Use of high-fidelity simulation technology in disasters: an integrative literature review

Masataka Gunshin,1 Kent Doi,2 and Naoto Morimura2

1Department of Emergency Medicine, Toranomon Hospital, and 2Department of Acute Medicine, The University of Tokyo Hospital, Tokyo, Japan

New innovative high-fidelity simulation (HFS) technologies, including augmented reality and virtual reality, have begun being used for disaster response and preparedness. However, few studies have assessed the merit of these technologies in disaster simulation. This integrative literature review of 21 studies assesses the role of HFS technology in disaster. Most studies used a quantitative methodology (71.4%), followed by mixed (19%) or qualitative methods (9.6%). Nearly 60% covered only disaster preparedness phase, whereas 10% addressed disasters in middle-income countries without including low-income nations. The four most frequently mentioned technologies were immersive virtual reality simulation, computerized virtual reality simulation, full-scale simulation, and augmented reality wearable smart glasses simulation. Nearly 50% of the studies used technology for purposes other than disaster simulation education, including telemedicine (14.3%), risk planning (14.3%), high-risk map generation for preparedness purposes (9.5%), or rehabilitation medicine (4.8%). HFS technologies must be further evaluated outside of high-income countries and in different disaster phases to better understand their full potential in disaster simulation. Future research should consider different health professions and more robust protocols to assist disaster response professionals and agencies in the adoption of HFS technologies.

Key words: Augmented reality, disaster medicine, high-fidelity simulation training, public health, virtual reality

BACKGROUND

The potential for disasters has required health care and public health systems to identify and refine their disaster emergency preparedness protocols and constantly improve the quality of health-care provider disaster education and training.1–3 Adequate disaster preparedness suffers from limited access to disaster training opportunities and costly and logistically challenging live disaster drills.3 Alternatively, the increased use of technology in health care has increased patient education and expectations and the implementation of innovative modalities for health care education.4 Simulation technology helps participants acquire, develop, and maintain the knowledge and skills necessary for safe and effective patient care.5 High-fidelity simulation (HFS) is particularly adept at providing a high-quality environment for developing nontechnical management skills including communication, teamwork, leadership, and decision making, which are necessary when practicing a response to disaster situations.4 Simulation fidelity is the similarity to reality achieved by the simulator. Simulations are considered high or low fidelity based on their similarity to reality (Table 1).6 Despite the potential utility of HFS technologies, insufficient literature has evaluated its effectiveness in disaster response. This review seeks to describe the current ability of HFS technologies to simulate disasters and recommends areas for future study.1

METHODS

This structured literature search identified works describing the use of HFS technologies in disaster response prior to October 1, 2019. All studies identified by selected search terms in the PubMed and Embase databases and published before the final search date were included. The earliest publication date included was September 30, 2014. Medical librarians and experts in simulation-based education and disasters determined the search terms. Search terms were ultimately adapted to meet the search criteria requirements for each included database (Table 2). Title/abstract and full-text reviews were performed. Only articles that used HFS technologies in real-life disaster or simulation scenarios were included. The following data were...
extracted using a custom tool: first author and year, data type (qualitative, quantitative, or mixed method), disaster type, disaster setting (country), World Bank status, disaster phase, responders involved, type of HFS technology, problems encountered, findings and significance, and additional comments. Because the primary focus was to characterize the contexts wherein HFS technologies were used rather than methodologic quality, quality assessment metrics were not used in our inclusion/exclusion criteria. Quantitative research deals with numbers and statistics, whereas qualitative research deals with words and meanings. Quantitative methods allow you to test a hypothesis by systematically collecting and analyzing data, while qualitative methods allow you to explore ideas and experiences in depth.

Summary statistics on all the extracted data were calculated to better identify the use of HFS technology in the selected literature. This was followed by two steps. Simple descriptive statistics on the use of HFS technology in disaster research were calculated, which included methods, location, and so on. The second step required a review of the type of HFS technologies discussed in each article. The most commonly used HFS technologies in real-life or simulated

| Table 1. A typology of fidelity within simulation adapted from Cant and Cooper⁶ |
|-------------------------------------------------|
| Simulation tools in order of increasing fidelity | Description of simulation activity |
| Partial task trainers | Replica models or manikins used to learn, practice, and gain competence in simple techniques and/or procedures |
| Screen-based computer simulators | Programs used to acquire knowledge, to assess competency of knowledge attainment, and to provide feedback related to clinical knowledge and critical thinking skills |
| Virtual reality simulation | Combines a computer-generated environment with tactile, auditory, and visual stimuli provided through sophisticated partial trainers to promote increased authenticity |
| Augmented reality simulation | Combines real-world and virtual reality-like haptic systems |
| Standardized patients | Use case studies and role playing in the simulated learning experience, in which individuals are taught to portray a patient in a realistic and consistent manner |
| Full-scale simulation | Simulation that incorporates a computerized full-body manikin that can be programmed to provide realistic physiological response to student actions |

| Table 2. Included databases, search terms, and search strategies |
|-------------------------------------------------|
| Included database, search terms, and search strategies |
| Databases | PubMed, Embase |
| Search terms | Disaster, mass casualty incident, high fidelity simulation, augmented reality, virtual reality |
| Search strategy (PubMed) | (((disaster[MeSH Terms]) OR disaster*[Text Word]) OR mass casualty incident[MeSH Terms]) OR mass casualty incident*[Text Word] AND (((((high fidelity simulation[MeSH Terms]) OR high fidelity simulation*[Text Word]) OR augmented reality[MeSH Terms]) OR augmented reality*[Text Word]) OR virtual reality[MeSH Terms]) OR virtual reality*[Text Word] | |
| Search strategy (Embase) | ‘disaster’ OR ‘mass casualty incident’ AND ‘high fidelity simulation’ OR ‘augmented reality’ OR ‘augmented realities’ OR ‘virtual reality’ OR ‘virtual realities’ |
| Search counts | PubMed: 98 Embase: 96 Total = 194 |

Field | Inclusion criteria | Exclusion criteria |
|-----------------|-----------------|-----------------|
| Inclusion criteria for review | | Non-English language |
| Language | English only | Gray literature, review papers, conference abstracts |
| Study design | Original research | More than 5 years |
| Year | Within 5 years, 2014–2019 | Research presents theoretical application of technology in disaster setting |
| Technology application | Real-world event | |
| Technology use | Augmented reality, virtual reality, high-fidelity simulation | Technology of interest is a survey, etc. |

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disasters were identified and their applications were recorded along with any unique or unexpected findings.

**RESULTS**

Of the 98 abstracts identified in the final search, 41 were excluded following title/abstract screening. Fifty-seven full texts were screened, and 36 were excluded: 13 were inaccessible, 11 were published more than 5 years prior, 8 were not original research, 4 were not relevant, 2 were duplicates, and 1 was not in English. The preferred reporting items for systematic reviews and meta-analyses (PRISMA) diagram for this work is shown in Figure 1.

**Descriptive research statistics**

Twenty-one articles were ultimately included (Table 3). More studies used quantitative methods (n = 15, 71.4%) than mixed (n = 4, 19%) or qualitative methods (n = 2, 9.6%). Of the included articles, 12 (57.1%) were published within the past 2 years, 14 (66.7%) covered only disaster preparedness. The articles originated from ten different countries, with only three being the source of more than two articles. The most cited countries were the United States (n = 10), Germany (n = 2), and Italy (n = 2). Most articles (n = 19, 90.5%) that reviewed HFS technologies were performed in high-income countries, two (9.5%) reviewed in middle-income countries, and none focused on low-income countries. There were nine separate disaster types. Mass casualty incidents and facility fires were addressed in eight (38.1%) and five (23.8%) articles, respectively. All articles clearly specified their intended subjects: seven (33.3%) listed first responders (paramedics: 42.9%, n = 3; nurses: 28.6%, n = 2; physicians: 28.6%, n = 2) as their targets, while the same proportion targeted professional degree-seeking students (nursing students: 57.1%, n = 4; paramedic students: 28.6%, n = 2; medical students: 14.3%, n = 1). Almost

![PRISMA diagram](image-url)
| Study | Year | Data type | Disaster phase | Country | World Bank status | Disaster type | Technologies | Purposes for technologies | Intended users | Challenges described? |
|-------|------|-----------|----------------|---------|-------------------|--------------|--------------|--------------------------|----------------|----------------------|
| 1     | 2018 | Mixed method | Preparedness | United States of America | High income | Mass casualty incident drills | Augmented reality with wearable smart glasses | Telemedicine Damage assessment: Triage | First responders paramedics | Yes |
| 2     | 2017 | Quantitative | Preparedness | China | Middle income | Virtual facility fires | Immersive virtual reality | Real-time stressful environment | First responders | Yes |
| 3     | 2015 | Qualitative | Preparedness | Italy | High income | Mass casualty incident drills | Augmented reality with wearable smart glasses | Telemedicine Damage assessment: Triage | First responders paramedics | Yes |
| 4     | 2017 | Quantitative | Preparedness | United States of America | High income | Virtual facility fires: OR | Immersive virtual reality simulation | First responder training: OR fire response | First responders surgeon, nurses, | Yes |
| 5     | 2017 | Quantitative | Preparedness | United States of America | High income | Virtual mass casualty incidents: ED | Computerized virtual reality simulation | First responder training: ED triage | First responders | Yes |
| 6     | 2019 | Mixed methods | Preparedness | United States of America | High income | Virtual miscellaneous disasters: NICU | Immersive virtual reality simulation | First responder training: NICU evacuation | First responders | Yes |
| 7     | 2015 | Quantitative | Preparedness | United States of America | High income | Virtual radiation-related disaster | Computerized virtual reality simulation | First responder training: Decontamination | Students nurse students | Yes |
| 8     | 2018 | Quantitative | Preparedness | Spain | High income | Virtual mass casualty incidents | Immersive virtual reality simulation | First responder training: Triage | Students nurse students | Yes |
| 9     | 2019 | Quantitative | Preparedness | Germany | High income | Mass casualty incident drills | Augmented reality with wearable smart glasses | Telemedicine Damage assessment: Triage | First responders paramedics | Yes |
| 10    | 2016 | Quantitative | Preparedness | Canada | High income | Virtual mass casualty incidents | Computerized virtual reality simulation | First responder training: Triage | Students paramedical students | Yes |
| 11    | 2019 | Quantitative | Preparedness | Germany | High income | Virtual facility fires | Immersive virtual reality simulation | Evacuation route decision making | All | Yes |
| Study  | Year  | Data type | Disaster phase | Country                      | World Bank status | Disaster type                                                                 | Technologies                                                                 | Purposes for technologies                                                                 | Intended users                                                                                     | Challenges described? |
|--------|-------|-----------|----------------|------------------------------|-------------------|-------------------------------------------------------------------------------|--------------------------------------------------------------------------------|------------------------------------------------------------------------------------|-----------------------------------------------------------------------------------------------|
| 12 Ko et al. | 2014  | Qualitative | Prevention/Mitigation preparedness Response resilience | United States of America | High income | Simulated hurricane/food poisoning/power shortage/traffics | Computational visual analytics simulation platform | Damage assessment Improve various disaster management/decision making Early warning system coverage/high-risk maps for preparedness Risk planning First responder training: Triage | National government (nonmilitary) Community                                                                 | Yes |
| 13 Lugi Ingrassia et al. | 2015  | Quantitative | Preparedness | Italy | High income | Virtual mass casualty incidents | Computerized virtual reality simulation Full-scale simulation | First responder training: Triage Students/medical students | Yes |
| 14 Mills et al. | 2019  | Quantitative | Preparedness | Australia | High income | Virtual mass casualty incidents | Computerized virtual reality simulation Full-scale simulation | First responder training: Triage Students (paramedical students) | Yes |
| 15 Ngo et al. | 2016  | Mixed method | Preparedness | United States of America | High income | Virtual earthquake/ hazmat/dirty bomb mass casualty incidents | Computerized virtual reality simulation Full-scale simulation | First responder training: Triage Students/nurse students | First responders EM residents Yes |
| 16 Smith et al. | 2018  | Mixed method | Preparedness | United States of America | High income | Virtual radiation-related disaster | Immersive virtual reality simulation | First responder training Decontamination Improve various disaster management/decision making | Students/nurse students | Yes |
| 17 So et al. | 2019  | Mixed method | Preparedness | United States of America | High income | Virtual smallpox outbreak | Virtual tabletop exercise simulation | Risk planning First responder training: triage/first aid | National government (nonmilitary) | Yes |
| 18 Unver et al. | 2018  | Quantitative | Preparedness | Turkey | Middle income | Earthquake drills | Full-scale simulation | Coverage/high-risk maps for preparedness Risk planning First responder training: triage/first aid | Students/nurse students | Yes |
| 19 Weichelt et al. | 2018  | Quantitative | Preparedness response | United States of America | High income | Facility fire drills | Augmented reality with hazard analysis Visual mapping display | National government (nonmilitary) Community First responders | Yes |
every article mentioned the challenges they faced during HFS technology implementation.

**Descriptive high-fidelity simulation technology statistics**

The HFS technologies evaluated can be divided into nine categories. Table 4 displays all the HFS technology categories with further details.

**Immersive virtual reality simulation** uses a motion-tracked stereoscopic 3D head-mounted display with motion-tracked hand controls. All articles covered only the preparedness phase of a disaster, and most assessed the effectiveness of immersive virtual reality simulation on training professional degree-seeking students \( n = 2, 33.3\% \) and first responders \( n = 2, 33.3\% \) for mass casualty incident triage, fire response, and chemical/radiological decontamination. However, some articles analyzed the capacity of immersive virtual reality simulation for evacuation route decision making. Immersive virtual reality simulation was shown to be a cost-effective, accessible, and viable method of both learning and retention in disaster preparedness and evacuation that required disaster-specific low-volume/high-risk skills.

**Computerized virtual reality simulation** uses a three-dimensional desktop computer environment and mouse-and-keyboard controls. All articles only covered a disaster’s preparedness phase and analyzed computerized virtual reality simulation with the intent of assessing its effectiveness for professional degree-seeking student \( n = 4, 66.6\% \) and first responder \( n = 2, 33.3\% \) training for natural disaster/mass casualty incident triage or chemical/radiological decontamination. Computerized virtual reality simulation was shown to be safe and cost-effective for preparing for mass casualty incidents or epidemics given its minimal resource utilization, training site flexibility, and ease of reconfiguring for training disaster-specific low-volume/high-risk skills that must be performed with accuracy.

**Full-scale simulation** combines mock injured high-fidelity manikins in a high-fidelity environment with digital video-recording and wireless communication to create realistic disaster conditions. All articles covered only the preparedness phase, and analyzed full-scale simulation with the intent for professional degree-seeking student \( n = 3, 75\% \) and first responder \( n = 1, 25\% \) training on various disaster management/decision-making skills for natural disaster/mass casualty incident triage or chemical/radiological decontamination. High-fidelity hybrid simulation using both full-scale simulation and standardized patients had clinical superiority in teaching complex clinical skills. Furthermore, full-scale simulation created a superior clinical training environment and provided the ability to repetitively...
train critical skills and actions in both patient care and disaster management, including teamwork, interpersonal communications, and coordination of care.\(^{19}\)

**Augmented reality wearable smart glasses simulation** displays clinical algorithm and telemedicine assistance with augmented reality displaying a triage algorithm within the glasses and using its integrated camera to connect with a senior physician. All three articles covered both preparedness and response phases and analyzed augmented reality wearable glasses with the intent of assessing their usability and reliability for first responder training on mass casualty incident triage with telemedical assistance.\(^{22-24}\) This simulation technology was promising as both a telemedicine and an augmented-reality disaster response support system.\(^{23}\)

**Simulation technology use in the prevention/mitigation phase**

Only two articles explored HFS technology use in the prevention/mitigation phase.\(^{25,26}\) One analyzed the computational virtual reality analytics simulation, wherein a computer graphics three-dimensional visual display simulates flooding dynamics for the assessment and management to plan disaster prevention measures and rescue interventions for national governments and communities.\(^{26}\) The other analyzed the computational visual analytics simulation—a visual analytics platform that consists of a desktop computer application, a component model, and a host of simulation components for modeling different societal threats to plan optimal mitigation measures for national governments and communities.\(^{25}\) These HFS technologies enabled prevention/mitigation planning, increased preparedness and response to a situation, and improved community resilience.\(^{25}\)

**Simulation technology use in the resilience phase**

Only three articles explored HFS technology use in the resilience phase.\(^{25-27}\) Two studies on computational virtual reality analytics simulation and computational visual analytics simulation were previously discussed.\(^{25,26}\) The third analyzed the virtual reality leap motion control simulation, and includes virtual reality games used in neurorehabilitation and provides the user with biofeedback to permit the training of fine motor tasks to improve hand function.\(^{27}\)

**DISCUSSION**

Today’s world is troubled with devastating natural disasters, terrorist attacks, and the pandemic viral infection. Disasters are complex and cause a level of confusion for those involved. Developing a simulation technology to effectively manage the situation is inherently challenging. It is significant that a simulated environment with a high level of detail and organization has been successfully implemented.\(^{19}\) HFS technology has been developed in recent decades. Simulation technology allows interactive and immersive activity by recreating all or part of a disaster experience without associated risks for those involved. The range of available technologies used in simulation is growing exponentially. These range from simple partial task trainers to highly sophisticated computer-driven HFS models, depending on fidelity (Table 1).\(^6\)

This integrative literature review of HFS technologies in disaster preparations revealed several important deficiencies that should be evaluated in future studies. More validated studies on the use of HFS in all disaster types and phases are required, and additional experimental design considerations to strengthen the scientific rigor and quality of HFS research are recommended.

Almost all articles included in this review discussed the use of HFS technologies to prepare for mass casualty incidents, facility fire, natural disasters of earthquake, hurricane, and flooding, or CBRNE (chemical, biological, radiological, nuclear, explosive disaster). These were motivated by the high number of articles that discussed the ability for simulation education to cover various types of disasters in the preparedness phases by creating safe realistic clinical learning experiences meticulously for professional degree-seeking students and first responders including paramedics, nurses, and physicians. However, according to an epidemiology report in 2015, 40% of all natural disaster-related deaths worldwide were caused by storms, 27% from extreme temperatures, and 26% from flooding.\(^{28}\) Therefore, further research could be needed to determine the use of HFS technologies more for these additional disaster types. Further, nearly all of articles that were identified in the review originated from high-income nations. However, 59% of global deaths from weather-related disasters occur in low- or middle-income countries (LMICs).\(^{28}\) Nearly 70% of the articles reporting on the use of HFS technology focused on the preparedness phase of the disaster cycle. Minimal work attempted to simulate the prevention/mitigation, response, and recovery phases. Literature reviews can suffer from reporting bias. This was minimized by using the best practice guidelines (PRISMA) to form the methodology of this review and its reporting.\(^8\) Included articles came from five disciplines: paramedical, nursing, medicine, rehabilitation, and disaster management. Most of the articles discussed the challenges of their protocol, citing limitations such as a small sample size and nonrandom allocation. The gold standard for scientific intervention research is the randomized
| Technology                                      | Number of articles | Purpose for technology (Top 3)                                    | Disaster type for technology (Top 3)                                      | Disaster phase of technology | Intended user | Location of technology |
|------------------------------------------------|--------------------|-------------------------------------------------------------------|--------------------------------------------------------------------------|-----------------------------|---------------|------------------------|
| Immersive virtual reality simulation           | 6                  | 1. First responder/student training                               | 1. Facility fire                                                          | Preparedness: 100%          | Students: 33.3% | High income: 83.3%     |
|                                                |                    | 2. Evacuation route decision making                               | 2. Chemical/Radiological                                                  |                             | First responders: 33.3% | Middle: 16.7%         |
|                                                |                    | 3. Decontamination training                                       | 3. Mass casualty incidents (miscellaneous)                               |                             | OR staff: 50%    |                        |
|                                                |                    |                                                                  |                                                                          |                             | NICU staff: 50% |                        |
|                                                |                    |                                                                  |                                                                          |                             | All: 33.3%      |                        |
| Computerized virtual reality simulation        | 6                  | 1. Student/first responder training                               | 1. Mass casualty incidents (miscellaneous)                               | Preparedness: 100%          | Students: 66.6% | High income: 100%      |
|                                                |                    | 2. Improve various disaster management/decision making            | 2. Earthquake                                                            |                             | Paramedical students: 50% |                   |
|                                                |                    | 2. Decontamination training                                       | 2. Chemical                                                              |                             | Nursing students: 25% |                   |
|                                                |                    |                                                                  | 2. Radiological                                                          |                             | Medical students: 25% |                   |
|                                                |                    |                                                                  |                                                                          |                             | First responders: 33.3% |                   |
|                                                |                    |                                                                  |                                                                          |                             | ED nurses: 50%   |                   |
|                                                |                    |                                                                  |                                                                          |                             | EM residents: 50% |                    |
| Full-scale simulation                          | 4                  | 1. Student training                                               | 1. Mass casualty incidents (miscellaneous)                               | Preparedness: 100%          | Students: 75%   | High income: 83.3%     |
|                                                |                    | 2. Improve various disaster management/decision making            | 2. Earthquake                                                            |                             | Nursing students: 66.6% |                   |
|                                                |                    |                                                                  | 3. Chemical                                                              |                             | Medical students: 33.3% |                   |
|                                                |                    |                                                                  |                                                                          |                             | First responders: 25% |                   |
|                                                |                    |                                                                  |                                                                          |                             | EM residents: 100% |                   |
| Augmented reality wearable smart glasses       | 3                  | 1. Telemedicine                                                   | 1. Mass casualty incidents (miscellaneous)                               | Preparedness: 100%          | First responders: 100% | High income: 100%     |
| simulation                                      |                    | 1. Damage assessment                                              |                                                                          | Response: 100%             | Paramedics 100% |                        |
| Augmented reality hazard analysis visual mapping simulation | 1                | 1. Coverage/high-risk maps for preparedness                      | 1. Facility fires                                                        | Preparedness: 100%          | National government: 100% | High income: 100%     |
|                                            |                    |                                                                  |                                                                          | Response: 100%             | (nonmilitary)     |                        |
| Virtual reality leap motion control simulation | 1                  | 1. Rehabilitation and biofeedback for hand burn/fine motor function | 1. Explosion                                                            | Resilience: 100%            | Patients/survivor: 100% | High income: 100%     |
| Virtual tabletop exercise simulation           | 1                  | 1. Improve various disaster management/decision making            | 1. Biological                                                            | Preparedness: 100%          | National government: 100% | High income: 100%     |

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controlled trial (RCT).\textsuperscript{29} RCTs in HFS can be done using parallel study or crossover study. However, out of the 21 reviewed articles across five health disciplines in ten countries, only one RCT\textsuperscript{24} was identified and it was not double blinded. The quality and scientific rigor of the HFS technology in each article were therefore not able to be assessed. By contrast, there was no evidence of negative outcomes on HFS technologies.

**LIMITATIONS**

THIS REVIEW INCLUDED only peer-reviewed scientific literature. Gray literature may provide additional examples of novel HFS technologies. This study addressed the scope of HFS technology use but not study quality. Finally, non-English language studies were not included.

**CONCLUSION**

AN INTEGRATIVE LITERATURE review that focused on the use of HFS technologies for disaster management had several important findings. Included articles largely focused on disaster simulation trainings for students and first responders in high-income countries. This may be the result of resource disparities between high-income countries and LMICs. Therefore, further studies that evaluate the utility of HFS technologies in LMICs are needed. The types of disasters in which HFS technologies were used did not reflect the human impact of natural disasters such as extreme temperatures. The articles in this review nearly overlooked the response phase, the recovery phase, and the prevention/mitigation phase, and did not evaluate potential users such as humanitarian aid workers and logistic specialists. Future research should be focused on economic disparities, disaster type and phase, and the potential for these technologies to simulate protracted or complex disasters that include multiple heterogeneous causes. This information would help future implementers in assessing how to deal with practical limitations especially in LMICs, such as nonexistent or failed infrastructure, and the technological and literacy challenges of potential users.

HFS has the potential to provide an authentic training environment, secure response, valuable risk planning, and smooth resilient opportunities for disasters while realistically simulating disaster experiences, in which to develop nontechnical skills, that is safe and controlled so that the participants are able to make mistakes, correct those mistakes in real time, and learn from them, without fear of

### Table 4. (Continued)

| Technology                          | Number of articles | Purpose for technology (Top 3)                                                                 | Disaster type for technology (Top 3) | Disaster phase of technology | Intended user | Location of technology |
|-------------------------------------|--------------------|------------------------------------------------------------------------------------------------|-------------------------------------|-------------------------------|---------------|------------------------|
| Computational virtual reality analytics simulation | 1                  | 1. Coverage/high-risk maps for preparedness 1. Improve various disaster management/decision making 1. Risk planning | 1. Flooding                        | Prevention/mitigation: 100% Preparedness: 100% Response: 100% Resilience: 100% | National government: 100% (nonmilitary) Community: 100% | High income: 100% |
| Computational visual analytics simulation | 1                  | 1. Coverage/high-risk maps for preparedness 1. Improve various disaster management/decision making 1. Risk planning 1. Early warning system | 1. Hurricane 1. Food contamination 1. Power shortage 1. Traffics | Prevention/mitigation: 100% Preparedness: 100% Response: 100% Resilience: 100% | National government: 100% (nonmilitary) Community: 100% | High income: 100% |

ED, emergency department; EM, emergency medicine; NICU, neonatal intensive care Unit; OR, operation room.
conducting the literature review. Besides, HFS may be less expensive and easier to organize than large-scale disaster drills; in particular, low- and medium-fidelity simulations may be less expensive and easier to organize than situational disaster task training. Future studies should expand the potential use of HFS technology to additional types of health-care providers, improve their experimental quality, and include cost-effectiveness measures. This will not only permit higher evidence-based HFSs but also bridge the gaps between HFS research and better disaster preparedness, response, resilience, and prevention.

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DISCLOSURE

Approval of the research protocol: N/A.
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