

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 ⁸ (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		
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	COVI D-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	COVI D-19	Medical students	Technical skills: donning and doffing of PPE	Demonstration/return demonstration; 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 (X ² (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	COVI D-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