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Training and education of healthcare workers during viral epidemics: A systematic review

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ABSTRACT

Objective

This study aimed to explore published literature in relation to training and education for viral epidemics and the effects of these training interventions to inform training of healthcare personnel in light of the ongoing COVID-19 pandemic.

Design: Systematic review

Method

Five databases were searched (PubMed, EMBASE, Cochrane Library, Web of Science and DOAJ) between 1 January 2000 and 24 April 2020 for studies reporting on educational interventions in response to recent major viral outbreaks (SARS, H1N1, MERS, EVD and COVID-19). Descriptive information was extracted and synthesized according to content, competency category, educational methodology, and effects of the educational intervention including level of educational outcome.

Results

A total of 15,676 records were identified of which 46 studies fulfilled inclusion criteria. Most studies were motivated by Ebola outbreak with doctors and nurses as the primary learners. Traditional didactic methods were commonly used to teach theoretical knowledge on for example infection prevention and control. Simulation-based training was utilized particularly for training of technical skills such as donning and doffing of personal protective equipment and in relation to airway/ventilation management. Evaluation of the interventions consisted mostly of surveys on learner satisfaction and confidence or tests of knowledge and skills. Only three studies investigated transfer to the clinical setting or effect on patient outcomes.

Conclusion

The included studies relay important educational experiences from past epidemics with a variety of educational content, design, and modes of delivery. High level educational evidence is limited, and implementation remains a challenge. Evidence-based and standardised training programs that are easily adapted locally are recommended in preparation for future outbreaks.

Keywords: viral diseases; epidemic; coronavirus; ebolavirus; training

Strengths and Limitations of this study

- Inclusion of educational interventional studies in the last twenty years, providing an overview of the currently published training programs for HCW and their evidence.
- Systematic search of five academic research databases (PubMed, Excerpta Medica (EMBASE)/Ovid, Cochrane Library, Web of Science, and Directory of Open Access Journals (DOAJ)) was performed following the Preferred Reporting Items for Systematic Reviews and Meta-Analyses (PRISMA) guidelines.
- Systematic review of forty-six studies reporting on training and educational interventions that were developed and implemented in response to five major viral epidemics: SARS, H1N1, EVD, MERS and COVID-19
- Exclusion of descriptive studies reporting on development of training programs without evaluation and those reporting on organizational or system-wide impact of interventions.
- Other important educational efforts that may not have been reported were not included.

INTRODUCTION

Global-scale infectious diseases engender threat, vulnerability, and risk to health and healthcare capacity as well as the economic and political stature of a nation.[1] In the last twenty years, the world has seen several major epidemic outbreaks caused by viral agents—namely severe acute respiratory syndrome (SARS) in 2003,[2] swine flu (H1N1 influenza virus infection)[3] in 2009–2019, Middle East respiratory syndrome (MERS) in 2012,[4] and Ebola virus disease (EVD) in 2014–2016.[5] Currently, the entire world is facing a pandemic with a novel coronavirus disease (COVID-19),[6] demonstrating how a new and fast spreading viral agent can challenge and even overwhelm healthcare delivery and capacity. As with previous large outbreaks, this prompts the need for global communities to swiftly plan, prepare, and ensure continuous healthcare functionality, resource availability, and skilled manpower.[7]

Healthcare professionals from across different areas were called on duty and needed to learn new procedures including correct use of personal protective equipment (PPE)[8] and management of critically ill patients on ventilatory support.[9] To ensure adequate resources and staffing, it was necessary to fast train a large number of healthcare workers (HCW) to be on the frontlines.

Ideally, training and education in preparation for a new infectious threat should be continuous and planned ahead of time. COVID-19 has highlighted that this often is not the case even in well-developed healthcare systems. There remains an urgent need for best practices on development and implementation of training programs during an epidemic.[10]

The overall aim of the study was to provide an overview of the published literature in relation to training and education for a viral epidemic and a status on the evidence of effects of these training interventions. We sought to answer these specific research questions:

1. What are the educational content and types of competencies being trained in relation to HCW as a result of a major viral epidemic?

2. How can training be delivered under these conditions?

3. What are the reported effects of the training interventions?

METHODS

This systematic review was conducted and reported in adherence with the Preferred Reporting Items for Systematic Reviews and Meta-analyses (PRISMA) guideline.[11]

Study eligibility

We considered all studies on educational or training interventions developed, evaluated and/or implemented in response to major global viral outbreaks transmitted via close person-to-person contact from 2000 to 2020: SARS, H1N1, MERS, EVD, and COVID-19. Inclusion criteria included studies reporting on development, implementation and evaluation of educational interventions for HCW while the exclusion criteria were studies that were not in English language, descriptive studies, and those reporting on organizational outcomes (Table 1).

Search strategy

The search strategy was designed to access published literature in health professions education and clinical journals. Five databases were searched from 1 January 2000–24 April 2020 (PubMed, Excerpta Medica (EMBASE)/Ovid, Cochrane Library, Web of Science, and Directory of Open Access Journals (DOAJ)) using the search terms *(training OR educat* OR teach*) AND (coronavirus OR SARS OR H1N1 OR MERS OR EBOLA OR COVID-19)*. See Table 2 for full search details.

Study selection

The search results were retrieved and imported into the Mendeley software (London, UK). Two authors (LJN and SA) independently reviewed and screened titles and abstracts, and eligible studies were included for full-text screening using Covidence (Veritas Health Innovation, Melbourne, Australia). The same reviewers independently screened the studies for eligibility and final inclusion. Disagreements were resolved with the remaining co-authors.

Data extraction and synthesis

A data extraction form was developed in REDCap (Vanderbilt University, USA) and was piloted with five randomly selected studies. Discrepancies in extraction and analysis by the two reviewers were discussed and the form was revised. The following details were extracted: general study information including study design; viral illness; target learner population and learner level; competency category; educational modality; description of intervention; description of educational outcomes; appraisal of the educational intervention;[12] and level of educational outcome based on Kirkpatrick's levels and education evidence.[13] Synthesis was aligned with the three research questions.

RESULTS

Study selection process

Flow chart is provided in Figure 1. A total of 15,676 records were identified through the searches. Of these, 10,092 studies remained after removal of duplicates and studies not reported in English. Three hundred four studies were included for full-text screening of which 46 studies fulfilled the inclusion criteria (Table S1). Heterogeneity of the included studies precluded metanalysis.

Study characteristics

Study characteristics are presented in Table 3. A majority of the studies reported on learning interventions developed in response to EVD (n=24, 52%),[14-37] eight studies were motivated by SARS (17%),[38-45] seven studies by H1N1 influenza (15%),[46-52] one study by MERS (2%),[53] and three studies were motivated by more than one disease.[54-56] Three studies were published in relation to COVID-19.[57-59]

The majority of the studies used a single-group study design (n=16, 37%) or were educational cohort studies (n=16, 35%). Two were non-randomised trials (4%)[30,41] and only six studies were randomised controlled trials (13%).[15,36,39,44,51,58] Medical doctors and nurses were the targeted learners in most of the studies (n=18 (39%) and n=25 (54%), respectively). Other healthcare professionals included were for example paramedics,[14,53] respiratory therapists,[32,44,52] pharmacists,[37,52,55] and midwives.[33,36,37] Students in relevant fields were included in some studies.[22,23,42,43,49,54,58,59]

Educational content and competency category

Theoretical knowledge. Thirty-five studies (76%) reported on development of theoretical courses to educate and inform HCW regarding general principles of epidemic preparedness, disease presentation, surveillance, and treatment. Resources for course content could originate for example from the World Health Organization (WHO), from the Centers for Disease Control

and Prevention (CDC)[60] or from official guidelines implemented by local health and infectious disease authorities to aid the hospitals.[20] Knowledge on infection prevention and control (IPC) including patient care principles and safety practices were central in many of the included studies.[17,21,27,30,31,37,41,45,54]

Technical skills. In 26 studies (57%), the focus was on technical skills particularly on risk management strategies such as donning and doffing of PPE.[14,15,21,22,25,30-32,34,37,46,53,57,58] One study reported that while PPE skills can be mastered in a controlled learning environment, maintaining the integrity of the procedure during critical situations is challenging.[14] Critical care management skills were also often trained including endotracheal intubation, airway management techniques, manual and mechanical ventilation;[21,32,54,59] advanced cardiac and airway life support (ACLS/AALS);[38,40] and extracorporeal membrane oxygenation (ECMO) management.[47,50]

"Non-technical" skills. Eight (17%) studies described a variety of other skills such as teamwork and cognitive load,[15] interpersonal skills, reporting and decision making,[43] attitude,[33] critical thinking skills,[55] concern and confidence.[26] Psychological support for HCW was highlighted in three studies that designed educational interventions on psychological first aid[36] and resilience.[51,56] Another study highlighted the importance of interpersonal skills for screening personnel to manage the high number of potentially anxious patients and visitors.[43]

Training delivery

Traditional didactics. Thirteen out of 46 studies (28%) used traditional didactics such as lectures and other adult learning strategies including interactive group and learner-led discussions,[46,48,55] case-based learning,[23,49] problem-based learning,[42] demonstrations/return demonstrations,[35,43] and role playing.[43,48] Most of the studies that aimed to convey theoretical knowledge consisted of brief sessions, i.e. less than a day (n=8/13, 62%).[35,36,42-45,55,56]

E-learning. E-learning has been used to rapidly disseminate information during an epidemic outbreak. One study found that e-learning could be used to significantly increase knowledge on a pre- and post-learning test as well as retention test.[26] Other studies used CD/DVD or USB drives to disseminate course materials for self-learning, as well as audio/ video mini lectures [29,41,51,54] and specific software for interactive online learning.[30,33]

Simulation-based training. In 31 studies (67%), simulation-based training (SBT) was an integral part of the training intervention. This ranged from skills stations to practice relevant clinical procedures such as airway management or central venous catheter placement,[21,32,57] to the use of high-fidelity and interactive simulation equipment for large scale scenario training.[18,21,38] The majority of the studies focused on training the correct use of PPE, while a few studies also used simulation to train interpersonal skills and team training.[32,50,52] The duration of SBT was variable across studies, ranging from shorter sessions[15,38,58] to multi-day courses.[20,27,30,31,37,47]

Effects and level of educational outcome

Eight out of 46 studies (17%) evaluated the learning outcome at Kirkpatrick level 1 i.e. the learners' satisfaction and experience with the training intervention. All these studies concordantly found that learners were satisfied with training regardless of the intervention.[18,25,31,38,43,47,54,56]

Modification of attitude or perceptions (Kirkpatrick level 2a) were an outcome in five studies (11%). In one of these studies it was reported that the participants felt more confident after the intervention that consisted of 80 hours of lectures and simulation-based training of care and management of the infected patient.[21]

The majority of the studies (n=29, 63%) reported on modification of knowledge and/or skills (Kirkpatrick level 2b) resulting from the educational intervention. A significant decrease in number of errors in donning and doffing of PPE was demonstrated in one study after a single

1-hour theoretical session combined with three simulation sessions, which were repeated after 72 hours.[22] A longer 3-day course of e-learning and simulation-based training regarding safety measures in EVD patient care reported a significant increase in knowledge scores from pre- to post-intervention as well as an overall high performance in the simulation scenario on PPE use.[30]

Only one study reported on behavioural change in the clinic among the participants who correctly used PPE after supplemental SBT as compared to the ones who underwent the standard training (Kirkpatrick level 3).[39] Change in organizational practice (Kirkpatrick level 4a) was reported following simulation-based training in IPC, which led to a decrease in infection rate amongst HCW.[17] Two studies included Kirkpatrick level 4b evaluation by demonstrating a benefit to patients or clients directly attributable to the training intervention.[17,50] In one of these, decreased mortality rates in ECMO patients was found after implementation of an ECMO training program (66.7% vs. 91.3%, p =0.013).[50]

DISCUSSION

In this systematic review, we identified 46 studies on training and educational interventions for HCW that were developed and implemented due to an ongoing or a recent major viral epidemic.

Target population and educational content

Most of the educational interventions were prompted by the urgent need to train HCW, especially in relation to the EVD outbreak, which had the highest case fatality rate at 40.4% compared with SARS (9.6%), MERS (34%), H1N1 (0.02%), and COVID-19 (3.4% as of 3 March 2020).[61] EVD training programs were initiated for all HCW who were deployed to the frontlines, mainly focused on IPC procedures and the proper use of PPE. For the other viral diseases, a surge of critically ill patients with respiratory failure has prompted many of the simulation-based interventions to train critical care management skills such as ACLS/AALS and ECMO.[38,40,47,50] All these high risk infections also expose HCW to psychological hazards such as fatigue, occupational burnout and distress, furthermore highlighting that psychological support to maintain the well-being of HCW during a pandemic is imperative, as seen in a number of studies.[28,36,56,62]

Educational strategies and implementation

The use of traditional didactic methods to teach theoretical knowledge is common when a large number of learners need to be targeted at the same time. Depending on the learning goals, theoretical knowledge can be efficiently delivered in less than a day, and briefer sessions are particularly efficient if modules are spaced (i.e. distributed learning) as demonstrated in several of the included studies.[22,40,55]

The advent of e-learning, including web-based and other technology enhanced learning, has opened immense opportunities for flexible dissemination of information notwithstanding time and location.[63] This poses an advantage, especially for HCW in remote locations, where

learning resources can be accessed in their own time and without potential transmission of infection between the learners. E-learning is dependent on online access which could be a challenge in rural communities with limited network coverage.[29] In light of COVID-19, the WHO Health Emergencies Programme has launched free online training resources, providing HCW and staff access to real-time knowledge on how to detect, prevent and respond to the new coronavirus.[64] In medical education, e-learning has been found to have large positive effects and is especially effective when combined with other educational modalities.[63]

SBT has also been increasingly utilized as an integral part of medical training with positive effects on knowledge, skills and behaviors.[65,66] In the context of a viral outbreak, simulation provides a safe and controlled environment for training of emergency response including teamwork and system readiness. This is corroborated by the included studies on PPE, which found that participants benefitted from repeated training of donning and doffing; of efficiently performing procedures whilst wearing a constricting PPE; and the use of full-scale scenarios for team-based training.[32,38]

These three major educational strategies can all be used in combination and integrated in a structured curriculum to achieve an optimized learning experience.[67] Several of the included studies achieved this for example by using e-learning to provide pre-course materials, allowing for self-learning prior to course start, then theoretical teaching through lectures and other interactive learning strategies such as group exercises and discussions, and finally practical skills training in a simulated setting.[68] Multi-modality and extensive training presents a challenge especially for countries with limited resources,[69] however, standardised training programs that are supported by the international communities and the local government bodies seem to help alleviate this.

Effect of training and level of educational outcome

In the included studies, effect of training varied across educational strategies and mode of evaluation. Interestingly, duration of the training intervention did not seem to correlate with the relative effect on the educational outcome: for example, a 3-day workshop on EVD management resulted in 29% increase in knowledge from pre- to post-workshop[20]; whereas a 3-hr training session on EVD awareness led to a 235% increase in knowledge from baseline to post-intervention[35]. This illustrates that training outcome is very much dependent on the objectives of the training and how it is evaluated. It is also important to be critical in regard to the size of the effects of training reported: a 2-hour session on SARS[41] reported a statistically significant increase in knowledge, however, the actual change in test scores from pre- to post-training intervention was only 3% and therefore of limited consequence.

Most of the included studies reported outcomes of the educational intervention at the level of learner satisfaction (level 1), modification of attitude (level 2a), and modification of knowledge and skills (level 2b) without evaluating if the training affected clinical practice. Learner satisfaction and attitude are typically measured using post-course surveys and changes in knowledge and skills by pre-and post-training tests. Unsurprisingly, these will almost always result in high levels of satisfaction, increase in confidence and improvement in knowledge and skills after intervention. Further, these outcomes provide little to no information on actual performance and translation into improved performance in the clinical environment and/or patient outcomes.[70]

Implications and perspectives

The current pandemic has highlighted that despite many relevant training interventions already developed, implementation remains a challenge. There is a need for structured and evidence-based training programs that are easily replicated and adaptable to local contexts and settings.[12] Development of educational interventions should follow a systematic approach for example Kern's six-step model:[67] starting with a general needs assessment to identify gaps and learner needs; a targeted needs assessment to align to targeted context; definition of goals and objectives including plans for assessment to ensure that the learning goals are met and that learning outcomes are measured appropriately (i.e. knowledge and skills transfer into the clinical environment);[71,72] selection of educational modalities, which could include different categories of knowledge, technical skills and "non-technical" skills);[67,73] and finally, plans for implementation and evaluation of the training program.

Training should be optimized and implemented based on learning needs, conditions and resources, allowing for deliberate and distributed practice over time.[74] Assessment of the effect of learning interventions plays a critical role and ultimately, provides evidence for improved patient outcomes.[67,75] At present, evidence regarding training and education in preparation for a viral epidemic is sparse and none any of the interventions included in this review has followed a structured model for curriculum development nor has undergone rigorous evaluation.

We recommend medical educators to share and publish their experiences as additional resources, in keeping with high standards and collect evidence for their educational interventions.[76] Interestingly, we note that scientific studies spike during or shortly after the onset of the viral epidemic and tend to decline after a few years. With more than 61,000 studies found in PubMed relating to the five viral diseases, less than 6% relates to education and training and of these, only 46 were educational interventional studies. This further highlights

the need for careful planning and refinement of training interventions also post-epidemic by systematically improving educational approach, study design and outcome measures so that these efforts can prepare the medical community best possibly for the next epidemic. Educational research should not solely be performed during an ongoing viral epidemic where the stakes are high and the conditions for teaching and training are far from optimal.

Strengths and limitations

A strength of this review is the inclusion of educational interventional studies in the last twenty years, providing an overview of the currently published training programs for HCW and their evidence. A limitation relates the exclusion of descriptive studies reporting on the development of training programs without evaluation. Many of the included studies were not conducted to the highest standards in medical education and published in minor clinical journals. We also think that there is a substantial educational effort that goes unreported. Finally, we did not include studies that solely evaluated organizational or system-wide impact of interventions because we aimed in this review to focus on how to train HCW rather than how to improve systems through training.

Conclusion

Published educational interventional studies in relation to training during viral epidemics demonstrate a scattered focus across educational content, design, strategies and modes of delivery. Overall, the included studies consistently reported positive benefits of any structured training intervention including positive effects on confidence and knowledge. However, there are very few studies evaluating that these training efforts transfer into improved clinical performance and better patient outcomes. Development and implementation of standardised training programs that can be easily adapted locally are required for the medical community to be well-prepared for the next viral epidemic outbreak.

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TABLE AND FIGURE LEGENDS

Figure 1. Preferred Reporting Items for Systematic Reviews and Meta-Analyses (PRISMA) flowchart of the study search and selection process for a systematic review on training and education of healthcare workers during viral epidemics

Table 1: Inclusion and exclusion criteria for inclusion in a systematic review on training and education of healthcare workers during viral epidemics

Table 2: Search strings used in a systematic review on training and education of healthcare workers during viral epidemics

Table 3: Characteristics of the educational interventional studies included in a systematic review on training and education of healthcare workers during viral epidemics

***Supplementary files**:*

Table S1: Overview of the educational interventional studies included in a systematic review on training and education of healthcare workers during viral epidemics including general descriptive information

Figure 1. Preferred Reporting Items for Systematic Reviews and Meta-Analyses (PRISMA)[11] flowchart of the study search and selection process for a systematic review on training and education of healthcare workers during viral epidemics

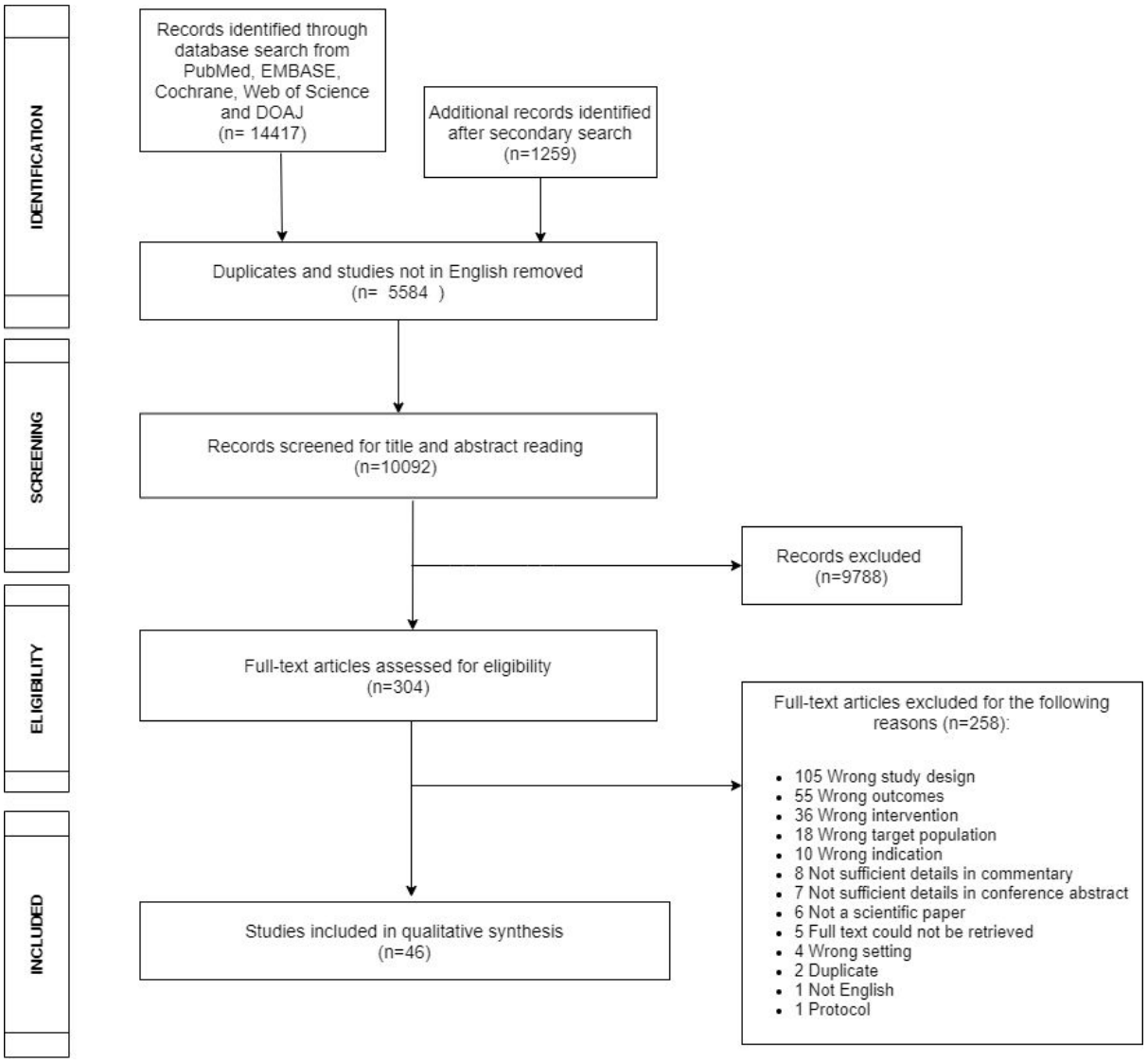

Table 1. Inclusion and exclusion criteria for inclusion in a systematic review on training and education of healthcare workers during viral epidemics

Inclusion criteria	*Exclusion criteria*
• Population: Healthcare professionals, healthcare workers and healthcare students at any level. • Intervention: Studies reporting on the development, evaluation and implementation of educational interventions regarding treatment and prevention control. • Comparison: Any studies investigating educational interventions. • Outcomes: Studies with learner outcome measures. • Design: Any quantitative or qualitative interventional study. • Context: Studies conducted in any healthcare or healthcare professions educational setting.	• Studies that were not in English language. • Unpublished literature or not available through online access. • Abstracts with insufficient description, quantitative or qualitative data • Descriptive papers that only describe development of the educational intervention without any evaluation. • Studies reporting on general or "system" outcome of the educational intervention.

Table 2: Search strings used in a systematic review on training and education of healthcare workers during viral epidemics

1. PubMed	(training OR educat* OR teach*) AND (coronavirus OR SARS OR H1N1 OR MERS OR EBOLA OR COVID-19)
1. Cochrane	**ID** **Search** #1 TRAINING #2 educat* #3 teach* #4 coronavirus #5 SARS #6 H1N1 #7 MERS #8 EBOLA #9 COVID-19 #10 #1 OR #2 OR #3 #11 #4 OR #5 OR #6 OR #7 or #8 OR #9 #12 #10 AND #11
2. EMBASE	(training OR educat* OR teach*) AND (coronavirus OR sars OR h1n1 OR mers OR ebola OR 'covid 19') AND [2000-2020]/py AND [english]/lim

3. Web of Science	(training OR educat* OR teach*) AND (coronavirus OR SARS OR H1N1 OR MERS OR EBOLA OR COVID-19)
4. DOAJ	Training AND coronavirus Training AND SARS Training AND H1N1 Training AND MERS Training AND COVID-19 Training AND Ebola Educat* AND coronavirus Educat* AND SARS Educat* AND H1N1 Educat* AND MERS Educat* AND EBOLA Educat* AND COVID-19 Teach* AND coronavirus Teach* AND SARS Teach* AND H1N1 Teach* AND MERS Teach* AND EBOLA Teach* AND COVID-19

Abbreviations: SARS- severe acute respiratory syndrome; H1N1- H1N1 influenza virus infection; MERS- Middle East respiratory syndrome; EVD- Ebola virus disease; COVID-19- corona virus disease 2019; EMBASE- Excerpta Medica; DOAJ- Directory of Open Access Journals

Table 3. Characteristics of the educational interventional studies included in a systematic review on training and education of healthcare workers during viral epidemics

Viral Illness	**$N_{studies}$**	**$N_{studies}$(%)**
SARS	8	17
H1N1	7	15
MERS	1	2
EVD	24	52
COVID-19	3	7
Multiple illnesses	3	7
Years		
2000–2005	1	2
2006–2010	8	17
2011–2015	12	26
2016–2020	25	54
Competency category		
Knowledge	35	76
Technical skills	26	57
"Non-technical" skills	8	17
Primary educational modality		
Traditional didactics	13	28
Simulation-based training	31	67
E-learning	6	13
Educational outcome (cf. Kirkpatrick's levels[13])		
Level 1	8	17
Level 2a	5	11
Level 2b	29	63
Level 3	1	2

Level 4a	1	2
Level 4b	2	4

Abbreviations: SARS- severe acute respiratory syndrome; H1N1- H1N1 influenza virus infection; MERS- Middle East respiratory syndrome; EVD- Ebola virus disease; COVID-19- corona virus disease 2019

Supplementary table

Table S1. Overview of the educational interventional studies included in a systematic review on training and education of healthcare workers during viral epidemics including general descriptive information

First author, year of publication	Country of first author	Viral illness	Participants	Competency category and overall educational content	Delivery		Educational Intervention Checklist[§]			Kirkpatrick's Levels	Main findings
					Main educational modality	Duration of training	Preparation (items 1–2), mean	Intervention (items 3–15), mean	Evaluation (items 16–17), mean	(1/2a/2b/3/4a/4b)*	(at the level of highest Kirkpatrick level)
Abrahamson, 2006	Canada	SARS	Doctors, nurses	Knowledge and technical skills on advanced cardiac life support protocol for SARS patients	Simulation-based training (scenario-based)	2-hour session	2.0	1.3	1.5	1	Participants rated the comprehensiveness, duration, and effectiveness of teaching methods favorably.
Abualenain, 2018	Saudi Arabia	EVD	Doctors, nurses, paramedics, anesthesia technicians, others	Technical skills: donning and doffing of PPE	Simulation-based training	Not specified	1.5	1.3	0.5	2b	Pre- and post-training test written scores for the participants improved significantly ($p < 0.01$) from 67% (range 57–75%) to 85% (range 81–91%), respectively. All 179 HCW completed the Ebola PPE checklist, about half compromised (different levels of compromising) the PPE protocol at some point.
Adini, 2012	Israel	H1N1	Doctors, nurses	Knowledge and technical skills related to avian flu (management of patient; donning and doffing of PPE)	Lectures; small group discussions and tabletop exercises	Not specified	1.5	0.5	0.5	2b	The overall mean score for the 14-item multiple choice questions for emergency department medical personnel was 75.6. The correlation between the level of knowledge related to pandemic flu and the performance in the avian flu exercise was not significant (Spearman's rho < 0.25)
Aiello, 2011	Canada	SARS, H1N1	Doctors, nurses, other hospital staff	"Non-technical" skill: resilience	Lectures	Multiple 1-hour sessions over a 5-month period	1.5	1.1	2.0	1	A high proportion of participants found the session relevant to work life and personal life, useful, helpful, and informative. Ten themes emerged from the comments: family-work balance, antiviral prophylaxis, need for information, education and preparedness, ethical concerns, visibility of leadership, valuing frontline staff, mistrust/fears, information relating to redeployment, need for ongoing resilience training.
Andonian, 2019	USA	EVD	HCW (not specified)	Technical skill: donning and doffing of PPE; "Non-technical" skills: teamwork, cognitive load	Lectures; video demonstrations, simulation-based training	2-hour session	1.5	1.0	0.5	2b	Any type of self-contamination was high in both groups (84.6–100 %) during doffing, but the intervention group contaminated fewer sites ($p = 0.002$). Intervention group demonstrated more teamwork behaviors (median 27.1) compared to controls (median 9.1). Participants in the intervention group perceived marginally higher mental demand than the controls ($p = 0.055$).

Bazeyo, 2015	Uganda	EVD	Doctors, nurses and other district HCW including lab technicians, immigration officers and security officers, media persons	Knowledge related to EVD	Small group work and discussions; demonstrations, visual aids, role play, case studies; practical exercises	5-day course	1.0	0.6	0.5	2b	Knowledge increased from ~56–78 % pre-intervention to ~68–88 % post-intervention on a knowledge test.
Bemah, 2019	Liberia	EVD	HCW (not specified)	Knowledge related to PPC, EVD and IPC	Classroom-based teaching; simulated patients; clinical mentoring	8-day course	1.0	1.1	0.5	4b	Both clinicians (n = 188) and non-clinicians (n = 149) showed statistically significant improvements in knowledge on clinical care and IPC concepts as measured by the 9-item pre-and post-training questionnaires (both $p < 0.001$). HCW infection rate was 9% by October 2014 (pre-course) and had dropped to 1% by January 2015 (post-course). Furthermore, after the conclusion of training in March 2015, no infections reported among HCW exposed to the confirmed cases despite the resurgence of Ebola cases in June and November 2015, and April 2016.
Brazzi, 2012	Italy	H1N1	Anesthesiologists	Knowledge: gas exchange during extracorporeal bypass; Technical skill: ECMO	Lectures; simulation-based training	3-day course	1.0	1.6	2.0	1	Participants rated the relevance, quality and efficacy of the training favorably.
Bredmose, 2014	Norway	EVD	Helicopter Emergency Medical Service (HEMS) crew	Technical skill: Helicopter Emergency Medical Service in relation to EVD patients	Simulation-based training (in-situ simulation)	Not specified	0.5	0.7	1.0	1	All participants reported high degrees of satisfaction and realism.
Bustamente, 2015	USA	EVD	Doctors, respiratory therapists	Technical skill: PPE	Simulation-based training	4 hours	0.5	0.8	1.0	2a	The intervention increased the confidence of participants. 95% and 87% of participants, respectively, rated the program and faculty as good or outstanding on a five-point Likert scale.
Carlos, 2015	Philippines	EVD	Doctors, medical technologists	Knowledge related to EVD	Lecture and practical hands-on workshop	3-day workshop	1.0	1.5	2.0	2b	The percentage of participants who correctly answered all 10 questions was 2.8% (8 of 285) and 22.5% (82 to 364) pre- and post the workshop, respectively. The number of questions correctly answered by participants increased from a pre-workshop median of 7 (IQR 6–8; range 3–10) to a post-workshop median of 9 (IQR 8–9; range 4–10) ($p < 0.009$).

Carrico, 2007	USA	SARS	Nurses	Knowledge of respiratory pathogen transmission as well as standard precautions; Technical skill: donning and doffing of PPE	Classroom training and simulation-based training	Not specified, but <1 day	1.0	1.6	1.0	3	Pre- and post-training test scores were similar for the two groups and increased from 0.64 to 0.76. Participants who received the visual training demonstrated use of PPE more often (74% vs 53%, respectively).
Carvalho, 2019	Spain	EVD	Doctors, nurses, cleaning personnel, nursing assistants, security personnel, stretcher bearers	Knowledge: principles of care and management of infected patient. Technical skill: donning and doffing of PPE, other procedures such as blood extraction, catheter placement, endotracheal intubation, hygiene, stool and vomit, cleaning, emergency situations, patient transfer	Classes and seminars; simulation-based training (full scale scenarios)	80-h course over 10 days	1.0	1.4	1.5	2a	Participants felt that the course increased their sense of security, predisposition to take care of these patients and confidence in management.
Casalino, 2015	France	EVD	Medical and nursing students	Knowledge related to EVD; Technical skill: donning and doffing of PPE	Classroom lecture; specific skills training	1--hour theoretical session; and a practical session repeated every 72 hours for each group	1.0	1.3	1.0	2b	In all 4 groups, the frequency and number of total errors and critical errors decreased significantly over the course of the training sessions ($p < .01$). The intervention was associated with a greater reduction in the number of total errors and critical errors ($p < .0001$). The B-PPE intervention groups had the fewest errors and critical errors ($p < .0001$).
Chen, 2009	Taiwan	SARS	Doctors	Technical skills: Advanced Airway Life Support	Lecture; simulation-based training	2-hour lecture, 4-hour hands-on workshop	1.5	1.8	1.5	2b	Residents received higher scores during re-simulation regardless of scoring methods.
Choi, 2020	Hongkong	COVID-19	Doctors and nurses	Technical skills: donning and doffing of PPE, intubation, central venous catheter	Simulation-based training	20-30 min simulation and 30-mins debriefing	1.0	1.08	1.0	2a	The domains for feedback and discussion included the following key events in chronological order: donning PPE, pre-intubation check, intubation procedure, and doffing PPE. Local guideline changes.

Christensen, 2020	Denmark	COVID-19	Medical students	Technical skills: donning and doffing of PPE	Demonstration/return demonstraion; video-based	2- to 3-hour training session for control group; intervention group watched videos as many times as they wished at home	1.0	1.25	0.5	2b	19 of 21 participants returned for 1-month post-instruction evaluation. In donning, the scores in the instructor group ranged from 67% to 100%, and the scores in the video group ranged from 62% to 100%. The overall mean donning score was 86.5/100; the mean score was 84.8 for the instructor group and 88.0 for the video group. In doffing, the scores in the instructor group ranged from 59% to 96%, and the scores in the video group ranged from 51% to 93%. The overall mean doffing score was 76.4/100; the mean score for the instructor group was 79.1, and it was 73.9 for the video group
Diaz, 2013	USA	H1N1	Doctors	Knowledge related to H1N1	Lecture, interactive group sessions, role play	3-day course	1.0	1.3	2.0	2b	Critical care knowledge improved significantly from before the training to immediately after (Caribbean site: 58–80%; Indonesia site: 56–75%; p <0.001 for both).
Diaz, 2018	Switzerland	H1N1	Undergraduate students in nursing and health sciences	Knowledge: Critical care management/(best ICU practices, ARDS, and pregnancy influenza	Lectures; case-based learning	3-day course	2.0	1.7	2.0	2b	Test scores improved significantly after training (p < .001) both in pilot and implementation phases; participants rated the learning units as good to very good (mean, 5-point Likert scale: 4.6–4.8).
Dube, 2018	USA	EVD	Natural and health science major undergraduate students	Knowledge related to EVD	Case-based learning	Integrated in undergraduate curriculum	2.0	1.3	2.0	2b	Students improved in relation to theoretical knowledge on all 10 questions (a mix of multiple choice questions, true/false statements and free text responses). Overall score (normalized) improved from ~47%–80%.
Eardley, 2015	UK	EVD	HCW, university and military staff	Knowledge related to EVD	Lectures; drills	4-day course	1.5	1.5	2.0	2b	Factual knowledge increased (a median change on the VAS of 4.0 by all delegates, p<0.001). Change in confidence in teaching increased (median change on the VAS of 5.0 for all delegates, p<0.001).
Eckes, 2016	USA	EVD	Nurses	Knowledge: Principles of EVD care and PPE; Technical skill: donning and doffing of PPE	Lectures; simulation-based training	Quarterly course (hours not mentioned)	1.5	1.3	1.0	1	Participants completed a return demonstration and written assessment. Further details not provided.
Elcin, 2016	Turkey	MERS	Paramedics	Knowledge related to MERS and PPE for healthcare providers	Simulation-based training	1-day course with 3 sessions	1.5	1.6	2.0	2b	16 of 19 (84%) teams recognized the possibility of MERS as a measure of their awareness in the baseline evaluation. The participating sites lacked PPE, which revealed their baseline level of preparedness for MERS. Certain improvements in donning and doffing PPE were observed in the post-training evaluation.

Ferranti, 2016	USA	EVD	Nurses	Knowledge related to EVD	E-learning: online PowerPoint slides	3-day course	1.5	1.7	0.5	2b	Knowledge increased significantly from pre- to post and retention test (75.9 % to 90.7 % and 89.8 %, respectively).
Hanley, 2008	USA	SARS, H1N1	Nurses, respiratory therapy students, general internists, physician assistants, nurse practitioners, non-critical-care nurses veterinarians, and physical therapists	Knowledge and technical skills: Infection control, manual ventilation, mechanical ventilation, airway maintenance, and airway suctioning.	E-learning: video (DVD); simulation-based training	Just-in-time training (90 mins)	2.0	1.1	1.0	1	No detailed information of results from the assessment, however, groups passed based on their cognitive scores to the questions and performance scores during the dry lab competency testing.
Jones-Konneh, 2017	Japan	EVD	Nurses, other HCW (not specified)	Knowledge related to EVD; Technical skills on PPE and other IPC skills such as hand hygiene, mixing of chlorine solutions, etc.	Simulation-based-training	3 phases of training: A. 3 days theory, 2 days for SBT; B. 1-day theory and 2 days SBT; C. 3 days for basic IPC/PPE	2.0	1.3	1.0	2a	Feeling of comfort decreased anxiety during patient care; no other quantification of training outcome presented. It is speculated that HCWs had improved understanding of EVD, IPC and patient care, which subsequently could have contributed to the survival of patients.
Kim, 2018	Korea	H1N1	Doctors, nurses	Knowledge: basic hemodynamics, ECMO physiology, circuit anatomy, and hemostasis of patients on ECMO; Technical and behavioral skills to manage ECMO scenarios; “Nontechnical" skills: team communication	Lectures; simulation-based training	Every month (duration not mentioned)	1.5	1.2	0.5	4b	Mortality rate of patients markedly lower during period 2 (after program implementation) as compared to period 1 (before implementation).

Klomp, 2020	USA	EVD	CDC staff (non-clinical deployers)	"Nontechnical skills": resilience	Traditional didactics	3-day training	1.5	1.3	0.5	2b	Pre- to post training knowledge in relation to key elements and resilience increased 2.95 points out of 30 (95% CI, 2.53-3.37). The Self-Efficacy Survey total score showed a significant improvement in overall self-efficacy. This suggests participants gained useful knowledge of resilience principles and strategies.
Lin, 2008	Taiwan	SARS	Patient-hired attendants and outsourced workers	Knowledge: control of nosocomial infections	Lecture; video-based demonstration (CD)	2-hour session	1.0	1.0	1.0	2b	Improvement from 88.5 to 91.4 points from pre to post-training on a knowledge test ($p < .001$).
Marshall, 2008	USA	SARS	Nurses, social workers and student, public health student	Knowledge: Bioterrorism preparedness	Problem-based learning	3-hour session; follow-up session 1 week later	1.5	1.6	2.0	2b	Increase in knowledge of bioevent preparedness (pre- and post-training knowledge test: overall mean score: 2.4 to 3.8, respectively). Participants found that the case is realistic (mean = 4.1), all health perspectives addressed (mean=3.8), that they had actively participated (mean = 4.6) and gave an overall review (8.5, based on 1-10 scale).
Mathias, 2015	USA	SARS, EVD, H1N1	Pharmacists	Knowledge related to EVD; roles pharmacists play as health care professionals; "Non-technical" skill: critical thinking skills	Learner-led discussions and presentations	3-hour/week, offered over two consecutive years	2.0	1.8	2.0	2b	Evaluation of knowledge and critical thinking skills, as well as performance within the group: assessment based on preparedness and participation in discussions, oral presentations, research paper and final examination. Overall grades for all categories: Cohort 1 from year 1(14 learners) = all received a final grade of A; Cohort 2 from the following year (year 2) (16 learners) = final grade A (n=10), B (n=5), C (n=1)
Maunder, 2010	Canada	H1N1	Nurses, other HCW (not specified)	"Non-technical" skill: Resilience	E-learning: Course materials on a flash drive for self-learning and audio and video mini lectures	3 course lengths (short/medium/long): 7/12/17 sessions	2.0	1.9	1.5	2b	Intention-to-treat analysis showed significant improvements in confidence in support and training, pandemic self-efficacy and interpersonal problems. Participants who under-utilized coping via problem-solving or seeking support or over-utilized escape-avoidance have experienced improved coping. Comparison of doses showed improved interpersonal problems in the medium and long course but not in the short course

Mc Kenna, 2019	Belgium	EVD	Community HCW	Knowledge related to EVD	E-learning: mobile training platform	Multiple modules, each approx. 5 minutes	1.5	1.5	2.0	2b	For module II (relevant to the disease), there was an increase of 3 % in CHCWs correctly answering >80 % of the questions. For CHCWs with 50-79 % correct answers there was a regression in performance after training.
McInnes, 2005	Canada	SARS	Security guards, volunteer students	Knowledge related to SARS; Technical skills: handwashing, putting on N-95; temperature taking; "Non-technical" skills: reporting, interpersonal skills, accurate decision making	Lectures; demonstrations and role playing	Education day (number of hours not detailed)	1.5	1.2	0.5	1	The training enabled the trainees to problem solve, think critically, and use the guidelines established by the screening tool to make decisions about individuals trying to enter the hospital. It also enabled them to realize the importance of their interpersonal skills through mock interactions with different people in a variety of circumstances.
MenkinSmith, 2018	USA	EVD	Medical fellows and residents, nursing specialty training, others (students)	Knowledge safety measures in Ebola patient care; Technical skills in donning and doffing of PPE, infection control practices	E-learning: information via online software; Simulation-based training (team training scenarios)	3-day course	1.5	1.8	2.0	2b	Both groups demonstrated a significant increase in their knowledge test scores after completing the online curriculum, with average scores for novices increasing from 19.7 to 24.3 ($n = 9$, $p < 0.01$) and average score in experienced participants increasing from 19.2 to 22.3 ($n = 9$, $p = 0.03$). Overall high performance of both groups in the simulation scenarios.
Narra, 2016	USA	EVD	HCW	Knowledge related to EVD, infection prevention and control; Technical skill: donning and doffing of PPE	Lectures; small-group discussions, and practical exercises	3-day course	2.0	1.8	2.0	1	This course quickly increased the number of clinicians who could provide care in West Africa ETUs, showing the feasibility of rapidly developing and implementing training in response to a public health emergency.
O'Keeffe, 2016	Ireland	EVD	Nurses, respiratory therapists, laboratory technicians, and ancillary staff	Knowledge related to EVD and safety management; Technical skills: donning and doffing of PPE, airway management, dressing care and IV infusion, urinary catheter care	Simulation-based training (interprofessional)	4-hour program	2.0	1.7	2.0	2b	Increased level of confidence in three key areas: Contamination breach (pre: 2.17; post: 3.71; p<.001), clinical skills in PPE (pre: 2.04; post: 3.82; p<.001), donning and doffing PPE (pre: 2.04; post: 3.88; p<.001).
Otu, 2016	Nigeria	EVD	Nurses, community HCW, midwives, laboratory scientists, auxiliary nurses, pharmacy technicians and health record staff.	Knowledge on EVD disease specific information; "Non-technical" skill: attitude	E-learning: tablet computers with Ebola awareness tutorial (EAT)	2 weeks allowed to review training materials	1.5	1.5	1.0	2b	Increased in knowledge pre- and post-intervention (61.2 to 68.2, 11% improvement < 0.05); Fear of EVD reduced significantly from 89 to 52%. Positive attitudes between pre- and post-EAT scores regarding contact with EVD patients: (83 to 92%); eating bush meat (57 to 64%) and risky burial practices (67 to 79%),

Phrampus, 2016	USA	EVD	Doctors, nurses, other response team members	Knowledge on Ebola, principles of PPE, response, equipment, personal safety, policies; Technical skills: donning and doffing of PPE;	Onsite and online pre-course modules; simulation-based training	4-hour sessions 4 days/week for 3 weeks	2.0	1.8	2.0	2a	Post-course evaluation using an 18-item tool= Median score for each item ranged from 8 to 9 (on a 9-point Likert scale), with interquartile range of 7-9 in all items
Rehman, 2020	Pakistan	EVD	Nurses	Knowledge: EVD awareness	Lectures; video demonstration and discussion	3-hour session	1.0	0.9	0.5	2b	Pre- and post-training test scores demonstrated improvement in knowledge. The mean baseline knowledge score was 3.93±2.519 while the intervention mean score was 13.18±1.192; difference was significant ($p<0.05$)
Rogers, 2019	USA	SARS	Nurses, respiratory therapists, certified nursing assistants, industrial hygienists, safety and occupational health professionals, infection preventionists , and others identified with respiratory protection practice	Knowledge: Respiratory protection practice such as infectious agent transmission routes, hand hygiene, hazard assessment, respirator selection and care, medical evaluation and monitoring, fit-testing and training, respirator donning/doffing and seal checks.	Educational program (lecture) Clinical observations, focus group interviews	Educational program: 1-day training	2.0	1.5	1.5	4a	In the educational program, 17 (68%) participants received either a higher or perfect score on the post-training test. Observations of HCW: 216 documented incident observations of individuals and worker groups that resulted in 253 actions or resolutions by the practice champions.
Sijbrandij, 2020	Netherlands	EVD	Nurses, community HCW, midwives, maternal health assistant, vaccinators, lab assistant, etc	Knowledge: psychological first aid (PFA)	Traditional didactics	one day (no. of hours not mentioned)	1.5	1.3	0.5	2b	Overall knowledge of appropriate psychosocial responses we found a significant effect of time, which was moderated by condition ($X2(2) = 28.63$; $p < 0.0001$). In the PFA group, knowledge about appropriate psychosocial responses increased relative to the control group. Post-hoc contrasts showed a medium to large effect size at the post-PFA assessment (mean estimated difference 1.73; $d = 0.50$; $t(486.01) = 4.54$; $p < 0.001$) and a medium effect size at the follow-up (mean estimated difference 1.54; $d = 0.43$; $t(329.28) = 3.87$; $p = 0.001$.
Soeters, 2018	USA	EVD	Doctors, nurses, pharmacists, laboratorian, health tech, midwife, admin, students,	Knowledge on IPC; Technical skills: donning and doffing of PPE, triage, waste management	Traditional didactics; hands-on training	First course: 3-days Second course: condensed 2 days	2.0	1.3	1.5	2b	Median test scores increased from 40% among HCW, 15% among IPC trainers, and 21% (among IPC supervisors to post-training test scores of 83%, 93%, and 93%, respectively (all $p<0.0001$).

			cleaner, others								
Watson, 2011	USA	H1N1	Doctors, nurses, respiratory therapist, support technicians, pharmacists, physician extenders and students	Technical skill: PPE adherence	Simulation-based training (in-situ)	8-week observation period	2.0	1.3	1.0	2b	Observed adherence with PPE use= 61% for eye shields, 81% for filtering facepiece respirators or powered air-purifying respirators, and 87% for gown/gloves. Use of a "gatekeeper" to control access and facilitate donning of PPE was associated with 100% adherence with gown and respirator precautions and improved respirator adherence. All simulations showed deviation from pediatric basic life support protocols. The median time to bag-valve-mask ventilation improved from 4.3 to 2.7 minutes with a gatekeeper present. Confidence in PPE use improved from 64% to 85% after the mock code and structured debriefing.
Wu, 2009	Taiwan	SARS	Nurses	Knowledge on IPC	Formal lectures, hands-on demonstrations, simulation scenarios, role play, brainstorming and group discussion	1-hour/week (total 16 hours).	1.5	1.3	0.5	2b	Intervention cohort improved significantly on pre- to post-training test and follow-up test (8.87, 9.85, 11.00 points, respectively) compared with the control cohort (8.87, 8.67, 8.70 points, respectively).
Zhou, 2020	China	COVID-19	Nurses and nursing students	Knowledge: emergency and critical care nursing; Technical skills: CPR, use of defibrillator, use of ECG, collection of various specimens, artificial airway techniques, usage of oropharyngeal ventilation tube and mask; gastric lavage technology of gastric lavage machine; Hemostasis, bandaging, and fixation technology	Traditional didactics and simulation-based training; micro-video (webcasts)	10-hr class sessions	2	1.75	2	2b	The total scores of theoretical assessment and practical assessment were 60 and 40, respectively, with 100 points in total. For the theory and practice of group 2: no significant difference between the two groups in terms of theory and practice ($p = 0.654$; $p = 0.813$; $p = 0.180$ Teaching satisfaction: the interns' teaching satisfaction of group 2 was higher than that of group 1: There was overall satisfaction; significant difference between the two groups ($p = 0.020$, $p = 0.039$; $p = 0.012$; $p = 0.029$). There was no significant difference in content rationality between the two groups

§ **Educational intervention checklist**[12]. Each item is assigned a score of 0/1/2 (higher is better) based on descriptive anchors.

* **Kirkpatrick levels**[13]**:** Level 1=learner's view regarding the educational experience; level 2a=modification of behaviour or attitude; level 2b=acquisition or modification of knowledge/skills; level 3=actual behavioural change documented by transfer of learning to the workplace; level 4a=changes in organisational practice that are attributable to the intervention; and level 4b= outcomes at the level of patient health and well-being

Abbreviations: SARS- severe acute respiratory syndrome; H1N1- H1N1 influenza virus infection; MERS- Middle East respiratory syndrome; EVD- Ebola virus disease; COVID-19- corona virus disease 2019; HCW – healthcare workers; PPE – personal protective equipment; IPC – infection prevention and control; ECMO – extracorporeal membrane oxygenation; SBT – simulation-based training; CPR- Cardiopulmonary resuscitation; ECG- electrocardiogram

PRISMA 2009 Checklist

Section/topic	#	Checklist item	Reported on page #
TITLE			
Title	1	Identify the report as a systematic review, meta-analysis, or both.	1
ABSTRACT			
Structured summary	2	Provide a structured summary including, as applicable: background; objectives; data sources; study eligibility criteria, participants, and interventions; study appraisal and synthesis methods; results; limitations; conclusions and implications of key findings; systematic review registration number.	2
INTRODUCTION			
Rationale	3	Describe the rationale for the review in the context of what is already known.	4
Objectives	4	Provide an explicit statement of questions being addressed with reference to participants, interventions, comparisons, outcomes, and study design (PICOS).	4-5
METHODS			
Protocol and registration	5	Indicate if a review protocol exists, if and where it can be accessed (e.g., Web address), and, if available, provide registration information including registration number.	-
Eligibility criteria	6	Specify study characteristics (e.g., PICOS, length of follow-up) and report characteristics (e.g., years considered, language, publication status) used as criteria for eligibility, giving rationale.	6
Information sources	7	Describe all information sources (e.g., databases with dates of coverage, contact with study authors to identify additional studies) in the search and date last searched.	6
Search	8	Present full electronic search strategy for at least one database, including any limits used, such that it could be repeated.	6
Study selection	9	State the process for selecting studies (i.e., screening, eligibility, included in systematic review, and, if applicable, included in the meta-analysis).	6
Data collection process	10	Describe method of data extraction from reports (e.g., piloted forms, independently, in duplicate) and any processes for obtaining and confirming data from investigators.	7
Data items	11	List and define all variables for which data were sought (e.g., PICOS, funding sources) and any assumptions and simplifications made.	7
Risk of bias in individual studies	12	Describe methods used for assessing risk of bias of individual studies (including specification of whether this was done at the study or outcome level), and how this information is to be used in any data synthesis.	6
Summary measures	13	State the principal summary measures (e.g., risk ratio, difference in means).	-
Synthesis of results	14	Describe the methods of handling data and combining results of studies, if done, including measures of consistency (e.g., I^2) for each meta-analysis.	7

PRISMA 2009 Checklist

Section/topic	#	Checklist item	Reported on page #
Risk of bias across studies	15	Specify any assessment of risk of bias that may affect the cumulative evidence (e.g., publication bias, selective reporting within studies).	-
Additional analyses	16	Describe methods of additional analyses (e.g., sensitivity or subgroup analyses, meta-regression), if done, indicating which were pre-specified.	-
RESULTS			
Study selection	17	Give numbers of studies screened, assessed for eligibility, and included in the review, with reasons for exclusions at each stage, ideally with a flow diagram.	8
Study characteristics	18	For each study, present characteristics for which data were extracted (e.g., study size, PICOS, follow-up period) and provide the citations.	8
Risk of bias within studies	19	Present data on risk of bias of each study and, if available, any outcome level assessment (see item 12).	-
Results of individual studies	20	For all outcomes considered (benefits or harms), present, for each study: (a) simple summary data for each intervention group (b) effect estimates and confidence intervals, ideally with a forest plot.	8-11
Synthesis of results	21	Present results of each meta-analysis done, including confidence intervals and measures of consistency.	8-11
Risk of bias across studies	22	Present results of any assessment of risk of bias across studies (see Item 15).	-
Additional analysis	23	Give results of additional analyses, if done (e.g., sensitivity or subgroup analyses, meta-regression [see Item 16]).	-
DISCUSSION			
Summary of evidence	24	Summarize the main findings including the strength of evidence for each main outcome; consider their relevance to key groups (e.g., healthcare providers, users, and policy makers).	12-16
Limitations	25	Discuss limitations at study and outcome level (e.g., risk of bias), and at review-level (e.g., incomplete retrieval of identified research, reporting bias).	16
Conclusions	26	Provide a general interpretation of the results in the context of other evidence, and implications for future research.	16
FUNDING			
Funding	27	Describe sources of funding for the systematic review and other support (e.g., supply of data); role of funders for the systematic review.	17

From: Moher D, Liberati A, Tetzlaff J, Altman DG, The PRISMA Group (2009). Preferred Reporting Items for Systematic Reviews and Meta-Analyses: The PRISMA Statement. PLoS Med 6(7): e1000097. doi:10.1371/journal.pmed1000097

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Training and education of healthcare workers during viral epidemics: A systematic review

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ABSTRACT

Background: It is necessary to train a large number of healthcare workers within a limited time to ensure adequate human resources during an epidemic. There remains an urgent need for best practices on development and implementation of training programs.

Objective: To explore published literature in relation to training and education for viral epidemics as well as the effect of these interventions to inform training of healthcare workers.

Data Sources: Systematic searches in five databases performed between 1 January 2000 and 24 April 2020 for studies reporting on educational interventions in response to major viral epidemics.

Study Eligibility Criteria: All studies on educational interventions developed, implemented and evaluated in response to major global viral outbreaks from 2000 to 2020.

Participants: Healthcare workers.

Interventions: Educational or training interventions.

Study Appraisal and Synthesis Methods: Descriptive information were extracted and synthesized according to content, competency category, educational methodology, educational effects and level of educational outcome. Quality appraisal was performed using a criterion-based checklist.

Results: A total of 15,676 records were identified and 46 studies were included. Most studies were motivated by the Ebola virus outbreak with doctors and nurses as primary learners. Traditional didactic methods were commonly used to teach theoretical knowledge. Simulation-based training was used mainly for training of technical skills, such as donning and doffing of personal protective equipment. Evaluation of the interventions consisted mostly of surveys on learner satisfaction and confidence or tests of knowledge and skills. Only three studies investigated transfer to the clinical setting or effect on patient outcomes.

Conclusions and Implications of findings

The included studies describe important educational experiences from past epidemics with a variety of educational content, design, and modes of delivery. High level educational evidence is limited. Evidence-based and standardized training programs that are easily adapted locally are recommended in preparation for future outbreaks.

Keywords: viral diseases; epidemic; coronavirus; ebolavirus; training

Strengths and Limitations of this study

- Inclusion of educational interventional studies in the last twenty years, providing an overview of currently published training programs for healthcare workers and evidence of educational impact.
- Systematic search of five academic databases according to the Preferred Reporting Items for Systematic Reviews and Meta-Analyses (PRISMA) guidelines.
- Final inclusion of forty-six studies reporting on educational interventions implemented in response to SARS, MERS, EVD and COVID-19.
- Exclusion of descriptive studies reporting on development of training programs without evaluation and studies reporting on organizational outcomes with no relevance to training nor evaluation of educational effects.
- Important educational efforts not described in published form were not included.

INTRODUCTION

Global-scale infectious diseases engender threat, vulnerability, and risk to health and healthcare capacity as well as the economic and political stature of a nation.[1] In the last twenty years, the world has seen several major epidemic outbreaks caused by viral agents—namely severe acute respiratory syndrome (SARS) in 2003,[2] swine flu (H1N1 influenza virus infection)[3] in 2009–2019, Middle East respiratory syndrome (MERS) in 2012,[4] and Ebola virus disease (EVD) in 2014–2016.[5] Currently, the entire world is facing a pandemic with a novel coronavirus disease (COVID-19),[6] a new and fast spreading viral agent that can challenged and even overwhelm healthcare delivery and capacity as well as human resources. These viral outbreaks have prompted the need for global communities to swiftly plan, prepare, and ensure continuous healthcare functionality, resource availability, and skilled manpower to increase surge capacity.[7]

Healthcare professionals from across different areas were called to help and needed to learn new procedures including correct use of personal protective equipment (PPE)[8] and management of critically ill patients on ventilatory support.[9] To ensure adequate resources and staffing, it was necessary to quickly train a large number of healthcare workers (HCW) to be on the frontlines. Ideally, training and education in preparation for a new infectious threat should be continuous and planned ahead of time. Specialized training equips healthcare workers with the knowledge and skills to safely provide patient care; to reduce fatalities during an outbreak; and to prevent and control nosocomial infections.[10-12]

The experiences learned from previous viral epidemics have helped some countries such as China and Saudi Arabia to deal with and respond to the current COVID-19 pandemic. [13,14] However, this is not always the case: some countries that ranked high in the preparedness for pandemics assessed via the Global Health Security Index showed inconsistencies with their actual performance during the current COVID-19 pandemic.[15] While there are key capacities

that were considered in this performance assessment, the current pandemic has highlighted the need to increase the number of sufficiently trained healthcare workers.[16] There remains an urgent need for best practices on development and implementation of training programs during an epidemic.

In this systematic review, we sought to answer three specific research questions:

1. What are the educational content and types of competencies being trained in relation to HCW as a result of a major viral epidemic?
2. How can training be delivered under these conditions?
3. What are the reported effects of the training interventions?

The overall aim of the study was to provide an overview of the published literature in relation to training and education of HCW during viral epidemics and to explore the educational content of these interventions and the level of competencies being trained. We also sought to present a status on the evidence of effects of these training interventions.

METHODS

This systematic review was conducted and reported in adherence with the Preferred Reporting Items for Systematic Reviews and Meta-analyses (PRISMA) guideline.[17]

Study eligibility

We considered all studies on educational or training interventions developed, evaluated and/or implemented in response to major global viral outbreaks transmitted via close person-to-person contact from 2000 to 2020: SARS, H1N1, MERS, EVD, and COVID-19. Inclusion criteria included studies reporting on development, implementation and evaluation of educational interventions for HCW while the exclusion criteria were studies that were not in English language, descriptive studies, and those reporting on organizational outcomes with no relevance to training nor any outcome measures to evaluate the effect of training (Table 1).

Search strategy

The search strategy was designed to access published literature in health professions education and clinical journals. Five databases were searched from 1 January 2000–24 April 2020 (PubMed, Excerpta Medica (EMBASE)/Ovid, Cochrane Library, Web of Science, and Directory of Open Access Journals (DOAJ)) using the search terms *(training OR educat* OR teach*) AND (coronavirus OR SARS OR H1N1 OR MERS OR EBOLA OR COVID-19)*. See Table 2 for full search details.

Study selection

The search results were retrieved and imported into the Mendeley software (London, UK). Two authors (LJN and SA) independently reviewed and screened titles and abstracts, and eligible studies were included for full-text screening using Covidence (Veritas Health Innovation, Melbourne, Australia). The same reviewers independently screened the studies for eligibility and final inclusion. Disagreements were resolved with the remaining co-authors.

Data extraction and synthesis

A data extraction form was developed in REDCap (Vanderbilt University, USA) and was piloted with five randomly selected studies. Discrepancies in extraction and analysis by the two reviewers were discussed and the form was revised. The following details were extracted: general study information including study design; viral illness; target learner population and learner level; competency category; educational modality; description of intervention; description of educational outcomes; quality appraisal of the educational intervention in different stages (preparation, intervention and evaluation) based on a structured criterion-based checklist;[18] and level of educational outcome based on Kirkpatrick's levels and education evidence.[19] Synthesis was aligned with the three research questions. It was decided a priori to forego meta-analyses because of our specific research questions and expected variety of study population, interventions, context and educational outcomes.

Patient and public involvement: There were no patients nor the public that were involved in the design, or conduct, or reporting, or dissemination plans of this systematic review.

RESULTS

Study selection process

Flow chart is provided in Figure 1. A total of 15,676 records were identified through the searches. Of these, 10,092 studies remained after removal of duplicates and studies not reported in English. Three hundred and four studies were included for full-text screening of which 46 studies fulfilled the inclusion criteria (Table S1).

Study characteristics

Study characteristics are presented in Table 3. A majority of the studies reported on learning interventions developed in response to EVD (n=24, 52%),[20-43] eight studies were motivated by SARS (17%),[44-51] seven studies by H1N1 influenza (15%),[52-58] one study by MERS (2%),[59] and three studies were motivated by more than one disease.[60-62] Three studies were published in relation to COVID-19.[63-65]

The majority of the studies used a single-group study design (n=16, 37%) or were educational cohort studies (n=16, 35%). Two were non-randomised trials (4%)[36,47] and six studies were randomised controlled trials (13%).[21,42,45,50,57,64] Medical doctors and nurses were the targeted learners in most of the studies (n=18 (39%) and n=25 (54%), respectively). Other healthcare professionals included were for example paramedics,[20,59] respiratory therapists,[38,50,58] pharmacists,[43,58,61] and midwives.[39,42,43] Students in relevant fields were included in some studies.[28,29,48,49,55,60,64,65]

Educational content and competency category

Theoretical knowledge. Thirty-five studies (76%) reported on development of theoretical courses to educate and inform HCW regarding general principles of epidemic preparedness, disease presentation, surveillance, and treatment. Resources for course content could originate from international agencies such as the World Health Organization (WHO), from the Centers for Disease Control and Prevention (CDC)[66] or from official guidelines implemented by local

health and infectious disease authorities to aid the hospitals.[26] Knowledge on infection prevention and control (IPC) including patient care principles and safety practices were central in many of the included studies.[23,27,33,36,37,43,47,51,60]

Technical skills. In 26 studies (57%), the focus was on technical skills particularly on risk management strategies such as donning and doffing of PPE.[20,21,27,28,31,36-38,40,43,52,59,63,64] One study reported that while PPE skills can be mastered in a controlled learning environment, maintaining the integrity of the procedure during critical situations is challenging, as well as measures to reduce risk of self-contamination.[20,21] Critical care management skills were also often trained including endotracheal intubation, airway management techniques, manual and mechanical ventilation;[27,38,60,65] advanced cardiac and airway life support (ACLS/AALS);[44,46] and extracorporeal membrane oxygenation (ECMO) management.[53,56]

"Non-technical" skills. Eight (17%) studies described a variety of other skills such as teamwork and cognitive load,[21] interpersonal skills, reporting and decision making,[49] attitude,[39] critical thinking skills,[61] concern and confidence.[32] Psychological support for HCW was highlighted in three studies that designed educational interventions on psychological first aid[42] and resilience.[57,62] Another study highlighted the importance of interpersonal skills for screening personnel to manage the high number of potentially anxious patients and visitors.[49]

Training delivery

Traditional didactics. Thirteen out of 46 studies (28%) used traditional didactics such as lectures and other adult learning strategies including interactive group and learner-led discussions,[52,54,61] case-based learning,[29,55] problem-based learning,[48] demonstrations/return demonstrations,[41,49] and role playing.[49,54] Most of the studies that aimed to convey theoretical knowledge consisted of brief sessions, i.e. less than a day (n=8/13, 62%).[41,42,48-51,61,62]

E-learning. E-learning has been used to rapidly disseminate information during an epidemic outbreak. One study found that e-learning could be used to significantly increase knowledge

on a pre- and post-learning test as well as retention test.[32] Other studies used CD/DVD or USB drives to disseminate course materials for self-learning, as well as audio/ video mini lectures [35,47,57,60] and specific software for interactive online learning.[36,39]

Simulation-based training. In 31 studies (67%), simulation-based training (SBT) was an integral part of the training intervention. This ranged from skills stations to practice relevant clinical procedures such as airway management or central venous catheter placement,[27,38,63] to the use of high-fidelity and interactive simulation equipment for large scale scenario training.[24,27,44] The majority of the studies focused on training of correct use of PPE, while a few studies also used simulation to train interpersonal skills and team training.[38,56,58] The duration of SBT was variable across studies, ranging from shorter sessions[21,44,64] to multi-day courses.[26,33,36,37,43,53]

Effects and level of educational outcome

Eight out of 46 studies (17%) evaluated the learning outcome at Kirkpatrick level 1 i.e. the learners' satisfaction and experience with the training intervention. All these studies concordantly found that learners were satisfied with training regardless of the intervention.[24,31,37,44,49,53,60,62]

Modification of attitude or perceptions (Kirkpatrick level 2a) were an outcome in five studies (11%). In one of these studies it was reported that the participants felt more confident after the intervention that consisted of 80 hours of lectures and simulation-based training of care and management of the infected patient.[27]

The majority of the studies (n=29, 63%) reported on modification of knowledge and/or skills (Kirkpatrick level 2b) resulting from the educational intervention. A significant decrease in number of errors in donning and doffing of PPE was demonstrated in one study after a single 1-hour theoretical session combined with three simulation sessions, which were repeated after 72 hours.[28] A longer 3-day course of e-learning and simulation-based training regarding safety

measures in EVD patient care reported a significant increase in knowledge scores from pre- to post-intervention as well as an overall high performance in the simulation scenario on PPE use.[36]

Only one study reported on behavioural change in the clinic among the participants who correctly used PPE after supplemental SBT as compared to the ones who underwent the standard training (Kirkpatrick level 3).[45] Change in organizational practice (Kirkpatrick level 4a) was reported following simulation-based training in IPC, which led to a decrease in infection rate amongst HCW.[23] Two studies included Kirkpatrick level 4b evaluation by demonstrating a benefit to patients or clients directly attributable to the training intervention.[23,56] In one of these, decreased mortality rates in ECMO patients was found after implementation of an ECMO training program (66.7% vs. 91.3%, p =0.013).[56]

DISCUSSION

In this systematic review, we identified 46 studies on training and educational interventions for HCW that were developed and implemented due to an ongoing or a recent major viral epidemic.

Target population and characteristics

Most of the educational interventions were prompted by the urgent need to train HCW, especially in relation to the EVD outbreak, which had the highest case fatality rate at 40.4% compared with SARS (9.6%), MERS (34%), H1N1 (0.02%), and COVID-19 (3.4% as of 3 March 2020).[67] EVD training programs were initiated for all HCW who were deployed to the frontlines mainly focused on IPC procedures and the proper use of PPE. For the other viral diseases, a surge of critically ill patients with respiratory failure has prompted many of the simulation-based interventions to train critical care management skills such as ACLS/AALS and ECMO.[44,46,53,56] All these high risk infections also expose HCW to psychological hazards such as fatigue, occupational burnout and distress, furthermore highlighting that psychological support to maintain the well-being of HCW during a pandemic is imperative, as seen in a number of studies.[34,42,62,68]

Educational content and competency category

The use of traditional didactic methods to teach theoretical knowledge is common when a large number of learners need to be targeted at the same time. Depending on the learning goals, theoretical knowledge can be efficiently delivered in less than a day, and brief sessions are particularly efficient if modules are spaced (i.e. distributed learning) as demonstrated in several of the included studies.[28,46,61]

The advent of e-learning, including web-based and other technology enhanced learning, has opened immense opportunities for flexible dissemination of information notwithstanding time and location.[69] This poses an advantage, especially for HCW in remote locations, where

learning resources can be accessed in their own time and without potential transmission of infection between the learners. E-learning is dependent on online access which could be a challenge in rural communities with limited network coverage.[35] In light of COVID-19, the WHO Health Emergencies Programme has launched free online training resources, providing HCW and staff access to real-time knowledge on how to detect, prevent and respond to the new coronavirus.[70] In medical education, e-learning has been found to have large positive effects and is especially effective when combined with other educational modalities.[69]

SBT has also been increasingly utilized as an integral part of medical training with positive effects on knowledge, skills and behaviors.[71,72] In the context of a viral outbreak, simulation provides a safe and controlled environment for training of emergency response including teamwork and system readiness. This is corroborated by the included studies on PPE, which found that participants benefitted from repeated training of donning and doffing; of efficiently performing procedures whilst wearing a constricting PPE; and the use of full-scale scenarios for team-based training.[38,44]

These three major educational strategies can all be used in combination and integrated in a structured curriculum to achieve an optimized learning experience.[73] Several of the included studies achieved this by using e-learning to provide pre-course materials, allowing for self-learning prior to course start, then theoretical teaching through lectures and other interactive learning strategies such as group exercises and discussions, and finally practical skills training in a simulated setting.[74] Multi-modality and extensive training presents a challenge especially for countries with limited resources,[75] however, standardised training programs that are supported by the international communities and the local government bodies seem to help alleviate this.

Training delivery and effects and level of educational outcome

In the included studies, effect of training varied across educational strategies and mode of evaluation. Interestingly, duration of the training intervention did not seem to correlate with the relative effect on the educational outcome: for example, a 3-day workshop on EVD management resulted in an increase of correctly answered questions from a pre-workshop median of 7 to a post-median of 9 (~29% increase); [26] whereas a 3-hr training session on EVD awareness demonstrated an improvement in knowledge from the mean baseline score of 3.93 to a mean score of 13.18 after intervention (~235% increase).[41] This illustrates that training outcome is very much dependent on the objectives of the training and how it is evaluated. It is also important to be critical in regard to the size of the effects of training reported: a 2-hour session on SARS[47] reported a statistically significant increase in knowledge, however, the actual change in test scores from pre- to post-training intervention was only 3% and therefore of limited consequence.

Most of the included studies reported outcomes of the educational intervention at the level of learner satisfaction (level 1), modification of attitude (level 2a), and modification of knowledge and skills (level 2b) without evaluating if the training affected clinical practice. Learner satisfaction and attitude are typically measured using post-course surveys and changes in knowledge and skills by pre-and post-training tests. Unsurprisingly, these will almost always result in high levels of satisfaction, increase in confidence and improvement in knowledge and skills after intervention.[76] Further, these outcomes provide little to no information on actual performance and translation into improved performance in the clinical environment and/or patient outcomes.[76]

Implications and perspectives

The current pandemic has highlighted that despite many relevant training interventions already developed, these seem to not have been widely adapted or implemented There is a need for structured and evidence-based training programs that are easily replicated and adaptable to local contexts and settings.[18] Development of educational interventions should follow a systematic approach such as Kern's six-step model:[73] starting with a general needs assessment to identify gaps and learner needs; a targeted needs assessment to align to targeted context; definition of goals and objectives including plans for assessment to ensure that the learning goals are met and that learning outcomes are measured appropriately (i.e. knowledge and skills transfer into the clinical environment);[77,78] selection of educational modalities, which could include different categories of knowledge, technical skills and "non-technical" skills);[73,79] and finally, plans for implementation and evaluation of the training program.

Training should be optimized and implemented based on learning needs, conditions and resources, allowing for deliberate and distributed practice over time.[80] Assessment of the effect of learning interventions plays a critical role and ultimately, provides evidence for improved patient outcomes.[73,81] At present, evidence regarding training and education in preparation for a viral epidemic is sparse and not any of the interventions included in this review has followed a structured model for curriculum development nor has undergone rigorous evaluation.

We recommend medical educators to share and publish their actual results or design of educational studies as additional resources in keeping with high standards and to collect evidence for their educational interventions.[82] To ensure that key information are gathered and reported, the criterion-based checklist that was used in this study can guide the development and implementation of quality educational interventions. Interestingly, we note that scientific studies spike during or shortly after the onset of the viral epidemic and tend to decline after a

few years. With more than 61,000 studies found in PubMed relating to the five viral diseases, less than 6% relates to education and training and of these, only 46 were educational interventional studies. This further highlights the need for careful planning and refinement of training interventions also post-epidemic, by systematically improving educational approach, study design and outcome measures so that these efforts can prepare the medical community best possibly for the next epidemic. Educational research should not solely be performed during an ongoing viral epidemic where the stakes are high and the conditions for teaching and training are far from optimal. We recommend that educational interventional studies such as randomised controlled trials are performed before another pandemic happens in order to gather and establish evidence-based educational practices that will best equip and certify healthcare workers with the competences needed in the front lines.

Strengths and limitations

A strength of this review is the inclusion of educational interventional studies in the last twenty years, providing an overview of the currently published training programs for HCW and their evidence. A limitation relates to the exclusion of descriptive studies reporting on the development of training programs without evaluation. Many of the included studies were not conducted to the highest standards in medical education. We also think that there is a substantial educational effort that goes unreported. Another limitation is the exclusion of non-English language studies which could have helped answer the first research question given that most of the reports concerning viral epidemics come from non-English speaking nations. Finally, we did not include studies that solely evaluated organizational or system-wide impact of interventions because we aimed in this review to focus on how to train HCW rather than how to improve systems through training.

Conclusion

Published educational interventional studies in relation to training during viral epidemics demonstrate a variety of educational content, design, strategies and modes of delivery. Overall, the included studies consistently reported positive benefits of any structured training intervention including positive effects on confidence and knowledge. However, there are very few studies evaluating that these training efforts transfer into improved clinical performance and better patient outcomes. Development and implementation of evidence-based training programs that can be easily adapted locally are required for the medical community to be well-prepared for the next viral epidemic outbreak.

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TABLE AND FIGURE LEGENDS

Figure 1. Preferred Reporting Items for Systematic Reviews and Meta-Analyses (PRISMA) flowchart of the study search and selection process for a systematic review on training and education of healthcare workers during viral epidemics

Table 1: Inclusion and exclusion criteria for inclusion in a systematic review on training and education of healthcare workers during viral epidemics

Table 2: Search strings used in a systematic review on training and education of healthcare workers during viral epidemics

Table 3: Characteristics of the educational interventional studies included in a systematic review on training and education of healthcare workers during viral epidemics

Supplementary files*:*

Table S1: Overview of the educational interventional studies included in a systematic review on training and education of healthcare workers during viral epidemics including general descriptive information

Table 1. Inclusion and exclusion criteria for inclusion in a systematic review on training and education of healthcare workers during viral epidemics

Inclusion criteria	*Exclusion criteria*
• Population: Healthcare professionals, healthcare workers and healthcare students at any level. • Intervention: Studies reporting on the development, evaluation and implementation of educational interventions regarding treatment and prevention control. • Comparison: Any studies investigating educational interventions. • Outcomes: Studies with learner outcome measures. • Design: Any quantitative or qualitative interventional study. • Context: Studies conducted in any healthcare or healthcare professions educational setting.	• Studies that were not in English language. • Unpublished literature or not available through online access. • Abstracts with insufficient description, quantitative or qualitative data • Descriptive papers that only describe development of the educational intervention without any evaluation. • Studies reporting on organizational outcomes with no relevance to training nor evaluation of educational or training effects.

Table 2: Search strings used in a systematic review on training and education of healthcare workers during viral epidemics

1. PubMed	(training OR educat* OR teach*) AND (coronavirus OR SARS OR H1N1 OR MERS OR EBOLA OR COVID-19)
1. Cochrane	**ID** **Search** #1 TRAINING #2 educat* #3 teach* #4 coronavirus #5 SARS #6 H1N1 #7 MERS #8 EBOLA #9 COVID-19 #10 #1 OR #2 OR #3 #11 #4 OR #5 OR #6 OR #7 or #8 OR #9 #12 #10 AND #11
2. EMBASE	(training OR educat* OR teach*) AND (coronavirus OR sars OR h1n1 OR mers OR ebola OR 'covid 19') AND [2000-2020]/py AND [english]/lim

3. Web of Science	(training OR educat* OR teach*) AND (coronavirus OR SARS OR H1N1 OR MERS OR EBOLA OR COVID-19)
4. DOAJ	Training AND coronavirus Training AND SARS Training AND H1N1 Training AND MERS Training AND COVID-19 Training AND Ebola Educat* AND coronavirus Educat* AND SARS Educat* AND H1N1 Educat* AND MERS Educat* AND EBOLA Educat* AND COVID-19 Teach* AND coronavirus Teach* AND SARS Teach* AND H1N1 Teach* AND MERS Teach* AND EBOLA Teach* AND COVID-19

Abbreviations: SARS- severe acute respiratory syndrome; H1N1- H1N1 influenza virus infection; MERS- Middle East respiratory syndrome; EVD- Ebola virus disease; COVID-19- corona virus disease 2019; EMBASE- Excerpta Medica; DOAJ- Directory of Open Access Journals

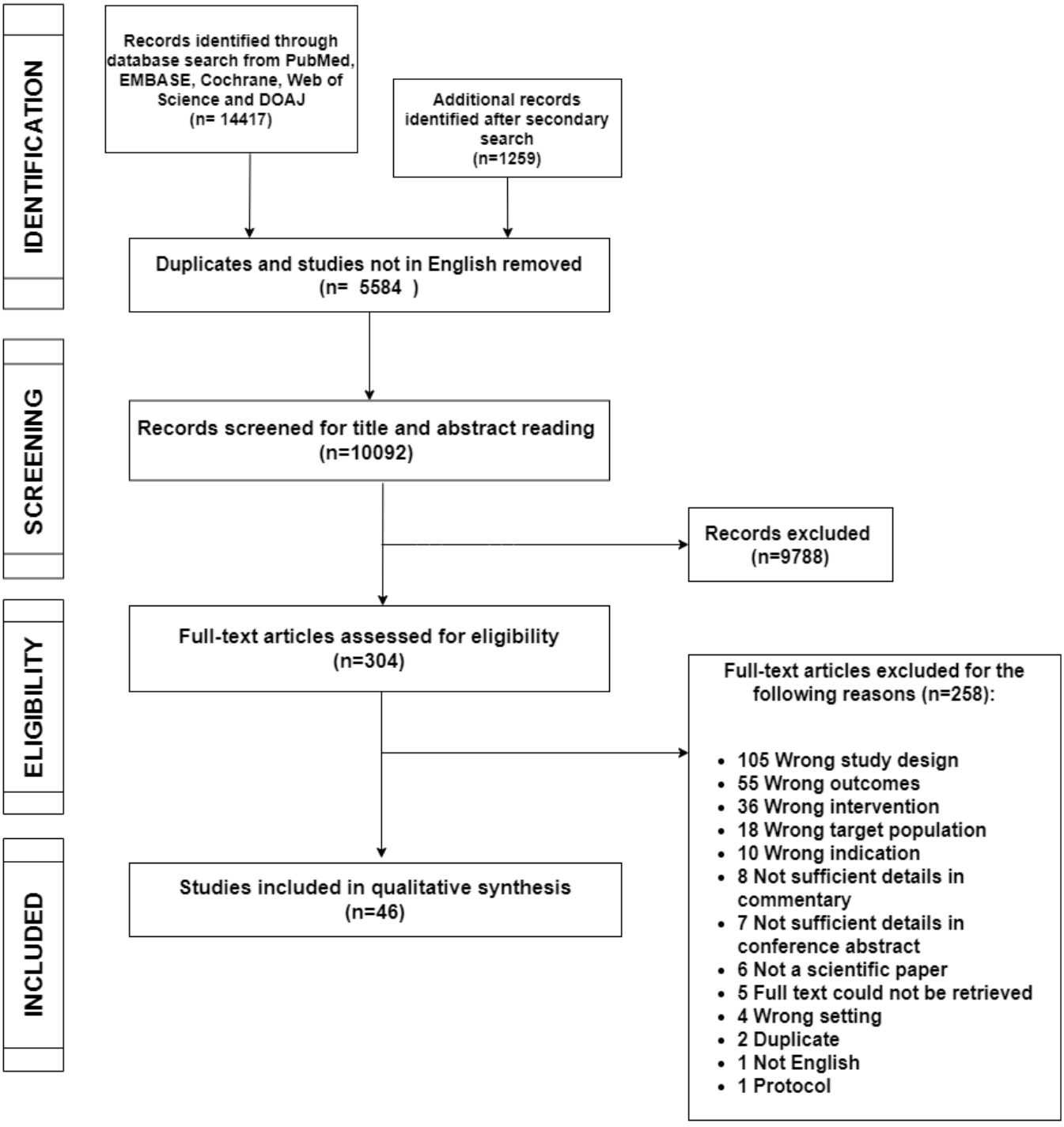
Table 3. Characteristics of the educational interventional studies included in a systematic review on training and education of healthcare workers during viral epidemics

Viral Illness	$N_{studies}$	$N_{studies}$(%)
SARS	8	17
H1N1	7	15
MERS	1	2
EVD	24	52
COVID-19	3	7
Multiple illnesses	3	7
Years		
2000–2005	1	2
2006–2010	8	17
2011–2015	12	26
2016–2020	25	54
Competency category		
Knowledge	35	76
Technical skills	26	57
"Non-technical" skills	8	17
Primary educational modality		
Traditional didactics	13	28
Simulation-based training	31	67
E-learning	6	13
Educational outcome (cf. Kirkpatrick's levels[13])		
Level 1	8	17
Level 2a	5	11
Level 2b	29	63
Level 3	1	2
Level 4a	1	2

Level 4b	2	4

Abbreviations: SARS- severe acute respiratory syndrome; H1N1- H1N1 influenza virus infection; MERS- Middle East respiratory syndrome; EVD- Ebola virus disease; COVID-19- corona virus disease 2019.

Figure 1. Preferred Reporting Items for Systematic Reviews and Meta-Analyses (PRISMA)[11] flowchart of the study search and selection process for a systematic review on training and education of healthcare workers during viral epidemics



Supplementary table

Table S1. Overview of the educational interventional studies included in a systematic review on training and education of healthcare workers during viral epidemics including general descriptive information

First author, year of publication	Country of first author	Viral illness	Participants	Competency category and overall educational content	Delivery		Quality Appraisal using the Educational Intervention Checklist[§] (Scoring: 0-2, *where* 2 is the highest score)			Kirkpatrick's Levels	Main findings
					Main educational modality	Duration of training	Preparation (items 1–2), mean	Intervention (items 3–15), mean	Evaluation (items 16–17), mean	(1/2a/2b/3/4a/4b)[*]	(at the level of highest Kirkpatrick level)
Abrahamson, 2006	Canada	SARS	Doctors, nurses	Knowledge and technical skills on advanced cardiac life support protocol for SARS patients	Simulation-based training (scenario-based)	2-hour session	2.0	1.3	1.5	1	Participants rated the comprehensiveness, duration, and effectiveness of teaching methods favorably.
Abualenain, 2018	Saudi Arabia	EVD	Doctors, nurses, paramedics, anesthesia technicians, others	Technical skills: donning and doffing of PPE	Simulation-based training	Not specified	1.5	1.3	0.5	2b	Pre- and post-training test written scores for the participants improved significantly ($p < 0.01$) from 67% (range 57–75%) to 85% (range 81–91%), respectively. All 179 HCW completed the Ebola PPE checklist, about half compromised (different levels of compromising) the PPE protocol at some point.
Adini, 2012	Israel	H1N1	Doctors, nurses	Knowledge and technical skills related to avian flu (management of patient; donning and doffing of PPE)	Lectures; small group discussions and tabletop exercises	Not specified	1.5	0.5	0.5	2b	The overall mean score for the 14-item multiple choice questions for emergency department medical personnel was 75.6. The correlation between the level of knowledge related to pandemic flu and the performance in the avian flu exercise was not significant (Spearman's rho < 0.25)
Aiello, 2011	Canada	SARS, H1N1	Doctors, nurses, other hospital staff	"Non-technical" skill: resilience	Lectures	Multiple 1-hour sessions over a 5-month period	1.5	1.1	2.0	1	A high proportion of participants found the session relevant to work life and personal life, useful, helpful, and informative. Ten themes emerged from the comments: family-work balance, antiviral prophylaxis, need for information, education and preparedness, ethical concerns, visibility of leadership, valuing frontline staff, mistrust/fears, information relating to redeployment, need for ongoing resilience training.
Andonian, 2019	USA	EVD	HCW (not specified)	Technical skill: donning and doffing of PPE; "Non-technical" skills: teamwork, cognitive load	Lectures; video demonstrations, simulation-based training	2-hour session	1.5	1.0	0.5	2b	Any type of self-contamination was high in both groups (84.6–100 %) during doffing, but the intervention group contaminated fewer sites ($p = 0.002$). Intervention group demonstrated more teamwork behaviors (median 27.1) compared to controls (median 9.1). Participants in the intervention group perceived marginally higher mental demand than the controls ($p = 0.055$).

Bazeyo, 2015	Uganda	EVD	Doctors, nurses and other district HCW including lab technicians, immigration officers and security officers, media persons	Knowledge related to EVD	Small group work and discussions; demonstrations, visual aids, role play, case studies; practical exercises	5-day course	1.0	0.6	0.5	2b	Knowledge increased from ~56–78 % pre-intervention to ~68–88 % post-intervention on a knowledge test.
Bemah, 2019	Liberia	EVD	HCW (not specified)	Knowledge related to PPC, EVD and IPC	Classroom-based teaching; simulated patients; clinical mentoring	8-day course	1.0	1.1	0.5	4b	Both clinicians (n = 188) and non-clinicians (n = 149) showed statistically significant improvements in knowledge on clinical care and IPC concepts as measured by the 9-item pre-and post-training questionnaires (both $p < 0.001$). HCW infection rate was 9% by October 2014 (pre-course) and had dropped to 1% by January 2015 (post-course). Furthermore, after the conclusion of training in March 2015, no infections reported among HCW exposed to the confirmed cases despite the resurgence of Ebola cases in June and November 2015, and April 2016.
Brazzi, 2012	Italy	H1N1	Anesthesiologists	Knowledge: gas exchange during extracorporeal bypass; Technical skill: ECMO	Lectures; simulation-based training	3-day course	1.0	1.6	2.0	1	Participants rated the relevance, quality and efficacy of the training favorably.
Bredmose, 2014	Norway	EVD	Helicopter Emergency Medical Service (HEMS) crew	Technical skill: Helicopter Emergency Medical Service in relation to EVD patients	Simulation-based training (in-situ simulation)	Not specified	0.5	0.7	1.0	1	All participants reported high degrees of satisfaction and realism.
Bustamente, 2015	USA	EVD	Doctors, respiratory therapists	Technical skill: PPE	Simulation-based training	4 hours	0.5	0.8	1.0	2a	The intervention increased the confidence of participants. 95% and 87% of participants, respectively, rated the program and faculty as good or outstanding on a five-point Likert scale.
Carlos, 2015	Philippines	EVD	Doctors, medical technologists	Knowledge related to EVD	Lecture and practical hands-on workshop	3-day workshop	1.0	1.5	2.0	2b	The percentage of participants who correctly answered all 10 questions was 2.8% (8 of 285) and 22.5% (82 to 364) pre- and post the workshop, respectively. The number of questions correctly answered by participants increased from a pre-workshop median of 7 (IQR 6–8; range 3–10) to a post-workshop median of 9 (IQR 8–9; range 4–10) ($p < 0.009$).

Carrico, 2007	USA	SARS	Nurses	Knowledge of respiratory pathogen transmission as well as standard precautions; Technical skill: donning and doffing of PPE	Classroom training and simulation-based training	Not specified, but <1 day	1.0	1.6	1.0	3	Pre- and post-training test scores were similar for the two groups and increased from 0.64 to 0.76. Participants who received the visual training demonstrated use of PPE more often (74% vs 53%, respectively).
Carvalho, 2019	Spain	EVD	Doctors, nurses, cleaning personnel, nursing assistants, security personnel, stretcher bearers	Knowledge: principles of care and management of infected patient. Technical skill: donning and doffing of PPE, other procedures such as blood extraction, catheter placement, endotracheal intubation, hygiene, stool and vomit, cleaning, emergency situations, patient transfer	Classes and seminars; simulation-based training (full scale scenarios)	80-h course over 10 days	1.0	1.4	1.5	2a	Participants felt that the course increased their sense of security, predisposition to take care of these patients and confidence in management.
Casalino, 2015	France	EVD	Medical and nursing students	Knowledge related to EVD; Technical skill: donning and doffing of PPE	Classroom lecture; specific skills training	1--hour theoretical session; and a practical session repeated every 72 hours for each group	1.0	1.3	1.0	2b	In all 4 groups, the frequency and number of total errors and critical errors decreased significantly over the course of the training sessions ($p < .01$). The intervention was associated with a greater reduction in the number of total errors and critical errors ($p < .0001$). The B-PPE intervention groups had the fewest errors and critical errors ($p < .0001$).
Chen, 2009	Taiwan	SARS	Doctors	Technical skills: Advanced Airway Life Support	Lecture; simulation-based training	2-hour lecture, 4-hour hands-on workshop	1.5	1.8	1.5	2b	Residents received higher scores during re-simulation regardless of scoring methods.
Choi, 2020	Hongkong	COVID-19	Doctors and nurses	Technical skills: donning and doffing of PPE, intubation, central venous catheter	Simulation-based training	20-30 min simulation and 30-mins debriefing	1.0	1.08	1.0	2a	The domains for feedback and discussion included the following key events in chronological order: donning PPE, pre-intubation check, intubation procedure, and doffing PPE. Local guideline changes.

Christensen, 2020	Denmark	COVID-19	Medical students	Technical skills: donning and doffing of PPE	Demonstration/return demonstraion; video-based	2- to 3-hour training session for control group; intervention group watched videos as many times as they wished at home	1.0	1.25	0.5	2b	19 of 21 participants returned for 1-month post-instruction evaluation. In donning, the scores in the instructor group ranged from 67% to 100%, and the scores in the video group ranged from 62% to 100%. The overall mean donning score was 86.5/100; the mean score was 84.8 for the instructor group and 88.0 for the video group. In doffing, the scores in the instructor group ranged from 59% to 96%, and the scores in the video group ranged from 51% to 93%. The overall mean doffing score was 76.4/100; the mean score for the instructor group was 79.1, and it was 73.9 for the video group
Diaz, 2013	USA	H1N1	Doctors	Knowledge related to H1N1	Lecture, interactive group sessions, role play	3-day course	1.0	1.3	2.0	2b	Critical care knowledge improved significantly from before the training to immediately after (Caribbean site: 58–80%; Indonesia site: 56–75%; p <0.001 for both).
Diaz, 2018	Switzerland	H1N1	Undergraduate students in nursing and health sciences	Knowledge: Critical care management/(best ICU practices, ARDS, and pregnancy influenza	Lectures; case-based learning	3-day course	2.0	1.7	2.0	2b	Test scores improved significantly after training (p < .001) both in pilot and implementation phases; participants rated the learning units as good to very good (mean, 5-point Likert scale: 4.6–4.8).
Dube, 2018	USA	EVD	Natural and health science major undergraduate students	Knowledge related to EVD	Case-based learning	Integrated in undergraduate curriculum	2.0	1.3	2.0	2b	Students improved in relation to theoretical knowledge on all 10 questions (a mix of multiple choice questions, true/false statements and free text responses). Overall score (normalized) improved from ~47%–80%.
Eardley, 2015	UK	EVD	HCW, university and military staff	Knowledge related to EVD	Lectures; drills	4-day course	1.5	1.5	2.0	2b	Factual knowledge increased (a median change on the VAS of 4.0 by all delegates, p<0.001). Change in confidence in teaching increased (median change on the VAS of 5.0 for all delegates, p<0.001).
Eckes, 2016	USA	EVD	Nurses	Knowledge: Principles of EVD care and PPE; Technical skill: donning and doffing of PPE	Lectures; simulation-based training	Quarterly course (hours not mentioned)	1.5	1.3	1.0	1	Participants completed a return demonstration and written assessment. Further details not provided.
Elcin, 2016	Turkey	MERS	Paramedics	Knowledge related to MERS and PPE for healthcare providers	Simulation-based training	1-day course with 3 sessions	1.5	1.6	2.0	2b	16 of 19 (84%) teams recognized the possibility of MERS as a measure of their awareness in the baseline evaluation. The participating sites lacked PPE, which revealed their baseline level of preparedness for MERS. Certain improvements in donning and doffing PPE were observed in the post-training evaluation.

Ferranti, 2016	USA	EVD	Nurses	Knowledge related to EVD	E-learning: online PowerPoint slides	3-day course	1.5	1.7	0.5	2b	Knowledge increased significantly from pre- to post and retention test (75.9 % to 90.7 % and 89.8 %, respectively).
Hanley, 2008	USA	SARS, H1N1	Nurses, respiratory therapy students, general internists, physician assistants, nurse practitioners, non-critical-care nurses veterinarians, and physical therapists	Knowledge and technical skills: Infection control, manual ventilation, mechanical ventilation, airway maintenance, and airway suctioning.	E-learning: video (DVD); simulation-based training	Just-in-time training (90 mins)	2.0	1.1	1.0	1	No detailed information of results from the assessment, however, groups passed based on their cognitive scores to the questions and performance scores during the dry lab competency testing.
Jones-Konneh, 2017	Japan	EVD	Nurses, other HCW (not specified)	Knowledge related to EVD; Technical skills on PPE and other IPC skills such as hand hygiene, mixing of chlorine solutions, etc.	Simulation-based-training	3 phases of training: A. 3 days theory, 2 days for SBT; B. 1-day theory and 2 days SBT; C. 3 days for basic IPC/PPE	2.0	1.3	1.0	2a	Feeling of comfort decreased anxiety during patient care; no other quantification of training outcome presented. It is speculated that HCWs had improved understanding of EVD, IPC and patient care, which subsequently could have contributed to the survival of patients.
Kim, 2018	Korea	H1N1	Doctors, nurses	Knowledge: basic hemodynamics, ECMO physiology, circuit anatomy, and hemostasis of patients on ECMO; Technical and behavioral skills to manage ECMO scenarios; “Nontechnical" skills: team communication	Lectures; simulation-based training	Every month (duration not mentioned)	1.5	1.2	0.5	4b	Mortality rate of patients markedly lower during period 2 (after program implementation) as compared to period 1 (before implementation).

Klomp, 2020	USA	EVD	CDC staff (non-clinical deployers)	"Nontechnical skills": resilience	Traditional didactics	3-day training	1.5	1.3	0.5	2b	Pre- to post training knowledge in relation to key elements and resilience increased 2.95 points out of 30 (95% CI, 2.53-3.37). The Self-Efficacy Survey total score showed a significant improvement in overall self-efficacy. This suggests participants gained useful knowledge of resilience principles and strategies.
Lin, 2008	Taiwan	SARS	Patient-hired attendants and outsourced workers	Knowledge: control of nosocomial infections	Lecture; video-based demonstration (CD)	2-hour session	1.0	1.0	1.0	2b	Improvement from 88.5 to 91.4 points from pre to post-training on a knowledge test ($p < .001$).
Marshall, 2008	USA	SARS	Nurses, social workers and student, public health student	Knowledge: Bioterrorism preparedness	Problem-based learning	3-hour session; follow-up session 1 week later	1.5	1.6	2.0	2b	Increase in knowledge of bioevent preparedness (pre- and post-training knowledge test: overall mean score: 2.4 to 3.8, respectively). Participants found that the case is realistic (mean = 4.1), all health perspectives addressed (mean=3.8), that they had actively participated (mean = 4.6) and gave an overall review (8.5, based on 1-10 scale).
Mathias, 2015	USA	SARS, EVD, H1N1	Pharmacists	Knowledge related to EVD; roles pharmacists play as health care professionals; "Non-technical" skill: critical thinking skills	Learner-led discussions and presentations	3-hour/week, offered over two consecutive years	2.0	1.8	2.0	2b	Evaluation of knowledge and critical thinking skills, as well as performance within the group: assessment based on preparedness and participation in discussions, oral presentations, research paper and final examination. Overall grades for all categories: Cohort 1 from year 1(14 learners) = all received a final grade of A; Cohort 2 from the following year (year 2) (16 learners) = final grade A (n=10), B (n=5), C (n=1)
Maunder, 2010	Canada	H1N1	Nurses, other HCW (not specified)	"Non-technical" skill: Resilience	E-learning: Course materials on a flash drive for self-learning and audio and video mini lectures	3 course lengths (short/medium/long): 7/12/17 sessions	2.0	1.9	1.5	2b	Intention-to-treat analysis showed significant improvements in confidence in support and training, pandemic self-efficacy and interpersonal problems. Participants who under-utilized coping via problem-solving or seeking support or over-utilized escape-avoidance have experienced improved coping. Comparison of doses showed improved interpersonal problems in the medium and long course but not in the short course

Mc Kenna, 2019	Belgium	EVD	Community HCW	Knowledge related to EVD	E-learning: mobile training platform	Multiple modules, each approx. 5 minutes	1.5	1.5	2.0	2b	For module II (relevant to the disease), there was an increase of 3 % in CHCWs correctly answering >80 % of the questions. For CHCWs with 50-79 % correct answers there was a regression in performance after training.
McInnes, 2005	Canada	SARS	Security guards, volunteer students	Knowledge related to SARS; Technical skills: handwashing, putting on N-95; temperature taking; "Non-technical" skills: reporting, interpersonal skills, accurate decision making	Lectures; demonstrations and role playing	Education day (number of hours not detailed)	1.5	1.2	0.5	1	The training enabled the trainees to problem solve, think critically, and use the guidelines established by the screening tool to make decisions about individuals trying to enter the hospital. It also enabled them to realize the importance of their interpersonal skills through mock interactions with different people in a variety of circumstances.
MenkinSmith, 2018	USA	EVD	Medical fellows and residents, nursing specialty training, others (students)	Knowledge safety measures in Ebola patient care; Technical skills in donning and doffing of PPE, infection control practices	E-learning: information via online software; Simulation-based training (team training scenarios)	3-day course	1.5	1.8	2.0	2b	Both groups demonstrated a significant increase in their knowledge test scores after completing the online curriculum, with average scores for novices increasing from 19.7 to 24.3 ($n = 9$, $p < 0.01$) and average score in experienced participants increasing from 19.2 to 22.3 ($n = 9$, $p = 0.03$). Overall high performance of both groups in the simulation scenarios.
Narra, 2016	USA	EVD	HCW	Knowledge related to EVD, infection prevention and control; Technical skill: donning and doffing of PPE	Lectures; small-group discussions, and practical exercises	3-day course	2.0	1.8	2.0	1	This course quickly increased the number of clinicians who could provide care in West Africa ETUs, showing the feasibility of rapidly developing and implementing training in response to a public health emergency.
O'Keeffe, 2016	Ireland	EVD	Nurses, respiratory therapists, laboratory technicians, and ancillary staff	Knowledge related to EVD and safety management; Technical skills: donning and doffing of PPE, airway management, dressing care and IV infusion, urinary catheter care	Simulation-based training (interprofessional)	4-hour program	2.0	1.7	2.0	2b	Increased level of confidence in three key areas: Contamination breach (pre: 2.17; post: 3.71; p<.001), clinical skills in PPE (pre: 2.04; post: 3.82; p<.001), donning and doffing PPE (pre: 2.04; post: 3.88; p<.001).
Otu, 2016	Nigeria	EVD	Nurses, community HCW, midwives, laboratory scientists, auxiliary nurses, pharmacy technicians and health record staff.	Knowledge on EVD disease specific information; "Non-technical" skill: attitude	E-learning: tablet computers with Ebola awareness tutorial (EAT)	2 weeks allowed to review training materials	1.5	1.5	1.0	2b	Increased in knowledge pre- and post-intervention (61.2 to 68.2, 11% improvement < 0.05); Fear of EVD reduced significantly from 89 to 52%. Positive attitudes between pre- and post-EAT scores regarding contact with EVD patients: (83 to 92%); eating bush meat (57 to 64%) and risky burial practices (67 to 79%),

Phrampus, 2016	USA	EVD	Doctors, nurses, other response team members	Knowledge on Ebola, principles of PPE, response, equipment, personal safety, policies; Technical skills: donning and doffing of PPE;	Onsite and online pre-course modules; simulation-based training	4-hour sessions 4 days/week for 3 weeks	2.0	1.8	2.0	2a	Post-course evaluation using an 18-item tool= Median score for each item ranged from 8 to 9 (on a 9-point Likert scale), with interquartile range of 7-9 in all items
Rehman, 2020	Pakistan	EVD	Nurses	Knowledge: EVD awareness	Lectures; video demonstration and discussion	3-hour session	1.0	0.9	0.5	2b	Pre- and post-training test scores demonstrated improvement in knowledge. The mean baseline knowledge score was 3.93±2.519 while the intervention mean score was 13.18±1.192; difference was significant ($p<0.05$)
Rogers, 2019	USA	SARS	Nurses, respiratory therapists, certified nursing assistants, industrial hygienists, safety and occupational health professionals, infection preventionists, and others identified with respiratory protection practice	Knowledge: Respiratory protection practice such as infectious agent transmission routes, hand hygiene, hazard assessment, respirator selection and care, medical evaluation and monitoring, fit-testing and training, respirator donning/doffing and seal checks.	Educational program (lecture) Clinical observations, focus group interviews	Educational program: 1-day training	2.0	1.5	1.5	4a	In the educational program, 17 (68%) participants received either a higher or perfect score on the post-training test. Observations of HCW: 216 documented incident observations of individuals and worker groups that resulted in 253 actions or resolutions by the practice champions.
Sijbrandij, 2020	Netherlands	EVD	Nurses, community HCW, midwives, maternal health assistant, vaccinators, lab assistant, etc	Knowledge: psychological first aid (PFA)	Traditional didactics	one day (no. of hours not mentioned)	1.5	1.3	0.5	2b	Overall knowledge of appropriate psychosocial responses we found a significant effect of time, which was moderated by condition ($X2(2) = 28.63$; $p < 0.0001$). In the PFA group, knowledge about appropriate psychosocial responses increased relative to the control group. Post-hoc contrasts showed a medium to large effect size at the post-PFA assessment (mean estimated difference 1.73; $d = 0.50$; $t(486.01) = 4.54$; $p < 0.001$) and a medium effect size at the follow-up (mean estimated difference 1.54; $d = 0.43$; $t(329.28) = 3.87$; $p = 0.001$.
Soeters, 2018	USA	EVD	Doctors, nurses, pharmacists, laboratorian, health tech, midwife, admin, students,	Knowledge on IPC; Technical skills: donning and doffing of PPE, triage, waste management	Traditional didactics; hands-on training	First course: 3-days Second course: condensed 2 days	2.0	1.3	1.5	2b	Median test scores increased from 40% among HCW, 15% among IPC trainers, and 21% (among IPC supervisors to post-training test scores of 83%, 93%, and 93%, respectively (all $p<0.0001$).

			cleaner, others								
Watson, 2011	USA	H1N1	Doctors, nurses, respiratory therapist, support technicians, pharmacists, physician extenders and students	Technical skill: PPE adherence	Simulation-based training (in-situ)	8-week observation period	2.0	1.3	1.0	2b	Observed adherence with PPE use= 61% for eye shields, 81% for filtering facepiece respirators or powered air-purifying respirators, and 87% for gown/gloves. Use of a "gatekeeper" to control access and facilitate donning of PPE was associated with 100% adherence with gown and respirator precautions and improved respirator adherence. All simulations showed deviation from pediatric basic life support protocols. The median time to bag-valve-mask ventilation improved from 4.3 to 2.7 minutes with a gatekeeper present. Confidence in PPE use improved from 64% to 85% after the mock code and structured debriefing.
Wu, 2009	Taiwan	SARS	Nurses	Knowledge on IPC	Formal lectures, hands-on demonstrations, simulation scenarios, role play, brainstorming and group discussion	1-hour/week (total 16 hours).	1.5	1.3	0.5	2b	Intervention cohort improved significantly on pre- to post-training test and follow-up test (8.87, 9.85, 11.00 points, respectively) compared with the control cohort (8.87, 8.67, 8.70 points, respectively).
Zhou, 2020	China	COVID-19	Nurses and nursing students	Knowledge: emergency and critical care nursing; Technical skills: CPR, use of defibrillator, use of ECG, collection of various specimens, artificial airway techniques, usage of oropharyngeal ventilation tube and mask; gastric lavage technology of gastric lavage machine; Hemostasis, bandaging, and fixation technology	Traditional didactics and simulation-based training; micro-video (webcasts)	10-hr class sessions	2	1.75	2	2b	The total scores of theoretical assessment and practical assessment were 60 and 40, respectively, with 100 points in total. For the theory and practice of group 2: no significant difference between the two groups in terms of theory and practice ($p = 0.654$; $p = 0.813$; $p = 0.180$ Teaching satisfaction: the interns' teaching satisfaction of group 2 was higher than that of group 1: There was overall satisfaction; significant difference between the two groups ($p = 0.020$, $p = 0.039$; $p = 0.012$; $p = 0.029$). There was no significant difference in content rationality between the two groups

§ **Quality Appraisal using the Educational intervention checklist[12]**. Each item is assigned a score of 0/1/2 (higher is better) based on descriptive anchors.

* **Kirkpatrick levels[13]:** Level 1=learner's view regarding the educational experience; level 2a=modification of behaviour or attitude; level 2b=acquisition or modification of knowledge/skills; level 3=actual behavioural change documented by transfer of learning to the workplace; level 4a=changes in organisational practice that are attributable to the intervention; and level 4b= outcomes at the level of patient health and well-being

Abbreviations: SARS- severe acute respiratory syndrome; H1N1- H1N1 influenza virus infection; MERS- Middle East respiratory syndrome; EVD- Ebola virus disease; COVID-19- corona virus disease 2019; HCW – healthcare workers; PPE – personal protective equipment; IPC – infection prevention and control; ECMO – extracorporeal membrane oxygenation; SBT – simulation-based training; CPR- Cardiopulmonary resuscitation; ECG- electrocardiogram

PRISMA 2009 Checklist

Section/topic	#	Checklist item	Reported on page #
TITLE			
Title	1	Identify the report as a systematic review, meta-analysis, or both.	1
ABSTRACT			
Structured summary	2	Provide a structured summary including, as applicable: background; objectives; data sources; study eligibility criteria, participants, and interventions; study appraisal and synthesis methods; results; limitations; conclusions and implications of key findings; systematic review registration number.	2
INTRODUCTION			
Rationale	3	Describe the rationale for the review in the context of what is already known.	4
Objectives	4	Provide an explicit statement of questions being addressed with reference to participants, interventions, comparisons, outcomes, and study design (PICOS).	4-5
METHODS			
Protocol and registration	5	Indicate if a review protocol exists, if and where it can be accessed (e.g., Web address), and, if available, provide registration information including registration number.	-
Eligibility criteria	6	Specify study characteristics (e.g., PICOS, length of follow-up) and report characteristics (e.g., years considered, language, publication status) used as criteria for eligibility, giving rationale.	6
Information sources	7	Describe all information sources (e.g., databases with dates of coverage, contact with study authors to identify additional studies) in the search and date last searched.	6
Search	8	Present full electronic search strategy for at least one database, including any limits used, such that it could be repeated.	6
Study selection	9	State the process for selecting studies (i.e., screening, eligibility, included in systematic review, and, if applicable, included in the meta-analysis).	6
Data collection process	10	Describe method of data extraction from reports (e.g., piloted forms, independently, in duplicate) and any processes for obtaining and confirming data from investigators.	7
Data items	11	List and define all variables for which data were sought (e.g., PICOS, funding sources) and any assumptions and simplifications made.	7
Risk of bias in individual studies	12	Describe methods used for assessing risk of bias of individual studies (including specification of whether this was done at the study or outcome level), and how this information is to be used in any data synthesis.	7
Summary measures	13	State the principal summary measures (e.g., risk ratio, difference in means).	-
Synthesis of results	14	Describe the methods of handling data and combining results of studies, if done, including measures of consistency (e.g., I^2) for each meta-analysis.	7

PRISMA 2009 Checklist

Section/topic	#	Checklist item	Reported on page #
Risk of bias across studies	15	Specify any assessment of risk of bias that may affect the cumulative evidence (e.g., publication bias, selective reporting within studies).	-
Additional analyses	16	Describe methods of additional analyses (e.g., sensitivity or subgroup analyses, meta-regression), if done, indicating which were pre-specified.	-
RESULTS			
Study selection	17	Give numbers of studies screened, assessed for eligibility, and included in the review, with reasons for exclusions at each stage, ideally with a flow diagram.	8
Study characteristics	18	For each study, present characteristics for which data were extracted (e.g., study size, PICOS, follow-up period) and provide the citations.	8
Risk of bias within studies	19	Present data on risk of bias of each study and, if available, any outcome level assessment (see item 12).	-
Results of individual studies	20	For all outcomes considered (benefits or harms), present, for each study: (a) simple summary data for each intervention group (b) effect estimates and confidence intervals, ideally with a forest plot.	8-11
Synthesis of results	21	Present results of each meta-analysis done, including confidence intervals and measures of consistency.	8-11
Risk of bias across studies	22	Present results of any assessment of risk of bias across studies (see Item 15).	-
Additional analysis	23	Give results of additional analyses, if done (e.g., sensitivity or subgroup analyses, meta-regression [see Item 16]).	-
DISCUSSION			
Summary of evidence	24	Summarize the main findings including the strength of evidence for each main outcome; consider their relevance to key groups (e.g., healthcare providers, users, and policy makers).	12-16
Limitations	25	Discuss limitations at study and outcome level (e.g., risk of bias), and at review-level (e.g., incomplete retrieval of identified research, reporting bias).	16
Conclusions	26	Provide a general interpretation of the results in the context of other evidence, and implications for future research.	17
FUNDING			
Funding	27	Describe sources of funding for the systematic review and other support (e.g., supply of data); role of funders for the systematic review.	18

From: Moher D, Liberati A, Tetzlaff J, Altman DG, The PRISMA Group (2009). Preferred Reporting Items for Systematic Reviews and Meta-Analyses: The PRISMA Statement. PLoS Med 6(7): e1000097. doi:10.1371/journal.pmed1000097

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