previous experience in

responding to various types of incidents and disasters and had been involved in prehospital drills. The demographic characteristics of the participants are summarized in Table 1.

**Main results**

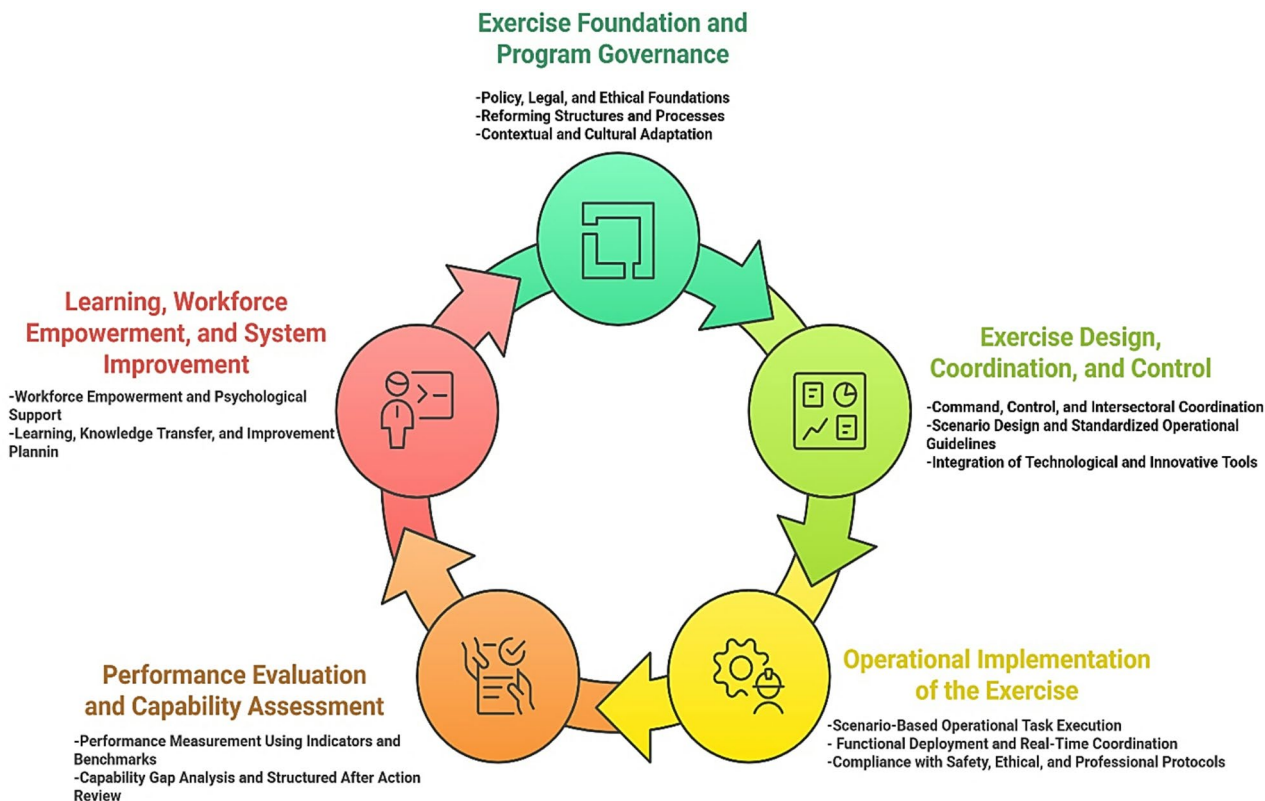
The data analysis yielded 386 distinct indicators and components (initial codes) related to the design, implementation, and evaluation of prehospital exercises for earthquake hazards. These codes were organized into five main categories and 13 subcategories, emerged after several rounds of data analysis and summarization, considering both similarities and differences. These main categories included “Exercise Foundation and Program Governance”, “Exercise Design, Coordination, and Control”, “Operational Implementation of the Exercise”, “Performance Evaluation and Capability Assessment” and “Learning, Workforce Empowerment, and System Improvement”. A summary of the results is presented in Table 2; Fig. 1.

**Main category 1: exercise foundation and program governance**

A comprehensive integration of organizational support, resource allocation, macro-policies, legal mandates, ethical standards, and cultural considerations must establish formal, sustainable frameworks to underpin the planning,

**Table 2** Categories, subcategories, and codes about Design, Implementation, and evaluation of prehospital earthquake exercises based on HSEEP framework

Main Category	Subcategories (Core Components)	Conceptual Focus	Example Indicators
Exercise Foundation and Program Governance	-Policy, Legal, and Ethical Foundations -Reforming Structures and Processes -Contextual and Cultural Adaptation	Establish governance structures, legal frameworks, ethical standards, and ensure exercises are aligned with local culture and policy to sustain preparedness	-Presence of national/provincial exercise policy -Documented organizational preparedness plans, resource allocation - Adaptation of scenarios to local culture and regulations
Exercise Design, Coordination, and Control	-Command, Control, and Intersectoral Coordination -Scenario Design and Standardized Operational Guidelines -Integration of Technological and Innovative Tools	Transform policies and capacities into realistic, coordinated, and controlled exercise designs using ICS structures, scenario-based planning, and technological support	- ICS activation and role clarity in exercises - Use of standardized operational checklists and scenario scripts -Incorporation of simulation software, decision support systems, or AI-based models
Operational Implementation of the Exercise	-Scenario-Based Operational Task Execution -Functional Deployment and Real-Time Coordination -Compliance with Safety, Ethical, and Professional Protocols	Test operational readiness under realistic conditions, including deployment, communication, and adherence to professional standards	-Time to complete simulated triage or patient transport - Accuracy and timeliness of team coordination and communication - Adherence to PPE, patient safety, and ethical protocols
Performance Evaluation and Capability Assessment	-Performance Measurement Using Indicators and Benchmarks -Capability Gap Analysis and Structured After Action Review	Systematically evaluate exercise outcomes, compare performance to benchmarks, identify gaps, and generate actionable lessons	-Scores on pre-defined operational metrics (e.g., response time, treatment accuracy) - Number of gaps identified and prioritized in AAR reports
Learning, Workforce Empowerment, and System Improvement	- Workforce Empowerment and Psychological Support -Learning, Knowledge Transfer, and Improvement Planning	Translate evaluation findings into actionable plans, strengthen workforce skills, promote psychological safety, and institutionalize lessons	- Participant self-efficacy surveys, psychological well-being assessments - Updated training manuals, revised SOPs, implementation of corrective actions



**Fig. 1** Categories and subcategories of prehospital earthquake exercises based on HSEEP framework

execution, and continuity of prehospital earthquake exercises. Establishing such a foundation ensures that these simulations effectively enhance system preparedness and operational efficacy.

#### **Subcategory 1.1: Policy, legal, and ethical foundations**

The successful execution of prehospital exercises necessitates strategic policy formulation and the establishment of robust legislative backing. By synchronizing training objectives with national protocols this programmatic strategy ensures the enduring sustainability of preparedness initiatives.

An interview explained: "All prehospital emergency services should annually establish a clear exercise framework outlining objectives, timelines, responsibilities, and protocols. Since earthquakes are a national priority hazard, they must remain the central focus of these preparedness programs." (P5).

A prehospital manager commented: "A major weakness in prehospital emergency services is the persistent underinvestment in preparedness. The response-focused mindset of senior officials limits proactive planning and weakens inter-sectoral coordination before disasters occur." (P8).

#### **Subcategory 1.2: Reforming structures and processes**

Technological advancements, particularly in analytical tools and information management platforms, contribute to enhanced operational estimates and response capabilities. Operational exercises are critical for organizational learning and for improving the competencies of prehospital personnel in earthquake scenarios. Realizing these objectives necessitates meticulous exercise design, comprehensive evaluation and continuous corrective actions informed by data analysis. The engagement of specialized teams possessing the requisite skills is paramount to minimizing operational errors. Furthermore, the development of realistic scenarios, thorough documentation of all exercise phases and the incorporation of both discussion-based and operations-based methodologies are essential for ensuring earthquake response readiness and robust evaluation framework facilitates the provision of feedback that can be used to refine protocols and enhance overall performance.

One interviewee stated: "Earthquake drills should follow a standardized, step-by-step model with realistic scenarios developed by experienced personnel. All exercise injects, resources, permits, schedules, and action sequences must be clearly defined and prepared in advance." (P5).

Another interviewee remarked: "During a full-scale earthquake exercise, inadequate planning led to resource

*depletion and mismanagement, highlighting the need for a dedicated logistics and HR plan. Assigning untrained personnel caused spoilage of supplies and unnecessary financial losses.” (P11).*

### **Subcategory 1.3: Contextual and cultural adaptation**

The regulations, guidelines, and structure of prehospital emergency exercises must be adapted to the country's specific cultural context, legal framework, and infrastructure. The direct application of international guidelines without considering organizational and societal culture can lead to diminished cooperation from personnel and reduce the overall effectiveness of the exercise.

An interview explained: *“When earthquake exercises are designed based on international guidelines and global experiences without being localized to our infrastructure and organizational culture, they become largely performative. This leads to a lack of motivation among prehospital personnel to participate.” (P11).*

Another interviewee said: *“We have repeatedly seen in earthquake drills that guidelines are copied directly from foreign sources. However, our urban infrastructure, public culture during emergencies, and even the capabilities of our prehospital emergency services differ from those in other countries. This mismatch with reality confuses prehospital staff as they try to perform their duties.” (P8).*

### **Main category 2: Exercise design, coordination, and control**

The convergence of targeted operations through a centralized command framework coupled with clearly defined communication protocols promotes synergy between responding agencies. This alignment serves as a fundamental driver for improved inter-organizational coordination and operational effectiveness. To advance beyond routine exercises and achieve genuine operational preparedness it is essential to develop risk-based scenarios and systematically convert lessons learned into measurable improvement plans. Furthermore, the implementation of advanced technologies and role-specific training enhances decision-making capabilities and delineates responsibilities thereby transforming exercises into robust instruments for the high-fidelity simulation of emergency environments.

#### **Subcategory 2.1: Command, control, and intersectoral coordination**

In an earthquake scenario, the exercise command chain ensures complete coordination among participating teams and agencies by establishing a unified command, clearly defining roles and responsibilities within the ICS, delineating communication pathways between command staff and operations, and specifying the position of each operational unit. In prehospital earthquake exercises, operational experience and inter-sectoral collaboration

profoundly influence exercise effectiveness. Individuals with a history of participation in previous crises and drills demonstrate a greater capacity for facilitating inter-organizational coordination. Effective interaction among different agencies fosters operational cohesion and mitigates the communication challenges that often arise among responding organizations.

One of the interviewees explained: *“Effective earthquake response depends on regularly updating the incident command structure and clearly defining roles during drills; lack of full participation can lead to coordination issues and reduced efficiency in real events.” (P2).*

A specialist in disaster and emergency health commented: *“The Incident Command Post (ICP) is crucial for managing operations and ensuring coordination between field units and the EOC during major earthquakes; drills should emphasize its timely activation, proper setup, and adequate resourcing.” (P4).*

Another participant stated: *“Joint exercises with other organizations improve prehospital teams' technical skills and foster stronger inter-agency communication and coordination, which are vital for effective earthquake response.” (P10).*

#### **Subcategory 2.2: Scenario design and standardized operational guidelines**

To facilitate the effective planning and execution of an earthquake exercise, a suitable framework must be established. Securing senior management engagement and buy-in, defining exercise priorities, developing a long-term exercise plan, specifying expected outcomes, and managing resources are all essential prerequisites for successful planning. The post-exercise improvement plan must translate the recommendations and suggestions from the after-action report into measurable and monitorable action items. Planning that is informed by hazard maps and risk priorities, and guided by clear objectives, leads to the development and updating of standardized field guidelines. By adopting evidence-based planning that leverages data from previous exercises, it is possible to make drills more targeted and prevent the implementation of performative exercises that are disconnected from actual operational needs.

One of the interviewees stated: *“Earthquake exercises should address shortcomings from previous drills with clearly defined objectives and strategies. However, a gap often exists between the annual preparedness plan and the actual exercises conducted.” (P7).*

#### **Subcategory 2.3: Integration of technological and innovative tools**

The use of a variety of operations-based and discussion-based exercises, combined with continuous training throughout the drill, leads to improved performance of

prehospital emergency teams in response to earthquake hazards. Key components of practical training include the use of digital tools, the development of a standardized exercise toolkit, and conducting tailored training sessions before, during, and after the exercise that are specific to the roles of the participants.

A prehospital interviewee emphasized: *“Participants must understand their roles before exercises, as confusion during drills often stems from inadequate training. Complex tasks like dispatching highlight gaps in preparedness and the need for better role-specific instruction.”* (P9).

One of the interviewees stated: *“The integration of virtual training and artificial intelligence facilitates dynamic scenario generation and comprehensive performance assessment, thereby enabling the precise identification of operational vulnerabilities.”* (P4).

### **Main category 3: Operational implementation of the exercise**

Exercises provide a crucial opportunity to operationalize and validate documented emergency operations plans in simulated real-world conditions. The efficacy of these simulations is contingent upon the realistic execution of tasks the congruence of scenarios with actual field conditions and the capacity of response teams to execute their designated roles with appropriate timing and coordination. When exercises transcend ceremonial or pro forma formats and more accurately reflect the disorder and uncertainty inherent in real-world crises they become significantly more effective in identifying procedural deficiencies and systemic limitations. Conversely superficial or overly predictable exercises impede the accurate assessment of operational challenges and substantially diminish the learning potential of the simulation.

#### **Subcategory 3.1: Scenario-based operational task execution**

Scenario realism and dynamism grounded in regional hazard risk assessments significantly enhance decision-making, coordination, and response effectiveness in simulated environments. Conversely discrepancies between scenarios and actual environmental conditions or the use of inflexible pre-scripted exercises impede the valid assessment and improvement of operational competencies, adaptive capabilities, and collective preparedness.

One interviewee noted: *“High-fidelity exercise scenarios revealed critical gaps in prehospital performance, including delays in dispatch, breakdowns in inter-team coordination, and logistical constraints in resource allocation. These gaps highlighted a clear disconnect between written preparedness plans and actual operational readiness.”* (P7).

One of the interviewees stated: *“When exercise scenarios lack realism and follow rigid, pre-determined scripts, they become largely ceremonial. Such conditions fail to*

*expose personnel to the uncertainty and decision-making pressure of real emergencies, leaving teams vulnerable to confusion and cognitive overload during actual crisis response.”* (P10).

#### **Subcategory 3.2: Functional deployment and real-time coordination**

In prehospital earthquake exercises, operational experience and inter-sectoral collaboration profoundly influence exercise effectiveness. Individuals with a history of participation in previous crises and drills demonstrate a greater capacity for facilitating inter-organizational coordination. Effective interaction among different agencies fosters operational cohesion and mitigates the communication challenges that often arise among responding organizations.

One interviewee noted: *“Establishing coordination provides a suitable foundation for effective exercises, but achieving this coordination among different organizations is challenging. Individuals with repeated exercise experience are more successful in interacting and coordinating with other agencies.”* (P3).

Another participant stated: *“Joint exercises with other organizations improve prehospital teams’ technical skills and foster stronger inter-agency communication and coordination, which are vital for effective earthquake response.”* (P10).

#### **Subcategory 3.3: Compliance with safety, ethical, and professional protocols**

The selection of a location for an earthquake exercise is critical and must be based on the exercise objectives while ensuring the health and safety of all participants. It is imperative to obtain the necessary legal permits for the exercise site, secure the perimeter to prevent the entry of unauthorized individuals, and conduct a thorough security risk assessment to guarantee a safe training environment.

One interviewee with experience in prehospital exercises noted: *“Issues related to the health and safety of prehospital emergency teams are sometimes neglected. It is essential to plan for necessary interventions in case a real incident occurs during the exercise, and the safety officer must clearly define prohibited actions.”* (P4).

Another participant remarked: *“Operational teams are often dispatched to the site without any prior assessment of the safety and security threats in the exercise environment.”* (P6).

### **Main category 4: Performance evaluation and capability assessment**

Evaluation serves as a strategic instrument for assessing resilience and advancing the genuine operational readiness of the prehospital emergency system. Analysing

operational performance following exercises facilitates the identification of disparities between codified protocols and actual execution. By generating corrective action plans, this process ensures the remediation of deficiencies and the sustainable enhancement of response capacities. Conversely, neglecting post-exercise analyses inevitably results in the persistence of organizational vulnerabilities.

#### **Subcategory 4.1: Performance measurement using indicators and benchmarks**

The primary goal of conducting prehospital exercises for earthquake hazards is to promote learning, allow personnel to practice their expected roles and functions, and enhance the organization's overall capacity to respond effectively. Operations-based exercises can simulate realistic conditions, while discussion-based exercises strengthen coordination and improve the ability to make critical, large-scale decisions during earthquake hazards. Collectively, these activities lead to the enhancement of operational functions and performance indicators for prehospital emergency services in disaster settings.

One participant observed: *"During an earthquake drill, we realized that our operational teams had weaknesses in ambulance staging, zone designation, triage, and patient transport to hospitals."* (P7).

Another interviewee explained: *"In large-scale earthquakes with damaged infrastructure, response operations become highly complex. Without prior familiarity with plans, policies, and coordination protocols, participants struggle with patient transport, treatment setup, and effective decision-making."* (P11).

#### **Subcategory 4.2: Capability gap analysis and structured after action review**

Exercises play a key role in finding problems in emergency services during disasters. Common issues include unsafe conditions for personnel poor command coordination, lack of teamwork between agencies and ineffective use of resources. Also, inadequate role-specific training and missing post-incident reviews create significant gaps. Not conducting after-action reviews can lead to repeated errors and increased risks in future emergencies.

One of the interviewees stated: *"Casualties among emergency personnel and damage to assets within the incident zone stemmed not from inevitable hazards, but rather from flawed decision-making, unfamiliarity with operational zoning, and command failures. These represent recurrent errors that persist in subsequent events due to inadequate post-incident analysis."* (P2).

Another participant remarked: *"The absence of structured debriefing following exercises resulted in the expiration of critical pharmaceuticals, the failure to replenish*

*stockpiles, and the deployment of untrained personnel during crises. Essentially, while the exercise was technically executed, true organizational preparedness and learning were never realized."* (P3).

#### **Main category 5: Learning, workforce empowerment, and system improvement**

Effective learning and improved disaster response rely on viewing the workforce as key players in development, not just as task executors. Lack of psychological support during training undermines professional growth and confidence. Poor documentation of experiences, knowledge sharing, and follow-up actions hinder continuous learning in prehospital care. To advance response systems sustainably, it is essential to protect personnel's mental health, engage them in learning, and turn experiences into clear corrective actions.

#### **Subcategory 5.1: Workforce empowerment and psychological support**

heavy workloads, often lack opportunities for psychological recovery. This exposes them to chronic fatigue, occupational burnout, and decreased motivation, which pose a threat to their mental and physical well-being. Even in simulated earthquake exercises, prehospital teams experience significant psychological pressure, stemming from the fear of being judged for operational weaknesses, coupled with fatigue from their routine duties and the compulsory nature of their participation. Providing psychological support can enhance learning and performance during these exercises.

One participant stated: *"Psychological readiness is as vital during exercises as in real emergencies. Conducting mental preparedness sessions, supporting less experienced staff, and providing post-drill debriefings can reduce stress and enhance team resilience."* (P9).

Another interviewee added: *"Managing the mental health of prehospital personnel is of utmost importance and should not be overlooked. Teams must be trained in emotional regulation for mass-casualty incidents like earthquakes. Maintaining psychological profiles for our personnel can help us identify and support at-risk individuals before they suffer significant harm."* (P5).

#### **Subcategory 5.2: Learning, knowledge transfer, and improvement planning**

The lack of structured processes for experience documentation, knowledge transfer between management and operations and the conversion of errors into lasting improvements contributes to the repetition of similar errors in future incidents and exercises. Additionally, elevated managerial turnover outdated disasters organizational frameworks and the use of non-specialist evaluators compromise post-incident learning thus

hindering the continuous evidence-driven improvement of response capabilities.

One interviewee noted: *“Exercises are conducted, yet the acquired experience is not disseminated to others. Managers rotate, and crisis structures remain outdated, compelling us to start from scratch every time. We are forced to explain repeatedly what transpired and what actions must be avoided, effectively operating as though no prior incident has ever occurred.”* (P5).

Another interviewee said: *“Following an exercise, fatigue sets in and the process is abruptly terminated. There is no rigorous debriefing to analyses delays, dispatch errors, or personnel unpreparedness. When evaluations do occur, this critical responsibility is often delegated to inexperienced individuals. Consequently, errors remain unrecorded and uncorrected. The result is the repetition of the same failures in actual crises or subsequent exercises”* (P1).

## Discussion

The following discussion synthesizes the empirical findings derived from participants' experiences to develop higher-level conceptual insights into the design, implementation, and evaluation of prehospital earthquake exercises within the HSEEP Framework. By aligning the identified indicators with the Homeland Security Exercise and Evaluation Program framework, this study offers an integrated systemic understanding of prehospital earthquake exercises. Findings revealed that transitioning from foundational preparedness toward organizational learning establishes a novel platform for enhancing prehospital emergency response during crises. This flexible yet methodical paradigm significantly improves efficiency and disaster readiness by empowering the system to adapt to dynamic circumstances.

### Exercise foundation and program governance

Robust governance and clear legal mandates are essential for improving prehospital earthquake preparedness. Strong policies and support make preparedness efforts meaningful and accountable. Poor governance and lack of investment increase vulnerabilities in health systems, leading to ineffective crisis responses. Additionally, not including exercises in national risk reduction policies hinders operational readiness [21]. Ethical standards, professional realism, and cultural compatibility were identified as critical success factors. Ceremonial or unrealistic exercises impede organizational learning and diminish personnel confidence [22, 23].

These findings align with research by Alanazi et al., highlighting that realistic scenarios are crucial for effective disaster exercise [24]. Including ethical principles in these training exercises is also important for improving response quality while ensuring victim dignity and

psychological resilience in tough situations [25, 26]. A major issue remains the mismatch between global emergency standards and the realities in developing countries which raises concerns about the effectiveness of protocols amid limited training and resources [27]. This study suggests adapting international frameworks to fit local cultural contexts legal needs and infrastructure. It argues that governance and legal frameworks are essential for effective exercise planning, helping to build resilience in prehospital systems against earthquakes.

### Exercise design, coordination, and control

Purposive organizational design and structured coordination are essential for developing effective exercises. The Incident Command System (ICS) provides command and control during disasters by clarifying roles and enhancing communication [28]. Research shows that familiarity with ICS and Hospital Command Centers (HCC) during exercises reduces role confusion and improves communication among agencies leading to better disaster risk management. Jensen et al. found that training in ICS boosts coordination and performance in real disaster situations [29]. Bulson established that simulations utilizing the Incident Command System significantly optimize the actual performance of operational teams. Personnel who master Hospital Command Center protocols through these exercises demonstrate superior communication and greater situational flexibility when responding to genuine disaster conditions [30].

Risk analysis-based scenario development is key to distinguishing effective exercises from those that are merely ceremonial [31]. Scenarios based on historical data and after-action reports offer better educational value and relate more closely to real-life situations. Modern tools like Intelligent Disaster Decision Support Systems (IDDSS), simulations, and artificial intelligence improve decision-making and enhance the exercises' impact by effectively modeling logistics and resources.

Gaps in earthquake preparedness highlight the need for disaster planning based on documented lessons [32, 33]. Toy et al. established that leveraging artificial intelligence to simulate disaster environments during exercises optimizes instructional methodologies and enhances prehospital emergency operational proficiency [34].

Synthesizing these findings with global evidence suggests that effective prehospital exercise hinges on design quality modern methodology and mature command systems rather than simply the presence of training. These components within a strategic organizational framework are essential for translating policy into effective emergency performance.

### Operational implementation of the exercise

The implementation phase is essential for assessing pre-hospital system capabilities in simulated environments. Simulation training for disaster response must include all response aspects, such as coordination and resource limits [35]. Realistic exercises reveal gaps in triage, ambulance dispatch, and decision-making, allowing for experiential learning. Hands-on training helps personnel better understand crisis challenges and improves decision-making. Participation in operational exercises enhances Emergency Medical Service (EMS) nurses' skills and their ability to respond quickly [36]. Structured decision-making training through simulation enhances communication, resource use, reduces errors, and boosts patient safety. Realistic scenarios are more effective than theoretical instruction [36–38]. Research by Bijl et al. shows that participation in operational exercises enhanced the professional skills and readiness of EMS nurses, facilitating superior decision-making and more rapid response execution compared to their peers during emergencies [39]. The authors maintain that operational exercises yield unique insights unattainable through discussion-based formats.

### Performance evaluation and capability assessment

Evaluation is an important but often overlooked part of the exercise cycle. Systematic analysis of behaviors performance and outcomes allows for objective measurement of team effectiveness [40]. Proper documentation helps compare actual performance with set standards revealing strengths and weaknesses. Without clear evaluation criteria practical learning suffers. Effective scenario design and involving expert evaluators are key for success. Immediate and delayed debriefing sessions improve learning by encouraging reflection and helping retain knowledge [41, 42]. Assessments should use established metrics and empirical data for feedback on accuracy and response times, ensuring the quality of training initiatives [43, 44].

Research by Poorsiahbidi et al. shows that using expert evaluators and corrective action plans greatly impacts emergency exercise results, highlighting the need for expertise in evaluations [45]. Mallory et al. found that predefined performance indicators help identify organizational strengths, improving disaster readiness and lowering vulnerability [46]. The authors emphasize that learning is sustainable only when evaluation results lead to measurable improvement plans and policy changes. Standardized checklists and assessment tools are essential for accurate data collection and enhancing team performance.

### Learning workforce empowerment and system improvement

Blended educational strategies that combine theory practical training and new technologies improve personnel skills. Standardized training is essential for emergency response teams. Poor training can negatively impact performance and responder well-being. Disaster preparedness involves learning, risk planning, and logistics [47, 48]. Research by Kou and Niu indicated that direct field experience during exercises minimizes rapid decision-making errors and improves coordination under high-stress conditions. Sustaining nursing team efficiency requires robust training initiatives, realistic scenario simulations and enhanced intersectoral coordination [49].

The authors argue that training programs using modern technologies boost teamwork while standard post-exercise evaluations pinpoint performance gaps and build confidence in high-stress situations. By aligning these methods with the Homeland Security Exercise and Evaluation Program the study shows that effective pre-hospital earthquake exercises are part of a comprehensive preparedness system and this approach improves governance, resilience, and readiness for emergency situations.

### Limitations and strengths of the research

This study has a strong point in its use of directed qualitative content analysis to find key elements for effective prehospital exercises, which is vital for improving the quality of such drills. The study also benefits from purposive sampling, interviewing individuals with direct experience in conducting these exercises. However, there are limitations. The data depend on the interviewees' memories which could lead to recall bias. Efforts were made to interview participants soon after getting ethical approval to reduce this risk. Additionally, the findings may not apply to countries with different emergency service structures and cultures. Although credibility was supported through methods like member checking and team consensus there is still a chance of interviewer bias and subjective interpretation. As the study focused on a national level applying these recommendations internationally should be done carefully.

### Practice and policy implications

The findings of this study are organized into five main themes, each with direct implications for practice and policy. These findings underscore that effective operational exercises transcend isolated training events, serving as fundamental elements within a broader framework of organizational learning and systemic preparedness. At the policy level institutionalizing realistic and localized drills within national frameworks strengthens systemic resilience and operational readiness. From a performance standpoint, systematic exercise design utilizing

the Incident Command System alongside scenarios informed by data and emerging technologies facilitates converting policy into tangible operational capability while optimizing coordination according to Homeland Security Exercise and Evaluation Program standards. Operational execution reveals functional gaps and promotes experiential learning, which improves response efficiency and patient safety more effectively than theoretical approaches. Capability assessment and performance evaluation serve as the core of the exercise cycle, proving vital for sustainable learning and policy reform. Evidence indicates that continuous learning and workforce empowerment, and systemic refinement are the long-term outcomes of rigorous implementation. Standardizing prehospital earthquake drills within the HSEEP framework embeds these activities into a continuous preparedness system. Such integration promotes governance and adaptability, and disaster resilience while simultaneously enhancing team competencies and organizational stability.

## Conclusion

Adopting a strategic and systemic perspective in the design and implementation of prehospital exercises is critical for their effectiveness. Modern technologies such as AI and advanced simulation when integrated with established incident command structures can reduce human error, improve coordination, and enhance the overall disaster response. Exercises provide an essential platform for the development of both technical and interpersonal skills among prehospital personnel. Strong policymaking realism in exercise scenarios and the localization of guidelines are fundamental prerequisites for improving and refining exercise processes. Ultimately, exercises must be transformed into continuous processes aimed at systematically enhancing the resilience of the prehospital emergency system. It is recommended that researchers and specialists prioritize the development of localized exercise programs and the creation of policy briefs to advocate for greater investment in exercise resources from policymakers. Future research could focus on the quantitative evaluation of the indicators identified in this study. By validating and measuring the impact of these factors such research could provide a stronger evidence base to inform policy and practice.

## Abbreviations

AI	Artificial Intelligence
EMS	Emergency Medical Services
EOC	Emergency Operations Center
ICS	Incident Command System
WHO	World Health Organization
HSEEP	Homeland Security Exercise and Evaluation Program

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## Author contributions

AA and HF conceived the study and prepared the analysis plan. AA conducted the analysis and drafted the manuscript. HF performed the literature search, screened studies for inclusion and exclusion, assessed the risk of bias, and contributed to drafting the manuscript. AS and AKH contributed to the preparation of the analysis plan and critically reviewed the manuscript. AM critically reviewed the manuscript. All authors approved the final version of the manuscript.

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## Data availability

The data sets generated during the current study are available from the corresponding author.

## Declarations

### Ethics approval and consent to participate

The Ethics Committee of Kerman University of Medical Sciences approved this study. The Ethic approval Code is IR.KMU.REC.1403.522. All methods were performed in accordance with the relevant guidelines and regulations; this article does not contain any studies with animals performed by any of the authors. Informed consent was obtained from all individual participants included in the study, and written informed consent was obtained from individual participants. Confidentiality and anonymity of the participants were ensured by coding the questionnaires. Study participants were clearly informed of their freedom to opt out of the study at any time without justification.

### Consent for publication

Not applicable.

### Competing interests

The authors declare no competing interests.

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