*Disaster Medicine and Public Health Preparedness*

**www.cambridge.org/dmp**

**Original Research**

**Cite this article:** Weinstein ES, Bortolin M, Lamine H, *et al*. The challenge of mass casualty incident response simulation exercise design and creation: A modified Delphi study. *Disaster Med Public Health Prep*. **17**(e396), 1–12. doi: https://doi.org/10.1017/dmp.2023.71.

**Keywords:**
MCI simulation; MCI full scale exercise; translational science; scoping review; delphi study

**Corresponding author:**
Eric S Weinstein,
Email: eswein402@gmail.com



SDMPH
SOCIETY FOR DISASTER MEDICINE & PUBLIC HEALTH

# The Challenge of Mass Casualty Incident Response Simulation Exercise Design and Creation: A Modified Delphi Study

Eric S Weinstein MD, MScDM[1,2], Michelangelo Bortolin MD[1,3,4], Hamdi Lamine MSc, PhD[1,2,5], Teri Lynn Herbert MS, MLIS[6], Ives Hubloue MD, PhD, CEDE, FESEM[7], Sofie Pauwels MD[7,8], Rita V Burke PhD, MPH[8], Mark X Cicero MD[9], Phoebe O Toups Dugas PhD[10], Elizabeth O Oduwole MBBS, DA[11], Luca Ragazzoni MD, PhD[1,2] and Francesco Della Corte MD[1,3]

[1]CRIMEDIM, Center for Research and Training in Disaster Medicine, Humanitarian Aid and Global Health, Università del Piemonte Orientale, Novara, Italy; [2]Department for Sustainable Development and Ecological Transition, Università del Piemonte Orientale, Vercelli, Italy; [3]Department of Translational Medicine, Università del Piemonte Orientale, Novara, Italy; [4]BIDMC Disaster Medicine Fellowship, Department of Emergency Medicine, Beth Israel Deaconess Medical Center, Boston, Massachusetts USA; [5]Faculty of Medicine, Ibn Aljazzar of Sousse, University of Sousse, Sousse, Tunisia; [6]Medical University of South Carolina Library, Charleston, South Carolina, USA; [7]Research Group on Emergency and Disaster Medicine, Vrije Universiteit Brussel, Brussels, Belgium; [8]Department of Population and Public Health Sciences and Department of Pediatrics, USC Gehr Family Center for Health Systems Science & Innovation, Keck School of Medicine, University of Southern California, Los Angeles, California, USA; [9]Department of Pediatrics, Yale University School of Medicine, New Haven, Connecticut, USA; [10]Department of Computer Science, New Mexico State University, Las Cruces, New Mexico, USA and [11]General Hospital, Apapa, Lagos, Nigeria

## Abstract

**Background:** A Mass Casualty Incident response (MCI) full scale exercise (FSEx) assures MCI first responder (FR) competencies. Simulation and serious gaming platforms (Simulation) have been considered to achieve and maintain FR competencies. The translational science (TS) T0 question was asked: how can FRs achieve similar MCI competencies as a FSEx through the use of MCI simulation exercises?

**Methods:** T1 stage (Scoping Review): PRISMA-ScR was conducted to develop statements for the T2 stage modified Delphi (mD) study. 1320 reference titles and abstracts were reviewed with 215 full articles progressing for full review leading to 97 undergoing data extraction.

T2 stage (mD study): Selected experts were presented with 27 statements derived from T1 data with instruction to rank each statement on a 7-point linear numeric scale, where 1 = disagree and 7 = agree. Consensus amongst experts was defined as a standard deviation ≤ 1.0.

**Results:** After 3 mD rounds, 19 statements attained consensus and 8 did not attain consensus.

**Conclusions:** MCI simulation exercises can be developed to achieve similar competencies as FSEx by incorporating the 19 statements that attained consensus through the TS stages of a scoping review (T1) and mD study (T2), and continuing to T3 implementation, and then T4 evaluation stages.

## Introduction

The complexity of an individual first responder participating in a sudden onset disaster mass casualty incident response (MCI),[1] involves their patient care or duty skills, and the layering of their participation in their agency's Incident Management System (IMS).[2] The first responder's usual, daily standard operation command and control, changes once the MCI is declared. The first responder must have the skills required for MCI patient care or duty station, but they must also operate in the rarely utilized agency MCI-plan IMS. A live full-scale exercise (FSEx) examines these relationships; the communication between the first responder and the patient, and the responder's IMS to prepare the first responder and system for an actual MCI response (Figure 1).

An FSEx presents obstacles and challenges for designers, developers, planners, and exercise conductors to fulfill the mission of ensuring first responder competencies and MCI plan effectiveness (Supplemental digital content Figure 1s).[3] Staff, stuff, and structures (SSS),[4] may be stretched thin to cover the daily need for medical services, l*et al*one devote staff for training to gather appropriate observers, evaluators, volunteers to recruit/ moulage patient actors, and the technical staff to conduct an FSEx. Furthermore, government permits may be needed to alter road, highway, plane, and train transportation routes and/ or ensure that ecological and environmental concerns are considered in the FSEx – all time-consuming activities.

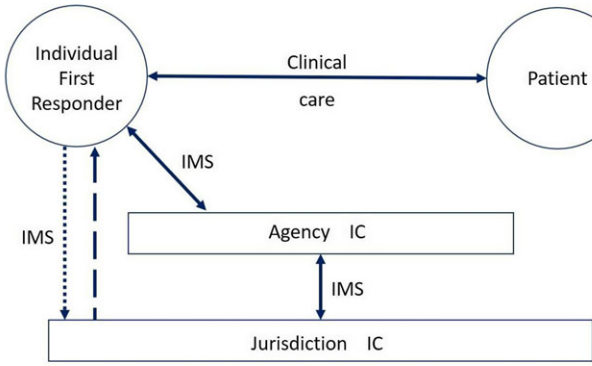


**Figure 1.** Relationships of the first responder in an MCI.
IC = Incident Command
IMS = Incident Management System
Agency = The pre-hospital or hospital, government or non-government, agency, organization, group, hospital, or health care delivery system of the individual first responder
Jurisdiction = The lead command and control health authority of the MCI response
←——→ Direct 2-way interaction between the first responder with the patient and simultaneously with their agency incident command
— — — — → Jurisdiction provides command and control to the First Responder
·········→ First Responder may provide information to the Jurisdiction Incident Command

Travel to a conference that features an FSEx adds a budgetary constraint and creates a void in the staffing schedule, and there may be no capable replacement for the first responder. Education and training budgets must include resources to devote to training for the rare MCI, when emergency medical services (EMS) and health care facility administrators must also assure appropriate education and training for staff to achieve competencies for daily operations. Even allocating assets for the planning and execution of a valid FSEx may be difficult, regardless of regulatory expectations (e.g., nuclear, airplane, train, manufacturing, etc.).[5,6] Financial and time constraints may limit the discussion and agreement process by health authorities, regulators, first response agency, and health care facility administrators. (Supplemental Digital Content Figure 2)

This dilemma was made vivid with the Coronavirus disease-2019 (COVID-19) response worldwide. Staff and facilities struggled to acquire and maintain SSS to mount a safe COVID-19 response. There was no way to gather responsible actors, create or revise an MCI plan, or develop and execute an FSEx. Face-to-face classroom learning and travel to conferences became a public health casualty to prevent the spread of COVID-19.

Simulation and serious gaming (Simulation) for skills-based medical education has become an effective adjunct to, or has supplanted conventional methodologies, and was considered to replace face-to-face MCI response education, and training to achieve similar or equal first responder competencies. The challenge of the realism that an FSEx creates for first responders' critical decisions has been postulated to be similar using other simulation methodologies but was not ready to be 'taken off the shelf' to incorporate into an MCI simulation exercise of any scale.

This study is designed to address the scope of the NO-FEAR Project (Network Of practitioners For Emergency medicAl systems and cRitical care) under work package number 5[7]: education and training of personnel and volunteers, regarding technical and non-technical skills, teamwork, critical thinking, clinical care, incident management, and psychological support. NO-FEAR asks for new simulation tools for education and training to achieve MCI response competencies (e.g., high-fidelity and live simulation, 2-dimensional enhanced and immersive simulation software, tools to provide quantitative, and qualitative evaluation of responders' performance during exercises).[7] The present research is aimed at describing the design needs for future MCI response training simulations through a combination of literature review and expert assessment that achieves equal or similar competencies as a FSEx. A competency component of the MCI response training simulation design is to approximate the realism of the FSEx to better prepare the first responder for an actual dynamic MCI response.

## Methods

This translational science (TS) study begins with the TS question (T0)[8]: How can first responders achieve similar MCI competencies as an FSEx using MCI simulation exercises?

The objective of this study produced the first stage (T1) scoping review and second stage (T2) modified Delphi study (mD) consensus statements that can be offered to formulate MCI simulation exercise guidelines in the future TS third (T3) MCI simulation exercise creation stage. The fourth TS (T4) stage that follows will study these MCI simulation exercises to determine if similar or equal FSEx competencies were obtained.

### *T1: Scoping review*

A systematic review following the Preferred Reporting Items for Systematic reviews and Meta-Analyses extension for Scoping Reviews (PRISMA-ScR),[9] was conducted from August 2021 through October 2021. Scoping reviews synthesize knowledge following a defined scientific process to identify sources that can be interrogated using a defined data extraction tool to determine concepts, theories, and knowledge gaps.[10] The study of MCI education, training, and exercises that lead to competencies is multi-disciplinary, creating a body of knowledge that is heterogeneous, and thus apropos for PRISMA-ScR methodology.[11]

#### *Literature search criteria*

A T0 research question was developed using the Patient, Intervention, Control/ Comparison, Outcome (PICO) standard to frame the search strategy.[12]

1) Population: MCI, pre-hospital and hospital providers, simulation training exercise, or drill.
2) Intervention: Not MCI simulation training exercise or drill, individual duty station competencies.
3) Comparison: Individual intra-agency and inter-agency IMS competencies.
4) Outcomes: Intra-agency and inter-agency IMS competencies.

#### *Literature search methods*

*Inclusion criteria.* The search strategy included only terms relating to or describing the intervention (Table 1). The review included English-language papers published from January 1, 1990, to July 1, 2021, in these databases:

1) PubMed (National Center for Biotechnology Information, National Institutes of Health, Bethesda, Maryland, USA)
2) SCOPUS (The largest and most comprehensive abstract and citation database of peer-reviewed literature from Elsevier, Netherlands)

https://doi.org/10.1017/dmp.2023.71 Published online by Cambridge University Press

**Table 1.** T1 scoping review search terms

| Database | Search terms |
|---|---|
| Scopus: | “‘disaster management”’ OR “‘disaster medicine”’ OR “‘disaster response”’ OR “‘disaster planning”’ OR “‘first responder*”’<br>AND<br>simulat* OR tabletop OR “‘tabletop”’ OR virtual OR computer OR “‘artificial reality”’ OR “‘augmented reality”’ OR gamification<br>AND<br>exercise* OR drill OR training OR education<br>AND<br>earthquake* OR terror* OR hurricane* OR “‘building collapse”’ OR “‘bridge collapse”’ OR “‘train crash”’ OR “‘plane crash”’ OR “‘train derailment”’ OR tornado OR “‘natural disaster’*” OR cyclone* OR explosion OR wildfire OR “‘airplane crash”’ OR avalanche OR landslide OR mudslide OR flood* OR disaster* OR “‘mass casualty”’ OR “‘sudden onset disaster*”’ OR bioterrorism OR tsunami* OR volcano* |
| DTIC (DoD): | disaster OR “‘mass casualty”’<br>AND<br>training OR education OR simulation OR virtual OR tabletop OR computer |
| PubMed: | disaster medicine [MeSH] OR “‘disaster management”’ OR “‘disaster medicine”’ OR “‘disaster response”’ OR “‘first responder*”’<br>AND<br>computer simulation [MeSH] OR simulat* OR tabletop OR “‘tabletop”’ OR virtual OR computer OR “‘artificial reality”’ OR “‘augmented reality”’ OR gamification<br>AND<br>disasters [MeSH] OR earthquake* OR terror* OR hurricane* OR “‘building collapse”’ OR “‘bridge collapse”’ OR “‘train crash”’ OR “‘plane crash”’ OR “‘train derailment”’ OR tornado OR “‘natural disaster*”’ OR cyclone* OR explosion OR wildfire OR “‘airplane crash”’ OR avalanche OR landslide OR mudslide OR flood* OR disaster* OR “‘mass casualty”’ OR “‘sudden onset disaster’*” OR bioterrorism OR tsunami* OR volcano* |
| CINAH: | Exp MH disaster planning OR “‘disaster management”’ OR “‘disaster medicine”’ OR “‘disaster response”’ OR “‘disaster planning”’ OR “‘first responder’*”<br>AND<br>Exp MH simulation OR Exp MH Computer simulation OR simulat* OR tabletop OR “‘tabletop”’ OR virtual OR computer OR “‘artificial reality”’ OR “‘augmented reality”’ OR gamification<br>AND<br>Exp MH disasters OR Exp MH natural disasters OR earthquake* OR terror* OR hurricane* OR “‘building collapse”’ OR “‘bridge collapse”’ OR “‘train crash”’ OR “‘plane crash”’ OR “‘train derailment”’ OR tornado OR “‘natural disaster*”’ OR cyclone* OR explosion OR wildfire OR “‘airplane crash”’ OR avalanche OR landslide OR mudslide OR flood* OR disaster* OR “‘mass casualty”’ OR “‘sudden onset disaster*”’ OR bioterrorism OR tsunami* OR volcan* |
| PsycInfo: | Exp MH emergency preparedness OR “‘disaster management”’ OR “‘disaster medicine”’ OR “‘disaster response”’ OR “‘disaster planning”’ OR “‘first responder*”’<br>AND<br>Exp MH simulation OR Exp MH Computer simulation OR simulat* OR tabletop OR “‘tabletop”’ OR virtual OR computer OR “‘artificial reality”’ OR “‘augmented reality”’ OR gamification<br>AND<br>Exp MH disasters OR earthquake* OR terror* OR hurricane* OR “‘building collapse”’ OR “‘bridge collapse”’ OR “‘train crash”’ OR “‘plane crash”’ OR “‘train derailment”’ OR tornado OR “‘natural disaster’*” OR cyclone* OR explosion OR wildfire OR “‘airplane crash”’ OR avalanche OR landslide OR mudslide OR flood* OR disaster* OR “‘mass casualty”’ OR “‘sudden onset disasterr*” OR bioterrorism OR tsunami* OR volcano* |
| ECRI: | disaster OR “‘mass casualty”’<br>AND<br>training OR education OR simulation OR virtual OR tabletop OR computer |

3) CINAHL (Cumulative Index to Nursing and Allied Health Literature, EBSCO, Elton B Stephens Company, Ipswich, Massachusetts, USA)
   - DTIC (Defense Technical Information Center, United States Department of Defense) database for reports and other government publications
   - ECRI (Emergency Care Research Institute, Plymouth Meeting, Pennsylvania, USA) Trust for published guidelines
   - PsycInfo (American Psychological Association, Washington District of Columbia, USA) validating surveys/questionnaires on disaster training databases.

Finally, an ancestry search was also performed to identify additional references from the bibliography of references when appropriate.

*Exclusion criteria.* References from the databases that did not meet the inclusion criteria, specifically did not study, or report an MCI/MCI exercise, were excluded.

PRISMA ScR Figure 2

2 review authors independently screened 1320 reference titles and abstracts to determine if inclusion criteria were met; any disagreement was resolved by discussion. Then each of the remaining 215 full articles was read by both authors to determine if inclusion criteria were met, and again any disagreement was resolved by discussion.

Of the remaining 97 included articles,[13–110] 47 discussed competencies,[16–19,24,29–39,41–44,46–55,71,84,90,91,95,96,99,100,103–110] and were split between 2 authors to extract data into an Excel database (Microsoft Corp., Redmond, Washington, USA) that was developed using themes and subthemes from MCI exercise publications to derive statements for the mD.[111–115] (Supplemental Digital Content link to Excel database)

### *T2: Modified Delphi study*

The mD method permits experts from various locations to independently review statements to attain consensus when no

https://doi.org/10.1017/dmp.2023.71 Published online by Cambridge University Press

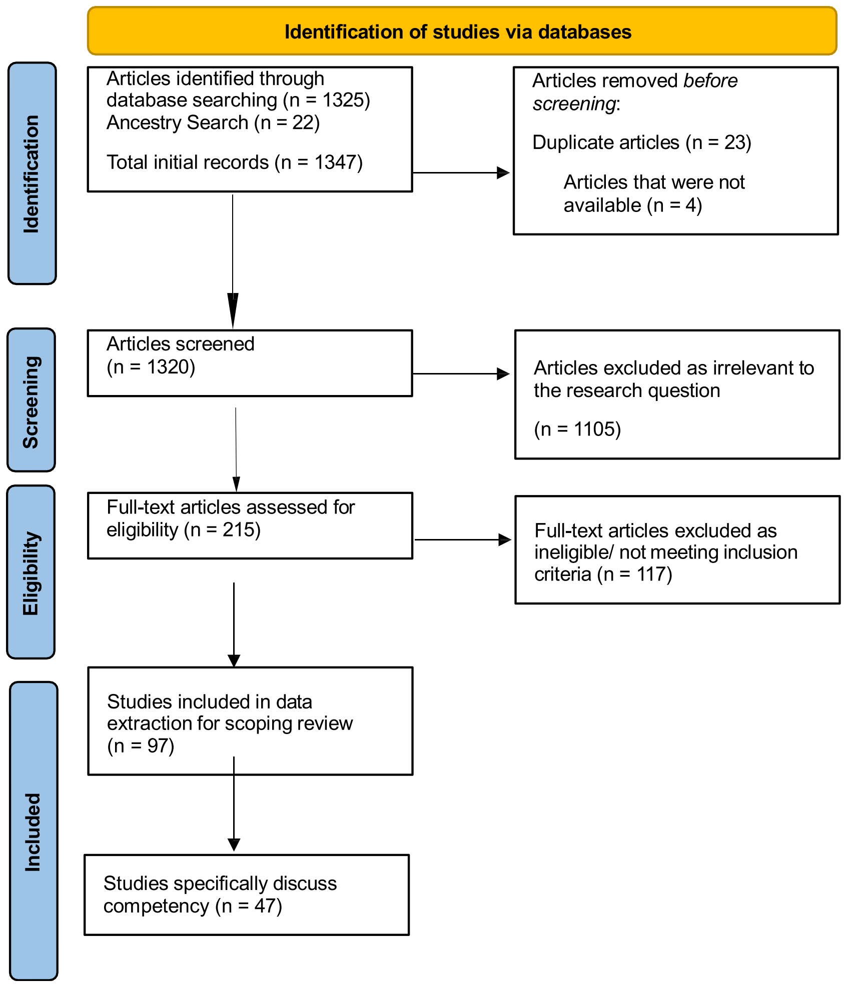


**Figure 2.** PRISMA flow diagram.[9]
Included References.[13–110]
Specifically discussing competencies.[16–19,24,29–39,41–44,46–55,71,84,90,91,95,96,99,100,103–110]

consensus existed previously.[9] The first stage of the mD began after the final database was analyzed by lead authors who created initial draft statements based on the most relevant datapoints. Then an internal focus group of authors discussed and edited these statements to meet the format of Delphi statements for the Stat59 statistical analysis platform (Stat59 Services Limited, Alberta, Canada).[116] An external focus group comprised of content experts in the field of MCI simulation exercises and NO-FEAR partners was established to further discuss and edit the draft statements to be clear and concise. After a video conference moderated by the lead authors, these experts discussed the draft statements. External focus group participants performed asynchronous editing via a shared online document producing the final 27 statements for the second stage of the mD.

A list of content experts, derived from the authors of included references, academicians, and researchers studying MCI simulation exercises was created to establish the mD expert panel. Introductory emails were sent explaining the project objectives and the mD to these mD experts.

mD experts that agreed were sent an email from the Stat59 (Stat59 Services Limited, Alberta, Canada) mD organizational program on the day that the mD began with a link to the Stat59 (Stat59 Services Limited, Alberta, Canada) website consent page. Each mD expert registered an account, validated it, and were sent a new email to log into their secure webpage to begin the first mD expert consensus round. 3 days later, mD experts that had not logged into the system were asked to verify their access and log in and asked to notify the author if they had not received the introductory email, with instructions on how to ensure future emails were received.

Once the mD experts logged in, they were provided with a formal explanation of the mD methodology and informed consent was obtained. For informed consent (Supplemental Digital Content link to Stat59 Consent Page), participants were notified that they were anonymous volunteers who could withdraw at any time, that participation or withdrawal would not impact their employment, and that their data was secure (Supplemental Digital Content link to Stat59 Security Page).

The next page was the list of 27 statements that were finalized in the T2 external focus group with instruction to rank each statement on a 7-point linear numeric scale, where 1 = disagree and 7 = agree. With this initial set of statements, the mD expert was asked to answer 4 demographic questions. Consensus amongst mD experts was defined as a standard deviation ≤ 1.0.

Statements that attained consensus after this first mD expert round were included in the final report. Each mD expert received an email from the Stat59 (Stat59 Services Limited, Alberta, Canada) program after the first mD expert round and a reminder email from

https://doi.org/10.1017/dmp.2023.71 Published online by Cambridge University Press

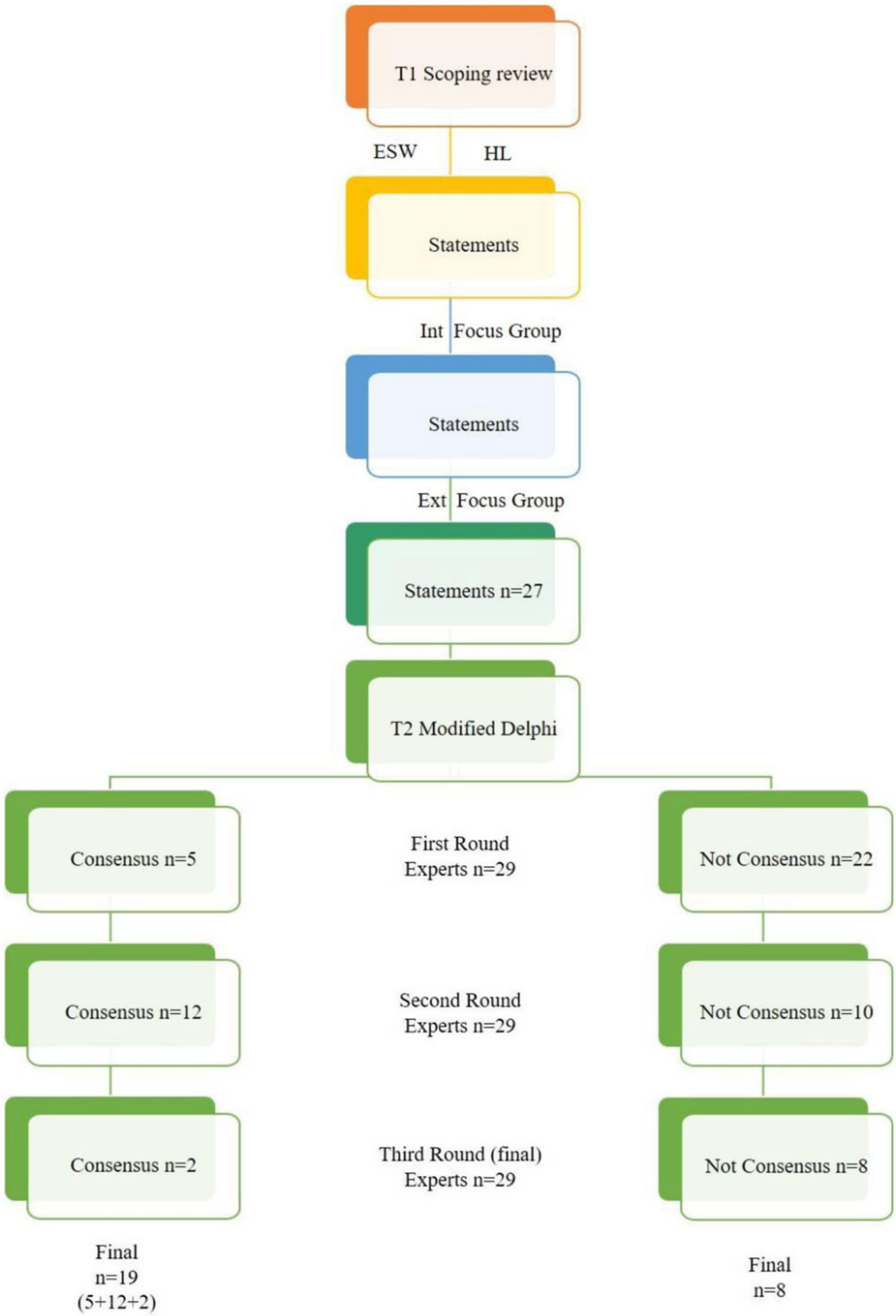


**Figure 3.** Modified Delphi statement creation.

the author shortly afterwards to log back into their Stat59 page that showed the mean response of all the mD experts for each statement that did not attain consensus, their own response for that specific remaining statement, and were asked to reconsider their 7-point linear numeric scale for these remaining statements.

This process was repeated after the second mD expert round with statements that attained consensus included in the final report. The statements that did not attain consensus were advanced to the third and final round with the mD experts asked to reconsider these statements. This third mD expert round produced the final statements that attained consensus to add to the first and second round consensus statements in the final report. Remaining statements after this third round were the final statements that did not attain consensus.

The McLeod Health Institutional Review Board Office (Florence, South Carolina USA) has determined that this study does meet the exemption criteria found at 45 CFR 46.104(d)(2).[117]

## Results

As summarized in Figure 3, 35 mD experts confirmed their participation and established a unique account on the Stat59

**Table 2.** Modified Delphi expert panel demographics

| Location of primary Mass Casualty Incident Response education, training, planning, or operations employment (n = 33, 2 experts did not complete the demographic survey) | |
|---|---|
| Sub-Saharan Africa | 0 |
| East Asia and Pacific | 2 |
| Europe and Central Asia | 9 |
| Middle East and North Africa | 5 |
| Latin America and Caribbean | 0 |
| North America | 17 |
| **Primary employment (n = 33)** | |
| University or research center | 27 |
| Governmental Organization | 6 |
| Non-Governmental Organization | 0 |
| Private sector | 0 |
| Other | 0 |
| **Current profession (n = 33)** | |
| Education/ training | 25 |
| Research | 18 |
| Response/ field operations | 8 |
| Physician | 19 |
| Nurse | 5 |
| EMT or paramedic | 2 |
| Fire fighter | 1 |
| Law enforcement | 0 |
| Public safety | 1 |
| Administration and support | 3 |
| Simulation coder, designer, creator | 10 |
| Other | 0 |
| **Years of expertise in this field (n = 33)** | |
| < 5 | 1 |
| 6- 10 | 5 |
| 11 - 15 | 7 |
| > 16 | 20 |

website (Table 2). 31 completed the first mD expert round that was open from January 17, 2022, until January 30, 2022. 5 statements attained statistical significance with a standard deviation ≤ 1.0 after this first mD expert round, and achieved consensus (Table 3, first round, first section in bold). The 22 statements that did not attain statistical significance, with standard deviation > 1.0, were advanced to the second mD expert round.

29 mD experts completed the second mD expert round that was open from January 31, 2022, to February 19, 2022. 12 of the 22 statements that advanced to the second mD expert round achieved consensus (Table 3, second round middle section). The remaining 10 statements were unable to attain consensus and advanced to the third mD expert round.

29 mD experts completed the third and final mD expert round that was open from February 23, 2022, to March 9, 2022. 2 of the remaining 10 statements achieved consensus, so a total of 19 statements achieving consensus. (Table 3 third round, last section in bold). The remaining 8 statements were unable to attain consensus after 3 T2 mD expert rounds and were not recommended for T3 consideration (Table 4).

## Limitations

The PRISMA-ScR produced a qualitative analysis of published studies and reports. Though the search followed this process, there may have been references that were not discovered.

The Delphi method seeks to arrive at group consensus by the aggregate of a panel of experts who rate a statement on a linear numeric scale. Internal validity is largely unknown; therefore, stability of response is more accurate to determine consensus or lack of consensus.

The objective of the distribution of mD experts was to represent MCI simulation exercise designers, developers, and those that would execute an exercise. The distribution of mD experts favor resource rich countries but all experts are involved in MCI exercises in a way.

An essential component of the Central Limit Theorem is that the average of sample means will be the population mean, or if 1 finds the average of all of the standard deviations in the sample, then 1 will find the actual standard deviation for the population.[118] This will hold true regardless of whether the source population is normal or skewed, provided the sample size is sufficiently large (usually ≥ 30, the number of mD experts in this study per round averaged 29.67).[119] The application of the Central Limit Theorem to this study infers that the 19 statements that attained consensus can be recommended to assist the T3 development of guidelines for MCI simulation exercises.

## Discussion

Providing MCI training can be challenging for several reasons: (1) provider schedules are often erratic and involve long hours; (2) there is a temporal dissociation between disaster response training and the application of the skills, leading to cognitive skill decay at the time the skill needs to be performed; and (3) traditional learning methods, such as didactic presentations, tabletop simulations, and FSExs require the physical presence of learners and educators at a certain place and time (synchronous learning).[36] In response, mD experts agreed, educators should design periodic simulation training to maintain competencies of rarely used skills that will deteriorate over time.

Briggs *et al.* showed that heterogeneous organizations with different command structures and missions participate in the response to a disaster, and therefore a clear objective of an MCI plan is to define the IMS of a region.[120] An example of a 2017 FSEx objective of Regional Operability in Ohio (United States) as reported by McElroy is that 'Participants shall identify the management structure to support effective operational coordination between all agencies and entities.'[83] The mD experts agreed that the simultaneous integration of patient care or duty skills (e.g., triage, utilization of resources, communication) and IMS skills should be incorporated into the exercise design to achieve the competency for the individual to recognize and assume their position in their agency MCI plan through situation awareness and critical decision-making.

As the layers of FSEx objectives are incorporated into the FSEx design, mD experts agreed that patient care or duty competencies can be evaluated using distinct separate modalities or as part of an exercise designed to include these skills with IMS skills. mD experts agreed that multiple exercise modalities should be considered to minimize time, cost, and impact to non-participants affected by the exercise. Conceptually a simulation exercise can be created to achieve one of

https://doi.org/10.1017/dmp.2023.71 Published online by Cambridge University Press

**Table 3.** Statements that attained consensus

| Statement | n | Mean | SD |
| --- | --- | --- | --- |
| **An exercise controller should build realism based on a prepared action script to anticipate and deliver injects based on participant's actions and responses to evaluate non-technical communication skills.** | **31** | **6.4** | **0.8** |
| **Educators should design periodic training to maintain competencies of rarely used skills that will deteriorate over time.** | **31** | **6.6** | **0.9** |
| **Safety is to be considered for all participants, non-participants and the surrounding environment that may be affected throughout the exercise.** | **31** | **7.0** | **0.2** |
| **Observers and evaluators should be content experts, considered to be external to the exercise, and use validated template scoring tools.** | **31** | **6.3** | **0.9** |
| **An IMS competency should be to utilize effective means of communication through redundant modalities.** | **31** | **5.9** | **0.9** |
| A competency should be for the individual to recognize and assume their duty position in their agency MCI plan. | 29 | 6.1 | 0.9 |
| Competencies of the individual at their duty station can be evaluated using distinct separate modalities or as part of an exercise designed to include these skills with IMS skills. | 29 | 5.5 | 1.0 |
| The realism created through moulage of simulated patients and the environmental special effects in any simulation setting should focus on the participant's situational awareness and not deter from the overall exercise objectives. | 29 | 6.1 | 1.0 |
| Before a participant begins an exercise, they should receive sufficient education and training to achieve competency in the exercise modalities to promote the overall objectives. | 29 | 6.4 | 0.8 |
| Exercise design and planners should have modality technicians supporting the exercise to be able to recognize and address any participant struggling with the modality to promote the overall objectives. | 29 | 6.0 | 1.0 |
| A semi-structured debrief based on validated formats should include all stakeholders to improve the exercise, using open-ended questions to determine simulation exercise areas of improvement. | 29 | 6.2 | 1.0 |
| The appreciation of the passage of time to accomplish an action should be an exercise component. | 29 | 5.9 | 0.9 |
| Exercise objectives can be to discover latent safety threats (LSTs), which may contribute to medical errors. | 29 | 5.8 | 1.0 |
| MCI triage will occur during the continuum from the initial first responder assessment until arrival at the definitive health care facility. | 29 | 6.1 | 0.8 |
| Multiple exercise modalities should be considered to minimize time, cost and impact to non-participants affected by the exercise. | 29 | 5.7 | 0.9 |
| An incident management competency should include the ability to deliver the right patient to the right alternate care facility or definitive health care facility capable of attending to the injuries of that patient. | 29 | 5.9 | 1.0 |
| The Public Information IMS duty position competency evaluation should encompass intelligence acquisition, vetting and transmission. | 29 | 5.4 | 0.9 |
| **A competency should be the activation by the individual of their specific agency MCI plan through situational awareness and critical decisions.** | **29** | **5.8** | **1.0** |
| **An incident management competency should include the ability to track patients from the scene to an alternate care facility or definitive health care facility.** | **29** | **6.0** | **0.9** |

Bold T2 mDE Rounds 1 and 3
Not Bold T2 mDE Round 2

**Table 4.** Statements that did not attain consensus

| Statement | n | Mean | SD |
| --- | --- | --- | --- |
| **The objective of a mass casualty incident (MCI) exercise should explore gaps in the situational awareness, critical decision-making competencies of an individual and their agency. The individual will represent their agency in their jurisdiction's MCI Incident Management System (IMS).** | 29 | 5.7 | 1.3 |
| **Each interaction between the participant and simulated patient in any modality should be captured to monitor and record accomplishment of specific competencies, and to evaluate and improve the simulation exercise.** | 29 | 5.6 | 1.3 |
| **Validated self-assessment pre- and post-exercise surveys should be designed to improve the education and training process leading to competencies.** | 29 | 5.6 | 1.6 |
| **Exercise objectives should inform the timing of validated post-exercise surveys to determine retention and maintenance of competencies.** | 29 | 5.1 | 1.5 |
| **Extended reality may lead to simulator sickness by stakeholders and should be considered in the exercise.** | 29 | 4.4 | 1.2 |
| **At least 2 trained independent observers and evaluators at the same exercise location should be utilized to provide inter-rater consistency.** | 29 | 5.8 | 1.3 |
| **Observers and evaluators with job action scripts should be able to inject or to alter the progression of the exercise based on their area of expertise.** | 29 | 4.2 | 1.8 |
| **The competency of a participant's decision to place a patient into a triage category should be consistent with their agency's methodology.** | 29 | 5.8 | 1.4 |

https://doi.org/10.1017/dmp.2023.71 Published online by Cambridge University Press

the many IMS competency objectives achieved by an FSEx as required by health authorities, regulators, IMS partners, and stakeholders:

1) Utilize effective means of inter- and intra-agency communication through redundant modalities;
2) Achieve the appropriate continuum of patient triage and treatment from the initial evaluation to definitive care;
3) Deliver the right patient to the right alternate care facility or definitive health care facility capable of attending to the injuries of that patient;
4) Maintain accurate patient tracking leading to expedient hospital registration;
5) Manage resources utilizing the supply chain in a resource scarce environment; and
6) Manage information and media through intelligence acquisition, vetting, and transmission.

MCI simulation education and training is multimodal: lectures, readings, and individual hands-on skill sessions to meet the requirements of the individual's MCI patient care duties. To do that, education must be active, interactive, and experiential, as well as participatory.[121] The additional layers in MCI education and training acknowledge that the individual is part of the IMS. The evolution of MCI simulation exercises will appreciate these complex simultaneous actions of the individual as they manage patient care and their role in the IMS, to achieve the same competencies that the FSEx will produce. To approximate the success of the FSEx, MCI exercise simulation must depend on high physical fidelity to develop the individual's manual abilities, as well as high conceptual fidelity to develop clinical reasoning and problem-solving skills.

Lastly, high emotional or experiential fidelity,[122] where the learner is emotionally invested in the simulation to a degree that memories of the experience are believable, will develop the individual's retention of the material.[44] There must be emotional learning in which positive emotions under stress facilitate greater retention of data. This success is *not* completely based on the realism of the simulation, but on the commitment of the participants in their roles; that there is an adequate connection between those involved; and that the student manages to actively link the social, psychological and clinical experiences lived.[123] The mD experts agreed that the realism created through moulage of simulated patients and environmental special effects in any simulation setting should focus on the participant's situation awareness and not deter from the overall exercise objectives. In 2019, Saunders *et al.*[97] published a study that demonstrated that virtual-reality-based law enforcement trainings, either by themselves or in combination with traditional hands-on training, can be as effective as highly resource-intensive practical training sessions.[123]

Individuals suspend disbelief during the FSEx to approximate the physical and emotional stress of an actual MCI (e.g., the demand of an unknown number of patients with unknown injuries, an unknown supply of SSS in a resource-scarce environment with sensory overload, and fear for their own safety, as well as a failure to accomplish their assignments, or letting their team/ agency down). A successful MCI simulation exercise would match the individual's pressure for realism through their critical decisions suspending disbelief in the simulation environment without the sensory elements inherent in an FSEx. This can be achieved following design principles explained by Alharthi *et al.,* along with the understanding that the designers must simulate the actual experience making the exercise practical through highly cognitive intense work and physical exertion immersing the individual in the simulation.[124] (Supplemental Digital Content Table 1)

To accomplish the objectives of an FSEx, controllers plan and manage exercise play, set up/ operate the exercise site, and act in the roles of organizations, agencies, or individuals that are not playing in the exercise.[125] Controllers direct the pace of the exercise, provide key data to players, and may prompt or initiate certain player actions to ensure exercise continuity. Simulators or facilitators provide feedback and cues based on predetermined expected actions of players as well as injects in response to player's actions that are not expected to maintain the flow of the exercise and to instruct. In addition, they issue exercise material to players as required, monitor the exercise timeline, and supervise the safety of all exercise participants and the surrounding environment.

mD experts agreed that an exercise controller should build realism based on a prepared action script to anticipate and deliver injects based on player's actions and responses to evaluate non-technical communication skills. MCI simulation exercise creators have the challenge to integrate live or reflex injects based on player's responses to the scenario, changes in patient's clinical conditions or other player's actions. An FSEx occurs in real time with all the agencies simultaneously responding; mD experts agreed that the challenge of MCI simulation exercises is the appreciation of the passage of time to accomplish an action as if in the real time of an FSEx. To achieve this level of realism, mD experts agreed that the exercise design should have modality technicians supporting the exercise to be able to recognize and address any participant struggling with the modality to promote the overall objectives.

A crucial component of any MCI simulation is the debriefing process following the activity; this provides a structured reflection for participants to analyze and self-correct their behavior, decisions, and thought processes to promote cognitive accommodation and assimilation of their learning experience into future professional practice.[52] mD experts agreed that observers and evaluators should be specific content experts external to the exercise and use validated template scoring tools to evaluate competencies of players, the exercise itself, and any documentation that is required of regulators or the health authority. These specific content experts can utilize 'debriefing through meaningful learning,'[126] to provide exercise objectives education. mD experts agreed that this debrief can discover latent safety threats through a frank non-punitive discussion to uncover potential actions that may lead to medical errors.[30] mD experts further agreed that a semi-structured debrief based on validated formats should include all stakeholders to improve the exercise, using open-ended questions to determine MCI simulation exercise areas of improvement.

## Conclusion

The modified Delphi experts agreed that the simultaneous integration of individual duty and incident management skills should be incorporated into simulation MCI exercise design to achieve competencies depending on high physical fidelity to develop the individual's manual abilities, as well as high conceptual fidelity, to develop the individual's clinical reasoning and problem-solving skills.

MCI simulation exercises can be developed to achieve similar competencies as FSExs incorporating the 19 statements that attained consensus through the TS stages of a scoping review (T1)

https://doi.org/10.1017/dmp.2023.71 Published online by Cambridge University Press

and mD (T2). The TS process should continue with development of these exercises in the T3 implementation stage and then evaluated in the T4 stage.

**Supplemental digital content.**

1) The database for this study can be found at: https://docs.google.com/spreadsheets/d/153CM_LhR8s0IRod9XbodeWK8wZN-m9NA/edit#gid=876207018
2) The Stat59 Security Page can be found at: https://www.stat59.com/about/security
3) The Stat59 Consent Page can be found at: https://www.stat59.com/projects/delphi-consent-view?pid=145.

**Supplementary material.** For supplementary material accompanying this paper visit https://doi.org/10.1017/dmp.2023.71

**Acknowledgements.** Samra Baxley, George Teo Voicescu and Dalton Weinstein for their administrative assistance; Monica Linty for her assistance with NO-FEAR; Ricardo Galesso with the External Focus Group; The modified Delphi Experts consented to be acknowledged: B Adini, E Alpert, P Andreatta, L Anthony, T Baxley, K Biggers, L Carenzo, D Cone, L Greci Cooke, M Dittmar, J Dohaney, C Evans, NP Foo, E Fragniere, P Halpern, A Hewitt, E Hsu, P Jacobson, K Johnson, D Lauwaert, S Magalini, G Mastoras, B Mills, S Morse, E Noste, M Pardo, P Pucher, A Redmond, R Ruffing, J Ryder, D Saber, P Severin, and J Tochkin.

Co-authors are DMPHP deputy editors (other co-authors are known to the DMPHP editorial staff and potential reviewers). The manuscript was blinded throughout the review process.

**Author contributions.** Study Concept: ESW, LR, FDC; Study Design: ESW, MB, LR; Scoping Review: ESW, MB, HL, TLH; Internal Focus Group: ESW, MB, HL, TLH, IH, SP, LR; External Focus Group: ESW, MB, HL, TLH, IH, SP, RVB, MXC, POTD, EO, LR; Primary writing: ESW; Editing, revising: ESW, HL, TLH, IH, SP, RVB, MXC, POTD, EO, LR

**Competing interest.** None

**Funding.** This NO-FEAR project has received funding from the European Union's Horizon 2020 research and innovation program under grant agreement No 786670 with only funds allocated for the STAT59 statistical program fee.

**Ethics.** The McLeod Health Institutional Review Board Office (Florence, South Carolina USA) has determined that this study does meet the exemption criteria found at 45 CFR 46.104(d)(2).

**Abbreviations.** CINAHL, Cumulated Index to Nursing and Allied Health (database); COVID-19, Coronavirus disease-2019 ; DTIC, Defense Technical Information Center (US Department of Defense database); EBSCO, Elton B Stephens Company; ECRI, Emergency Care Research Institute (guidelines database); ED, Emergency Department; EMS, Emergency Medical Services; FSEx, Full-Scale Exercise; IMS, Incident Management System; MCI, Sudden Onset Mass Casualty Incident Response; mD: modified Delphi Study; NO-FEAR, Network Of practitioners For Emergency medicAl systems and cRitical care; PICO, Patient, Intervention, Control/ Comparison, Outcome (framework); PRISMA-ScR, Preferred Reporting Items for Systematic reviews and Meta-Analyses, extension for Scoping Reviews; Simulation, Simulation and Serious Gaming; SSS: Staff, Stuff and Structures; Stat59, Stat59 Services Limited, Edmonton, Alberta, Canada (Statistical Analysis Platform); TS, Translational Science; WHO, World Health Organization

## References

1. **Auf der Heide E.** *Disaster response: principles of preparation and coordination.* St. Louis: Mosby; 1989.
2. **Federal Emergency Management Agency (FEMA)**. *National Incident Management System.* https://www.fema.gov/emergency-managers/nims. Accessed November 1, 2022.
3. **World Health Organization (WHO)**. *WHO simulation exercise manual.* Published February 2017. https://apps.who.int/iris/bitstream/handle/10665/254741/WHO-WHE-CPI-2017.10-eng.pdf;sequence=1. Accessed August 20, 2021.
4. **Kaji A, Koenig KL, Bey T.** Surge capacity for healthcare systems: a conceptual framework [published correction appears in *Acad Emerg Med.* 2007;14(1):22.]. *Acad Emerg Med.* 2006;13(11):1157-1159. doi: 10.1197/j.aem.2006.06.032
5. **Centers for Medicare and Medicaid Services**. *Emergency preparedness rule.* https://www.cms.gov/Medicare/Provider-Enrollment-and-Certification/SurveyCertEmergPrep/Emergency-Prep-Rule. Accessed March 3, 2022.
6. **USNRC, Federal Emergency Management Agency (FEMA).** *Criteria for preparation and evaluation of radiological emergency response plans and preparedness in support of nuclear power plants.* https://www.fema.gov/sites/default/files/2020-06/nureg-0654_fema-rep-1_rev2_change_summary__dec_2019.pdf. Accessed March 4, 2022.
7. **NO-FEAR**. Network Of practitioners For Emergency medicAl systems and cRitical care. https://no-fearproject.eu/. Accessed May 6, 2021.
8. **Weinstein ES, Cuthbertson JL, Ragazzoni L, Verde M.** A T2 translational science modified Delphi study: spinal motion restriction in a resource-scarce environment. *Prehosp Disaster Med.* 2020;35(5):538-545. doi: 10.1017/S1049023X20000862
9. **PRISMA**. PRISMA for scoping Reviews. https://www.prisma-statement.org/Extensions/ScopingReviews. Accessed July 10, 2021.
10. **Munn Z, Peters MDJ, Stern C, Tufanaru C, McArthur A, Aromataris E.** Systematic review, or scoping review? Guidance for authors when choosing between a systematic or scoping review approach. *BMC Med Res Methodol.* 2018;18(1):143. doi: 10.1186/s12874-018-0611-x
11. **Tricco AC, Lillie E, Zarin W, *et al.*** PRISMA extension for scoping reviews (PRISMA-ScR): checklist and explanation. *Ann Intern Med.* 2018;169(7):467-473. doi: 10.7326/M18-0850
12. **da Costa Santos CM, de Mattos Pimenta CA, Nobre MR.** The PICO strategy for the research question construction and evidence search. *Rev Lat Am Enfermagem.* 2007;15(3):508-511. doi: 10.1590/s0104-11692007000300023
13. **Achatz G, Friemert B, Trentzsch H, *et al.*** Terror and disaster surgical care: training experienced trauma surgeons in decision making for a MASCAL situation with a tabletop simulation game. *Eur J Trauma Emerg Surg.* 2020;46(4):717-724. doi: 10.1007/s00068-020-01441-x
14. **Alexander AJ, Bandiera GW, Mazurik L.** A multiphase disaster training exercise for emergency medicine residents: opportunity knocks. *Acad Emerg Med.* 2005;12(5):404-409. doi: 10.1197/j.aem.2004.11.025
15. **Anan H, Otomo Y, Kondo H, *et al.*** Development of mass-casualty life support-CBRNE (MCLS-CBRNE) in Japan. *Prehosp Disaster Med.* 2016;31(5):547-550. doi: 10.1017/S1049023X16000686
16. **Andreatta PB, Maslowski E, Petty S, *et al.*** Virtual reality triage training provides a viable solution for disaster-preparedness. *Acad Emerg Med.* 2010;17(8):870-876. doi: 10.1111/j.1553-2712.2010.00728.x
17. **Ashkenazi I, Ohana A, Azaria B, *et al.*** Assessment of hospital disaster plans for conventional mass casualty incidents following terrorist explosions using a live exercise based upon the real data of actual patients. *Eur J Trauma Emerg Surg.* 2012;38(2):113-117. doi: 10.1007/s00068-011-0154-x
18. **Atack L, Bull E, Dryden T, Maher J, Rocchi M.** An evaluation of learner perception of competency and satisfaction with three models of an interdisciplinary surge capacity course. *J Allied Health.* 2012;41(3):106-112.
19. **Austin EN, Bastepe-Gray SE, Nelson HW, *et al.*** Pediatric mass-casualty education: experiential learning through university-sponsored disaster simulation. *J Emerg Nurs.* 2014;40(5):428-433. doi: 10.1016/j.jen.2014.05.015
20. **Bartley BH, Stella JB, Walsh LD.** What a disaster?! Assessing utility of simulated disaster exercise and educational process for improving hospital preparedness. *Prehosp Disaster Med.* 2006;21(4):249-255. doi: 10.1017/s1049023x00003782
21. **Bentley S, Iavicoli L, Boehm L, *et al.*** A simulated mass casualty incident triage exercise: SimWars [published correction appears in MedEdPORTAL.

2019;15:10879]. *MedEdPORTAL.* 2019;15:10823. doi: 10.15766/mep_2374-8265.10823
22. **Berndt H, Wessel D, Mentler T, Herczeg M.** Human-centered design of a virtual reality training simulation for mass casualty incidents. In: 10th International conference on virtual worlds and games for serious applications, VS-games 2018. 2018:8493427.
23. **Berndt H, Wessel D, Willer L, Herczeg M, Mentler T.** Immersion, and presence in virtual reality training for mass casualty incidents. In: Proceedings of the 15th ISCRAM Conference 2018. 2018(5):797-805.
24. **Betka AA, Bergren MD, Rowen JL.** Improving rural disaster response preparedness. *Public Health Nurs.* 2021;38(5):856-861. doi: 10.1111/phn.12924
25. **Bieler D, Franke A, Blätzinger M, *et al.*** Evaluation of the terror and disaster surgical care course. *Eur J Trauma Emerg Surg.* 2020;46(4):709-716. doi: 10.1007/s00068-020-01418-w
26. **Bilek N, Feldhofer A, Moser T.** Virtual reality based mass disaster triage training for emergency medical services. In: IEEE Conference on virtual reality and 3D user interfaces abstracts and workshops 2021. 2021:13.
27. **Carenzo L, Barra FL, Ingrassia PL, Colombo D, Costa A, Della Corte F.** Disaster medicine through Google Glass. *Eur J Emerg Med.* 2015;22(3): 222-225. doi: 10.1097/MEJ.0000000000000229.
28. **Carenzo L, Ragozzino F, Colombo D, Barra FL, Della Corte F, Ingrassia PL.** Virtual laboratory and imaging: an online simulation tool to enhance hospital disaster preparedness training experience. *Eur J Emerg Med.* 2018;25(2):128-133. doi: 10.1097/MEJ.0000000000000421
29. **Carenzo L, Bazurro S, Colombo D, Petrini F, Ingrassia PL.** An island-wide disaster drill to train the next generation of anesthesiologists: the SIAARTI academy experience. *Disaster Med Public Health Prep.* 2020;15(2):151-154. doi: 10.1017/dmp.2019.163
30. **Carmichael H, Mastoras G, Nolan C, *et al.*** Integration of in situ simulation into an emergency department code orange exercise in a tertiary care trauma referral center. *AEM Educ Train.* 2020;5(2):e10485. doi: 10.1002/aet2.10485
31. **Castoldi L, Greco M, Carlucci M, Lennquist Montán K, Faccincani R.** Mass casualty incident (MCI) training in a metropolitan university hospital: short-term experience with MAss Casualty SIMulation system MACSIM®. *Eur J Trauma Emerg Surg.* 2022;48(1):283-291. doi: 10.1007/s00068-020-01541-8
32. **Ceresa IF, Savioli G, Angeli V, *et al.*** Preparing for the maximum emergency with a simulation: a table-top test to evaluate bed surge capacity and staff compliance with training. *Open Access Emerg Med.* 2020;12:377-387. doi: 10.2147/OAEM.S267069
33. **Cicero MX, Whitfill T, Munjal K, *et al.*** 60 seconds to survival: a pilot study of a disaster triage video game for prehospital providers. *Am J Disaster Med.* 2017;12(2):75-83. doi: 10.5055/ajdm.2017.0263
34. **Cicero MX, Whitfill T, Overly F, *et al.*** Pediatric disaster triage: multiple simulation curriculum improves prehospital care providers' assessment skills. *Prehosp Emerg Care.* 2017;21(2):201-208. doi: 10.1080/10903127.2016.1235239
35. **Cicero MX, Golloshi K, Gawel M, Parker J, Auerbach M, Violano P.** A tabletop school bus rollover: Connecticut-wide drills to build pediatric disaster preparedness and promote a novel hospital disaster readiness checklist. *Am J Disaster Med.* 2019;14(2):75-87. doi: 10.5055/ajdm.2019.0318
36. **Cicero MX, Whitfill T, Walsh B, *et al.*** Correlation between paramedic disaster triage accuracy in screen-based simulations and immersive simulations. *Prehosp Emerg Care.* 2019;23(1):83-89. doi: 10.1080/10903127.2018.1475530
37. **Claudius I, Kaji A, Santillanes G, *et al.*** Comparison of computerized patients versus live moulaged actors for a mass-casualty drill. *Prehosp Disaster Med.* 2015;30(5):438-442. doi: 10.1017/S1049023X15004963
38. **Cole LA, Natal B, Fox A, *et al.*** A course on terror medicine: content and evaluations. *Prehosp Disaster Med.* 2016;31(1):98-101. doi: 10.1017/S1049023X15005579
39. **Collander B, Green B, Millo Y, Shamloo C, Donnellan J, DeAtley C.** Development of an 'all-hazards' hospital disaster preparedness training course utilizing multi-modality teaching. *Prehosp Disaster Med.* 2008;23(1):63-69. doi: 10.1017/s1049023x00005598
40. **Cone DC, Serra J, Kurland L.** Comparison of the SALT and Smart triage systems using a virtual reality simulator with paramedic students. *Eur J Emerg Med.* 2011;18(6):314-321. doi: 10.1097/MEJ.0b013e328345d6fd
41. **Dickerson-Young T, Keilman A, Yoshida H, Jones M, Cross N, Thomas A.** Pediatric emergency medicine disaster simulation curriculum: the 5-minute trauma assessment for pediatric residents (TRAP-5). *MedEdPORTAL.* 2020;16:10940. doi: 10.15766/mep_2374-8265.10940
42. **Donevant SB, Svendsen ER, Richter JV, *et al.*** Designing and executing a functional exercise to test a novel informatics tool for mass casualty triage. *J Am Med Inform Assoc.* 2019;26(10):1091-1098. doi: 10.1093/jamia/ocz087
43. **Farra S, Hodgson E, Miller ET, *et al.*** Effects of virtual reality simulation on worker emergency evacuation of neonates. *Disaster Med Public Health Prep.* 2019;13(2):301-308. doi: 10.1017/dmp.2018.58
44. **Ferrandini Price M, Escribano Tortosa D, Nieto Fernandez-Pacheco A, *et al.*** Comparative study of a simulated incident with multiple victims and immersive virtual reality. *Nurse Educ Today.* 2018;71:48-53. doi: 10.1016/j.nedt.2018.09.006
45. **Fletcher L, Justice S, Rohrig L.** Designing a disaster. *J Trauma Nurs.* 2015;22(1):35-40. doi: 10.1097/JTN.0000000000000098
46. **Foo NP, So EC, Lu NC, *et al.*** A 36-hour unplugged full-scale exercise: closing the gaps in interagency collaboration between the disaster medical assistance team and urban search and rescue team in disaster preparedness in Taiwan. *Emerg Med Int.* 2021;2021:5571009. doi: 10.1155/2021/5571009
47. **Gable BD, Misra A, Doos DM, Hughes PG, Clayton LM, Ahmed RA.** Disaster day: a simulation-based disaster medicine curriculum for novice learners. *J Med Educ Curric Dev.* 2021;8:23821205211020751. doi: 10.1177/23821205211020751
48. **Gillett B, Peckler B, Sinert R, *et al.*** Simulation in a disaster drill: comparison of high-fidelity simulators versus trained actors. *Acad Emerg Med.* 2008;15(11):1144-1151. doi: 10.1111/j.1553-2712.2008.00198.x
49. **Glow SD, Colucci VJ, Allington DR, Noonan CW, Hall EC.** Managing multiple-casualty incidents: a rural medical preparedness training assessment. *Prehosp Disaster Med.* 2013;28(4):334-341. doi: 10.1017/S1049023X13000423
50. **Gofrit ON, Leibovici D, Shemer J, Henig A, Shapira SC.** The efficacy of integrating "smart simulated casualties" in hospital disaster drills. *Prehosp Disaster Med.* 1997;12(2):97-101. doi: 10.1017/S1049023X00037365
51. **Greci LS, Ramloll R, Hurst S, *et al.*** vTrain: a novel curriculum for patient surge training in a multi-user virtual environment (MUVE). *Prehosp Disaster Med.* 2013;28(3):215-222. doi: 10.1017/S1049023X13000083
52. **Greco S, Lewis EJ, Sanford J, Sawin EM, Ames A.** Ethical reasoning debriefing in disaster simulations. *J Prof Nurs.* 2019;35(2):124-132. doi: 10.1016/j.profnurs.2018.09.004
53. **Green GB, Modi S, Lunney K, Thomas TL.** Generic evaluation methods for disaster drills in developing countries. *Ann Emerg Med.* 2003;41(5): 689-699. doi: 10.1067/mem.2003.147
54. **Gryth D, Rådestad M, Nilsson H, *et al.*** Evaluation of medical command and control using performance indicators in a full-scale, major aircraft accident exercise. *Prehosp Disaster Med.* 2010;25(2):118-123. doi: 10.1017/s1049023x00007834
55. **Hartman EN, Daines B, Seto C, Shimshoni D, Feldman ME, LaBrunda M.** Sort, assess, life-saving intervention, triage with drone assistance in mass casualty simulation: Analysis of educational efficacy. *Cureus.* 2020;12(9):e10572. doi: 10.7759/cureus.10572
56. **Heinrichs WL, Youngblood P, Harter P, Kusumoto L, Dev P.** Training healthcare personnel for mass-casualty incidents in a virtual emergency department: VED II. *Prehosp Disaster Med.* 2010;25(5):424-432. doi: 10.1017/s1049023x00008505
57. **High EH, Lovelace KA, Gansneder BM, Strack RW, Callahan B, Benson P.** Promoting community preparedness: lessons learned from the implementation of a chemical disaster tabletop exercise. *Health Promot Pract.* 2010;11(3):310-319. doi: 10.1177/1524839908325063
58. **Imamedjian I, Maghraby NHM, Homier V.** A hospital mass casualty exercise using city buses and a tent as a hybrid system for patient decontamination. *Am J Disaster Med.* 2017;12(3):189-196. doi: 10.5055/ajdm.2017.0273

59. **Ingrassia PL, Prato F, Geddo A, *et al.*** Evaluation of medical management during a mass casualty incident exercise: an objective assessment tool to enhance direct observation. *J Emerg Med.* 2010;39(5):629-636. doi: 10.1016/j.jemermed.2009.03.029
60. **Ingrassia PL, Ragazzoni L, Carenzo L, Colombo D, Ripoll Gallardo A, Della Corte F.** Virtual reality, and live simulation: a comparison between two simulation tools for assessing mass casualty triage skills. *Eur J Emerg Med.* 2015;22(2):121-127. doi: 10.1097/MEJ.0000000000000132
61. **Jacobson PA, Severin PN, Rumoro DP, Shah S.** Mass-casualty training exercise using high-fidelity computerized simulators and involving time and resource limitation. *Prehosp Disaster Med.* 2021;36(3):313-320. doi: 10.1017/S1049023X21000327
62. **Jain TN, Ragazzoni L, Stryhn H, Stratton SJ, Della Corte F.** Comparison of the Sacco triage method versus START triage using a virtual reality scenario in advance care paramedic students. *CJEM.* 2016;18(4):288-292. doi: 10.1017/cem.2015.102
63. **Jorm C, Roberts C, Lim R, *et al.*** A large-scale mass casualty simulation to develop the non-technical skills medical students require for collaborative teamwork. *BMC Med Educ.* 2016;16:83. doi: 10.1186/s12909-016-0588-2
64. **Jung D, Carman M, Aga R, Burnett A.** Disaster preparedness in the emergency department using in situ simulation. *Adv Emerg Nurs J.* 2016;38(1):56-68. doi: 10.1097/TME.0000000000000091
65. **Kaplan BG, Connor A, Ferranti EP, Holmes L, Spencer L.** Use of an emergency preparedness disaster simulation with undergraduate nursing students. *Public Health Nurs.* 2012;29(1):44-51. doi: 10.1111/j.1525-1446.2011.00960.x
66. **Kim CH, Shin SD, Park JO, Kim SC, Coule PL.** The effects of a community-based disaster drill of simulating Disaster Medical Assistance Team (DMAT) on the knowledge and attitudes. *Ulus Travma Acil Cerrahi Derg.* 2021;27(2):174-179. doi: 10.14744/tjtes.2020.93947
67. **Kim J, Lee O.** Effects of a simulation-based education program for nursing students responding to mass casualty incidents: a pre-post intervention study. *Nurse Educ Today.* 2020;85:104297. doi: 10.1016/j.nedt.2019.104297
68. **Kim TE, Shankel T, Reibling ET, *et al.*** Healthcare students interprofessional critical event/disaster response course. *Am J Disaster Med.* 2017;12(1):11-26. doi: 10.5055/ajdm.2017.0254
69. **Klima DA, Seiler SH, Peterson JB, *et al.*** Full-scale regional exercises: closing the gaps in disaster preparedness. *J Trauma Acute Care Surg.* 2012;73(3):592-598. doi: 10.1097/TA.0b013e318265cbb2
70. **Knight JF, Carley S, Tregunna B, *et al.*** Serious gaming technology in major incident triage training: a pragmatic controlled trial. *Resuscitation.* 2010;81(9):1175-1179. doi: 10.1016/j.resuscitation.2010.03.042
71. **Koutitas G, Smith KS, Lawrence G, *et al.*** A virtual and augmented reality platform for the training of first responders of the ambulance bus. In: *ACM Int Conf Proc Series.* 2019:299-302
72. **Kurenov SN, Cance WW, Noel B, Mozingo DW.** Game-based mass casualty burn training. *Stud Health Technol Inform.* 2009;142:142-144. doi: 10.3233/978-1-58603-964-6-142
73. **Kyle RR, Via DK, Lowy RJ, Madsen JM, Marty AM, Mongan PD.** A multidisciplinary approach to teach responses to weapons of mass destruction and terrorism using combined simulation modalities. *J Clin Anesth.* 2004;16(2):152-158. doi: 10.1016/j.jclinane.2003.09.003
74. **Lee CW, McLeod SL, Van Aarsen K, Klingel M, Franc JM, Peddle MB.** First responder accuracy using SALT during mass-casualty incident simulation. *Prehosp Disaster Med.* 2016;31(2):150-154. doi: 10.1017/S1049023X16000091
75. **Lee WH, Kuan JT, Shiau YW, *et al.*** Designation of a new training model of a local disaster medical system with tabletop exercises. *Chang Gung Med J.* 2003;26(12):879-888.
76. **Legemaate GA, Burkle FM Jr, Bierens JJ.** The evaluation of research methods during disaster exercises: applicability for improving disaster health management. *Prehosp Disaster Med.* 2012;27(1):18-26. doi: 10.1017/S1049023X11006789
77. **Leiba A, Goldberg A, Hourvitz A, *et al.*** Who should worry for the 'worried well?' Analysis of mild casualties' center drills in non-conventional scenarios. *Prehosp Disaster Med.* 2006;21(6):441-444. doi: 10.1017/s1049023x00004179
78. **Leow JJ, Brundage SI, Kushner AL, *et al.*** Mass casualty incident training in a resource-limited environment. *Br J Surg.* 2012;99(3):356-361. doi: 10.1002/bjs.7762
79. **Lerner EB, Schwartz RB, Coule PL, Pirrallo RG.** Use of SALT triage in a simulated mass-casualty incident. *Prehosp Emerg Care.* 2010;14(1):21-25. doi: 10.3109/10903120903349812
80. **Liu A, Acosta E, Cope J, *et al.*** The wide area virtual environment: a new paradigm for medical team training. In: Schmorrow D, Fidopiastis C, eds. *Augmented cognition: users and contexts. AC 2018 Lecture Notes in Computer Science.* New York: Springer; 2018:293-304.
81. **Lowe J, Peng C, Winstead-Derlega C, Curtis H.** 360 virtual reality pediatric mass casualty incident: a cross sectional observational study of triage and out-of-hospital intervention accuracy at a national conference. *J Am Coll Emerg Physicians Open.* 2020;1(5):974-980. doi: 10.1002/emp2.12214
82. **Ma D, Shi Y, Zhang G, Zhang J.** Does theme game-based teaching promote better learning about disaster nursing than scenario simulation: a randomized controlled trial. *Nurse Educ Today.* 2021;103:104923. doi: 10.1016/j.nedt.2021.104923
83. **McElroy JA, Steinberg S, Keller J, Falcone RE.** Operation continued care: a large mass-casualty, full-scale exercise as a test of regional preparedness. *Surgery.* 2019;166(4):587-592. doi: 10.1016/j.surg.2019.05.045
84. **Mills B, Dykstra P, Hansen S, *et al.*** Virtual reality triage training can provide comparable simulation efficacy for paramedicine students compared to live simulation-based scenarios. *Prehosp Emerg Care.* 2020;24(4):525-536. doi: 10.1080/10903127.2019.1676345
85. **Molka-Danielsen J, Prasolova-Forland E, Fominykh M, Lamb K.** Use of a collaborative virtual reality simulation for multi-professional training in emergency management communications. In: IEEE International Conference on Teaching, Assessment, and Learning for Engineering (TALE). Wollongong: IEEE. 2019;408-415.
86. **Ngo J, Schertzer K, Harter P, Smith-Coggins R.** Disaster medicine: a multi-modality curriculum designed and implemented for emergency medicine residents. *Disaster Med Public Health Prep.* 2016;10(4):611-614. doi: 10.1017/dmp.2016.8
87. **Nieto Fernández-Pacheco A, Castro Delgado R, Arcos González P, *et al.*** Analysis of performance and stress caused by a simulation of a mass casualty incident. *Nurse Educ Today.* 2018;62:52-57. doi: 10.1016/j.nedt.2017.12.016
88. **Nilsson H, Rüter A.** Management of resources at major incidents and disasters in relation to patient outcome: a pilot study of an educational model. *Eur J Emerg Med.* 2008;15(3):162-165. doi: 10.1097/MEJ.0b013e3282f4d14b
89. **Nilsson H, Jonson CO, Vikström T, *et al.*** Simulation-assisted burn disaster planning. *Burns.* 2013;39(6):1122-1130. doi: 10.1016/j.burns.2013.01.018
90. **Obaid JM, Bailey G, Wheeler H, *et al.*** Utilization of functional exercises to build regional emergency preparedness among rural health organizations in the US. *Prehosp Disaster Med.* 2017;32(2):224-230. doi: 10.1017/S1049023X16001527
91. **Phattharapornjaroen P, Glantz V, Carlström E, Dahlén Holmqvist L, Khorram-Manesh A.** Alternative leadership in flexible surge capacity — the perceived impact of tabletop simulation exercises on Thai emergency physicians' capability to manage a major incident. *Sustainability.* 2020;12(15):6216. doi: 10.3390/su12156216
92. **Pryor E, Heck E, Norman L, *et al.*** Integrated decision-making in response to weapons of mass destruction incidents: development and initial evaluation of a course for healthcare professionals. *Prehosp Disaster Med.* 2006;21(1):24-30. doi: 10.1017/s1049023x00003289
93. **Pucher PH, Batrick N, Taylor D, Chaudery M, Cohen D, Darzi A.** Virtual-world hospital simulation for real-world disaster response: design and validation of a virtual reality simulator for mass casualty incident management. *J Trauma Acute Care Surg.* 2014;77(2):315-321. doi: 10.1097/TA.0000000000000308
94. **Riley PW, Dalby DJ, Turner EA.** Making acute hospital exercises more realistic without impacting on healthcare delivery. *J Bus Contin Emer Plan.* 2012;6(2):143-150.

95. **Rusling M, Masin D, Voss M, *et al.*** Medical student coping and performance in simulated disasters. *Anxiety Stress Coping.* 2021;34(6):766-777. doi: 10.1080/10615806.2021.1916481
96. **Saber DA, Strout K, Caruso LS, Ingwell-Spolan C, Koplovsky A.** An interprofessional approach to continuing education with mass casualty simulation: planning and execution. *J Contin Educ Nurs.* 2017;48(10): 447-453. doi: 10.3928/00220124-20170918-05
97. **Saunders J, Davey S, Bayerl PS, Lohrmann P.** Validating virtual reality as an effective training medium in the security domain. In: 26th IEEE conference on virtual reality and 3D user interfaces, VR. 2019;1908-1911.
98. **Schulz CM, Skrzypczak M, Raith S, *et al.*** High-fidelity human patient simulators compared with human actors in an unannounced mass-casualty exercise. *Prehosp Disaster Med.* 2014;29(2):176-182. doi: 10.1017/S1049023X14000223
99. **Sena A, Forde F, Yu C, Sule H, Masters MM.** Disaster preparedness training for emergency medicine residents using a tabletop exercise. *MedEdPORTAL.* 2021;17:11119. doi: 10.15766/mep_2374-8265.11119
100. **Shah VS, Pierce LC, Roblin P, Walker S, Sergio MN, Arquilla B. Waterworks**, a full-scale chemical exposure exercise: interrogating pediatric critical care surge capacity in an inner-city tertiary care medical center. *Prehosp Disaster Med.* 2014;29(1):100-106. doi: 10.1017/S1049023X13009096
101. **Silenas R, Akins R, Parrish AR, Edwards JC.** Developing disaster preparedness competence: an experiential learning exercise for multi-professional education. *Teach Learn Med.* 2008;20(1):62-68. doi: 10.1080/10401330701798311
102. **Smithers B, Tenhunen ML.** Planning and implementing disaster drills for undergraduate nursing students. *Nurs Educ Perspect.* 2020;41(2):130-131. doi: 10.1097/01.NEP.0000000000000430
103. **So M, Dziuban EJ, Franks JL, *et al.*** Extending the reach of pediatric emergency preparedness: a virtual tabletop exercise targeting children's needs. *Public Health Rep.* 2019; 134(4):344-353. doi: 10.1177/0033354919849880
104. **Start E, Culley JM, Tavakoli A, Polyakova-Norwood V.** Students experience mass casualty nursing from the patient perspective in a simulated mass casualty exercise. *Nurs Educ Perspect.* 2021;42(3):174-176. doi: 10.1097/01.NEP.0000000000000646
105. **Strout K, Saber DA, Caruso LS, *et al.*** Interprofessional mass casualty incident simulation design protocol to prepare prelicensure nursing students to respond to a disaster. *Nurse Educ.* 2017;42(5):E1-E4. doi: 10.1097/NNE.0000000000000365
106. **Thomas TL, Hsu EB, Kim HK, Colli S, Arana G, Green GB.** The incident command system in disasters: evaluation methods for a hospital-based exercise. *Prehosp Disaster Med.* 2005;20(1):14-23. doi: 10.1017/s1049023x00002090
107. **Waddington RM, Reeves TC, Kalin EJ, *et al.*** Value of a ludic simulation in training first responders to manage blast incidents. *Int J Gaming Comput Mediat Simul.* 2013;5(2):60-72. doi: 10.4018/jgcms.2013040104
108. **Whitfill T, Auerbach M, Diaz MCG, *et al.*** Cost-effectiveness of a video game versus live simulation for disaster training. *BMJ Simul Technol Enhanc Learn.* 2020;6(5):268-273. doi: 10.1136/bmjstel-2019-000497
109. **Whitney RE, Burke RV, Lehman-Huskamp K, Arora G, Park DB, Cicero MX.** On shaky ground: learner response and confidence after tabletop earthquake simulation. *Pediatr Emerg Care.* 2016;32(8):520-524. doi: 10.1097/PEC.0000000000000681
110. **Wilkerson W, Avstreih D, Gruppen L, Beier KP, Woolliscroft J.** Using immersive simulation for training first responders for mass casualty incidents. *Acad Emerg Med.* 2008;15(11):1152-1159. doi: 10.1111/j.1553-2712.2008.00223.x
111. **US Fire Administration (USFA), Federal Emergency Management Agency (FEMA).** *Operational templates and guidance for EMS mass incident deployment.* https://www.usfa.fema.gov/downloads/pdf/publications/templates_guidance_ems_mass_incident_deployment.pdf. Accessed August 20, 2021.
112. **Federal Emergency Management Agency (FEMA).** *Homeland Security Exercise and Evaluation Program (HSEEP).* https://www.fema.gov/sites/default/files/2020-04/Homeland-Security-Exercise-and-Evaluation-Program-Doctrine-2020-Revision-2-2-25.pdf. Accessed August 20, 2021.
113. **Federal Emergency Management Agency (FEMA).** *Safe exercise best practice.* https://www.fema.gov/sites/default/files/documents/fema_safe-exercise-best-practice_06072021.pdf. Accessed August 21, 2021.
114. **Federal Emergency Management Agency (FEMA).** *Virtual exercise best practices.* https://www.fema.gov/sites/default/files/documents/fema_virtual-exercise-best-practice.pdf. Accessed August 20, 2021.
115. **World Health Organization (WHO).** *WHO simulation exercise manual.* https://apps.who.int/iris/bitstream/handle/10665/254741/WHO-WHE-CPI-2017.10-eng.pdf;sequence=1. Accessed August 20, 2021.
116. Stat59 Services. Stat59. http://www.STAT59.com. Accessed December 1, 2021.
117. **Office for Human Research Protections (OHRP).** *OHRP exemptions.* https://www.hhs.gov/ohrp/regulations-and-policy/regulations/45-cfr-46/common-rule-subpart-a-46104/index.html. Accessed December 2, 2021.
118. **Central limit theorem: Definition and examples.** Statisticshowto. https://www.statisticshowto.com/probability-and-statistics/normal-distributions/central-limit-theorem-definition-examples. Accessed May 9, 2022.
119. **Boston University Master of Public Health Module.** The role of probability. https://sphweb.bumc.bu.edu/otlt/mph-modules/bs/bs704_probability/BS704_Probability12.html#:~:text=The%20central%20limit%20theorem%20states,will%20be%20approximately%20normally%20distributed. Accessed April 12, 2022.
120. **Briggs SM.** Regional interoperability: making systems connect in complex disasters. *J Trauma.* 2009;67(2 Suppl):S88-S90. doi: 10.1097/TA.0b013e3181adbcc0
121. **Kagawa F, Selby D.** Ready for the storm: Education for disaster risk reduction and climate change adaptation and mitigation. *J Educ Sustain Dev.* 2012;6(2):207-217. doi: 10.1177/0973408212475200
122. **Johnson GG, Brindley PG, Gillman LM.** Fidelity in surgical simulation: Further lessons from the STARTT course. *Can J Surg.* 2020;63(2): E161-E163. doi: 10.1503/cjs.017818
123. **Medical Bioformatics.** Virtual reality simulators. https://bioinformaticamedicablog.wordpress.com/2017/11/07/simuladores-de-realidad-virtual/. Accessed November 7, 2021.
124. **Alharthi, SA, LaLone N, Khalaf AS, *et al.*** Practical insights into the design of future disaster response training simulations. https://par.nsf.gov/biblio/10061145. Accessed July 7, 2021.
125. **Toups ZO, Hamilton WA, Alharthi SA.** Playing at planning. Proceedings of the 2016 Annual Symposium on Computer-Human Interaction in Play. Published online October 15, 2016. doi: 10.1145/2967934.2968089
126. **Dreifuerst KT.** Getting started with debriefing for meaningful learning. *Clin Simul Nurs.* 2015;11(5):268-275. doi: 10.1016/j.ecns.2015.01.005