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Personal protective equipment for preventing highly infectious diseases due to exposure to contaminated body fluids in healthcare staff (Review)

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[Intervention Review]

Personal protective equipment for preventing highly infectious diseases due to exposure to contaminated body fluids in healthcare staff

Jos H Verbeek[1], Blair Rajamaki[2], Sharea Ijaz[3], Riitta Sauni[4], Elaine Toomey[5], Bronagh Blackwood[6], Christina Tikka[7], Jani H Ruotsalainen[8], F Selcen Kilinc Balci[9]

[1]Cochrane Work Review Group, Academic Medical Center, University of Amsterdam, Amsterdam, Netherlands. [2]School of Pharmacy, University of Eastern Finland, Kuopio, Finland. [3]Population Health Sciences, Bristol Medical School, University of Bristol, Bristol, UK. [4]University of Tampere, Tampere, Finland. [5]Galway, Ireland. [6]Centre for Experimental Medicine, School of Medicine, Dentistry and Biomedical Sciences, Queen's University Belfast, Belfast, UK. [7]Finnish Institute of Occupational Health, TYÖTERVEYSLAITOS, Finland. [8]Assessment of Pharmacotherapies, Finnish Medicines Agency, Kuopio, Finland. [9]National Personal Protective Technology Laboratory (NPPTL), National Institute for Occupational Safety and Health (NIOSH), Centers for Disease Control and Prevention (CDC), Pittsburgh, PA, USA

Contact address: Jos H Verbeek, jverbeek@cochrane.org, jos@jverbeek.eu.

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ABSTRACT

Background

In epidemics of highly infectious diseases, such as Ebola, severe acute respiratory syndrome (SARS), or coronavirus (COVID-19), healthcare workers (HCW) are at much greater risk of infection than the general population, due to their contact with patients' contaminated body fluids. Personal protective equipment (PPE) can reduce the risk by covering exposed body parts. It is unclear which type of PPE protects best, what is the best way to put PPE on (i.e. donning) or to remove PPE (i.e. doffing), and how to train HCWs to use PPE as instructed.

Objectives

To evaluate which type of full-body PPE and which method of donning or doffing PPE have the least risk of contamination or infection for HCW, and which training methods increase compliance with PPE protocols.

Search methods

We searched CENTRAL, MEDLINE, Embase and CINAHL to 20 March 2020.

Selection criteria

We included all controlled studies that evaluated the effect of full-body PPE used by HCW exposed to highly infectious diseases, on the risk of infection, contamination, or noncompliance with protocols. We also included studies that compared the effect of various ways of donning or doffing PPE, and the effects of training on the same outcomes.

Data collection and analysis

Two review authors independently selected studies, extracted data and assessed the risk of bias in included trials. We conducted random-effects meta-analyses were appropriate.

Main results

Earlier versions of this review were published in 2016 and 2019. In this update, we included 24 studies with 2278 participants, of which 14 were randomised controlled trials (RCT), one was a quasi-RCT and nine had a non-randomised design.

Eight studies compared types of PPE. Six studies evaluated adapted PPE. Eight studies compared donning and doffing processes and three studies evaluated types of training. Eighteen studies used simulated exposure with fluorescent markers or harmless microbes. In simulation studies, median contamination rates were 25% for the intervention and 67% for the control groups.

Evidence for all outcomes is of very low certainty unless otherwise stated because it is based on one or two studies, the indirectness of the evidence in simulation studies and because of risk of bias.

Types of PPE

The use of a powered, air-purifying respirator with coverall may protect against the risk of contamination better than a N95 mask and gown (risk ratio (RR) 0.27, 95% confidence interval (CI) 0.17 to 0.43) but was more difficult to don (non-compliance: RR 7.5, 95% CI 1.81 to 31.1). In one RCT (59 participants), people with a long gown had less contamination than those with a coverall, and coveralls were more difficult to doff (low-certainty evidence). Gowns may protect better against contamination than aprons (small patches: mean difference (MD) −10.28, 95% CI −14.77 to −5.79). PPE made of more breathable material may lead to a similar number of spots on the trunk (MD 1.60, 95% CI −0.15 to 3.35) compared to more water-repellent material but may have greater user satisfaction (MD −0.46, 95% CI −0.84 to −0.08, scale of 1 to 5).

Modified PPE versus standard PPE

The following modifications to PPE design may lead to less contamination compared to standard PPE: sealed gown and glove combination (RR 0.27, 95% CI 0.09 to 0.78), a better fitting gown around the neck, wrists and hands (RR 0.08, 95% CI 0.01 to 0.55), a better cover of the gown-wrist interface (RR 0.45, 95% CI 0.26 to 0.78, low-certainty evidence), added tabs to grab to facilitate doffing of masks (RR 0.33, 95% CI 0.14 to 0.80) or gloves (RR 0.22, 95% CI 0.15 to 0.31).

Donning and doffing

Using Centers for Disease Control and Prevention (CDC) recommendations for doffing may lead to less contamination compared to no guidance (small patches: MD −5.44, 95% CI −7.43 to −3.45). One-step removal of gloves and gown may lead to less bacterial contamination (RR 0.20, 95% CI 0.05 to 0.77) but not to less fluorescent contamination (RR 0.98, 95% CI 0.75 to 1.28) than separate removal. Double-gloving may lead to less viral or bacterial contamination compared to single gloving (RR 0.34, 95% CI 0.17 to 0.66) but not to less fluorescent contamination (RR 0.98, 95% CI 0.75 to 1.28). Additional spoken instruction may lead to fewer errors in doffing (MD −0.9, 95% CI −1.4 to −0.4) and to fewer contamination spots (MD −5, 95% CI −8.08 to −1.92). Extra sanitation of gloves before doffing with quaternary ammonium or bleach may decrease contamination, but not alcohol-based hand rub.

Training

The use of additional computer simulation may lead to fewer errors in doffing (MD −1.2, 95% CI −1.6 to −0.7). A video lecture on donning PPE may lead to better skills scores (MD 30.70, 95% CI 20.14 to 41.26) than a traditional lecture. Face-to-face instruction may reduce noncompliance with doffing guidance more (odds ratio 0.45, 95% CI 0.21 to 0.98) than providing folders or videos only.

Authors' conclusions

We found low- to very low-certainty evidence that covering more parts of the body leads to better protection but usually comes at the cost of more difficult donning or doffing and less user comfort, and may therefore even lead to more contamination. More breathable types of PPE may lead to similar contamination but may have greater user satisfaction. Modifications to PPE design, such as tabs to grab, may decrease the risk of contamination. For donning and doffing procedures, following CDC doffing guidance, a one-step glove and gown removal, double-gloving, spoken instructions during doffing, and using glove disinfection may reduce contamination and increase compliance. Face-to-face training in PPE use may reduce errors more than folder-based training.

We still need RCTs of training with long-term follow-up. We need simulation studies with more participants to find out which combinations of PPE and which doffing procedure protects best. Consensus on simulation of exposure and assessment of outcome is urgently needed. We also need more real-life evidence. Therefore, the use of PPE of HCW exposed to highly infectious diseases should be registered and the HCW should be prospectively followed for their risk of infection.

PLAIN LANGUAGE SUMMARY

Protective clothes and equipment for healthcare workers to prevent them catching coronavirus and other highly infectious diseases

Background

Healthcare workers treating patients with infections such as coronavirus (COVID-19) are at risk of infection themselves. Healthcare workers use personal protective equipment (PPE) to shield themselves from droplets from coughs, sneezes or other body fluids from infected

patients and contaminated surfaces that might infect them. PPE may include aprons, gowns or coveralls (a one-piece suit), gloves, masks and breathing equipment (respirators), and goggles. PPE must be put on correctly; it may be uncomfortable to wear, and healthcare workers may contaminate themselves when they remove it. Some PPE has been adapted, for example, by adding tabs to grab to make it easier to remove. Guidance on the correct procedure for putting on and removing PPE is available from organisations such as the Centers for Disease Control and Prevention (CDC) in the USA.

This is the 2020 update of a review first published in 2016 and previously updated in 2019.

What did we want to find out?

We wanted to know:

what type of PPE or combination of PPE gives healthcare workers the best protection;

whether modifying PPE for easier removal is effective;

whether following guidance on removing PPE reduced contamination;

whether training reduced contamination.

What did we find?

We found 24 relevant studies with 2278 participants that evaluated types of PPE, modified PPE, procedures for putting on and removing PPE, and types of training. Eighteen of the studies did not assess healthcare workers who were treating infected patients but simulated the effect of exposure to infection using fluorescent markers or harmless viruses or bacteria. Most of the studies were small, and only one or two studies addressed each of our questions.

Types of PPE

Covering more of the body leads to better protection. However, as this is usually associated with increased difficulty in putting on and removing PPE, and the PPE is less comfortable, it may lead to more contamination. Coveralls are the most difficult PPE to remove but may offer the best protection, followed by long gowns, gowns and aprons. Respirators worn with coveralls may protect better than a mask worn with a gown, but are more difficult to put on. More breathable types of PPE may lead to similar levels of contamination but be more comfortable. Contamination was common in half the studies despite improved PPE.

Modified PPE

Gowns that have gloves attached at the cuff, so that gloves and gown are removed together and cover the wrist area, and gowns that are modified to fit tightly at the neck may reduce contamination. Also, adding tabs to gloves and face masks may lead to less contamination. However, one study did not find fewer errors in putting on or removing modified gowns.

Guidance on PPE use

Following CDC guidance for apron or gown removal, or any instructions for removing PPE compared to an individual's own preferences may reduce self-contamination. Removing gown and gloves in one step, using two pairs of gloves, and cleaning gloves with bleach or disinfectant (but not alcohol) may also reduce contamination.

User training

Face-to-face training, computer simulation and video training led to fewer errors in PPE removal than training delivered as written material only or a traditional lecture.

Certainty of the evidence

Our certainty (confidence) in the evidence is limited because the studies simulated infection (i.e. it was not real), and they had a small number of participants.

What do we still need to find out?

There were no studies that investigated goggles or face shields. We are unclear about the best way to remove PPE after use and the best type of training in the long term.

Hospitals need to organise more studies, and researchers need to agree on the best way to simulate exposure to a virus.

In future, simulation studies need to have at least 60 participants each, and use exposure to a harmless virus to assess which type and combination of PPE is most protective.

It would be helpful if hospitals could register and record the type of PPE used by their workers to provide urgently needed, real-life information.

Search date

This review includes evidence published up to 20 March 2020.

SUMMARY OF FINDINGS

Summary of findings 1. Personal protective equipment (PPE) types: powered, air-purifying respirator (PAPR) plus coverall versus N95 mask plus gown

PAPR versus enhanced respiratory and contact precautions (E-RCP) attire for preventing contact with contaminated body fluids in healthcare staff

Patient or population: healthcare staff volunteers
Settings: simulation study
Intervention: PPE with PAPR

Control: E-RCP attire according to 2005 CDC recommendation

Outcomes	Illustrative comparative risks* (95% CI)		Relative effect (95% CI)	Number of participants (studies)	Certainty of the evidence (GRADE)	Comments
	Assumed risk	Corresponding risk				
	E-RCP attire	PAPR attire				
Any contamination: fluorescent marker Follow-up: post intervention	**960 per 1000**	**259 per 1000** (163 to 413)	**RR 0.27** (0.17 to 0.43)	50 (1 cross-over RCT)	⊕⊖⊖⊖ **Very low** [1,2,3]	Analyses presented in this table are unadjusted for the paired nature of the cross-over design but similar to the results that the study authors presented while taking the cross-over into account
Compliance: noncompliance with donning guidance Follow-up: post intervention	**40 per 1000**	**300 per 1000** (72 to 1000)	**RR 7.5** (1.81 to 31.1)	50 (1 cross-over RCT)	⊕⊖⊖⊖ **Very low** [1,2,3]	
Compliance: noncompliance with doffing guidance Follow-up: post intervention	**240 per 1000**	**120 per 1000** (48 to 295)	**RR 0.5** (0.2 to 1.23)	50 (1 cross-over RCT)	⊕⊖⊖⊖ **Very low** [1,2,3]	

*The basis for the **assumed risk** is the control group risk. The **corresponding risk** (and its 95% confidence interval) is based on the assumed risk in the comparison group and the **relative effect** of the intervention (and its 95% CI).
CDC: Centers for Disease Control and Prevention; **CI:** confidence interval; **E-RCP:** enhanced respiratory and contact precautions; **PAPR:** powered, air-purifying respirator; **PPE:** personal protective equipment; **RCT:** randomised controlled trial; **RR:** risk ratio

GRADE Working Group grades of evidence

High certainty: we are very confident that the true effect lies close to that of the estimate of the effect.

Moderate certainty: we are moderately confident in the effect estimate; the true effect is likely to be close to the estimate of the effect, but there is a possibility that it is substantially different.

Low certainty: our confidence in the effect estimate is limited; the true effect may be substantially different from the estimate of the effect.

Very low certainty: we have very little confidence in the effect estimate; the true effect is likely to be substantially different from the estimate of effect.

[1]Simulation study, downgraded one level for indirectness.
[2]One cross-over study with 50 participants, downgraded one level for imprecision.
[3]HIgh risk of bias, downgraded one level for study limitations.

Summary of findings 2. Personal protective equipment (PPE) types: more protective versus less protective

Three types of PPE attire compared by number of contaminated spots

Patient or population: healthcare worker volunteers
Settings: simulation study
Intervention: more protective attire, not permeable not breathable (A)
Comparison: less protective attire: permeable but breathable (B); fairly permeable, not breathable (D)

Outcomes	Illustrative comparative risks* (95% CI)		Number of participants (studies)	Certainty of the evidence (GRADE)	Comments
	Assumed risk	Corresponding risk			
	Less protective type of PPE (B or D)	Most protective type of PPE attire (A)			
Number of contaminated spots: trunk Fluorescent marker Follow-up: post-intervention	The mean number of contaminated spots in control group **B** was **1.62 spots**	The mean number of contaminated spots in the intervention group **A** was 1.60**lower** (3.35 lower to 0.15 higher)	50 (1 study)	⊕⊖⊖⊖ **Very low** [1,2,3]	
Number of contaminated spots: neck Fluorescent marker Follow-up: post-intervention	The mean number of contaminated spots in control group **B** was **0.12 spots**	The mean number of contaminated spots in the intervention group **A** was **0.7 higher** (0.26 lower to 1.66 higher)	50 (1 study)	⊕⊖⊖⊖ **Very low** [1,2,3]	
Number of contaminated spots: foot Fluorescent marker	The mean number of contaminated spots in the control group **B** was **2.86 spots**	The mean number of contaminated spots in the intervention group **A** was	50 (1 study)	⊕⊖⊖⊖ **Very low** [1,2,3]	

Follow-up: post-intervention		**0.96 lower** (2.35 lower to 0.43 higher)			
Number of contaminated spots: palm Fluorescent marker Follow-up: post-intervention	The mean number of contaminated spots in the control group **B** was **17.83**	The mean number of contaminated spots in the intervention group **A** was **7.72 lower** (15.65 lower to 0.21 higher)	50 (1 study)	⊕⊖⊖⊖ **Very low** [1,2,3]	
Number of contaminated spots: trunk or neck Fluorescent marker Follow-up: post-intervention	The mean number of contaminated spots in the control group **D** was **0**				Because no standard deviations were provided no analysis was possible
Number of contaminated spots: foot Fluorescent marker Follow-up: post-intervention	The mean number of contaminated spots in the control group **D** was **4.96**	The mean number of contaminated spots in the intervention group **A** was **4.1 lower** (6.94 to 1.26 lower)	50 (1 study)	⊕⊖⊖⊖ **Very low** [1,2,3]	
Number of contaminated spots: palm Fluorescent marker Follow-up: post-intervention	The mean number of contaminated spots in the control group **D** was **20.49**	The mean number of contaminated spots in the intervention group **A** was **12.76 lower** (21.62 to 3.9 lower)	50 (1 study)	⊕⊖⊖⊖ **Very low** [1,2,3]	
Usability score Range 1 to 5, higher indicating better	Mean score for group **B** was 4.02	The mean score of intervention group **A** was 0.46 lower (0.84 to 0.08 lower)	50 (1 study)	⊕⊖⊖⊖ **Very low** [1,2,3]	
Compliance with guidance	See comment	See comment	0 (0 studies)	See comment	No studies evaluated the effect of the interventions on compliance with guidance.

*The basis for the **assumed risk** is the control group risk. The **corresponding risk** (and its 95% confidence interval) is based on the assumed risk in the comparison group.
CI: confidence interval; **PPE:** personal protective equipment

GRADE Working Group grades of evidence

High certainty: we are very confident that the true effect lies close to that of the estimate of the effect.

Moderate certainty: we are moderately confident in the effect estimate; the true effect is likely to be close to the estimate of the effect, but there is a possibility that it is substantially different.

Low certainty: our confidence in the effect estimate is limited; the true effect may be substantially different from the estimate of the effect.

Very low certainty: we have very little confidence in the effect estimate; the true effect is likely to be substantially different from the estimate of effect.

[1]Simulation study, downgraded one level for indirectness.
[2]One study with 100 participants, 25 participants per arm, downgraded one level for imprecision.
[3]Unclear risk of bias in the study, downgraded one level.

Summary of findings 3. Personal protective equipment (PPE) types: gowns versus aprons

Gowns versus aprons for preventing highly infectious diseases due to contact with contaminated body fluids in healthcare workers

Patient or population: healthcare worker volunteers
Settings: simulation study
Intervention: gowns versus aprons

Outcomes	Illustrative comparative risks* (95% CI)		Number of participants (studies)	Certainty of the evidence (GRADE)	Comments
	Assumed risk	Corresponding risk			
	Aprons	Gowns			
Contamination with marker: individual type of doffing Follow-up: post-intervention	The mean contamination with marker in the control groups was **16.98 small spots**	The mean contamination with marker in the intervention groups was **10.28 lower** (14.77 to 5.79 lower)	50 (1 study)	⊕⊖⊖⊖ **Very low** [1,2,3]	Cross-over study; the analyses were unadjusted for the paired nature of the data but similar to the analysis of the study authors, who took this into account
Contamination with marker: CDC-recommended doffing Follow-up: post-intervention	The mean contamination with marker in the control groups was **1.88 small spots**	The mean contamination with marker in the intervention groups was **0.62 lower** (1.75 lower to 0.51 higher)	50 (1 study)	⊕⊖⊖⊖ **Very low** [1,2,3]	
Compliance with guidance	See comment	See comment	0 (0 studies)	See comment	No studies evaluated the effect of the interventions on compliance with guidance.

*The basis for the **assumed risk** is the control group risk. The **corresponding risk** (and its 95% confidence interval) is based on the assumed risk in the comparison group.

CDC: Centers for Disease Control and Prevention; **CI:** confidence interval

GRADE Working Group grades of evidence

High certainty: we are very confident that the true effect lies close to that of the estimate of the effect.

Moderate certainty: we are moderately confident in the effect estimate; the true effect is likely to be close to the estimate of the effect, but there is a possibility that it is substantially different.

Low certainty: our confidence in the effect estimate is limited; the true effect may be substantially different from the estimate of the effect.

Very low certainty: we have very little confidence in the effect estimate; the true effect is likely to be substantially different from the estimate of effect.

[1]Randomisation method unclear, downgraded one level.
[2]Simulation study, downgraded one level for indirectness.
[3]Single cross-over study with 50 participants, downgraded one level for imprecision.

Summary of findings 4. Personal protective equipment (PPE) types: different types of PPE attire

One type of full-body PPE compared to another type for preventing highly infectious diseases due to exposure to contaminated body fluids in healthcare workers

Patient or population: healthcare workers
Setting: simulation study
Intervention: one type of full-body PPE
Comparison: another type

Outcomes	Impact	Number of participants (studies)	Certainty of the evidence (GRADE)	Comments
Any contamination	In 1 RCT (59 participants) people with a long gown had less contamination than those with a coverall and those with a coverall less than those with an isolation gown. In 1 observational study (11 participants) there were too few events to enable comparison of contamination rates between 5 types of PPE In 1 observational study (10 participants), out of 10 different ensembles there were contaminations in only 4, of these 3 used coveralls	59 participants (1 RCT) 21 participants (2 observational studies)	⊕⊕## **Low** [1,2] ⊕### **Very low** [3]	
Compliance	Isolation gown was easiest to don and doff, coverall was more difficult to doff	59 participants (1 RCT)	⊕### **Very low** [1,2]	

*__The risk in the intervention group__ (and its 95% confidence interval) is based on the assumed risk in the comparison group and the **relative effect** of the intervention (and its 95% CI).

PPE: personal protective equipment; **RCT:** randomised controlled trial

GRADE Working Group grades of evidence
High certainty: we are very confident that the true effect lies close to that of the estimate of the effect
Moderate certainty: we are moderately confident in the effect estimate: the true effect is likely to be close to the estimate of the effect, but there is a possibility that it is substantially different
Low certainty: our confidence in the effect estimate is limited: the true effect may be substantially different from the estimate of the effect
Very low certainty: we have very little confidence in the effect estimate: the true effect is likely to be substantially different from the estimate of effect

[1] One study with 59 participants, downgraded by one level because of imprecision.
[2]Risk of bias in the study was unclear and so we downgraded by one level.
[3]The simulated exposure was very low. This resulted in a lack of power to detect differences, We downgraded by one level.

Summary of findings 5. Modified personal protective equipment (PPE): sealed gown-glove interface versus standard gown

Sealed gown-glove interface compared to standard gown for preventing highly infectious diseases due to exposure to contaminated body fluids in healthcare workers

Patient or population: healthcare workers
Setting: simulation study
Intervention: sealed gown-glove interface
Comparison: standard gown

Outcomes	Anticipated absolute effects* (95% CI)		Relative effect (95% CI)	Number of participants (studies)	Certainty of the evidence (GRADE)	Comments
	Risk with traditional suit	Risk with sealed suit				
Contamination: fluorescent lotion	733 per 1000	198 per 1000 (66 to 572)	RR 0.27 (0.09 to 0.78)	30 (1 RCT)	⊕### **Very low** [1,2,3]	
Contamination: MS2	1000 per 1000	680 per 1000 (470 to 980)	RR 0.68 (0.47 to 0.98)	30 (1 RCT)	⊕### **Very low** [1,2,3]	

*__The risk in the intervention group__ (and its 95% confidence interval) is based on the assumed risk in the comparison group and the **relative effect** of the intervention (and its 95% CI).

CI: confidence interval; **RCT:** randomised controlled trial; **RR:** risk ratio

GRADE Working Group grades of evidence

High certainty: we are very confident that the true effect lies close to that of the estimate of the effect.

Moderate certainty: we are moderately confident in the effect estimate; the true effect is likely to be close to the estimate of the effect, but there is a possibility that it is substantially different.

Low certainty: our confidence in the effect estimate is limited; the true effect may be substantially different from the estimate of the effect.

Very low certainty: we have very little confidence in the effect estimate; the true effect is likely to be substantially different from the estimate of effect.

[1]Unclear risk of bias, downgraded by one level.
[2]This is a simulation study so we downgraded by one level because of indirectness.
[3]One study with 30 participants so we downgraded by one level because of imprecision.

Summary of findings 6. Modified personal protective equipment (PPE): gown - easy to doff compared to standard gown

Easy-to-doff gown compared to standard gown for preventing highly infectious diseases due to exposure to contaminated body fluids in healthcare workers

Patient or population: healthcare workers
Setting: simulation study
Intervention: gown: easy to doff
Comparison: standard gown

Outcomes	Anticipated absolute effects* (95% CI)		Relative effect (95% CI)	Number of participants (studies)	Certainty of the evidence (GRADE)	Comments
	Risk with standard gown	Risk with easy-to-doff gown				
Contamination: fluorescent marker	419 per 1000	34 per 1000 (4 to 231)	RR 0.08 (0.01 to 0.55)	62 (1 RCT)	⊕⊕## **Low** [1,2]	
Contamination: bacteriophage	613 per 1000	325 per 1000 (178 to 576)	RR 0.53 (0.29 to 0.94)	62 (1 RCT)	⊕⊕## **Low** [1,2]	

***The risk in the intervention group** (and its 95% confidence interval) is based on the assumed risk in the comparison group and the **relative effect** of the intervention (and its 95% CI).

CI: confidence interval; **RCT:** randomised controlled trial; **RR:** risk ratio

GRADE Working Group grades of evidence

High certainty: we are very confident that the true effect lies close to that of the estimate of the effect.

Moderate certainty: we are moderately confident in the effect estimate; the true effect is likely to be close to the estimate of the effect, but there is a possibility that it is substantially different.

Low certainty: our confidence in the effect estimate is limited; the true effect may be substantially different from the estimate of the effect.

Very low certainty: we have very little confidence in the effect estimate; the true effect is likely to be substantially different from the estimate of effect.

[1]Simulation study, downgraded by one level.
[2]One small study, downgraded by one level.

Summary of findings 7. Modified personal protective equipment (PPE): gown with gown-glove improvement compared to standard gown and gloves

Gown with gown-glove improvement compared to standard gown and gloves for preventing highly infectious diseases due to exposure to contaminated body fluids in healthcare workers

Patient or population: healthcare workers
Setting: simulation study
Intervention: gown with gown-glove improvement
Comparison: standard gown and gloves

Outcomes	Anticipated absolute effects* (95% CI)		Relative effect (95% CI)	Number of participants (studies)	Certainty of the evidence (GRADE)	Comments
	Risk with standard gown and gloves	Risk with gown with gown-glove improvement				
People with contamination	410 per 1000	185 per 1000 (107 to 320)	RR 0.45 (0.26 to 0.78)	50 (2 RCTs)	⊕⊕## **Low** [1,2]	Cross-over study analysed as parallel study

*__The risk in the intervention group__ (and its 95% confidence interval) is based on the assumed risk in the comparison group and the **relative effect** of the intervention (and its 95% CI).

CI: confidence interval; **RCT:** randomised controlled trial; **RR:** risk ratio

GRADE Working Group grades of evidence

High certainty: we are very confident that the true effect lies close to that of the estimate of the effect.

Moderate certainty: we are moderately confident in the effect estimate; the true effect is likely to be close to the estimate of the effect, but there is a possibility that it is substantially different.

Low certainty: our confidence in the effect estimate is limited; the true effect may be substantially different from the estimate of the effect.

Very low certainty: we have very little confidence in the effect estimate; the true effect is likely to be substantially different from the estimate of effect.

[1]Study at high risk of performance bias, otherwise unclear risk of bias, downgraded one level.
[2]Simulation study, downgraded by one level.

Summary of findings 8. Modified personal protective equipment (PPE): gloves with tab versus standard gloves

Gloves with tab compared to standard gloves for preventing highly infectious diseases due to exposure to contaminated body fluids in healthcare workers

Patient or population: healthcare workers
Setting: simulation study
Intervention: gloves with tab
Comparison: standard gloves

Outcomes	Anticipated absolute effects* (95% CI)		Relative effect (95% CI)	Number of participants (studies)	Certainty of the evidence (GRADE)	Comments
	Risk with standard gloves	Risk with gloves with tab				
Any contamination of hands	733 per 1000	161 per 1000 (110 to 227)	RR 0.22 (0.15 to 0.31)	317 (1 RCT)	⊕### **Very low** [1,2]	

***The risk in the intervention group** (and its 95% confidence interval) is based on the assumed risk in the comparison group and the **relative effect** of the intervention (and its 95% CI).

CI: confidence interval; **RCT:** randomised controlled trial; **RR:** risk ratio

GRADE Working Group grades of evidence

High certainty: we are very confident that the true effect lies close to that of the estimate of the effect.

Moderate certainty: we are moderately confident in the effect estimate; the true effect is likely to be close to the estimate of the effect, but there is a possibility that it is substantially different.

Low certainty: our confidence in the effect estimate is limited; the true effect may be substantially different from the estimate of the effect.

Very low certainty: we have very little confidence in the effect estimate; the true effect is likely to be substantially different from the estimate of effect.

[1]Clusters of healthcare workers who were present at work were allocated to intervention or control on alternating days and so we downgraded by two levels because of study limitations.
[2]This is a simulation study so we downgraded by one level because of indirectness.

Summary of findings 9. Modified personal protective equipment (PPE): mask plus tabs versus standard masks

Mask tabs compared to no mask tabs for preventing highly infectious diseases due to exposure to contaminated body fluids in healthcare workers

Patient or population: healthcare workers
Setting: simulation study
Intervention: mask tabs
Comparison: no mask tabs

Outcomes	Anticipated absolute effects* (95% CI)		Relative effect (95% CI)	Number of participants (studies)	Certainty of the evidence (GRADE)	Comments
	Risk with No mask tabs	Risk with Mask tabs				
Contamination of mask from hands	1000 per 1000	330 per 1000 (140 to 800)	RR 0.33 (0.14 to 0.80)	20 (1 RCT)	⊕### **Very low** [1,2,3]	Analyses presented in this table are unadjusted for the paired nature of the cross-over design but similar to the results that the study authors presented while taking the cross-over into account.
Contamination of head from hands	867 per 1000	832 per 1000 (719 to 971)	RR 0.96 (0.83 to 1.12)	20 (1 RCT)	⊕### **Very low** [1,2,3]	Analyses presented in this table are unadjusted for the paired nature of the cross-over design but similar to the results that the study authors presented while taking the cross-over into account.

***The risk in the intervention group** (and its 95% confidence interval) is based on the assumed risk in the comparison group and the **relative effect** of the intervention (and its 95% CI).

CI: confidence interval; **RCT:** randomised controlled trial; **RR:** risk ratio

GRADE Working Group grades of evidence

High certainty: we are very confident that the true effect lies close to that of the estimate of the effect.

Moderate certainty: we are moderately confident in the effect estimate; the true effect is likely to be close to the estimate of the effect, but there is a possibility that it is substantially different.

Low certainty: our confidence in the effect estimate is limited; the true effect may be substantially different from the estimate of the effect.

Very low certainty: we have very little confidence in the effect estimate; the true effect is likely to be substantially different from the estimate of effect.

[1]The randomisation procedure was unclear and the cross-over procedure was unclear so we downgraded by one level because of study limitations.
[2]This is a simulation study so we downgraded by one level because of indirectness.
[3]One study only with 20 participants and so we downgraded by one level because of imprecision.

Summary of findings 10. Procedures: doffing according to Centers for Disease Control and Prevention method versus individual doffing

Centers for Disease Control and Prevention (CDC) method versus individual doffing for preventing contact with contaminated body fluids in healthcare workers

Patient or population: healthcare worker volunteers
Settings: simulation study
Intervention: CDC method of doffing

Control: individual method of doffing

Outcomes	Illustrative comparative risks* (95% CI)		Relative effect (95% CI)	Number of participants (studies)	Certainty of the evidence (GRADE)	Comments
	Assumed risk	Corresponding risk				
	Individual doffing method	CDC-recommended doffing method				
Contamination with fluor marker when using gowns Follow-up: post-intervention	The mean contamination with fluor marker in the control group was **6.7 small spots**	The mean contamination with fluor marker in the intervention group was **5.44 lower** (7.43 to 3.45 lower)		50 (1 study)	⊕⊖⊖⊖ **Very low** [1,2,3]	Cross-over study; the analyses were unadjusted for the paired nature of the data but similar to the analysis of the study authors, who took this into account.
Contamination with fluor marker when using aprons Follow-up: post-intervention	The mean contamination with fluor marker in the control group was **16.98 small spots**	The mean contamination with fluor marker in the intervention group was **15.1 lower** (19.28 to 10.92 lower)		50 (1 study)	⊕⊖⊖⊖ **Very low** [1,2,3]	

*The basis for the **assumed risk** is the control group risk. The **corresponding risk** (and its 95% confidence interval) is based on the assumed risk in the comparison group.
CDC: Centers for Disease Control and Prevention; **CI:** confidence interval

GRADE Working Group grades of evidence

High certainty: we are very confident that the true effect lies close to that of the estimate of the effect.

Moderate certainty: we are moderately confident in the effect estimate; the true effect is likely to be close to the estimate of the effect, but there is a possibility that it is substantially different.

Low certainty: our confidence in the effect estimate is limited; the true effect may be substantially different from the estimate of the effect.

Very low certainty: we have very little confidence in the effect estimate; the true effect is likely to be substantially different from the estimate of effect.

[1]The randomisation procedure was unclear and so we downgraded by one level due to study limitations.
[2]This is a simulation study so we downgraded by one level because of indirectness.
[3]One cross-over study with 50 participants and so we downgraded by one level due to imprecision.

Summary of findings 11. Procedures: single-step doffing compared to Centers for Disease Control and Prevention standard

Single-step doffing compared to Centers for Disease Control and Prevention (CDC) standard for preventing highly infectious diseases due to exposure to contaminated body fluids in healthcare workers

Patient or population: preventing highly infectious diseases due to exposure to contaminated body fluids in healthcare workers
Setting: simulation study
Intervention: single-step doffing
Comparison: CDC standard

Outcomes	Anticipated absolute effects* (95% CI)		Relative effect (95% CI)	Number of participants (studies)	Certainty of the evidence (GRADE)	Comments
	Risk with CDC standard	Risk with single-step doffing				
Fluorescent contamination	917 per 1000	898 per 1000 (688 to 1000)	RR 0.98 (0.75 to 1.28)	22 (1 RCT)	⊕### **Very low** [1,2,3]	
Bacterial contamination	667 per 1000	133 per 1000 (33 to 513)	RR 0.20 (0.05 to 0.77)	27 (1 RCT)	⊕### **Very low** [1,2,4]	

***The risk in the intervention group** (and its 95% confidence interval) is based on the assumed risk in the comparison group and the **relative effect** of the intervention (and its 95% CI).

CDC: Centers for Disease Control and Prevention; **CI:** confidence interval; **RCT:** randomised controlled trial; **RR:** risk ratio

GRADE Working Group grades of evidence

High certainty: we are very confident that the true effect lies close to that of the estimate of the effect.

Moderate certainty: we are moderately confident in the effect estimate; the true effect is likely to be close to the estimate of the effect, but there is a possibility that it is substantially different.

Low certainty: our confidence in the effect estimate is limited; the true effect may be substantially different from the estimate of the effect.

Very low certainty: we have very little confidence in the effect estimate; the true effect is likely to be substantially different from the estimate of effect.

[1]Simulation study, downgraded by one level.
[2]Large difference in effects between fluorescent contamination and bacterial contamination.
[3]Confidence Interval contains harms and benefits.
[4]Confidence interval contains both very large effects and very small effects.

Summary of findings 12. Procedures: doffing with double gloves compared to doffing with single gloves

Doffing with double gloves compared to doffing with single gloves for preventing highly infectious diseases due to exposure to contaminated body fluids in health-care workers

Patient or population: healthcare workers
Setting: simulation study
Intervention: doffing with double gloves
Comparison: doffing with single gloves

Outcomes	Anticipated absolute effects* (95% CI)		Relative effect (95% CI)	Number of participants (studies)	Certainty of the evidence (GRADE)	Comments
	Risk with doffing with single gloves	Risk with doffing with double gloves				
Contamination: virus detected - all body parts	733 per 1000	249 per 1000 (125 to 484)	RR 0.34 (0.17 to 0.66)	58 (1 RCT, 1 observational study)	⊕⊖⊖⊖ **Very low** [1,2,3]	
Contamination: virus detected - face	17 per 1000	73 per 1000 (9 to 606)	RR 4.39 (0.53 to 36.37)	58 (1 RCT, 1 observational study)	⊕⊖⊖⊖ **Very low** [1,2,3]	
Contamination: virus detected - shirt	567 per 1000	572 per 1000 (448 to 731)	RR 1.01 (0.79 to 1.29)	58 (1 RCT, 1 observational study)	⊕⊖⊖⊖ **Very low** [1,2,4]	
Contamination: virus detected - pants	611 per 1000	556 per 1000 (318 to 966)	RR 0.91 (0.52 to 1.58)	36 (1 observational study)	⊕⊖⊖⊖ **Very low** [2,4]	
Non-compliance: any error	667 per 1000	720 per 1000 (467 to 1000)	RR 1.08 (0.70 to 1.67)	36 (1 observational study)	⊕⊖⊖⊖ **Very low** [2,4]	
Contamination with fluorescent	917 per 1000	898 per 1000 (688 to 1000)	RR 0.98 (0.75 to 1.28)	22 (1 RCT)	⊕⊖⊖⊖ **Very low** [1,2,4]	

*The risk in the intervention group (and its 95% confidence interval) is based on the assumed risk in the comparison group and the **relative effect** of the intervention (and its 95% CI).

CI: confidence interval; **RCT:** randomised controlled trial; **RR:** risk ratio

GRADE Working Group grades of evidence

High certainty: we are very confident that the true effect lies close to that of the estimate of the effect.

Moderate certainty: we are moderately confident in the effect estimate; the true effect is likely to be close to the estimate of the effect, but there is a possibility that it is substantially different.

Low certainty: our confidence in the effect estimate is limited; the true effect may be substantially different from the estimate of the effect.

Very low certainty: we have very little confidence in the effect estimate; the true effect is likely to be substantially different from the estimate of effect.

[1]Difference in viral/bacterial outcomes and fluorescent marker outcomes, downgraded one level.
[2]Simulation studies, downgraded one level.
[3]Confidence interval contains both very large and moderate effects.
[4]Confidence interval contains both harms and benefits.

Summary of findings 13. Procedures: donning and doffing with instructions compared to without instruction

Donning and doffing with instructions compared to without instructions for preventing highly infectious diseases due to exposure to contaminated body fluids in healthcare workers

Patient or population: healthcare workers
Setting: simulation study
Intervention: donning and doffing with instructions
Comparison: without instructions

Outcomes	Anticipated absolute effects* (95% CI)		Relative effect (95% CI)	Number of participants (studies)	Certainty of the evidence (GRADE)	Comments
	Risk with without instructions	Risk with donning and doffing with instructions				
People with one or more errors	467 per 1000	145 per 1000 (51 to 434)	RR 0.31 (0.11 to 0.93)	120 (1 observational study)	⊕⊖⊖⊖ **Very low** [1,2,3]	
Mean errors	The mean errors was 1.15	MD 0.89 lower (1.36 lower to 0.41 lower)	-	120 (1 observational study)	⊕⊖⊖⊖ **Very low** [1,2]	

Fluorescence contamination	The mean fluorescence contamination was 11	MD 5 lower (8.08 lower to 1.92 lower)	-	24 (1 RCT)	⊕⊕⊖⊖ **Low** [4,5]

*__The risk in the intervention group__ (and its 95% confidence interval) is based on the assumed risk in the comparison group and the **relative effect** of the intervention (and its 95% CI).

CI: confidence interval; **MD:** mean difference; **RCT:** randomised controlled trial; **RR:** risk ratio

GRADE Working Group grades of evidence

High certainty: we are very confident that the true effect lies close to that of the estimate of the effect.

Moderate certainty: we are moderately confident in the effect estimate; the true effect is likely to be close to the estimate of the effect, but there is a possibility that it is substantially different.

Low certainty: our confidence in the effect estimate is limited; the true effect may be substantially different from the estimate of the effect.

Very low certainty: we have very little confidence in the effect estimate; the true effect is likely to be substantially different from the estimate of effect.

[1]Unblinded outcome assessors with subjective outcome, downgraded one level.
[2]Simulated donning/doffing, downgraded one level.
[3]Confidence Interval includes very large effect size and small effect size.
[4]Simulation study, downgraded one level.
[5]One small study only, downgraded one level.

Summary of findings 14. Procedures: doffing with extra sanitation of gloves compared to standard no sanitation

Doffing with extra sanitation of gloves compared to standard no sanitation for preventing highly infectious diseases due to exposure to contaminated body fluids in healthcare workers

Patient or population: healthcare workers
Setting: simulation study
Intervention: doffing with extra sanitation of gloves
Comparison: standard no sanitation

Outcomes	Anticipated absolute effects* (95% CI)		Relative effect (95% CI)	Number of participants (studies)	Certainty of the evidence (GRADE)	Comments
	Risk with standard no sanitation	Risk with doffing with extra sanitation of gloves				

Bacterial contamination: alcohol-based hand rub	667 per 1000	500 per 1000 (260 to 967)	RR 0.75 (0.39 to 1.45)	46 (1 RCT, 1 observational study)	⊕⊕⊖⊖ **Low** [1,2]	In the observational study, bacterial contamination (2.2 CFUs) did not significantly reduce compared to no sanitation (2.4 CFUs)
Bacterial contamination: quaternary ammonium				20 (1 observational study)	⊕⊖⊖⊖ **Very low** [1,3,4]	Bacterial contamination significantly reduced from 2.4 CFUs to 0 CFUs and compared to 2.2 CFUs without sanitation
Bacterial contamination: bleach				20 (2 observational studies)	⊕⊖⊖⊖ **Very low** [1,3,4]	In one study, bacterial contamination significantly reduced from 2.4 CFUs to 0 CFUs and compared to 2.2 CFUs without sanitation. In another study there was collinearity between PPE use and other variables, which precluded analysis.

*__The risk in the intervention group__ (and its 95% confidence interval) is based on the assumed risk in the comparison group and the **relative effect** of the intervention (and its 95% CI).

CFU: colony-forming unit; **CI:** confidence interval; **PPE:** personal protective equipment; **RCT:** randomised controlled trial; **RR:** risk ratio

GRADE Working Group grades of evidence

High certainty: we are very confident that the true effect lies close to that of the estimate of the effect.

Moderate certainty: we are moderately confident in the effect estimate; the true effect is likely to be close to the estimate of the effect, but there is a possibility that it is substantially different.

Low certainty: our confidence in the effect estimate is limited; the true effect may be substantially different from the estimate of the effect.

Very low certainty: we have very little confidence in the effect estimate; the true effect is likely to be substantially different from the estimate of effect.

[1]Simulation study, downgraded by one level.
[2]Confidence interval contains both harms and benefits.
[3]Study at high risk of selection bias, downgraded one level.
[4]One small study with 20 participants, downgraded one level.

Summary of findings 15. Procedures: doffing with hypochlorite versus doffing with alcohol-based glove sanitiser

Doffing with hypochlorite compared to doffing with alcohol-based glove sanitiser for preventing highly infectious diseases due to exposure to contaminated body fluids in healthcare workers

Patient or population: healthcare workers
Setting: simulation study
Intervention: doffing with hypochlorite

Comparison: doffing with alcohol-based glove sanitiser

Outcomes	Anticipated absolute effects* (95% CI)		Relative effect (95% CI)	Number of participants (studies)	Certainty of the evidence (GRADE)	Comments
	Risk with doffing with alcohol-based glove sanitiser	Risk with doffing with hypochlorite				
Contamination: MS2	Study population		RR 4.00 (0.47 to 34.24)	15 (1 observational study)	⊕⊝⊝⊝ **Very low** [1,2,3]	
	100 per 1000	400 per 1000 (47 to 1000)				
Contamination: Ph6	Study population		Not estimable	15 (1 observational study)	-⊕⊝⊝⊝ **Very low** [1,2,3]	
	0 per 1000	0 per 1000 (0 to 0)				

*__The risk in the intervention group__ (and its 95% confidence interval) is based on the assumed risk in the comparison group and the **relative effect** of the intervention (and its 95% CI).

CI: confidence interval; **RR:** Risk ratio

GRADE Working Group grades of evidence

High certainty: we are very confident that the true effect lies close to that of the estimate of the effect.

Moderate certainty: we are moderately confident in the effect estimate; the true effect is likely to be close to the estimate of the effect, but there is a possibility that it is substantially different.

Low certainty: our confidence in the effect estimate is limited; the true effect may be substantially different from the estimate of the effect.

Very low certainty: we have very little confidence in the effect estimate; the true effect is likely to be substantially different from the estimate of effect.

[1]Allocation to intervention was based on belonging to last five participants, which is an unclear selection procedure and so we downgraded by one level because of study limitations.
[2]This is a simulation study so we downgraded by one level because of indirectness.
[3]The study had a small number of participants and so we downgraded by one level because of imprecision.

Summary of findings 16. Teaching: video-based learning versus traditional lecture

Video-based learning compared to traditional lecture for preventing highly infectious diseases due to exposure to contaminated body fluids in healthcare workers

Patient or population: healthcare workers
Setting: simulation studies

Intervention: video-based learning
Comparison: traditional lecture

Outcomes	Anticipated absolute effects* (95% CI)		Relative effect (95% CI)	Number of participants (studies)	Certainty of the evidence (GRADE)	Comments
	Risk with traditional lecture	Risk with video-based learning				
Skills in PPE donning Assessed with assessment scale. Scale from: 0% to 100%; higher is better	The mean skills in PPE donning was 47.4%	MD 30.7% higher (20.14 higher to 41.26 higher)	-	26 (1 RCT)	⊕⊖⊖⊖ **Very low** [1,2,3]	

*__The risk in the intervention group__ (and its 95% confidence interval) is based on the assumed risk in the comparison group and the **relative effect** of the intervention (and its 95% CI).

CI: confidence interval; **MD:** mean difference; **PPE:** personal protective equipment; **RCT:** randomised controlled trial

GRADE Working Group grades of evidence

High certainty: we are very confident that the true effect lies close to that of the estimate of the effect.

Moderate certainty: we are moderately confident in the effect estimate; the true effect is likely to be close to the estimate of the effect, but there is a possibility that it is substantially different.

Low certainty: our confidence in the effect estimate is limited; the true effect may be substantially different from the estimate of the effect.

Very low certainty: we have very little confidence in the effect estimate; the true effect is likely to be substantially different from the estimate of effect.

[1]The randomisation and allocation procedures were unclear and so we downgraded by one level because of study limitations.
[2]This is a simulation study so we downgraded by one level because of indirectness.
[3]One study with only 26 participants and so we downgraded by one level because of imprecision.

BACKGROUND

Description of the condition

Over 59 million people are employed in the healthcare sector worldwide (WHO 2006). Some of these healthcare workers (HCW) are at risk of developing life-threatening infectious diseases due to contact with patients' blood or body fluids such as mucus, vomit or exhaled droplets. The risk of infection and its consequences vary, but it is well recognised as an occupational risk (Heptonstall 2010; Sepkowitz 2005). Especially during epidemics, these risks become more visible as the infection rate among HCW is higher than in the general population. Another risk of HCW infection is that infected HCWs will infect patients or that they will act as a vector for the transfer of the disease between patients. In addition, during epidemics, infected HCW will further diminish the capacity of an already overburdened healthcare system.

The 2013 to 2015 Ebola Virus Disease (EVD) epidemic put HCW at high risk of a disease with a very high fatality rate in the epidemic areas (Ebola 2014). According to the World Health Organization (WHO), healthcare workers were between 21 and 32 times more likely to be infected with Ebola than people in the general adult population (Forrester 2014; WHO 2015a). According to the statistics from the 2013-2015 West Africa EVD epidemic, there were 1049 registered cases of infected HCW with 535 deaths (Kilmarx 2014; WHO 2015b).

Just a decade earlier during the 2002 to 2003 Severe Acute Respiratory Syndrome (SARS) epidemic, 20% of all patients were healthcare workers of whom about 10% lost their lives (WHO 2003).

During the COVID-19 pandemic, HCW are at higher risk of infection than the general population, just as during other epidemics. Experts strongly urge the use of proper personal protective equipment (PPE) for the HCWs' and patients' safety (Adams 2020; Chang 2020). In a Chinese case-series of 138 consecutive patients that were hospitalised in Wuhan, China during the month of January 2020, 30% were HCW, which is considerably higher than expected (Wang 2020). Remuzzi 2020 reports that in Lombardy, Italy as of 12 March 2020, 20% of HCW at intensive care units became infected, while Giwa 2020 estimates that at least 10% of HCW in Italy will become infected in spite of using PPE.

HCW may become infected through various routes of transmission, depending on the pathogen. Infection can occur through splashes and droplets of contaminated body fluids on non-intact skin, or via needle-stick injuries through intact skin. Infection can also occur when splashes or droplets of contaminated body fluids land on the mucous membranes in the eyes, mouth or nose, or when the same mucous membranes come into contact with contaminated skin, such as when rubbing the eyes with a hand carrying pathogens after touching a patient or contaminated surface (Siegel 2019). For EVD, contact transmission is the main route of transmission. For SARS, the highest risk of infection was due to inhalation of aerosols, but the disease was also transmitted through droplet and contact infection. For COVID-19 the main route of exposure is through droplet transmission and contact transmission but other transmission routes are also possible (Chang 2020; Otter 2016; Peng 2020).

Here, we focus on highly infectious diseases, which means that contamination with infectious material can readily lead to clinical disease. We also focus on those infections that have serious consequences, such as a high case fatality rate, because the motivation of HCW to protect themselves will be different in situations where the risk is low and the consequences are not serious. The term 'high consequence pathogen' is also used but the list of what constitutes a high consequence pathogen varies from country to country. The European Network for Infectious Diseases defines highly infectious disease as an infectious disease easily transmitted from person to person, causing life-threatening disease, presenting a serious hazard in healthcare settings and in the community, and requiring specific control measures (Brouqui 2009).

Description of the intervention

In the occupational health field, the 'hierarchy of controls' is best practice. This means that measures with a general effect such as control of exposure should have priority over more individual control measures such as PPE. Exposure of HCW can be best controlled by organisational measures that minimise the exposure to contaminated body fluids or infected patients. The most important preventive measure is the proper organisation of the hospital or healthcare unit to avoid unnecessary contact. Once this has been implemented, the main strategy for reducing physical exposure to highly infectious diseases is through PPE. Both in the European Union (EU) and in the USA, it is mandatory for employers to protect their workers against blood-borne pathogens and other infections at work (OSHA 2012; EU 2010).

Coveralls, gowns, hoods, masks, goggles and face shields, among others, are used to prevent skin and mucous membranes from becoming contaminated and respirators are used to prevent inhalation. Depending on the transmission route and the specifics of the infection, different types of PPE are recommended. PPE in health care are usually considered as part of what is called transmission-based precautions. Standard precautions or universal precautions are based on the principle that all blood, body fluids, secretions, excretions except sweat, non-intact skin, and mucous membranes may contain transmissible infectious agents. Depending on anticipated exposure, hand hygiene and the use of PPE such as gloves, gowns, masks, eye protection (i.e. goggles or face shields) should be implemented. When the route(s) of transmission is (are) not completely interrupted using standard precautions alone, there are three categories that elaborate the precautions to be taken: contact precautions, droplet precautions, and airborne precautions (Siegel 2019).These precautions contain a number of measures including appropriate PPE to prevent the specific modes of transmission.

PPE will only be effective if the equipment can form a barrier between the HCW and the contaminated body fluids. Therefore, standards have been developed that, when complied with, ensure that PPE is of sufficient quality to protect against biohazards (Mäkelä 2014; NIOSH 2014). Even though the biohazard symbol (Figure 1), is widely used to indicate the presence of biohazards, it is not a label for protective clothing. For biohazards, these standards are based on laboratory tests that evaluate to what extent the fabric and the seams of protective clothing are leak-tight, that is, are they impermeable for liquids, viruses, or both at certain pressure levels. The standards in the EU and the USA are different. PPE should contain a label that specifically indicates the standards against which it has been tested.

Figure 1. International symbol indicating biohazards

Technical standards for PPE

Technical standards for PPE are complicated and the categorisation is confusing. In the EU, there is standard EN 14126 for clothing, specifically coveralls that protect workers against biological hazards from micro-organisms. Clothing compliant with the standard EN 14126 is further classified according to routes of contamination and the circumstances in which contamination may occur (pressurized contaminated liquid, mechanical contact with substances containing contaminated liquid, contaminated liquid aerosols, contaminated solid particles) based on ISO 2004a and ISO 2004b test methods. There is a separate standard for surgical gowns, EN 13795, but this standard is specifically designed to protect the patient.

In the USA, ANSI/AAMI PB70 2012 standard classifies surgical and isolation gowns according to their liquid barrier performance with four levels of protection, with level 4 offering the most protection against viral and liquid penetration but level 1 offering only minimal water resistance. There are several differences between ANSI/AAMI PB70 2012 and EN 13795 surgical gown classifications. Because the test methods and performance requirements cannot be compared directly, it is difficult to assign equivalency between surgical gowns classified according to ANSI/AAMI PB70 2012 and EN 13795. There is also US standard NFPA 1999 which was specifically developed to address a range of different protective clothing items worn by emergency medical service first responders, and also applies to medical first receivers. NFPA 1999 lists many performance requirements for protective clothing used by emergency medical personnel, including (but not limited to) viral penetration resistance, tensile strength, liquid integrity, and seam strength.

To summarise, the qualities of protective clothing certified by different standards are not fully comparable and complex. Nonetheless, they all aim to ensure that protective clothing is of a quality that prohibits water and blood-like fluids with virus particles, applied under a specified amount of pressure, from passing through. In addition, some standards have requirements that the whole piece of clothing, including the seams, must be non-permeable to liquids (NFPA 1999).

Clothing that is manufactured according to the standards mentioned above, at the appropriate level of protection, is impermeable to body fluids and viruses and will technically prevent skin contamination. However, this review does not deal with the technical physical standards of equipment, but rather whether and how its use in practice will prevent contamination and infection.

Guidelines for choosing proper PPE

In 2014, the WHO developed a guideline for infection prevention and control of epidemic- and pandemic-prone acute respiratory infections in health care. The guideline strongly recommends using appropriate PPE as determined by risk assessment (according to the procedure and suspected pathogen). Appropriate PPE when providing care to patients presenting with acute respiratory infection (ARI) syndromes may include a combination of: medical mask (surgical or procedure mask); gloves; long-sleeved gowns; and eye protection (goggles or face shields). For aerosol-generating procedures (AGPs) this combination including a surgical or a procedural mask or a particulate respirator is conditionally recommended. If splashing with blood or other body fluids is anticipated and gowns are not fluid-resistant, a waterproof apron should be worn over the gown (WHO 2014).

For COVID-19, recommendations for PPE are gloves, masks, goggles or face shields, and long-sleeved gowns (WHO 2020a; WHO 2020b) with N95 respirators recommended over masks for AGPs, consistent with the WHO 2014 guideline. Masks are further described as medical mask (flat, pleated or cup-shaped, affixed to head with a strap). Otherwise there are no quality criteria provided for the PPE parts. This is especially worrying because isolation gowns can have very different qualities, of which the end users are usually not aware (Kilinc-Balci 2016). Most isolation gown models also leave the neck unprotected, which could be a source of contamination (Zamora 2006). Centers for Disease Control and Prevention (CDC) recommends that non-sterile, disposable patient isolation gowns, which are used for routine patient care in healthcare settings, are appropriate for use by HCW when caring for patients with suspected or confirmed COVID-19. Current US guidelines do not require use of gowns that conform to any standards (CDC 2020a). If there is a medium to high risk of contamination, CDC recommends isolation gowns that claim moderate to high barrier protection (ANSI/AAMI PB70 2012 level 3 or 4; CDC 2020b). For a proper overview of requirements for and use of isolation gowns see Kilinc-Balci 2015 and Kilinc-Balci 2016.

During the EVD epidemic, several guidelines became available for choosing proper PPE (Australian NHMRC 2010; CDC 2014; ECDC 2014; WHO 2016). Even though all guidelines propose using similar protective clothing, there are differences. For example, ECDC 2014 proposes taping gloves, boot covers and goggles onto the coveralls to prevent leaving any openings but the other guidelines do not recommend this. Most guidelines have recently been updated. There are also recommendations for the technical quality of the PPE to be used with Ebola. For gowns, WHO 2016 currently recommends EN 13795 high-performance surgical gowns or ANSI/AAMI PB70 2012 level 3 (option 1), or level 4 (option 2), or equivalent. As the first option for coveralls, WHO currently recommends

protection equivalent to EN 14126, level 3 protection against blood level 2 against viruses.

Overprotection can be a problem. Some propose using three layers of gloves, because according to their experience, this is best practice (Lowe 2014). However, it may make work more difficult, and eventually lead to an increased rather than a decreased risk of infection, especially during doffing (i.e. removing the PPE). For example, the combined use of several respirators probably does not lead to more protection, but considerably increases the burden on the worker (Roberge 2008a; Roberge 2008b).

Donning and doffing of PPE

Despite using proper PPE, probably the biggest risk of infection is associated with self-contamination by HCW inappropriately removing the PPE (Fischer 2014). Some types of PPE make donning and doffing more difficult, thereby increasing the risk of contamination (Zamora 2006). There is evidence that when doffing PPE, the use of a double pair of gloves decreases the risk of contamination (Casanova 2012). How contamination of PPE occurs has also been clearly illustrated with a simulation study about cleaning up vomit (Makison 2014). The results of such simulation studies should increase HCW's confidence in executing the donning and doffing procedures correctly, and thus can also be an incentive for their uptake and compliance with the guidelines. Therefore, specific guidance has been developed for donning and doffing PPE (CDC 2014; WHO 2016).

Compliance with guidance on correct PPE use in health care is historically poor. HCW sometimes distrust infection control, and using PPE is stressful (Zelnick 2013). For respiratory protection such as masks and respirators, compliance has been reported to be around 50% on many occasions (Nichol 2008). Due to lack of proper fitting and incorrect use, real field conditions almost never match laboratory standards (Coia 2013; Howie 2005). Also, reports of hand hygiene show that there is still much room for improvement, and guidelines recommend education and training in combination with other implementation measures (WHO 2009). From reports of HCW, it is clear that most appropriate PPE is not user-friendly in tropical conditions. It prevents heat loss through sweating because it is not made of breathable material. A common reason for a breach in the barrier of the PPE is the worker sweating and then instinctively wiping their face (Cherrie 2006).

In this review, we only concentrated on PPE for highly infectious diseases that have serious consequences for health, such as EVD and COVID-19. We excluded other highly infectious, but less serious viral infections, such as norovirus, as we expected the effect of PPE to be different. We included SARS as it was highly infectious to HCW, sometimes fatal, and had similar recommendations on PPE use and training to COVID-19.

We did not specifically study the effects of hand hygiene or of respiratory protection to prevent transmission through inhalation. Hand hygiene is also crucial in preventing skin contamination, but this has already been covered in another review (Gould 2010). The protective effect of different types of respiratory protection, and effects of interventions to increase their uptake are covered in two other reviews (Jefferson 2011; Luong Thanh 2016).

How the intervention might work

First, HCW, their supervisors, or occupational health professionals should choose the proper type of PPE, as indicated in the guidance described above. Then, the HCW needs to know how to don and doff PPE according to the guidelines provided. Next, the HCW needs to comply with established procedures for correctly using, donning and doffing PPE. Education and training are used to increase compliance. The emphasis in teaching the correct use of PPE is on doing everything slowly and carefully to minimise the risk of making a mistake. Often an assistant or buddy, sometimes coupled with a mirror, is used while donning PPE, while a hygienist supervises doffing.

Compliance can be increased by personal supervision and instruction, checklists, audits of performance, by providing feedback, and by allowing sufficient time for donning and doffing. Education and training on uptake and compliance with PPE should have an effect in both the short term and the long term (Northington 2007; Ward 2011). Education and training can be seen as one method to increase compliance (Gershon 2009; Hon 2008). Compliance with PPE can also be improved by providing sufficient, comfortable, well-fitting, and more user- and patient-friendly PPE. Compliance with guidelines has been studied for hand hygiene. There is some evidence that multifaceted interventions and staff involvement are important, but altogether, there is little evidence that allows firm conclusions (Gould 2010).

Why it is important to do this review

From studies conducted during the SARS epidemic and the EVD epidemic it has become clear that the use of gloves, gowns and masks each help to reduce the infection rate in HCW (Appendix 1, Verbeek 2016a). More consistent use of gloves, gowns, masks and goggles was each related to fewer infections among HCW. Also, theoretically, protecting the skin and the mucous membranes of the mouth nose and eyes will prevent transmission. We have therefore little doubt that in a technical sense PPE will help and that the minimum amount of PPE needed is gloves, gown, and mouth, nose and eye protection, as recommended by WHO and CDC. The guidance does not, however, indicate which type or quality-level of PPE is most protective. In this review, we concentrate on finding out which PPE protects best by only including studies that compare one type of PPE against an alternative type of PPE, such as gowns against coveralls or goggles against face shields only when used as part of full PPE. We do not include studies that compare the use of PPE against no PPE, or studies comparing one type of PPE to another when not used as part of a set of full-body PPE.

There is still uncertainty about the optimal type, composition, amount, and ways of using full-body PPE to prevent skin and mucous membrane contamination of HCW while treating patients infected with highly infectious diseases. This is also reflected in the different ways guidelines for PPE are implemented in Europe (De Iaco 2012), and acknowledged in current WHO guidelines regarding EVD (WHO 2016). WHO realises that a safer, more comfortable and culturally appropriate protective system commensurate with the risk is needed and has provided guidance for industry, health workers, engineers, innovators, medical and scientific researchers, and others to re-think, energise, and innovate for a better PPE system for the HCW responding to Ebola virus outbreaks in tropical climates (WHO 2018).

Since full-body protection has mainly evolved as a direct result of experiences gained from the recent outbreaks of deadly viruses, there are still many types of PPE available with varying types of components. The comparative effectiveness of one type against another is still unknown. Regarding the equipment, there is uncertainty whether face shields protect as well as goggles, especially when goggles are combined with a hood. There is uncertainty whether and when double or triple gloves would be more protective than single gloves. Regarding suits, it is unclear if gowns are as protective as coveralls, and how breathable and impermeable for liquids or viruses they should be. Some argue that using more breathable material would decrease the risk of contamination (Kuklane 2015).

When it comes to donning and doffing procedures for EVD, there is uncertainty about the effect of integrity checks of gloves and other equipment, and whether gloves should be changed when highly contaminated. With doffing especially, it is unclear if this should be done in pairs with a helper buddy removing part of the PPE, or if this can be done alone. Another element of the doffing procedure that is uncertain is if spraying with a disinfectant such as chlorine spray is more protective than not using spray. It is not clear which disinfectant is the best antiviral: chlorine solution or alcohol gel, and at which concentration.

Also, for COVID-19, different procedures for donning and doffing PPE are recommended. Giwa 2020 proposes a specific procedure of doffing PPE, but the procedure is not consistent with the procedures proposed by CDC (CDC 2020c). Others, including the CDC, have proposed that gown and gloves should be doffed in a one-step procedure (Osei-Bonsu 2019), to minimise self-contamination.

It is also unclear what are the best ways to train HCW and how to best maintain the skills needed for proper use of PPE.

This review is a timely update of the Verbeek 2019 review, the results of which indicated that more research is still needed to answer the review's questions.

OBJECTIVES

To evaluate which type of full-body PPE and which method of donning or doffing PPE have the least risk of contamination or infection for HCW, and which training methods increase compliance with PPE protocols. In particular, we evaluated the effect of:

- different types of PPE on contamination and infection rates or on compliance (one type or component of full-body protection PPE versus another);
- different donning or doffing procedures on contamination and infection rates or on compliance (one procedure for donning and doffing full-body PPE versus another); and
- different types of education and training aiming to improve compliance with guidelines for full-body PPE on compliance, contamination and infection rates, (one type of training versus another).

METHODS

Criteria for considering studies for this review

Types of studies

Since the circumstances for evaluation studies are difficult during epidemics, we anticipated including a broad range of study designs.

We included any prospective or retrospective controlled field study. Field study here refers to a study that tests interventions with healthcare staff in a real-life exposure situation. This also includes case-control studies that compare the use of interventions retrospectively between cases that have become infected and comparable controls that did not get infected.

We also included randomised as well as non-randomised prospective controlled studies that simulated exposure to contaminated body fluids with the use of marker chemicals or harmless viruses or bacteria.

We excluded studies without a comparison group, but did not exclude studies on the basis of type of comparison group.

Types of participants

For simulation studies, we included any type of participants (volunteers or HCW) using PPE designed for EVD or comparable highly infectious diseases with serious consequences.

For field studies, we included studies only if they were conducted with HCW or ancillary staff exposed to body fluids from patients in the form of splashes, droplets, or aerosols contaminated with particles of highly infectious diseases that have serious consequences for health such as EVD, SARS, or COVID-19.

We excluded studies conducted with laboratory staff because the preventive measures in labs are more detailed and easier to comply with.

Types of interventions

1. We included studies that evaluated the effectiveness of different types of full-body protection (PPE), or comparing different types, compositions, or amounts of the following PPE components:

- body protection such as gowns, coveralls, or hazardous materials (hazmat) suits;
- eye and face protection such as glasses, goggles, face shields or visors, or masks or hoods that cover the entire head;
- hand protection: gloves; and
- foot protection: overshoes or boots.

We defined PPE as any of the equipment listed above that is designed or intended to protect healthcare staff from contamination with infected patients' body fluids.

2. We included studies that evaluated the effectiveness of different PPE parts or different procedures or protocols for donning and doffing of the PPE.

For example, extra assistance during donning and doffing, extra disinfection, or the use of extra gloves to prevent contamination in comparison to standard protocols.

3. We included studies that evaluated the effectiveness of training to increase compliance with existing guidance on the selection or use of PPE, including but not limited to:

- education (courses);
- practical training;
- information only (such as posters, guideline leaflets, etc.);
- audit and feedback; or
- monetary or organisational incentives.

Types of outcome measures

Primary outcomes

We included all studies that had measured the effectiveness of interventions as:

- contamination of skin or clothing, measured with any type of test material to visualise contamination (e.g. stains made visible with UV light) or harmless viruses or bacteria;
- infection with EVD, another viral haemorrhagic fever, or comparable highly infectious disease with serious consequences such as SARS, or COVID-19;
- compliance with guidance on selection of type and use of PPE measured, for example, with an observation checklist.

Secondary outcomes

- User-reported assessment of comfort and convenience
- Costs or resource use
- Time to don and doff the PPE

The secondary outcomes were not a criterion for including studies in this review.

Search methods for identification of studies

Electronic searches

We conducted a systematic literature search to identify all published and unpublished trials that could be considered eligible for inclusion in this review. We adapted the search strategy we developed for Medline through PubMed (see Appendix 2) for use in the other electronic databases. The literature search identified potential studies in all languages.

We searched the following electronic databases from inception to the dates presented underneath for identifying potential studies (search dates provided below). We searched with different interfaces for the various updates. The searches are listed in the appendices for all interfaces. For the 2020 update we did not search OSH-Update because the earlier search yielded so little.

- Cochrane Central Register of Controlled Trials (CENTRAL; 2020, Issue 3) via Wiley Online Library (Appendix 3);
- MEDLINE (Ovid) (Appendix 2; Appendix 4) until 20 March 2020;
- Embase (OVID) (Appendix 5; Appendix 6; Appendix 7) to 20 March 2020;
- CINAHL (EBSCOhost) (Appendix 8; Appendix 9) to 20 March 2020;
- NIOSHTIC (OSH-UPDATE) (Appendix 10) to 31 December 2018;
- NIOSHTIC-2 (OSH-UPDATE) to 31 December 2018;
- HSELINE (OSH-UPDATE) to 31 December 2018;
- CISDOC (OSH-UPDATE) to 31 December 2018;

We also conducted a search of ClinicalTrials.gov (www.ClinicalTrials.gov), and the WHO trials portal (www.who.int/ictrp/en/), which includes the Pan African Registry for potential studies on EVD for the 2016 and 2019 updates. For the 2020 update we searched the WHO trials portal for COVID 19/SARS-CoV-2. We searched all databases from their inception to the present for the first versions of the review. We searched from the earliest date of search to the present for updates of the review. We did not impose a restriction on language of publication.

Searching other resources

We checked reference lists of all primary studies and reviewed articles for additional references. For the 2016 version of the review, we contacted non-governmental organisations involved in medical relief operations in the high-risk EVD areas to identify additional unpublished materials on protection against EVD (Médécins Sans Frontières (MSF) and Save the Children). We also used Twitter to ask for unpublished reports from people in the field. Evidence Aid helped in locating relevant organisations and in asking them for unpublished reports. We also contacted DuPont, and 3M, PPE manufacturers, to request unpublished studies.

In addition, we used Google to find any unpublished or grey literature on our question that may not be available from the sources listed above by using the following terms: 'personal protective equipment ebola'. For the March 2020 update we conducted a search of Google Scholar using the search phrase ('SARS CoV 2' OR 'COVID' AND 'protective equipment' AND 'healthcare worker').

Data collection and analysis

Selection of studies

Pairs of review authors (JV, RS, BR, ET, BB, CT, SI, JR) independently screened titles and abstracts of all systematic search results to identify studies for inclusion. The same review authors coded them as 'retrieve' (eligible or potentially eligible/unclear) or 'do not retrieve'. We retrieved the full-text study reports/publication and pairs of review authors (JV, ET, BR, RS, BB, CT, SI, JR) independently screened the full text, identified studies for inclusion, and identified and recorded reasons for exclusion of the ineligible studies. We used the computer programme Covidence for the selection of references and full-text studies. We resolved any disagreement through discussion, except in two cases where a third-person assessment (SI or CT) was needed. We identified and excluded duplicates and collated multiple reports of the same study so that each study rather than each report is the unit of interest in the review. We recorded the selection process and completed a PRISMA flow diagram (Moher 2009), for the search for our original review (Figure 2), our updated review (Figure 3) and this update (Figure 4). We also completed a 'Characteristics of excluded studies' table.

Figure 2. PRISMA study flow diagram for search up to January 2016

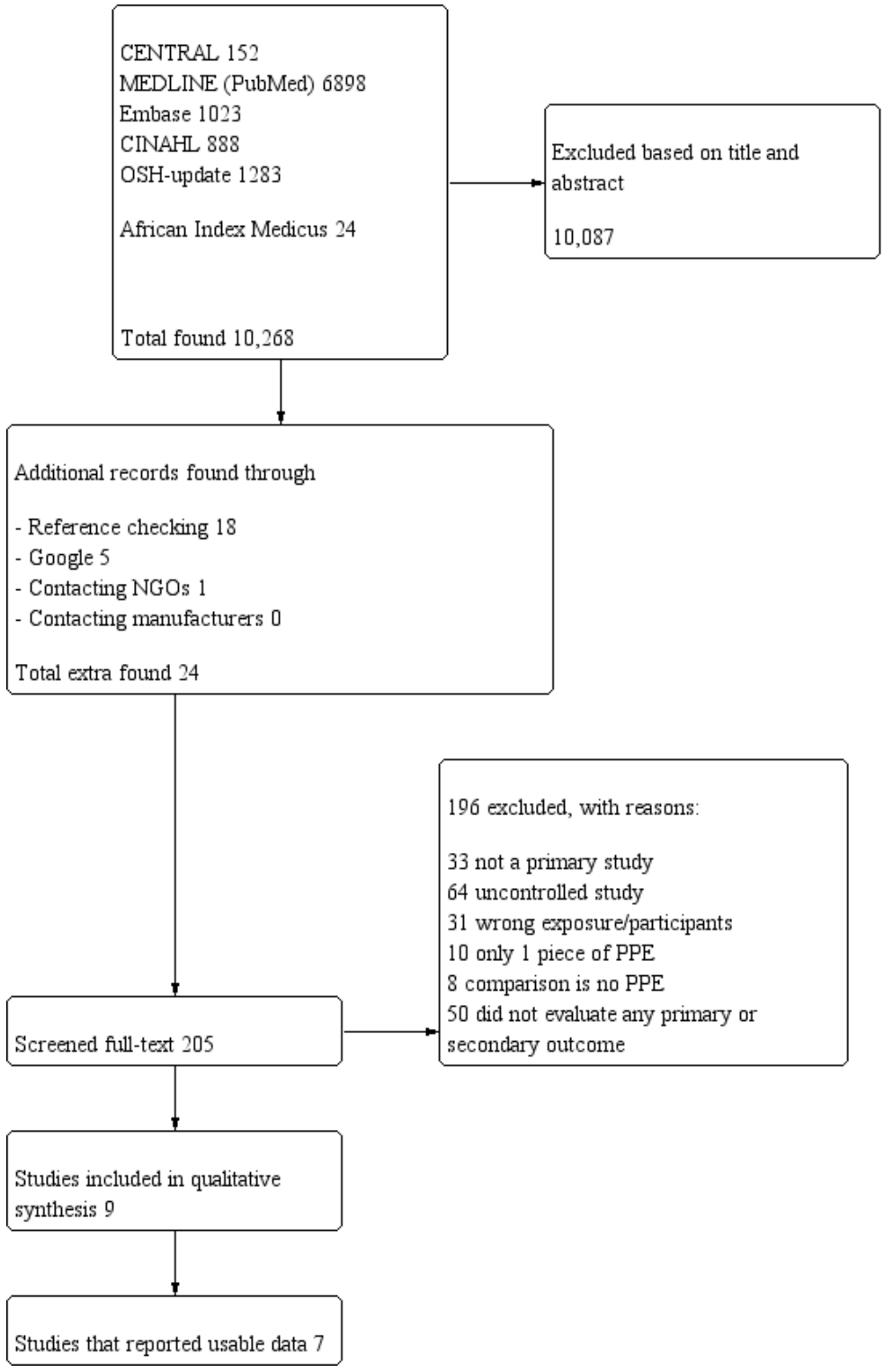


Figure 3. PRISMA study flow diagram for search between 2016 and 2018

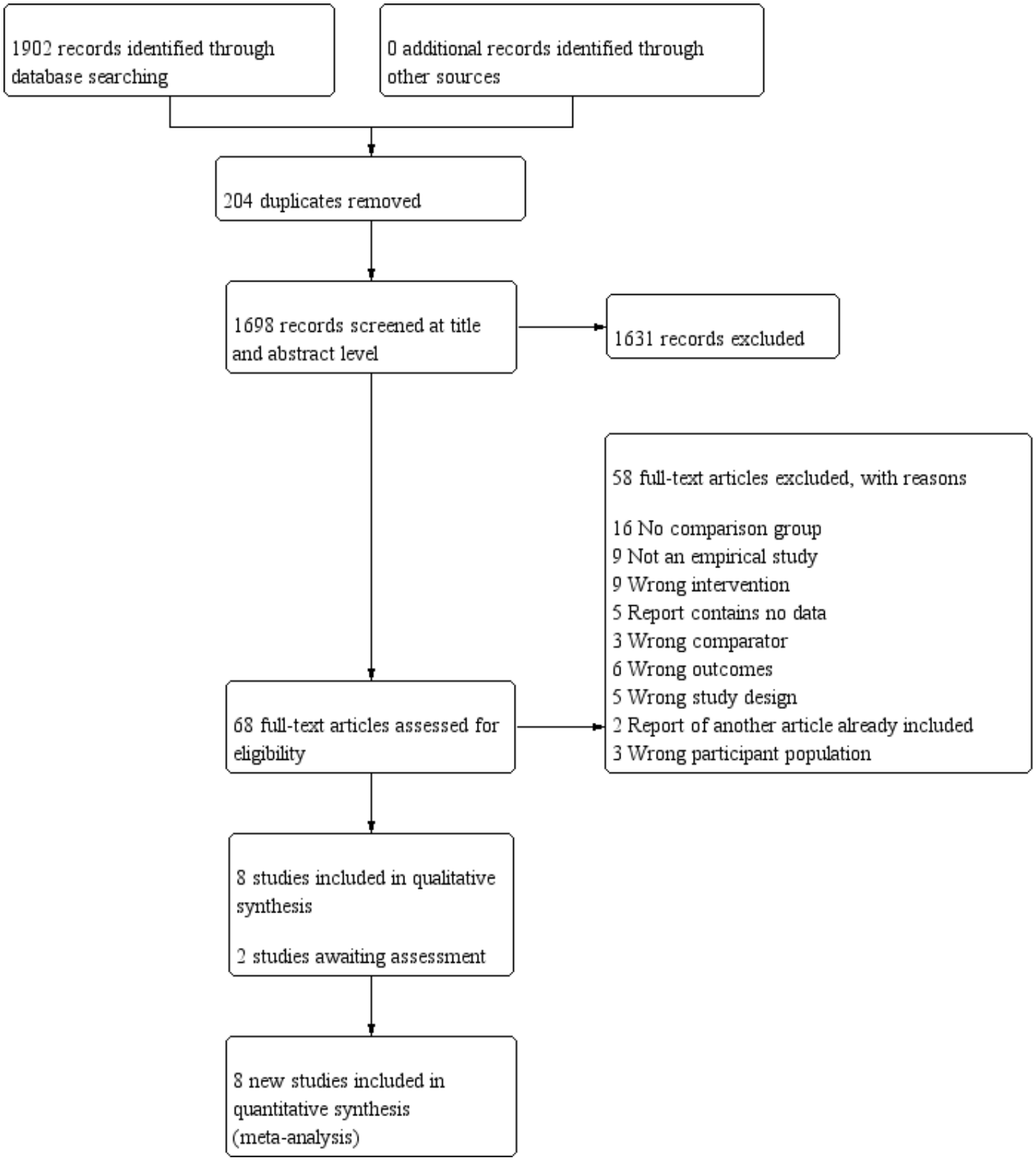
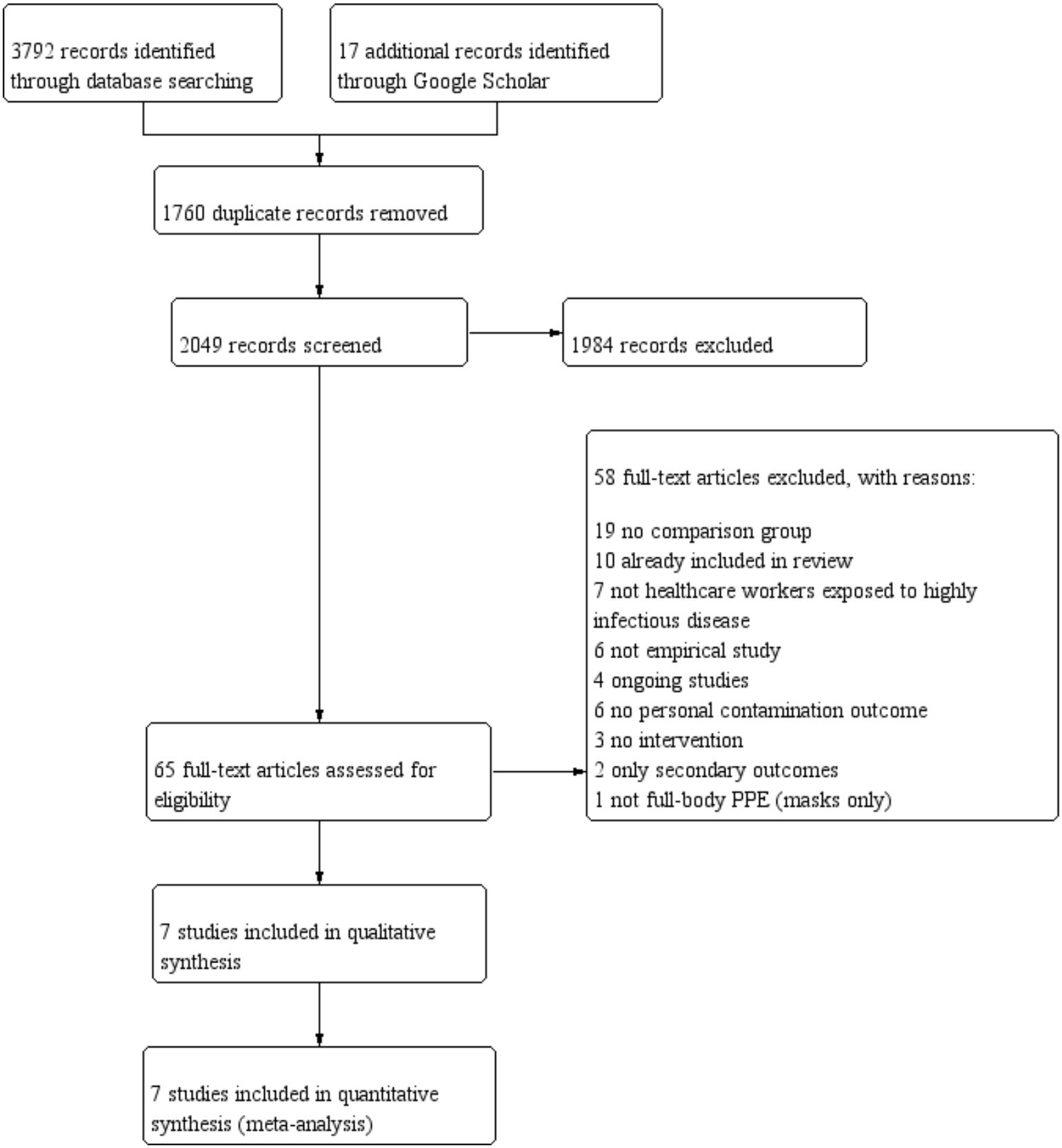


Figure 4. Study flow diagram for 2020 April update



Data extraction and management

We used Covidence for extracting study characteristics and outcome data. Two review authors (JV, BR, BB, ET, CT, RS, SI, JR) independently extracted the following study characteristics from included studies.

- Methods: study design, total duration of study, study location, study setting, withdrawals, and date of study
- Participants: number, mean age or age range, sex, severity of condition, diagnostic criteria if applicable, inclusion criteria, and exclusion criteria
- Interventions: description of intervention, comparison, duration, intensity, content of both intervention and control condition, and co-interventions
- Outcomes: description of primary and secondary outcomes specified and collected, and at which time points reported
- Notes: funding for trial, and notable conflicts of interest of trial authors, country where trial was conducted

Pairs of review authors (JV, BR, CT, SI, JR, ME, RS) independently extracted outcome data from included studies. We noted in the 'Characteristics of included studies' table if outcome data were not reported in a usable way. We resolved disagreements by consensus so there was no need to involve a third review author. One review author (JV or BR) transferred the data into Review Manager 5 (Review Manager 2014). We double-checked that data had been entered correctly by comparing the data presented in the systematic review with the study reports. A second review author (CT or JV) spot-checked study characteristics for accuracy against the trial report.

Assessment of risk of bias in included studies

Pairs of two review authors (JV, BR, CT, SI, JR, ME, RS) independently assessed risk of bias for each randomised study using the criteria outlined in the *Cochrane Handbook for Systematic Reviews of Interventions* (Higgins 2017). We resolved any disagreements by discussion so there was no need to involve another review author. We assessed the risk of bias according to the following domains in all RCTs.

1. Random sequence generation
2. Allocation concealment
3. Blinding of participants and personnel
4. Blinding of outcome assessment
5. Incomplete outcome data
6. Selective outcome reporting, and
7. Other bias

We rated each potential source of bias as high, low, or unclear and provided a quote from the study report or study author together with a justification for our judgment in the 'Risk of bias' table. We summarised the 'Risk of bias' judgements across different studies for each of the domains listed. For compliance, we considered blinding to PPE type significant for the outcome assessor only. Where information on risk of bias relates to unpublished data or correspondence with a study author, we noted this in the 'Risk of bias' table.

We considered randomised studies to have a low overall risk of bias when we judged random sequence generation and blinded outcome assessment to have a low risk of bias and none of the other domains to have a high risk of bias.

We used the domains blinding of participants and personnel, blinding of outcome assessment, incomplete outcome data, selective outcome reporting, and other bias for all non-randomised studies. Instead of the domains random sequence generation and allocation concealment, we used the following items as suggested in the ROBINS-I tool (Sterne 2016), for the assessment of risk of bias in non-randomised intervention studies.

- Bias due to confounding. We made an overall assessment of risk of bias based on the following questions if the signalling question, 'Is confounding of the effect of intervention unlikely in this study?' was answered with no.
  * Did the authors use an appropriate analysis method that adjusted for all the critically important confounding domains?
  * Were confounding domains that were adjusted for measured validly and reliably by the variables available in this study? For this review question, we considered baseline differences between compared groups in the following factors significant: prior experience with PPE, healthcare qualification, or education of HCW, age and sex, ambient temperatures, and stressful activities.
- Bias due to selection of participants into the study. We made an overall assessment of this risk of bias based on the following questions if the signalling questions, 'Was selection into the study unrelated to intervention or unrelated to outcome?, and 'Do start of follow-up and start of intervention coincide for most participants?' were answered with no.
  * Were adjustment techniques used that are likely to correct for the presence of selection biases?
  * For case-control studies: were the controls sampled from the population that gave rise to the cases, or using another method that avoids selection bias?

We considered the domains of confounding and selection of participants to yield high, low, or unclear risk of bias. For a non-randomised study as a whole, we considered the study to have a low risk of bias if all domains received a judgment of low risk of bias comparable to an RCT. This means receiving a low 'Risk of bias' judgment on the two domains listed above as well as domains three to seven in the previous section.

When considering treatment effects, we took into account the risk of bias for the studies that contributed to that outcome.

We judged studies to have a low overall risk of bias if we judged them to have a low risk of bias in the following domains: both random allocation and allocation concealment, or both confounding and selection bias, and incomplete outcome data and selective reporting. We considered the blinding of participants and outcome assessors less important because the outcomes were objective or we could not imagine that participants would have an interest in a certain type of attire and outcome.

Assessment of bias in conducting the systematic review

We conducted the review according to the published protocol (Verbeek 2015), and where there were deviations from it, we reported these in the 'Differences between protocol and review' section of the systematic review.

Measures of treatment effect

We entered the outcome data for each study into the data tables in Review Manager 2014 to calculate the treatment effects. We used risk ratios (RRs) for dichotomous outcomes, and mean differences (MDs) or standardised mean differences (SMDs) for continuous outcomes. When studies reported only effect estimates and their 95% confidence intervals or standard errors, we entered these data into Review Manager 2014 using the generic inverse variance method. When study authors used multivariate analyses, we used the most adjusted OR (odds ratios) or RRs. We ensured that higher scores for continuous outcomes had the same meaning for the particular outcome, explained the direction and reported where the directions were reversed, if this was necessary. If, in future updates of this review, we come across studies reporting results that we cannot enter in either way, we will describe them in the 'Characteristics of included studies' table, or we will enter the data into additional tables. For cohort studies that compare an exposed to a non-exposed population we intended to report both the RR for the intervention versus the control at baseline and at follow-up for dichotomous outcomes to indicate the change brought about by the intervention but we did not find any such studies.

Unit of analysis issues

If in future updates of this review we come across studies that employ a cluster-randomised design and that report sufficient data to be included in the meta-analysis but do not make an allowance for the design effect, we will calculate the design effect based on a fairly large assumed intra-cluster correlation of 0.10. We based this assumption of 0.10 being a realistic estimate by analogy on studies about implementation research (Campbell 2001). We will follow the methods stated in the *Cochrane Handbook for Systematic Reviews of Interventions* (Higgins 2011) for the calculations.

We intended to take the paired nature of the cross-over design in the included studies into account in our data analysis. However, the included studies did not present sufficient data to do so and the results presented here are based on the unpaired test that is implemented in Review Manager 2014 which resulted in wider confidence intervals than with the use of a paired t-test.

Dealing with missing data

We contacted investigators to verify key study characteristics and obtain missing numerical outcome data where possible (e.g. when a study was identified as abstract only). If in future updates of this review we come across studies where this is not possible, and the missing data are thought to introduce serious bias, we will explore the impact of including such studies in the overall assessment of results by a sensitivity analysis.

Similarly, if in future updates of this review we come across studies where numerical outcome data are missing, such as SDs or correlation coefficients and they cannot be obtained from the authors, we will calculate them from other available statistics such as P values, according to the methods described in the *Cochrane Handbook for Systematic Reviews of Interventions* (Deeks 2017).

Assessment of heterogeneity

We assessed the clinical homogeneity of the results of included studies based on similarity of population, intervention, outcome and follow-up. We considered populations as similar when they were HCWs directly engaged in patient treatment (nurses, doctors, paramedics) versus those who were not involved in patient therapy directly (cleaning and transport staff).

We considered interventions as similar when they fell into one of the intervention categories as stated in Types of interventions.

We considered any assessment of contamination of the skin or mucous membranes as similar enough to combine.

We considered the following follow-up times as similar: from immediately following a procedure up until the end of the work shift (short-term), and any time after the incubation time (long-term).

If in future updates of this review we come across studies with results that we can pool with meta-analysis, we will use the I^2 statistic (Higgins 2003), to measure heterogeneity among the trials in each analysis. Where we identify substantial heterogeneity, we will report it and explore possible causes by prespecified subgroup analysis. We will regard an I^2 value above 50% as substantial heterogeneity (Deeks 2017).

Assessment of reporting biases

For a future update, if we are able to pool more than five trials in any single meta-analysis, we will create and examine a funnel plot to explore possible small study biases.

Data synthesis

In future updates of this review we will pool data from studies we judge to be clinically homogeneous using Review Manager software (RevMan Web 2019). If more than one study provides usable data in any single comparison, we will perform meta-analysis. We will use a random-effects model when I^2 is above 40%; otherwise we will use a fixed-effect model. When I^2 is higher than 75% we will not pool results of studies in meta-analysis. We will include a 95% confidence interval (CI) for all estimates (Deeks 2017).

We will describe the results in the case of skewed data reported as medians and interquartile ranges.

Where multiple trial arms are reported in a single trial, we will include only the relevant arms. If two comparisons are combined in the same meta-analysis, we will halve the control group to avoid double-counting.

Subgroup analysis and investigation of heterogeneity

If future updates of this review find a sufficient number of studies, we will carry out the following subgroup analyses:

- high income versus low and middle-income countries; and
- PPE that is certified for biological hazards versus PPE that does not have such a certification.

We will also use our primary outcomes in subgroup analyses, and we will use the Chi^2 test, as implemented in RevMan Web 2019, to test for subgroup interactions. At this time, we have not identified enough studies to allow for such a subgroup analysis.

Sensitivity analysis

If future updates of this review find a sufficient number of studies, we will perform sensitivity analyses defined a priori to assess the robustness of our conclusions. This involves including only studies

we judge to have a low risk of bias. At this time we have not identified enough studies to allow such a sensitivity analysis.

Reaching conclusions

We based our conclusions only on findings from the quantitative or narrative synthesis of included studies that we judged to have the lowest risk of bias. Consequently, we used findings from non-randomised studies when we did not find evidence from randomised studies. We avoided making recommendations for practice based on more than just the evidence, such as values and available resources. Our implications for research suggest priorities for future research and outline what the remaining uncertainties are in the area.

Summary of findings and assessment of the certainty of the evidence

Studies used numerous comparisons to measure the effect of PPE and we limited the 'Summary of findings' tables to the findings of the comparisons we judged most useful. We created a series of 'Summary of findings' tables to present the primary outcomes for different types of PPE (one type versus another) and donning or doffing procedures (one procedure versus another). We used the five GRADE considerations (study limitations, consistency of effect, imprecision, indirectness and publication bias) to assess the certainty of a body of evidence as it related to the studies that contributed results data for the prespecified outcomes. We used methods and recommendations described in Section 8.5 (Higgins 2017), and Chapter 12 (Schünemann 2017), of the *Cochrane Handbook for Systematic Reviews of Interventions*, using GRADEpro GDT software. We justified all decisions to down- or upgrade the certainty of evidence using footnotes and we made comments to aid reader's understanding of the review where necessary. With non-randomised studies, we started at low-certainty evidence and with randomised studies at high-certainty evidence. In future updates of this review, if the outcomes are measured in many different ways, we will prioritise the reporting of outcomes as follows: infection rates, contamination rates and compliance rates.

RESULTS

Description of studies

Results of the search

The search to January 2016 resulted in 10,268 references for screening (see Figure 2). From these references we selected 205 articles for full-text assessment. Through checking the references of included articles we found 18 additional articles. We found another five articles by using Google, and we found one more through contacting NGOs (Tomas 2015). Our contacts with the manufacturers did not yield any responses or data. Most of the studies that we located outside our electronic searches were studies of PPE use during the SARS epidemic that did not make reference to any type of PPE in the title or abstract. For the same reason we did not locate Nyenswah 2015 because there was no reference to PPE. By using Google search, we found one additional article (Bell 2015), that was not indexed in any of the databases that we searched. Based on a request of one of the peer referees we also searched the African Index Medicus, which yielded 24 references but no new studies to include. Contacting PPE manufacturers did not lead to any responses. This added up to 205 papers that we checked full-text for inclusion. Of these, we excluded 196. This resulted in nine included studies.

We updated the searches in Embase up to 22 May 2018, in Medline through PubMed up to 15 July 2018, in CINAHL up to 31 July 2018, in OSH-update on 31 December 2018, and in CENTRAL up to 18 June 2019. We did not have access to Embase after May 2018 and used Scopus to update the Embase search up to 18 June 2019. This yielded 1698 new references after de-duplication. We assessed 68 articles in full-text and subsequently we excluded 58 articles. This resulted in 10 new studies that fulfilled our inclusion criteria (see Figure 3) of which we could include eight in the review and two were awaiting assessment.

For the 2020 update we reran the searches including the search word 'decontamination' and PPE as a MeSH term in Medline. We did not update the OSHupdate search because this yielded so little for the previous version. We also searched African Index Medicus but it did not add any new articles. Altogether we retrieved 3792 references through database searching and 17 additional records through searching Google Scholar. We removed 1760 duplicates (see Figure 4). Thus, we screened 2049 records, which led to 65 full-text assessments. Of these, we excluded 58 records, mainly because the studies did not have a comparison or were already included in the review. The selection process finally resulted in seven new studies included in the review which includes the two studies awaiting assessment in the previous version of this review (Andonian 2019; Chughtai 2018; Drews 2019; Hajar 2019; Kpadeh Rogers 2019; Osei-Bonsu 2019; Suen 2018).

Included studies

We contacted Bell 2015; Casalino 2015; Casanova 2016; Curtis 2018; Drews 2019; Hall 2018; Suen 2018 and we got additional information from all but Casanova 2016. We entered this information in the 'Characteristics of included studies' table.

Study types

We included 24 studies in total. Twenty-two were simulation studies, of which 18 simulated exposure to contaminated body fluids and measured contamination outcomes, and four studies provided alternative PPE or procedures and measured compliance with donning and doffing procedures.

Of these simulation studies 14 were randomised trials (seven with parallel groups (Andonian 2019; Bell 2015; Curtis 2018; Hung 2015; Osei-Bonsu 2019; Tomas 2016; Wong 2004), seven had a cross-over design (Chughtai 2018; Hajar 2019; Guo 2014; Mana 2018; Strauch 2016; Suen 2018; Zamora 2006)), and one was a quasi-RCT (Gleser 2018).

There were seven non-randomised controlled studies (five with a cross-over design ((Buianov 2004; Casanova 2012; Drews 2019; Kpadeh Rogers 2019; Hall 2018) and two with parallel groups (Casalino 2015; Casanova 2016)).

In addition, we found two retrospective cohort studies. One study evaluated the effect of PPE training on SARS infection rates and noncompliance with the doffing protocol (Shigayeva 2007). In this study, the authors located all HCW that had been exposed to SARS patients and assessed, by questionnaire, compliance with PPE guidelines and PPE doffing guidelines. Houlihan 2017 evaluated the risk of EVD infection according to donning and doffing practices and

the use of disinfectant in HCW that had been deployed in West Africa during the EVD epidemic.

Participants

In the simulation studies, researchers included 816 intervention and 367 control participants, when we take into account that studies used a cross-over design and thus all participants were intervention participants. In the cohort studies, there were 863 intervention and 232 control participants. Altogether there were 2278 participants.

The participants in all studies were healthcare workers with a mixture of occupations, but mainly physicians, nurses and respiratory technicians. One study included medical students during their internships (Casalino 2015). No studies included other healthcare staff such as people working in emergency services or cleaning staff.

In the two retrospective cohort studies, exposure of participants was to the SARS epidemic in one study (Shigayeva 2007), and to the EVD epidemic in another study (Houlihan 2017).

In the simulation studies, 12 studies simulated exposure using a fluorescent agent, three studies exposed participants to a harmless virus or microbes, and another three studies used both ways of exposure simulation. Studies used a wide range of different fluorescent agents and a range of exposure methods that varied from rubbing 0.5 mL of fluorescent agent over the gloved hands to throwing 100 mL of fluorescent agent onto the torso of the gown (see Table 1). The situation was similar in the studies that used viruses or bacteria to simulate exposure. Four studies simulated donning and doffing to assess compliance with guidance (Casalino 2015; Curtis 2018; Drews 2019; Hung 2015).

Countries

Twelve studies were performed in the USA, four in China and Hong Kong, two in Canada, two in the UK, one each in Australia, Germany and Russia, and one was performed in three countries at the same time: France, Mexico and Peru (Casalino 2015). One study in Canada was performed during the SARS epidemic and one study in the UK was among HCW that had returned from the West-African EVD epidemic.

Time period

All studies were conducted after the year 2000, with six before, and 18 after 2015.

Interventions and comparisons

Of the 24 included studies, 17 studies evaluated an intervention and a control condition. Four studies (Buianov 2004; Guo 2014; Houlihan 2017; Shigayeva 2007), evaluated two interventions. One study compared three types of PPE (Suen 2018), one study five types (Hall 2018), and one study 10 types (Chughtai 2018).

Fourteen studies compared one type of PPE to one or more other types. Eight studies compared two or more different ways of donning and doffing. One of these studies named the intervention 'enforced training' but we categorised it under different ways of doffing because it entailed giving instructions during the donning and doffing process versus not giving instructions (Casalino 2015). Three studies evaluated the effect of training.

Comparison of different types or parts of full-body PPE

Fourteen simulation studies compared different types or parts of full-body PPE outfits or compared an adapted design versus a standard design PPE, but all in a different way. Only a couple of studies were similar enough to allow us to combine their results. None of the included studies used a standardised classification of the properties of the PPE that protect against viral penetration such as the EN 14126.

Two simulation studies compared different types of masks or respirators as part of full-body PPE. Buianov 2004 compared two different types of powered, air-purifying respirator (PAPR) that were especially developed for this project in Russia to protect healthcare personnel against Ebola and similar viruses. Buianov 2004 also compared the effect of different airflow rates that varied from 50 L to 300 L per minute. The intervention participants were required to carry out a step test that lasted for four hours. The study authors did not describe the equipment they tested in sufficient detail for us to be able to judge their technical qualities. Zamora 2006 compared PPE combined with a PAPR in use at the study hospital with PPE without a PAPR according to CDC recommendations to prevent respiratory infection at the time of the study, the so-called Enhanced Respiratory and Contact Precautions (E-RCP).

Six simulation studies compared different types of gowns and protective clothing. Wong 2004 compared four types of PPE according to their material properties. First, they tested the material according to the American Association of Textile Chemists and Colorists' standards 22 and 127. We excluded the surgical-gowns-only category since it had no water repellency and insufficient viral barrier properties. Type A had good water repellency and water penetration resistance, but at the cost of poor air permeability. Type B had good water repellency and good air permeability, but poor water penetration resistance. Type C was the surgical gown with both poor water repellency and water penetration resistance. Type D, Barrierman, was made of Tyvek and had good water repellency, poor air permeability and fair water resistance. Bell 2015 compared commercially available PPE, compliant with CDC recommendations, with locally available clothing, such as rain coats that were thought to be as protective as the commercially available ones. Guo 2014 compared three types of PPE: a disposable water-resistant, non-woven gown, a reusable, woven, cotton gown, and a disposable non-woven plastic apron. The second one was a cotton, water permeable gown, like a surgical gown. We left this arm out of the analysis because surgical gowns alone are not used for EVD. The study authors tested the fabrics for water repellency and liquid penetration according to the American Association of Textile Chemists and Colorists' standard 22. The gown and the apron received ratings of 4 and 5 respectively on a scale of 0 to 5 for water repellency. One simulation study compared different full-body PPE ensembles. Hall 2018 compared five different PPE ensembles used in EVD surge units in hospitals, which all met the guidance of the Advisory Committee on Dangerous Pathogens endorsed by Public Health England (PHE). Three ensembles used gowns while two ensembles used coveralls. Some PPE ensembles were comprised of gowns with surgical caps and other ensembles of coveralls with hoods. Some PPE comprised boots only and others boot covers. Some taped the second pair of gloves whereas others did not. Suen 2018 compared three types of PPE, which differed with respect to the use of a waterproof gown, isolation gown, or coverall. Chughtai 2018 compared 10 different outfits that complied with guidance given by

WHO or in specific countries, including the guidance for donning and doffing.

Modifications to existing PPE

Strauch 2016 compared a N95 filtering face piece respirator (FFR) mask to a modified FFR mask with tabs placed on the elastic band as a doffing aid. The study authors reported having evaluated contamination of the hands and head in two different trials but they reported their results in the same article.

Tomas 2016 compared a standard gown to a prototype seamless PPE that consisted of a polyethylene gown with nitrile gloves attached by a contact bond adhesive to enable the removal of the gown and gloves at the same time. Mana 2018 compared a standard polyethylene gown to a modified gown with a double elastic neck closure for easier removal, more gown coverage on the palm of the hand and smaller thumb holes and elastic wrist bands to create a snugger fit. Hajar 2019 also evaluated a gown with improved glove gown interface.

One simulation study compared different types of gloves. Gleser 2018 compared a modified glove with a small tab near the thumb to aid in glove removal without contamination to standard medical examination gloves. Both types of gloves were made of the same material from the same company. The study authors did not provide any more information.

Studies comparing different types of eye protection or footwear are missing.

Contamination rates are not only determined by the type of PPE but also by the donning and doffing procedures. All studies had a priori determined donning and doffing procedures. It should be noted that these studies evaluated the totality of the type of PPE inclusive of the donning and doffing procedure. We have described the procedures in the 'Characteristics of included studies' table.

Donning or doffing procedures (one procedure for donning or doffing versus another)

Eight studies compared different donning or doffing procedures.

Extra gloves

Casanova 2012 compared the effect of wearing two pairs of gloves with wearing one pair of gloves on contamination rates. We classified the study under methods of doffing because the intention of the double-gloving was to decrease contamination during doffing. Doffing was done as per CDC recommendation, which describes how to do both single-gloving and double-gloving. Osei-Bonsu 2019 also compared the CDC procedure for doffing with doffing with double gloves.

Structured procedures versus individual ways of donning and doffing

One simulation study compared individual's own versus recommended procedures. Guo 2014 compared the effect of doffing a gown or an apron according to an individual's own views versus the procedure recommended by CDC in the USA in 2007. Participants were given the following instructions: "Gown front and sleeves are contaminated! Unfasten neck, then waist ties. Remove gown using a peeling motion; pull gown from each shoulder toward the same hand. Gown will turn inside out. Hold removed gown away from body, roll into a bundle and discard into waste or linen receptacle".

Alternative procedures versus CDC procedure

One study (Osei-Bonsu 2019) compared the CDC procedure for doffing with a one-step procedure in which gloves are doffed at the same time as the gown.

Extra instruction

Two simulation studies compared the effect of extra assistance during donning or doffing versus no instructions. Casalino 2015 compared standard (unassisted) donning or doffing procedure to reinforced (extra assistance) procedures. The reinforcement consisted of an instructor saying out loud the next step of donning or doffing. The study authors used the reinforcement with both basic PPE (impermeable apron without a hood) and enhanced PPE (full-body suit and hood). Andonian 2019 compared training in teamwork to conventional donning and doffing.

Disinfection procedures

Four simulation studies, and one field study, compared donning or doffing procedures with extra disinfection during the process. Casanova 2016 compared the self-contamination of skin with two surrogate viruses when either an alcohol-based hand rub or hypochlorite solution was used for the glove hygiene step of a PPE doffing protocol. Houlihan 2017 intended to compare the PPE removal with and without chlorine spray and also with and without assistance but there was collinearity between these variables and being in clinical work or in laboratory work. All those that were in clinical work reported having used chlorine spray and assistance whereas those in laboratory work did not. Therefore we could not analyse these data. Kpadeh Rogers 2019 compared the effect of alcohol-based hand rub, quaternary ammonium or bleach to no glove disinfection. Osei-Bonsu 2019 compared the recommended CDC procedure to the same procedure plus extra hand hygiene with alcohol-based hand rub.

Type of training or education (one type of training or education versus another)

Three studies evaluated different training methods for donning and doffing procedures.

Hung 2015, a simulation study, compared a conventional training session for donning and doffing procedures to a procedure in which the conventional session was complemented with a computer simulation later.

Shigayeva 2007, a field study, evaluated the effect of active and passive training versus no training on compliance rates. We defined active training as training that involved any group or face-to-face interaction. We defined passive training as watching a video or receiving written instructions. This allowed us to make an indirect comparison between the effect of active and passive training. We calculated the effect of active training compared to passive training by subtracting the OR for passive training from the OR for active training, as outlined in the *Cochrane Handbook for Systematic Reviews of Interventions* (Higgins 2011). We calculated the variance of this indirect comparison by summing the variances of both direct comparisons. Then we calculated the standard error by taking the square root of the combined variance. We used this as input for the generic inverse variance method in Review Manager 2014.

Curtis 2018, a simulation study, compared a video-based learning session on instructions for PPE use for patient decontamination as

part of a disaster medicine training to a traditional lecture before participating in a practical exercise.

Outcomes

Infection rates

One study (Houlihan 2017), evaluated the effect of interventions on infection rates. The study authors measured the level of immunoglobulin G (IgG) specific for EVD in an oral fluid sample to assess if there had been undetected infections in HCW exposed to EVD.

Contamination outcomes

Simulation studies measured contamination either as the proportion of people contaminated, as the number of contaminated spots, or as the area of the body contaminated in studies using a fluorescent marker (see Table 1). Study authors measured contamination with the help of a UV lamp (when using fluorescent marker), or by directly measuring viral or microbe presence or viral or microbial load (when using a non-pathogenic virus or microbes). However, across studies, different body locations were contaminated and also different body locations were measured for the contamination outcome. In the control groups there was a median of 67% of participants contaminated and across intervention groups this was 25%. There were two studies in which there were participants that had zero contamination with a specific PPE outfit (Chughtai 2018; Hall 2018).

Compliance with guidance: noncompliance rates with donning and doffing procedures

Ten studies evaluated the effect of interventions on noncompliance (Casalino 2015; Casanova 2012; Curtis 2018; Drews 2019; Hajar 2019; Hung 2015; Shigayeva 2007; Suen 2018; Zamora 2006)

Four contamination simulation studies (Casanova 2012; Drews 2019; Hajar 2019; Zamora 2006), measured non-compliance as the number of participants that did not follow the correct order of the protocol, omitted elements, or did not use the correct equipment.

Shigayeva 2007 measured noncompliance in their training study as the number of violations against protocol as recorded from interviews. There were two different compliance outcomes. One was called consistent adherence and was calculated as the proportion of exposure episodes with full compliance with PPE. The other one was called unsafe doffing, measured if one or more of the elements of the doffing procedure were violated. We recalculated outcomes in such a way that they represented the frequency of noncompliance.

Hung 2015 measured compliance as a total score on a 16-item checklist for donning and 20-item checklist for doffing. To get results comparable to the other studies we subtracted the mean compliance values from the maximum score and used these as noncompliance values.

Casalino 2015 measured noncompliance as the number of errors per person for donning and for doffing and the number of people with one or more errors as measured by the specialist trainer or instructor, who also gave the spoken instructions in case of reinforcement. The study authors also measured critical errors, which were those where there was contact between skin and potentially contaminated PPE, but we did not consider this a valid measure of contamination and disregarded it. We took measurement of the errors at the last training session as the effect of the intervention. We disregarded the error measurements at earlier training sessions.

Suen 2018 measured non-compliance as the average of the percentage errors of all items of a checklist.

Curtis 2018 measured compliance as the percentage of the maximum attainable score that an external evaluator gave on a practical skills test for both donning and doffing PPE.

Secondary and other relevant outcomes

No studies reported on costs or other economic outcomes such as resource use.

Wong 2004 and Lai 2011a measured time, and Wong 2004 and Drews 2019 measured satisfaction. Buianov 2004 measured heart rate and body temperature. We chose to report the results of this outcome as well, as we identified it as an additional outcome that appeared relevant to the questions being addressed.

Excluded studies

Description of case series or outbreak

One reason for excluding important studies was that the researchers only described a case-series of HCW cases' use of PPE for EVD (Muyembe-Tamfum 1999), Marburg Haemorraghic Fever infection (MHF) (Borchert 2007; Colebunders 2004; Jeffs 2007; Kerstiens 1999), Congo Crimean Haemorraghic Fever (CCHF) (Gozel 2013), or for SARS (Christian 2004; Ho 2003; Ofner 2003; Ofner-Agostini 2006). None of these studies described the use of PPE by the cases in such detail that they could be replicated. In combination with the lack of a control condition, it is difficult to conclude how much PPE, or the lack thereof, contributed to the infection. The only different study of a series of cases during an outbreak was the study by Dunn 2015 that contained proper descriptions of PPE.

Description of PPE use only

We excluded studies if they only described how and what PPE was used without relation to an outcome (Beam 2016a; Beam 2016b; Franklin 2016; Lee 2017; Lowe 2014; Marklund 2002; Minnich 2003).

One type of PPE only, no comparison

Alraddadi 2016, Delaney 2016, Drew 2016, Elcin 2016, Luo 2011, Kwon 2017 and Tomas 2015 evaluated only one type of PPE without a comparison in a simulation study. Also for the 2020 update we excluded many studies because of the lack of a control group (Abualenain 2018; Casanova 2018; Kogutt 2019; Mumma 2018; Parveen 2018; Williams 2019; Weber 2018).

No infection rates contamination or compliance outcomes

Some studies measured only performance with PPE compared to no PPE use and not infection rates, contamination or compliance (Castle 2009; Coates 2000; Garibaldi 2019; Hendler 2000). Other studies did not measure personal but only environmental contamination (Jaffe 2019; Lai 2011; Porteous 2018; Visnovsky 2019).

Comparison with no PPE only

We excluded studies that only compared PPE use with no PPE and not with alternative PPE use (Lu 2006; Schumacher 2010; Teleman 2004).

Studies that evaluated only one type of PPE and not part of full-body PPE

Ogendo 2008 measured eye protection only. Bearman 2007 measured universal glove use only. Chughtai 2013, Lindsley 2012 and Lindsley 2014 measured masks or face shields only. Even though these studies yield valuable information, it is unclear how well the results also cover the use of these items as part of full-body protection and therefore we excluded these studies.

Participants not exposed to highly infectious diseases with serious consequences

Many studies evaluated PPE use for diseases other than EVD and related haemorraghic fevers, such as HIV or other nosocomial infections that were not considered highly infectious or having serious consequences, or both, and we excluded these studies (Anderson 2017; Bischoff 2019; Malik 2006; Makovicka 2018; Ransjo 1979; Sorensen 2008). In another study participants were not HCW (Kahveci 2019).

Training or simulation studies without a control group

There were a number of studies that evaluated training but that did not use a control group. This makes it difficult to draw inferences about the effect of one type of training compared to another (Abrahamson 2006; Beam 2014; Hon 2008; Northington 2007; Tomas 2015).

Inconsistent use of PPE during the SARS epidemic

After intensive discussion, we excluded 11 studies that measured the use of PPE (mask, gloves, gowns, goggles) during the SARS outbreak and related that to the risk of SARS infection. One line of thinking was that these studies did not fulfil the inclusion criteria because the comparison here was not clearly one type of PPE versus another type of PPE. Another line of thinking was that the studies compared different types of PPE composition and thus would fulfil the inclusion criteria. We finally decided to deal with these studies in the discussion section only (Ho 2004; Lau 2004; Le 2004; Liu 2009; Loeb 2004; Nishiura 2005; Park 2004; Pei 2006; Scales 2003; Seto 2003; Teleman 2004).

Risk of bias in included studies

See Figure 5 for an overview of our judgment of the risk of bias per study. Figure 6 gives an overview of risk of bias per domain. Since the figures contain the 'Risk of bias' assessments for both randomised and non-randomised studies, not all cells are applicable to both study types and those that are not applicable remain empty.

Figure 5. 'Risk of bias' summary: review authors' judgements about each 'Risk of bias' item for each included study

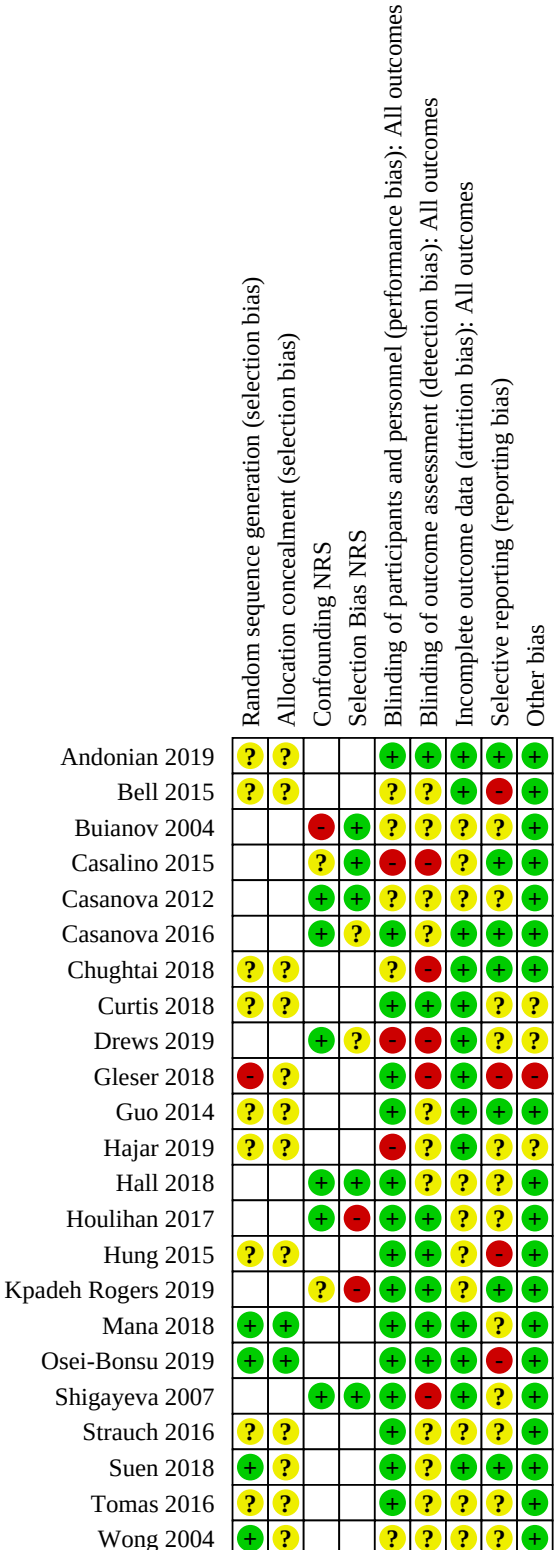


Figure 5. (Continued)

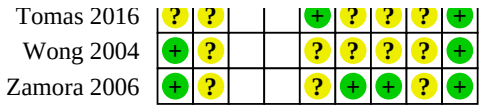
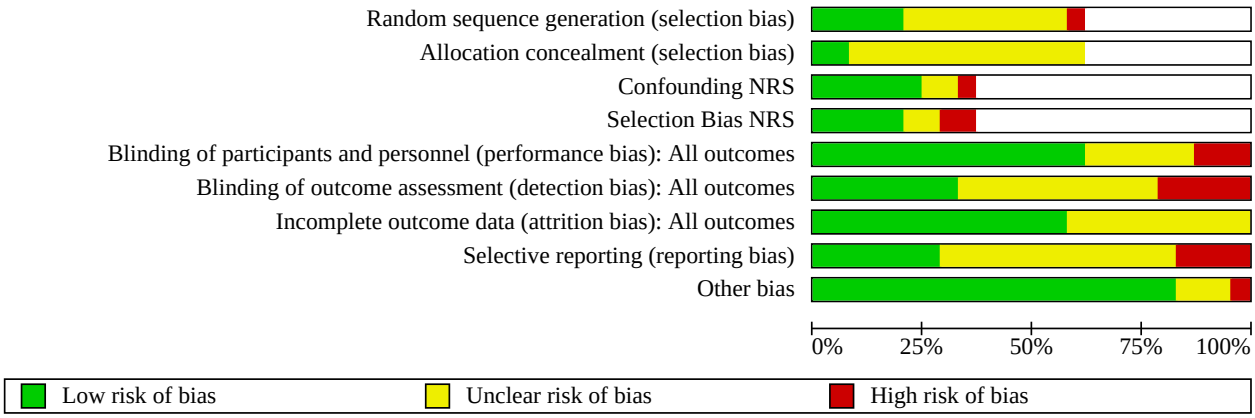


Figure 6. 'Risk of bias' graph: review authors' judgements about each 'Risk of bias' item presented as percentages across all included studies



Allocation

Allocation was random in 14 studies but only five of them stated adequately what method they had used for generating the random sequence and where thus rated as at low risk of bias for random sequence generation. Five studies reported an appropriate method (Osei-Bonsu 2019; Suen 2018; Wong 2004; Zamora 2006), and for one we received additional information from the study authors (Mana 2018). One used alternation and we rated it as having a high risk of bias (Gleser 2018). The other studies were rated at unclear risk of bias

Allocation concealment was unclear in all but two of the randomised studies (Mana 2018; Osei-Bonsu 2019). We judged only these two studies to have a low risk of selection bias.

Blinding

In the simulation studies, the participants could not be blinded for the type of attire they were wearing or the type of donning or doffing procedure they were following. It is unclear if they could have contaminated themselves more with attire that they thought was not good, or they did not like, but for the majority of the studies we considered this unlikely and assessed the risk of performance bias to be low. For one study, Casalino 2015, we rated the risk of performance bias as high because the instructors who provided the intervention were very much aware if instruction was given or not and they were the also the assessors. We also rated the risk of performance bias as high for Drews 2019 and Hajar 2019 because the outcomes were subjective and the participants unblinded. We judged the risk of performance bias as low in 15 studies.

For the non-randomised SARS study (Shigayeva 2007), we considered the risk of performance bias low because the study was retrospective and the participants did not know they were part of a study.

The risk of detection bias was unclear in most studies, as they did not report whether outcome assessors were blinded. We considered the risk to be high in one study (Casalino 2015), as providers of the intervention were also the assessors of compliance, and in a second study (Shigayeva 2007), because the intervention and the outcome were assessed with the same questionnaire at the same time. We judged the risk to be low in four studies because the study authors stated that assessors were blind to group status (Curtis 2018; Hung 2015; Mana 2018; Zamora 2006). We judged the risk of detection bias to be low for Houlihan 2017 because they used antibodies against Ebola, an objective outcome, which would not be affected by assessors' knowledge of treatment. All in all, we judged the risk of detection bias as low in eight studies.

Incomplete outcome data

We judged the risk of attrition bias to be low in 14 studies and unclear in 10 studies. All but two studies were short-term experiments and therefore most had a complete follow-up of all participants.

Selective reporting

It was difficult for us to judge selective reporting because none of the included studies had published a protocol. We judged seven studies (Andonian 2019; Casalino 2015; Casanova 2016; Chughtai 2018; Guo 2014; Kpadeh Rogers 2019; Suen 2018), to have a low risk of reporting bias as the study authors appeared to have reported all relevant data as specified in their articles' methods. We judged Bell 2015 to be at high risk of reporting bias because they did not report outcomes separately for the intervention and the control. We also judged Hung 2015 to have a high risk of reporting bias as the study

authors did not fully report the results of the computer usability questionnaire. In addition, Gleser 2018 and Osei-Bonsu 2019 did not fully report all results. In total we judged four studies to be at high risk of reporting bias.

Other potential sources of bias

We did not consider that any of the included studies were at risk of other sources of bias except for Gleser 2018, where we considered that there was a substantial financial conflict of interest because the first author was also the director of the company that produced the gloves that were part of the intervention.

Bias due to confounding (non-randomised studies)

We judged there to be a low risk of bias due to confounding in six non-randomised studies (Casanova 2012; Casanova 2016; Drews 2019; Hall 2018; Houlihan 2017; Shigayeva 2007), unclear risk in two non-randomised studies (Casalino 2015; Kpadeh Rogers 2019), and a high risk in one non-randomised study (Buianov 2004).

Bias due to selection of participants into the study (non-randomised studies)

We judged there to be a low risk of bias due to selection of participants into the study for five non-randomised studies (Buianov 2004; Casalino 2015; Casanova 2012; Hall 2018; Shigayeva 2007), and unclear for one study (Casanova 2016). We considered the risk of selection bias to be high in two studies. Houlihan 2017, because they recruited participants based on snowball sampling, and Kpadeh Rogers 2019, where different HCW performed tests with different bacteria.

Overall risk of bias per study

We judged none of the included studies to be at low risk of bias overall. According to our judgment they were all at either unclear (N = 15) or at high risk of bias (N = 9).

Effects of interventions

See: **Summary of findings 1** Personal protective equipment (PPE) types: powered, air-purifying respirator (PAPR) plus coverall versus N95 mask plus gown; **Summary of findings 2** Personal protective equipment (PPE) types: more protective versus less protective; **Summary of findings 3** Personal protective equipment (PPE) types: gowns versus aprons; **Summary of findings 4** Personal protective equipment (PPE) types: different types of PPE attire; **Summary of findings 5** Modified personal protective equipment (PPE): sealed gown-glove interface versus standard gown; **Summary of findings 6** Modified personal protective equipment (PPE): gown - easy to doff compared to standard gown; **Summary of findings 7** Modified personal protective equipment (PPE): gown with gown-glove improvement compared to standard gown and gloves; **Summary of findings 8** Modified personal protective equipment (PPE): gloves with tab versus standard gloves; **Summary of findings 9** Modified personal protective equipment (PPE): mask plus tabs versus standard masks; **Summary of findings 10** Procedures: doffing according to Centers for Disease Control and Prevention method versus individual doffing; **Summary of findings 11** Procedures: single-step doffing compared to Centers for Disease Control and Prevention standard; **Summary of findings 12** Procedures: doffing with double gloves compared to doffing with single gloves; **Summary of findings 13** Procedures: donning and doffing with instructions compared to without instruction; **Summary of findings 14** Procedures: doffing with extra sanitation of gloves compared to standard no sanitation; **Summary of findings 15** Procedures: doffing with hypochlorite versus doffing with alcohol-based glove sanitiser; **Summary of findings 16** Teaching: video-based learning versus traditional lecture

1. Different types of PPE compared

1a Different types of mouth and nose protection

1.1 Powered air-purifying respirator (PAPR) versus PPE for enhanced respiratory and contact precautions (E-RCP)

Outcome: contamination with fluorescent marker

Zamora 2006 found that the PAPR system in use in their hospital led to less contamination than using the E-RCP system (RR 0.27, 95% CI 0.17 to 0.43; Analysis 1.1). Other ways of measuring contamination also led to less contamination with the PAPR system: contamination more than 1 cm (RR 0.21, 95% CI 0.12 to 0.36). The total contaminated area was also less with a mean difference of −81.10 cm^2 (95% CI −96.07 to −66.13). This was mainly due to a lack of protection of the neck in the E-RCP system.

Outcomes: compliance with guidance - donning and doffing noncompliance

Noncompliance with donning guidelines occurred more with the PAPR system as this consists of more elements (RR 7.50, 95% CI 1.81 to 31.10; Analysis 1.4; Zamora 2006). Noncompliance with doffing guidelines was more frequent with the E-RCP system, but this was not statistically significant (RR 0.50; 95% CI 0.20 to 1.23; Analysis 1.5).

Outcomes: donning and doffing time

The donning (MD = 259 seconds) and doffing time (MD = 337 seconds) were considerably longer with the PAPR system (Analysis 1.6; Analysis 1.7; Zamora 2006).

1.2 One type of PAPR versus another and different airflow rates

Outcome: contamination with microbial aerosol

Buianov 2004 found that the suit that had the hood attached to the suit (СКБ-I) had a lower 'contamination penetration rate' than the suits that had separate hoods and coveralls with a percentage of 8.10^{-8} for the suit and 2.10^{-1} for the coveralls. However, we could not understand the meaning of the penetration rate and we decided that we would not use these results for our conclusions (their results are not shown in data tables).

Outcomes: heart rate and body temperature

Buianov 2004 also found that contamination stopped beyond the 250 L/minute airflow rates. Body temperature and heart rates were also lower at these airflow rates.

1b Different types of body protection

1.3 Four types of PPE versus another

Wong 2004 compared four types of PPE according to their material properties. Type A had good water repellency and water penetration resistance but at the cost of poor air permeability. Type B had good water repellency and good air permeability but poor water penetration resistance. Type C was the surgical gown with both poor water repellency and water penetration resistance. Type

D, Barrierman, was made of Tyvek and had good water repellency, poor air permeability, and fair water resistance.

Outcomes: contamination, user-reported assessment of comfort and convenience - usability, donning and doffing times

There were no considerable differences in contamination (Analysis 2.1) between Type A and Type B for face, neck, trunk, foot, or hand, but Type B scored about 10% higher on usability (MD −0.46, 95% CI −0.84 to −0.08; Analysis 2.2); this was due especially to better breathability of the fabric. There were no considerable differences in donning and doffing times (Analysis 2.3; Analysis 2.4).

There were considerable differences in contamination of the foot (MD −4.1 spots, 95% CI −6.94 to −1.26) and the hand (MD −12.76 spots, 95% CI −21.62 to −3.9) between Type A and Type D (Analysis 2.5). Donning (MD 33 seconds, Analysis 2.7) and doffing (MD 17 seconds, Analysis 2.8) times were also much worse for Type D. Usability was rated as not considerably differently (MD 0.25, 95% CI −0.12 to 0.62; Analysis 2.6).

It was unclear how many participants had no contamination. On average, all types of PPE had some contamination.

1.4 Formal PPE versus locally available PPE

Outcome: contamination with fluorescent marker

Bell 2015 compared contamination in four participants with formal PPE with four participants with locally available protective gear, such as raincoats. They found contamination in one participant in both study arms. The study was so small that it is difficult to draw conclusions (Analysis 3.1).

1.5 Gown versus apron

Outcome: contamination with fluorescent marker

Guo 2014 compared a gown with an apron and found that the gown left less contamination than an apron, regardless of the way of doffing (Analysis 4.1; Analysis 4.2).

1.6 Five types of PPE attire compared

Outcome: contamination with fluorescent marker

Hall 2018 compared post-doffing contamination of five types of PPE ensembles used in different hospital wards across the UK. No analysis of contamination rates of the different suits was available since the authors reported the data on contamination sites only and not according to type of attire. They argued that the contamination rates were too low to provide a valid comparison.

1.7 Three different types of PPE attire compared

Outcome: contamination with fluorescent marker

Suen 2018 measured small and large patches of contamination in three different ensembles with PPE 1, a surgical gown used with EVD with a hood covering the neck, PPE 2, a coverall also used for EVD, and PPE 3, an isolation gown. They reported the median number of patches across 10 body sites and four environmental contamination sites. The median number of contaminations for small patches was respectively 5, 7 and 7 and for large patches it was 39, 43 and 47. These differences were reported as being statistically significantly different but there were insufficient data to check this. This would mean that a long gown protects better than a coverall and that the commonly used isolation gown protects least. According to the study authors, the reduced protection for the isolation gown is especially due to the lack of coverage of the neck, "which resulted in many small or extra-large patches in the anterior and posterior neck region after spraying of the fluorescent solution onto the face shield and anterior surfaces of the gown".

Outcomes: compliance with guidance - donning and doffing noncompliance

Suen 2018 also measured compliance and reported the average percentage of errors across the items measured. For PPE 1, PPE 2 and PPE 3, the averages for donning were 6.1, 6.0 and 3.7 and for doffing 3.0, 9.5 and 3.5. This seems to give an indication that coveralls are more difficult to doff.

Outcomes: time for donning and doffing

Suen 2018 also measured the time needed to don and doff the PPE (Analysis 5.1; Analysis 5.2). PPE 3, the isolation gown, was quickest to don and doff, while the coverall doffing took significantly longer, with on average more than 10 minutes for doffing. The attire with the long surgical gown took twice as long as the isolation gown to put on and was also slower to doff because more PPE items were used. We were not able to conduct a proper paired analysis because of the lack of detail in the study report. We analysed the trial as if it were a two-group parallel trial, which leads to too wide confidence intervals.

1.8 Ten different types of PPE ensembles compared

Outcome: contamination with fluorescent marker

Chughtai 2018 evaluated 10 different PPE ensembles recommended for use with EVD by global and national authorities. Six of these used coveralls and four used gowns. There were also differences in the use of a PAPR or a respiratory mask. Each ensemble was tested in total three times by part of 10 volunteers. There were only four ensembles that led to contamination: the ensemble recommended by WHO, North Carolina authorities, CDC and Health Canada. The first three consist of coveralls and the last one is a gown.

Outcome: user satisfaction

Chughtai 2018 also asked users to rate the ease of donning and doffing. The ECDC coverall and protocol was rated highest for ease of donning and doffing. Since there were only three ratings per ensemble, this has only a limited meaning.

2. Modifications versus standard gear

2.1 Sealed gown-glove interface versus traditional gown-glove interface

Outcome: contamination

Tomas 2016 found that participants doffing a gown that had continuous coverage of skin from arm to hand (sealed suit) were less likely to contaminate themselves with fluorescent lotion than those doffing traditional PPE of gown and glove (RR 0.27; 95% CI 0.09 to 0.78; Analysis 6.1). The study authors obtained similar results when they used MS2 bacteriophage as the contaminate (RR 0.68; 95% CI 0.47 to 0.98; Analysis 6.2).

2.2 Easy-doffing gown versus traditional gown

Outcome: contamination

Mana 2018 compared a gown with modified neck and wrist design to facilitate doffing with a traditional gown and found fewer people with contamination with both fluorescent marker (RR 0.08, 95% CI 0.01 to 0.55; Analysis 7.1) and with harmless virus (RR 0.53, 95% CI 0.29 to 0.94; Analysis 7.2). Even though we received additional information from the study authors we were unable to conduct a proper paired analysis.

2.3. Modified gown-glove interface versus standard gown-glove interface

Outcome: contamination

Hajar 2019 modified the gown-glove interface with more overlap between gown and glove. They evaluated this in two different groups. In one they compared the modified gown to a standard gown and in the other they added extra education to both intervention and control group. This led to considerably less contamination (RR 0.45, 95% CI 0.26 to 0.78, Analysis 8.1) in the meta-analysis of the two trials. We could not take into account that the trials had a cross-over design but analysed these as if they were parallel trials with twice the number of participants. This may have led to a slight overestimation of the precision.

2.4. Modified-inside gown versus standard gown

Outcome non-compliance: errors during donning, doffing, performance

Drews 2019 redesigned the gown based on observed errors during doffing, donning and performing tasks. They found a similar number of people with errors while donning (RR 0.93, 95% CI 0.50 to 1.72; Analysis 9.1), while performing tasks (MD −0.30, 95% CI −0.67 to 0.07; Analysis 9.2) and while doffing (RR 0.81, 95% CI 0.33 to 2.00; Analysis 9.3).

2.5 Gloves with tabs versus gloves without tabs

Outcome: contamination

Gleser 2018 found a decrease in people with contamination when doffing gloves with tab near thumb and wrist compared to standard gloves (RR 0.22, 95% CI 0.15 to 0.31; Analysis 10.1).

2.6 Masks with tabs versus masks without tabs

Outcome: contamination

Strauch 2016 found that contamination from hands to the head was less when the participant doffed a mask with tabs on the strap engineered as a doffing aid compared to a mask without tabs (RR 0.33, 95% CI 0.14 to 0.80; Analysis 11.1). There was no difference in contamination rates when participants doffed a contaminated mask that either had or did not have tabs (RR 0.96; 95% CI 0.83 to 1.12; Analysis 11.2).

3. Changes in donning or doffing procedures

3.1 Double-gloving versus single-gloving

Outcome: contamination with MS2 virus

Both Casanova 2012 and Osei-Bonsu 2019 found that contamination with the use of double gloves was less than with single gloves. We felt that the studies were comparable even though the first used harmless virus and the second harmless bacteria as the simulated exposure. When all contaminated sites were taken together the RR was 0.34 (95% CI 0.17 to 0.66; Analysis 12.1). For the specific body parts the reduction was less clear (Analysis 12.1). Also when measured with fluorescent marker, there was no difference between double- and single-gloving (RR 0.98, 95% CI 0.75 to 1.28; Analysis 12.4).

All participants had some level of contamination. Measured as the quantity of virus found, the hands were less contaminated after degloving when participants used double gloves but due to missing data we could not test this.

Outcome: compliance with guidance - compliance errors

No more errors in compliance occurred with the donning or doffing protocol for double-gloving compared to single gloving (RR 1.08, 95% CI 0.70 to 1.67; Analysis 12.3).

3.2 CDC-recommended procedure versus individual doffing

Outcome: contamination

Guo 2014 found that the CDC's recommended way of doffing a gown or an apron led to a different decrease in contamination compared to individually chosen doffing. When doffing the gown, there were 5.4 fewer smaller contamination patches (95% CI −7.4 to −3.4) and 5.2 fewer stains in the environment (95% CI −7.3 to −3.3), but no difference in small contamination patches on the hands, shoes or underwear. With doffing the apron, there were fewer smaller stains, stains on the hands, shoes, and environment, but more large stains and a similar number of stains on the underwear (Analysis 13.1; Analysis 13.2).

3.3 CDC-recommended procedure versus single step

Outcome: contamination

Osei-Bonsu 2019 evaluated doffing gown and gloves in a single step versus the standard gloves first procedure and found no difference in contamination with fluorescent marker (RR 0.98, 95% CI 0.75 to 1.28; Analysis 14.1) but with bacterial contamination there was a considerable difference (RR 0.20, 95% CI 0.05 to 0.77; Analysis 14.2). It is unclear what would cause this difference in effect between the two outcome measures. We would be inclined to assume that the bacterial simulation is more realistic than the fluorescent powder.

3.4 Doffing with extra disinfection of gloves

a. Alcohol-based sanitation of gloves versus no extra glove sanitation

Outcome: bacterial contamination

Osei-Bonsu 2019 compared alcohol-based glove sanitation versus no glove sanitation and found no considerable reduction in the number of people contaminated (RR 0.75, 95% CI 0.39 to 1.45; Analysis 15.1). Kpadeh Rogers 2019 found a non-significant reduction in bacterial contamination from a median 2.4 colony-forming units (CFUs) to 2.2 CFUs for both bacteria used when alcohol-based hand rub was used versus no extra sanitation of gloves.

b. Quaternary ammonium versus no extra glove sanitation

Outcome: bacterial contamination

Kpadeh Rogers 2019 found a significant reduction in bacterial contamination from a median 2.4 CFUs to 0 CFUs for both bacteria

used for simulating exposure when quaternary ammonium-based hand rub was used versus no extra sanitation of gloves.

c. Bleach versus no extra glove sanitation

Outcome: bacterial contamination

Kpadeh Rogers 2019 found a significant reduction in bacterial contamination from a median 2.4 CFUs to 0 CFUs for both bacteria used for simulating exposure when bleach-based hand rub was used versus no extra sanitation of gloves.

d. Hypochlorite sanitation versus alcohol-based sanitation

Outcome: viral contamination

Casanova 2016 found non-significantly greater self-contamination of bacteriophage MS2 to the hands, face or scrubs when hypochlorite solution was used for the glove sanitising step of the doffing protocol compared to the use of an alcohol-based hand rub (RR 4.00, 95% CI 0.47 to 34.24; Analysis 18.1). The study authors did not detect contamination of bacteriophage Ph6 when using either alcohol-based hand rub or the hypochlorite solution (Analysis 18.2).

e. Chlorine spray versus no spray

Houlihan 2017 compared the risk of HCW contracting Ebola when either using or not using a chlorine spray during the doffing of PPE. However, there was no variation in the use of chlorine spray among clinical workers. The use only varied between clinical and laboratory workers. Since it is not possible to disentangle risk of exposure and the use of hypochlorite solution, no conclusions can be drawn from this study with regard to PPE.

3.5 Additional spoken personal instructions versus no such instructions

3.5.1. Outcome: compliance with guidance - noncompliance

Casalino 2015 found that there were substantially less noncompliance (people with one or more errors) after additional spoken instruction compared to no instructions with (RR 0.31, 95% CI 0.11 to 0.93) and also that the mean number of errors fell by on average almost one (MD −0.89, 95% CI −1.36 to −0.41) in the group with spoken instructions (Analysis 16.1; Analysis 16.2).

Andonian 2019 organised team work between the person with PPE and doffing assistants who guided the donning and doffing process and found a decrease in the number of sites contaminated with either fluorescent marker or particles (MD −5.00, 95% CI −8.08 to −1.92). We assumed that the median reported by the study authors would be roughly equal to the mean and the interquartile range equalled, 1.35 SD.

3.5.2. Outcome: infection rate

One study compared infection rates between people who had instructions while donning and doffing versus rates in those without instructions. Due to the fact that the exposure was also different between these two groups, we were unable to draw conclusions about the protective effect of instructions (Houlihan 2017).

4. Training and instructions

4a. Training and instruction for proper and complete PPE use

4a.1 Active training versus passive training

4a.1.1 Outcome: compliance with guidance - noncompliance with PPE guidance

Shigayeva 2007 defined consistent adherence as always wearing gloves, gown, mask, and eye protection. We transformed this to inconsistent use as being noncompliant with the guidance. The study found that active training led to less noncompliance than no training (OR 0.37, 95% CI 0.2 to 0.58). For passive training, they found a lower risk of noncompliance compared to no training (OR 0.58, 95% CI 0.33 to 1.00). For the indirect comparison, active versus passive training, the OR was 0.63 (95% CI 0.31 to 1.30; Analysis 20.1).

4b. Training and instruction for PPE donning and doffing

4b.1. Active versus passive instruction

4b.1.2. Outcome: compliance with guidance - noncompliance with doffing procedures

Shigayeva 2007 found no considerable effect of active (OR 0.70, 95% CI 0.45 to 1.11) or passive training (OR 1.56, 95% CI 0.83 to 2.94) compared to no training on the number of errors in compliance with the doffing protocol. For the indirect comparison, active versus passive training, the OR was 0.45 (95% CI 0.21 to 0.98; Analysis 19.1).

4b.2. Additional computer simulation versus no additional computer simulation

4b.2.1. Outcome: compliance with guidance - noncompliance

Even though the number of errors was already low, Hung 2015 found that adding computer simulation reduced the number of errors with on average half an error for donning (MD, −0.52, 95% CI −0.90 to −0.14; Analysis 20.1) and with more than one error for doffing (MD −1.16, 95% CI −1.63 to −0.69; Analysis 20.2).

4b.3 Video-based learning versus traditional learning

Curtis 2018 compared skills in donning PPE when taught with a video-based learning method versus a traditional lecture. Those that participated in the video learning had a higher mean score on the post-exam than those who attended a traditional lecture. (MD 30.7, 95% CI 20.14 to 41.26; Analysis 21.1).

5. Subgroup and sensitivity analysis

We planned a subgroup analysis of studies conducted in high- versus low- and middle-income countries. However, there were not enough studies for such a subgroup analysis to be meaningful.

We also planned a sensitivity analysis including only studies we judged to have a low risk of bias. As none of the included studies fulfilled this criterion, we could not perform this analysis.

6. Certainty of the evidence

We judged if there was a reason to downgrade the certainty of the evidence for each domain of GRADE. Since we judged all studies to have a high or unclear risk of bias, we downgraded the evidence for all comparisons by one level. We considered simulation studies to be indirect evidence, and downgraded the evidence yielded by these studies by one level as well. In addition, when there was only one small study, we downgraded because of imprecision. All in all, the certainty of the evidence is low to very low for all comparisons.

For the non-randomised studies, there were no reason to upgrade the certainty of the evidence.

DISCUSSION

Summary of main results

Almost all findings are based on one or at most two small simulation studies. Therefore, we judged the certainty of the evidence as very low or low.

One type of PPE compared to another

One study found less contamination when a PAPR with hood and coverall was used compared to a gown and a N95 mask but there were more errors in donning with the PAPR (Summary of findings 1).

Three studies compared different types of body protection. One study found that more protective gear protected slightly better but was more uncomfortable because of lack of breathability (Summary of findings 2). Another study found gowns to be better than aprons (Summary of findings 3). The third study did not provide data.

Three studies compared more recently proposed PPE ensembles according to different guidelines. One study found too few contamination events to draw conclusions. Another study found that long gowns protected better than a coverall or isolation gown and the coverall was difficult to doff (Summary of findings 4).

Modifications versus standard attire

Three studies compared changes to gowns especially related to improved doffing and changed glove-gown interface and found considerably less contamination (Summary of findings 5; Summary of findings 6; Summary of findings 7). One study modified the inside of the gown and the closure system but found no difference in errors with donning or doffing or during performance.

Two studies evaluated the effect of tabs to improve ease of donning and found less contamination with tabs on masks or gloves (Summary of findings 8; Summary of findings 9).

One type of donning or doffing procedure compared to another

There are eight studies that compared donning and doffing procedures.

Following CDC recommendations for doffing gowns and aprons compared to individually chosen ways may decrease the risk of contamination (Summary of findings 10). Doffing of gloves and gown in one step may also decrease the risk of contamination (Summary of findings 11).

For doffing, there is very low-certainty evidence that double-gloving as part of full-body PPE may reduce the risk of contamination and reduce the viral load on the hands without increasing the frequency of noncompliance with the doffing protocol (Summary of findings 12). Instructions during doffing may increase compliance (Summary of findings 13). Adding extra steps to the process in the form of glove disinfection may not be effective for alcohol-based rub but may decrease viral and bacterial contamination when quaternary ammonium or bleach is used (Summary of findings 14). There is no difference in contamination between using alcohol-based hand rub during doffing and using chlorine based disinfection (Summary of findings 15).

One type of training versus another

Three studies compared training models. There is very low-certainty evidence from one SARS-related study and two simulation studies that more active training in PPE use decreases noncompliance with donning and doffing guidance more than passive training. The active training used in the studies was video or computer simulation or face-to-face training compared to lectures (passive) only (Summary of findings 16).

We found no audit reports or other unpublished reports or data from our contact efforts to manufacturers and other organisations.

Overall completeness and applicability of evidence

Most studies provided sparse descriptions of the level of chemical protection (ISO 2013), or viral protection (EN 14126; ISO 2004a), of the PPE they used, or the outfits used varied so much in their components that it was impossible to make uniform comparisons.

For some PPE parts such as face shields and goggles, we found no studies that compared the two. There is, however, evidence from studies with viruses that do not have serious consequences and from simulation studies with manikins that each protects compared to no intervention (Agah 1987; Lindsley 2014). In a thorough overview of face shields for infection prevention, Roberge 2016 concludes that even though face shields can considerably reduce droplet contamination of the face, more research is needed into their efficacy. Other technical laboratory studies without involvement of humans also support the findings of this review. Kahveci 2019 found that double gloving can reduce contamination by reducing the fluid leakages through the glove-gown interface.

Doffing procedures are fairly easy to evaluate in simulation studies. We found several studies that confirmed that it is important to follow procedures. However, all studies were small and only the comparisons about double-gloving disinfection procedures and spoken instructions had more than one study. It seems that it would not be difficult to perform more and better simulation studies to find out how important these procedures are.

Because studies seem feasible and because we searched exhaustively, there must be other reasons why there is so little evidence available with infection rates as an outcome. One of these is probably the highly politicised context in which such a study has to be performed during an epidemic. However, retrospective cohort and case-control studies are possible as has been shown during the SARS epidemic. The studies conducted after the SARS epidemic show that the consistent use of PPE rather than type of PPE was most important (see Appendix 1). At the start of the epidemic, SARS patients were not appropriately diagnosed, and the importance of PPE was not immediately clear. PPE compliance was higher in the later stages, and infections occurred less frequently (Nishiura 2005). SARS also affected comparatively higher-income countries such as China, Hong Kong and Canada. The experiences from retrospective studies during Ebola epidemics are similar. During the 1995 Ebola epidemic in Kikwit in the Democratic Republic of the Congo, a study also reported that once PPE and other control measures were used, there were very few HCW infections (Kerstiens 1999). Dunn 2015 is a case study from the Ebola epidemic that also provided systematic information on the use of PPE and infection rates. We reanalysed

the excluded study by Dunn 2015 as a cohort study of exposed HCW (Verbeek 2016a). The risk ratio of contracting Ebola infection for HCW using gloves only versus those not using PPE was 0.16 (95% CI 0.04 to 0.71) indicating that using gloves already provides a lot of protection. For using gloves or a gown or more compared to no PPE, the RR was 0.03 (95% CI 0.00 to 0.57; Verbeek 2016a). This is very similar to the findings of the SARS studies mentioned above. It is also, to a certain extent, reassuring for those situations during an epidemic or in low- and middle- income countries, when sufficient PPE is not available (see Levy 2015), that some PPE decreases the risk of infection considerably. In this version of the review we were able to include one retrospective cohort study from the 2015 West Africa Ebola epidemic. Unfortunately, the information on PPE was not detailed enough to be able to draw conclusions.

While the included studies show that more active training prevented errors, it is not clear how long the effects of training last. Northington 2007 showed that at six months after training, only 14% of participants were able to correctly don and doff PPE. It is unclear from the included studies, if fit-testing of masks is part of training. This is a commonly accepted prerequisite for proper functioning of respiratory protection.

We included only one study conducted in a low- and middle-income country. Since most serious haemorrhagic fever epidemics occur in some parts of Africa, this is a serious disadvantage of the current evidence. However, in such resource-poor settings, appropriate research is the lowest priority for the local decision makers. Consequently, the initiative has to come from WHO and international organisations that work in these epidemics.

Quality of the evidence

We rated the certainty of the evidence as very low or low for all comparisons, mainly because our conclusions are based on single studies or two small studies and all the included studies had a high or unclear risk of bias. The retrospective cohort studies have a high risk of recall bias because participants had to recall their use of PPE after the epidemic occurred. The simulation studies had small sample sizes or very few events across compared groups.

One of the major problems is that most of the studies did not indicate if the PPE that they used complied with one or more of the international standards for protective clothing and whether they used whether they used protective clothing that is constructed with viral resistant fabrics and seams. The lack of attention to the designation of PPE as being protective for viruses is also problematic in practice.Also the lack of description of the PPE significantly reduces the ability make clear conclusions.

The many different labels and standards that are in use to designate protection make it almost impossible for a HCW in practice to make the right choice. For EVD, it was especially problematic because HCW needed the highest standard of protection. The confusing language of infection control has also been reported for isolation practices in general. This is why Landers 2010 called for the adoption of internationally accepted and standardised category terms for isolation precautions. Others have tried to improve the standardisation by providing HCW with a summary card of the various types of precautions that have to be taken and indicated that this increased the implementation of precautionary measures (Russell 2015).

In simulation studies, it is not clear how well the exposure represents real life exposure. Some studies used 'high volume exposure to simulate splash' (Bell 2015), whereas other studies only used a powdered fluorescent marker spread in the room (Beam 2011). It is also not clear how well the fluorescent marker can indicate that there is no viral contamination. Casanova 2008 showed that in spite of no fluorescent marker being detected, there could still be viral contamination with bacteriophage MS2. On the other hand, Osei-Bonsu 2019 did not find a difference in effect with fluorescent marker as the outcome but did find a difference with bacterial exposure.

Only one of the case studies that we collected (Dunn 2015), properly described the use of PPE. Better description would enable better analysis.

Potential biases in the review process

We excluded all studies that evaluated only one piece of PPE, such as goggles or masks. However, none of these excluded studies would have answered the questions that in our current review remained unanswered. From Casanova 2012, it became clear that using double gloves as part of full-body PPE is important, because it facilitates the removal of the other pieces of PPE without contaminating the hands. This shows that it is important to consider the effect of one piece of PPE as part of full-body PPE. In addition, seldom is there only one clear transmission route. Even with SARS, which, as a respiratory infection, was spread by droplets and aerosols, consistent use of other pieces of PPE besides respiratory protection was still important to prevent contact transmission. Therefore, we think that our strict inclusion criteria did not bias the results of our review.

We assumed that adherence to PPE use and training would work in a similar way between SARS, EVD, and simulation studies. However, there is an important difference. At the start of the SARS epidemic, the causal virus and its transmission were unclear and workers were probably not instructed well enough to protect themselves. On the other hand, it has been known for years that EVD is a highly contagious disease with a very high fatality rate. Thus, compliance and effectiveness of training concerning EVD might be higher than we concluded from the SARS study. In the SARS studies that we excluded, there was high heterogeneity in the effects of consistently wearing PPE that we could not explain. The heterogeneity in effect is also underpinned by studies that did not find any SARS infections in spite of imperfect protection with PPE. This means that at best the effectiveness of PPE is not fully understood.

Twelve of the included simulation studies are cross-over studies. But the authors of only four studies analysed the data with tests that took into account the paired nature of the data: Zamora 2006 used the Mailand-Gart test; Guo 2014 used repeated measures; and Casanova 2012 and Strauch 2016 the paired t-test but the methods used in Mana 2018 were unclear. We could not use the results of these tests in our analyses in Review Manager 2014, which resulted in wider confidence intervals than using a paired analysis. There were insufficient data in the studies to properly adjust for the cross-over effect in our analyses. However, all results that were reported as being statistically significant were also statistically significant in our analyses. Therefore, we think that this has not biased our results.

With the simulation studies the way exposure was simulated is an important element to consider. This varied highly between the studies. However, most studies used a worst case scenario, spraying fluorescent marker over large parts of the body but some studies applied only small amounts. Hall 2018 used a sophisticated manikin with an internal mechanism simulating exposure as described by Poller 2018. Future studies urgently need consensus from experts in the field on how exposure can be best simulated. This is best possible under the auspices of WHO or other internationally recognised bodies.

With the included non-randomised studies, we assessed risk of bias with a hybrid version of the Cochrane 'Risk of bias tool' (Higgins 2017) and the recently developed ROBINS-I tool (Sterne 2016). This might not have been the optimal way to assess risk of bias. However, we believe that the limitations of the available studies are profound and a more rigorous 'Risk of bias' assessment could not have lowered (or improved) our confidence in the evidence any further.

Agreements and disagreements with other studies or reviews

We found two other reviews that have evaluated the effect of PPE for highly infectious diseases with serious consequences in HCW: Hersi 2015 and Fischer 2015. Hersi 2015 was commissioned by WHO to underpin the PPE guidelines issued for HCW exposed to EVD. The authors originally included only controlled studies of interventions to protect HCW against EVD and similar haemorrhagic fever infections with infection rates as outcomes. During the review process the authors decided to also include case studies and case series but they were not able to draw conclusions from these studies because the PPE use was not well described. Fischer 2015 took a more pragmatic but unsystematic approach and included all articles pertaining to filovirus transmission and PPE and in addition articles that evaluated donning and doffing strategies. They conclude that there is a lack of evidence but that simulation studies could provide evidence for guidelines.

Heat stress and breathability is an important issue in PPE especially for Ebola. Kuklane 2015 argued that using other materials would substantially reduce the heat stress but these come at a tenfold higher price. Other researchers that have looked into this problem have found inconsistent results. Coca 2015 found that PPE on manikins led to a critical body core temperature of 38.4°C in one hour. On the other hand, Grélot 2015 found that HCW caring for Ebola patients had only a 0.46°C rise in core body temperature after being at work for one hour. Of the 25 workers studied, only four reached a core body temperature over 38.5°C.

An independent panel of experts that evaluated the Ebola response concluded, among many other things, that a coordinated research effort is needed to build a better global system for infectious disease outbreak and response (Moon 2015). Their recommendation is that research funders should establish a worldwide research and development financing facility for outbreak-relevant drugs, vaccines, diagnostics, and non-pharmaceutical supplies (such as PPE). This is very much in line with what we experienced and found in this review.

Missair 2014 reviewed implications of EVD patient management for anaesthetists based on a literature review of all types of studies on EVD. This is why their inclusion criteria were very broad and non-specific. Finally the authors relied on PPE guidelines as provided by WHO and MSF to make recommendations with no evidence of their comparability. This makes their results difficult to compare to ours.

Moore 2005 reviewed all measures to prevent healthcare workers from SARS and other respiratory pathogens in a narrative format, from 168 publications. They concluded that a positive safety climate is the most important factor for adherence to universal precautions. They recommend using adequate PPE, but they do not define 'adequate'. Their inclusion criteria were much broader than ours and their results are difficult to compare with ours. The same research group formulated valuable advice about research gaps based on this review but focused only on respiratory protection (Yassi 2005). They corroborate the findings of Jefferson 2011, that N95 respirators may not be superior, citing the early containment of the SARS epidemic without these in Hanoi.

The Cochrane Review by Jefferson 2008, updated in Jefferson 2011, evaluated the effect of physical interventions to interrupt the spread of respiratory viruses for all patient and staff populations. Even though they only included studies on respiratory infections and any type of protection for any person at risk, 10 studies in their review are about SARS and protecting HCW. The authors did not conduct a subgroup or additional analysis of these HCW studies because the infection risk for HCW is substantially different from the populations they protect. The Jefferson 2011 results are not applicable to HCW.

AUTHORS' CONCLUSIONS

Implications for practice

In addition to other infection control measures, consistent use of full-body personal protective equipment (PPE) can diminish the risk of infection for healthcare workers (HCW). EN (European) and ISO (international) standards for protective clothing and fabric permeability for viruses are helpful to determine which PPE should technically protect sufficiently against highly infectious diseases. However, the risk of contamination depends on more than just these technical factors. In simulation studies, contamination happened in almost all intervention and control arms.

For choosing between PPE types, there is very low-certainty evidence, based on single-exposure simulation studies. Covering more parts of the body leads to better protection but usually comes at the cost of more difficult donning (putting on) or doffing (taking off) and user comfort, and may therefore even lead to more contamination. A powered, air-purifying respirator (PAPR) with a hood may protect better than an N95 mask with a gown but is more difficult to don. A long gown may be the best compromise between protection and ease of doffing. Coveralls may be more difficult to doff. A more breathable fabric may still lead to similar levels of contamination protection to less breathable fabric, and may be preferred by users.

For changes to PPE, there is low- to very low-certainty evidence that adding tabs to gloves or masks or closer fit of gowns at the neck or the wrist may decrease contamination, even though one study could not show a decrease in donning or doffing errors.

For different procedures of donning and doffing, there is very low-certainty evidence that double gloves, as part of PPE and following Centers for Disease Control and Prevention (CDC) guidelines, and

providing users with help or spoken instructions during donning and doffing may reduce the risk of contamination. Extra disinfection of gloves with bleach or quaternary ammonium may decrease hand contamination but not alcohol-based hand rub.

For various training procedures there is very low-certainty evidence that more active training (including video or computer simulation or spoken instructions) may increase compliance with instructions compared to passive training (lectures or no added instructions). No studies compared methods to retain PPE skills needed for proper donning and doffing in the long term.

The certainty of the evidence is low to very low for all comparisons because conclusions are based on one or two small studies and a high or unclear risk of bias in studies, indirectness of evidence, and small numbers of participants. This means that we are uncertain about the estimates of effects and it is therefore possible that the true effects may be substantially different from the ones reported in this review.

Implications for research

We concur with the World Health Organization (WHO) that there is a need to carry out a re-evaluation of how PPE is standardised, designed, and tested (WHO 2018). What is missing is a harmonised set of PPE standards and a unified design for PPE to be used when taking care of patients with highly infectious diseases. This holds for PPE as used for preventing contact transmission as well as other ways of transmission. There is, for example, no unified technical standard for isolation gowns. There is also a need for a more transparent and uniform labelling of infection control measures, such as droplet precautions, and the protection level of PPE for HCW. We believe that this is an important prerequisite for the universal implementation of infection control measures for HCW.

Simulation studies are a feasible and relatively simple way to compare different types of PPE and to find out which protects best against contamination. It is a prerequisite for a reliable answer that methods of simulation studies are standardised in terms of exposure and outcome measurement. We recommend developing a core outcome set (COS) in this field that would provide critical outcomes measures to enable better comparisons and synthesis across trials. Viral marker bacteriophage MS2 seems to be the most sensitive marker and we would advocate using this. Studies should have sufficient power. A sample size of 62 would be needed to be able to detect a relatively large risk ratio of 0.5 with a large control group rate of contamination of 0.7, assuming $\alpha = 0.05$ and $\beta = 0.80$. In addition, it would help evidence synthesis if study authors would better adhere to the appropriate reporting guidelines (Cheng 2016).

To find out how PPE behaves under real exposure, we need prospective follow-up of HCW involved in the treatment of patients with highly infectious diseases, with careful registration of PPE, donning and doffing and risk of infection. Here, the effect sizes would be smaller and thus the sample size should be bigger than 60.

In addition, case-control studies comparing PPE use among infected HCW and matched healthy controls, using rigorous collection of exposure data, can provide information about the effects of PPE on the risk of infection. The sample sizes should be much bigger than the current case studies because we would like to detect small but important differences in effect between various combinations of PPE such as gowns versus coveralls. There is a need for collaboration between organisations serving epidemic areas to carry out this important research in circumstances with limited resources, and during the throes of an outbreak.

We also need more randomised controlled studies of the effects of one type of training versus another, to find out which training works best, especially at long-term follow-up of one year or more. Here also, the effect size seems to be quite large and thus a sample size of around 60 seems to provide adequate power.

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* Indicates the major publication for the study

CHARACTERISTICS OF STUDIES

Characteristics of included studies *[ordered by study ID]*

Andonian 2019

Study characteristics

Methods	**Study design:** RCT
	Study grouping: parallel group

Andonian 2019 *(Continued)*

For simulation study, what was used for the exposure (virus, fluorescent fluid etc): 1. The optimised fluorescent slurry consisted of fluorescent powder (Glitter Bug, Brevis Corporation, Salt Lake City, UT; 75 mg/mL) in a viscous suspension of grape-seed oil and water (1:6 oil-to-water ratio) 2. Fluorescent 2-µm polystyrene latex bead (PLSs) (G0200, Thermo Fisher Scientific, Waltham, MA) diluted in water. PLSs are commonly utilised in aerosol research and were used to simulate pathogens

Exposure simulation: 1. Fluorescent tracer mixture was applied to PPE using 1000 mL in a pesticide hand sprayer (RL Flo-Master, Lowell, MI; 2000 mL capacity) and 5 sweeping passes of sprayer from head to feet on the front and back of the HCW. 2. A PLS suspension (25 mL) was aerosolised using a 3-jet Collison nebuliser (Mesa Laboratories, Inc, Butler, NJ) for 4 min of continuous aerosol generation while the HCW turned 90° every 60 s

Participants

Baseline characteristics

48 participants were included in the study

Enhanced doffing protocol

- *Male %*: not reported
- *Age (m ± SD)*: not reported
- *Occupations*: 13 HCWs and 13 doffing assistants
- *Employment duration*: not reported

CDC doffing protocol

- *Male %*: not reported
- *Age (m ± SD)*: not reported
- *Occupations*: not reported
- *Employment duration*: not reported

Overall

- *Male %*: not reported
- *Age (m ± SD)*: not reported
- *Occupations*: total 48 participants
- *Employment duration*: not reported

Inclusion criteria: not reported, but study authors included: adults (male/female) with no prior experience doffing enhanced PPE

Excluded criteria: not reported

Interventions

Intervention characteristics

Enhanced doffing protocol: doffing with extra instructions

- *Intervention aim*: to mitigate the risk of self-contamination during PPE doffing
- *Content of the intervention*: participants received approximately 2 h of training prior to doffing PPE. The curriculum for both the treatment and control groups included a basic introduction to germ theory, modes of pathogen transmission, types and purpose of PPE, and basic tenets of infection prevention. Both control and intervention groups were shown the PPE components they would doff during the study. The intervention group participants watched a video about teamwork concepts and their application in healthcare. The training included information about potential risks in the doffing process, the benefit of teamwork in PPE doffing, and the roles and responsibilities of the doffing team members. Participants were instructed on teamwork strategies including use of verbal and nonverbal communication (e.g. closed-loop communication); developing, maintaining, and updating situational awareness (e.g. monitoring inadvertent contact of the HCW with other team members or room surfaces); mutually supporting team members; and the importance of verbalising safety concerns. They were then shown a video that demonstrated the intervention package doffing process. The intervention package addressed various components of the doffing process, including tools/technology (e.g. PPE selection), people (e.g. roles, teamwork), task (e.g. technical aspects of PPE removal), and envi-

Andonian 2019 *(Continued)*

	ronment (e.g. doffing room characteristics). PPE consisted of surgical gown, isolation gown, inner and outer gloves, PAPR, PAPR hood, tape on sleeves and boot covers. The intervention group had, in addition, examination gloves. The boot covers differed between intervention and control group. CDC doffing protocol • *Intervention aim*: same goal • *Intervention duration per session*: not reported • *Intervention frequency per week*: once only • *Intervention duration (months)*: N/A • *Provider of the intervention*: CDC • *Content of the intervention*: after training, the control group participants watched a video that highlighted general facts about respiratory etiquette and the importance of covering your cough to prevent the spread of respiratory infections, followed by a video that demonstrated enhanced PPE doffing based on the 2015 CDC recommendations
Outcomes	**How the outcome was measured**: from the fluorescent tracer slurry - detection was by direct visualisation in a dark room using ultraviolet light. (1) The number of body sites contaminated and (2) the extent of contamination at each site were recorded. PLS detection was performed by (3) counting via epifluorescent microscopy and (4) quantifying the number PLSs per cm^2 of skin or per m^3 of sampled air. (5) Teamwork dynamics were assessed via video and coded using a task analysis of the process sets and subsets (checklist). (6) The National Aeronautics and Space Administration (NASA) Task Load Index (NASA-TLX) questionnaire assessed perceptions of workload during doffing (7) The Team Strategies and Tools to Enhance Performance and Patient Safety Teamwork Attitudes Questionnaire (T-TAQ) assessed attitudes toward teamwork *Body sites with fluorescent marker* • **Outcome type**: dichotomous outcome • **Reporting**: fully reported • **Unit of measure**: body site • **Direction**: lower is better • **Data value**: endpoint *Body sites with PLS* • **Outcome type**: dichotomous outcome • **Reporting**: fully reported • **Unit of measure**: body site • **Direction**: lower is better • **Data value**: endpoint
Notes	**Outcomes** Median and IQR of 22 possible contaminated sites reported. For Fluor Marker: intervention 1 (1-2) control 5 (2-5) For PLS out of 12 possible contaminated sites: intervention 4 (2-5) control 5 (5-8). These were transformed to means and SDs for use in the data tables.

Risk of bias

Bias	Authors' judgement	Support for judgement
Random sequence generation (selection bias)	Unclear risk	Quote: "randomly assigned to the control or intervention condition and then to the role of HCW or DA." Judgement comment: method of random assignment not reported
Allocation concealment (selection bias)	Unclear risk	Judgement comment: method of allocation concealment was not reported

Andonian 2019 *(Continued)*

Blinding of participants and personnel (performance bias) All outcomes	Low risk	Quote: "role as either HCW or DA." Quote: "After training, all participants were given the opportunity to ask questions and were informed about their randomly assigned" Quote: "Study participants were blind to their group assignment." Judgement comment: group assignment (intervention and control) was blinded; role was blinded to participants until after training and before the doffing intervention
Blinding of outcome assessment (detection bias) All outcomes	Low risk	Quote: "The contamination forms were deidentified and assigned randomized numbers for scoring purposes. Two IPs, blinded to experimental assignment, independently scored each form" Judgement comment: infection preventionists were the outcome assessors and were blinded to intervention group
Incomplete outcome data (attrition bias) All outcomes	Low risk	Quote: "Forty-eight study participants (35 females, 13 males) were randomly assigned to the control (n = 22) or intervention group (n = 26)." Quote: "Participants in each study arm were randomly assigned to the role of control HCW (n = 11), control DA (n = 11), intervention HCW (n = 13), or intervention DA (n = 13). For the fluorescent tracer, 11 HCWs (84.6%) in the intervention group and all 13 control HCWs (100%) contaminated at least 1 body area." Quote: "Coding and scoring of teamwork behaviors exhibited in the videotaped doffing sessions were completed for 10 intervention and 11 control teams. Technical difficulties resulted in missing videotapes for 3 intervention teams." Judgement comment: main outcomes were listed within the methods (but scattered and hard to find). All recruited participants completed the interventions and outcomes were collected. 1 typographical error (I assume) in reporting fluorescent tracer contamination (they reported 13 control HCWs but there were only 11). 3 sets of teamwork behaviour outcomes recorded in videos from the intervention group were lost. However, despite the missing data, there was a plausible difference in median (IQR) between groups that may not have impacted the observed effect size.
Selective reporting (reporting bias)	Low risk	Judgement comment: the availability of the study protocol is not reported in the paper, but it is clear that the published report includes all expected outcomes for this type of study.
Other bias	Low risk	Judgement comment: no other bias detected

Bell 2015

Study characteristics	
Methods	Randomised, 2 parallel groups; simulation study
Participants	N = 8, nurses (6), physicians 2; women 7/8 Intervention: 4, control: 4 Volunteer healthcare providers, no further details provided

Bell 2015 *(Continued)*

	Location: USA
Interventions	*Intervention: different types of PPE compared: commercially available PPE:* neck-to-ankle coverall (type not reported), water impermeable surgical gown, knee-length impermeable leggings, Stryker hood, double gloves with outer arm-length surgical gloves, N95 masks; meeting CDC recommendations; each participant was assisted in PPE donning by an experienced trainer. *Control*: local, readily available attire: 2 plastic gowns worn over the front and the back of the torso, rain-suit pants and hood, spark-shield as face-cover, ankle length shoe covers, double gloves with outer arm-length surgical gloves, N95 masks; meeting CDC recommendations; each participant was assisted in PPE donning by an experienced trainer.
Outcomes	Contamination: measured in mL of fluorescent agent with LED black light after doffing. Random order of 2 types of exposure: high volume or standard. High volume meant 100 mL of fluorescent agent splashed on the torso. Standard meant working on a manikin contaminated with fluorescent agent. Fluorescent liquid mimicked body fluids and consisted of fluorescent powder, clothes detergent, fluorescent tablets
Notes	No funding or conflict of interest reported Apparently tape was used to put attire together; this resulted in more difficult doffing but no figures reported; costs of locally available equipment was USD 36 US, that of commercial material not reported

Risk of bias

Bias	Authors' judgement	Support for judgement
Random sequence generation (selection bias)	Unclear risk	Quote: "randomized to one of two PPE ensembles"
Allocation concealment (selection bias)	Unclear risk	Not reported
Blinding of participants and personnel (performance bias) All outcomes	Unclear risk	Not reported
Blinding of outcome assessment (detection bias) All outcomes	Unclear risk	Not reported
Incomplete outcome data (attrition bias) All outcomes	Low risk	No incomplete outcome data
Selective reporting (reporting bias)	High risk	Contamination outcomes reported but no separate outcomes for high or normal exposure, however small sample and no statistical analysis by study authors
Other bias	Low risk	No indication

Buianov 2004

Study characteristics

Buianov 2004 *(Continued)*

Methods	Controlled simulation study, not randomised; probably cross-over study
Participants	N = 9 volunteers that carried out a 4-h step test of average workload at a temperature of 20° C and 60% relative humidity, no further details provided
Interventions	*Intervention: different types of PPE compared: different types of respirators* Positive pressure suit (special biological suit, СКБ-I) consisting of a rubber hood connected to a PA-PR and a 'dust-proof' coverall in 1 piece with different rates of air supply: initially 250 L/min, then 50, 100, 150, 200, 250, 300 L/min. No information about the filtering piece. PPE was especially developed for highly infectious diseases such as Ebola, Marburg and Lassa fever intended for use by HCW, such as doctors, nurses and orderlies *Comparison*: 2 different types of positive pressure hoods (ЛИЗ-4 and ПШБ-3) together with a coverall type Biotekhnolog -1 *Procedure*: tests are carried out in a so-called Meltserovsky room (individual room with quarantine). The pressure suit or hood and coverall is put on before entering and checked whether it functions by attaching the connecting pipe to the air supply system. Then the worker enters the buffer zone (gateway with entrance and exit) and proceeds to the individual measurement room. After the step test in the individual room the HCW goes to the buffer zone in order to treat the outside surface of the pressure suit. The worker attaches the suit to the connecting pipe of the air supply system and treats the suit with the help of aerosol disinfectant, usually 3%-6% hydrogen peroxide (2-3 aerosol generators are situated at different heights). After the aerosol rests are pumped out of the buffer zone the HCW leaves through the gateway, takes off the pressure suit and places it in the special container for final disinfection.
Outcomes	Contamination exposure: Participants were exposed to a microbial aerosol with a concentration of 10^8 CFU/m^3. No further details on the spray aerosol provided. Contamination outcome measured aerosol particles on different parts of the body (neck, shoulder, forearm, chest, loin, thigh, shin) and the suit with 'washouts' and triple agar prints. Only data from triple agar prints are presented since the 'washouts' resulted in unreliable data (because the textile materials used in the pressure suit were impregnated with hydrophobic materials). Triple agar prints were taken from the outside surface of the pressure suit, inside surface of the pressure suit, clothes and skin areas at different parts of the body (neck, shoulder and forearm, chest, loin, thigh and shin). The outcome was both expressed as CFU/m^3 and as penetration rate as a percentage of the outside that has leaked inside the PPE. It was unclear if these outcomes were expressed as an average across the participants and what the variation was. The study authors conclude that "despite the significant concentration of microbial aerosol in the experimental room (10^7-10^5 cfu/m^3) no microbial aerosol was measured on skin areas with air supply speeds of 250 L/min and higher". Additionally, the study authors assessed skin temperature, heart rate, breath rate, and moisture loss
Notes	Article in Russian, data retrieved with help of a native speaker (AP) Article difficult to judge due to cultural differences in style and translation

Risk of bias

Bias	Authors' judgement	Support for judgement
Confounding NRS	High risk	No confounders reported
Selection Bias NRS	Low risk	Selection of volunteers unrelated to intervention or to outcome. Start follow-up and intervention coincide for all participants.

Buianov 2004 *(Continued)*

Blinding of participants and personnel (performance bias) All outcomes	Unclear risk	Not reported
Blinding of outcome assessment (detection bias) All outcomes	Unclear risk	Not reported
Incomplete outcome data (attrition bias) All outcomes	Unclear risk	Unclear if data reported for all nine participants
Selective reporting (reporting bias)	Unclear risk	All data announced in methods reported in results
Other bias	Low risk	No other biases assessed

Casalino 2015

Study characteristics	
Methods	Controlled before-after study of 2 training variants
Participants	N = 120, 63% nursing students, 37% medical students Age 21.2 +/- 3.5 years, 35% male The study authors did not present demographic data per group Location: Paris (France), Lima (Peru), and Guadalajara (Mexico), in December 2014 and January 2015 with no previous training in PPE use, with no special intention to be involved in Ebola care
Interventions	*Intervention: doffing with extra instructions* There were 2 intervention groups that only differed in type of PPE used 1. Basic PPE + reinforced training (N = 30); basic PPE consisted of boots, goggles, surgical mask, surgical cap, impermeable apron (11 pieces of equipment) with 6 steps for donning and 13 steps for doffing. 2. Enhanced PPE + reinforced training (N = 30); enhanced PPE consisted of boots, full-body impermeable suit, hood with surgical cap and mask, double gloves, impermeable apron (9 pieces of equipment) with 6 steps for donning and 12 steps for doffing. Training for all participants consisted of 60 min of theoretical course including 10 min of donning instruction and 20 min of doffing instruction. In addition, there were 3 practical training sessions per 2 students who mutually assisted each other observed by a specialist trainer who intervened in case of non-compliance. The sessions were held with 3-day intervals. Compared to the control group the additional intervention was that the specialist trainer "repeated aloud each of the steps and technical skills or processes necessary" to comply with the standard during the practical training sessions. The sessions were also reviewed comprehensively. *Control group*: There were 2 control groups that differed in type of PPE used just as in the intervention groups 1. Basic PPE + conventional training (N = 30) 2. Enhanced PPE + conventional training (N = 30)

Casalino 2015 *(Continued)*

	These groups received the same training as the intervention group but the specialist-trainer did not repeat aloud the necessary steps.
Outcomes	*Primary outcome:* number of errors per person for donning and for doffing and the number of people with ≥ 1 errors measured by the specialist trainer. The study authors also measured critical errors, which were those where there was contact between skin and potentially contaminated PPE, but we did not consider this a valid measure of contamination and disregarded this. We took measurement of the errors at the last training session as the effect of the intervention. We disregarded the error measurements at earlier training sessions. *Secondary outcomes*: errors for doffing of the gown, full-body suit and boots; duration of donning and doffing in min at the last training session
Notes	Country: France, Peru Mexico; no funding reported; no conflict of interest reported The first study author, Enrique Casalino, answered some of our questions regarding the study, but we were unable to retrieve more information on the group allocation and therefore classified the study as non-randomised.

Risk of bias

Bias	Authors' judgement	Support for judgement
Confounding NRS	Unclear risk	None of the confounders mentioned
Selection Bias NRS	Low risk	Students were randomly chosen and did not have any experience or intention to use the knowledge and skills.
Blinding of participants and personnel (performance bias) All outcomes	High risk	Blinding not possible but students could be motivated to perform better because of knowing that they were in the intervention group and not as a result of the oral instructions.
Blinding of outcome assessment (detection bias) All outcomes	High risk	Providers were also the assessors of compliance. We asked study authors for more information but did not get any information that increased our confidence in the outcome assessment
Incomplete outcome data (attrition bias) All outcomes	Unclear risk	Not reported if all data were available
Selective reporting (reporting bias)	Low risk	All outcomes in methods section reported; no protocol available
Other bias	Low risk	No other biases assessed

Casanova 2012

Study characteristics

Methods	Controlled simulation study, non-randomised, first intervention then control condition for all participants
Participants	N = 18 volunteer healthcare providers > 18 years of age; exclusion criteria: pregnant, latex allergy, skin disorder, previous fit-testing for N95 respirator; 17/18 right handed, 18/18 previous experience with PPE

Casanova 2012 *(Continued)*

	Location: USA
Interventions	*Intervention: doffing with double gloves* 2 pairs of latex gloves; inner glove under the cuff of the gown sleeve, the outer glove, 1 size larger worn over the gown cuff; in addition, full PPE consisted of contact isolation gown, N95 respirator and eye protection *Control:* 1 pair of latex gloves in addition to similar full PPE as in intervention group Doffing was performed according to CDC instructions: gloves, goggles, gown, mask or respirator in case of single gloves; in case of double gloves, outer pair of gloves first and inner pair last
Outcomes	1. Contamination of the hands, face, gloves and scrubs with bacteriophage MS2 virus; hands sampled with "glove juice method", face with a swab at the edge of the N95 respirator, shirt, pants and gloves were immersed in beef extract. All eluants were assayed by 'most probable number enrichment infectivity assay' (MPN). Detection level 0.15 log 10 MPN; Used paired t-test for the analysis of continuous data to take the cross-over into account 2. Noncompliance with doffing guidelines Contamination with bacteriophage MS2 was put on front shoulder of the gown, right side of respirator, right front of eye protection and palm of dominant hand by simulated droplet contamination; before doffing participants had to perform neck and wrist pulses on manikin
Notes	No funding or conflict of interest reported

Risk of bias

Bias	Authors' judgement	Support for judgement
Confounding NRS	Low risk	No apparent confounders for this type of study and outcome
Selection Bias NRS	Low risk	No apparent selection of participants into the study
Blinding of participants and personnel (performance bias) All outcomes	Unclear risk	No blinding, but performance bias not likely because participants would not have an interest with either intervention
Blinding of outcome assessment (detection bias) All outcomes	Unclear risk	Not reported
Incomplete outcome data (attrition bias) All outcomes	Unclear risk	Not reported
Selective reporting (reporting bias)	Unclear risk	Some data only in figures and not in tables
Other bias	Low risk	No other biases anticipated

Casanova 2016

Study characteristics

Casanova 2016 *(Continued)*

Methods	Non-randomised simulation study *How was the simulation performed?* Each participant was verbally guided through the donning process of EVD PPE using the CDC protocol. After the exposure contamination was applied to the PPE worn, all participants performed a gown change on a manikin. Participants were then verbally guided through the doffing process using the CDC checklist either using a hypochlorite spray or an alcohol-based hand rub for all six hand or glove cleaning steps during doffing. *How was the exposure simulated?* Exposure to a mixture of MS2 and Φ6 suspended in phosphate-buffered saline was applied to 4 sites: (1) the palm of the dominant hand, (2) the shoulder of the gown opposite the dominant hand, (3) the top side of the face shield on the same side as the dominant hand, and (4) the toe of the rubber boot opposite the dominant hand. A total of 25 µL was applied to each site in 5 drops of 5 µL each to simulate droplet exposure, particularly small droplet exposure of which the HCW may not be aware. The mean virus titre applied to each site in 25 µL was 1×10^8 for MS2 and 5×10^7 for Φ6, based on reports of viral load in body fluids during acute phases of EVD.
Participants	N= 15 (11 RNs and 4 MDs) no further details given Intervention: 5, control: 10 Study participants were all members of the Ebola care team at a large tertiary care academic medical centre. Members of the Ebola team were > 18 years of age and had undergone extensive training in a simulation laboratory in the use of EVD-specific PPE, including donning and doffing
Interventions	*Intervention*: doffing with extra glove sanitation Hypochlorite glove sanitiser: liquid hypochlorite at a concentration of 1850 ppm was applied by spraying it on the gloves for each hand or glove sanitising step of the 16-step doffing protocol that was used. This was the only alternation of the usual doffing protocol. *Control*: alcohol-based hand rub: 70% ethanol gel was used for each hand or glove sanitising step of the 16-step doffing protocol that was used
Outcomes	Contamination: 1. MS2 bacteriophage (non-enveloped surrogate virus) 2. Φ6 bacteriophage (enveloped surrogate virus, such as Ebola) We took from the study authors' report contamination found on scrubs, or on the bare hands or on the face of the participant
Notes	Country: USA; no conflict in interests reported; funded with CDC grant

Risk of bias

Bias	Authors' judgement	Support for judgement
Confounding NRS	Low risk	Differences related to: 1. prior experience with PPE - no 2. healthcare qualification or education of HCW - no 3. age-no information, unlikely 4. sex-no information, unlikely 5. ambient temperatures - no, assumed similar 6. stressful activities - no
Selection Bias NRS	Unclear risk	Allocation to group was based on belonging to the last 5 participants

Casanova 2016 *(Continued)*

Blinding of participants and personnel (performance bias) All outcomes	Low risk	Participants were asked to close their eyes when simulated exposure was applied to them. However, it is unlikely that they did not notice where simulation exposure was applied. Participants were not blinded to the intervention, however, it is unlikely that they behaved differently with hypochlorite or alcohol sanitiser
Blinding of outcome assessment (detection bias) All outcomes	Unclear risk	No information
Incomplete outcome data (attrition bias) All outcomes	Low risk	No incomplete outcome data
Selective reporting (reporting bias)	Low risk	No protocol, but selective reporting unlikely
Other bias	Low risk	No other bias observed

Chughtai 2018

Study characteristics	
Methods	**Study design:** RCT **Study grouping:** cross-over **Simulation study? If so, describe exposure simulation**: after donning PPE, inert fluorescent lotion was applied on external surfaces of the PPE to simulate contamination. Participants were given 0.5 mL of lotion and were instructed to rub the lotion on their hand and apply to the PPE. Fluorescent lotion was also sprayed on the front and sides, from approximately 1 m, to mimic droplet infection. **For simulation study: what was used for the exposure (virus, fluorescent fluid etc)**: fluorescent spray: GlitterBug. Glitterbug kits. Available from: glitterbug.net.au/products/. Accessed 2 January 2018
Participants	**Baseline characteristics** Overall • *Male %*: 5/10 (50%) • *Age (m ± SD)*: 25-34 years (80%) • *Occupations*: 5 staff, 5 students • *Employment duration*: not reported **Included criteria**: not reported other than "Staff and students of the University of New South Wales". Assuming adult, both genders **Excluded criteria:** excluded participants with any pre-existing respiratory condition, heart disease, or pregnancy
Interventions	**Intervention characteristics:** different types of PPE compared with various donning and doffing protocols • *Intervention aim*: the study authors compared 10 different donning and doffing protocols to assess the risk of self-contamination • *Provider of the intervention*: 1. WHO, gown and N952. WHO, coverall and N953. CDC, coverall and PAPR4. CDC, coverall and N955. ECDC, coverall and N956. Health Canada, gown and N957. North Caroli-

Chughtai 2018 *(Continued)*

	na (NC), coverall and N958. New South Wales (NSW), Clinical Excellence Commission (CEC), gown and PAPR9. New SouthWales (NSW), Clinical Excellence Commission (CEC), gown and N9510. MSF, coverall and N95 • *Content of the intervention*: protocol specific to each provider
Outcomes	*Small patches of contamination* • **Outcome type**: dichotomous outcome • **Reporting**: fully reported • **Scale**: surface < 1 cm^2 • **Range**: 0-infinity • **Unit of measure**: patch • **Direction**: lower is better • **Data value**: endpoint *Large patches of contamination* • **Outcome type**: dichotomous outcome • **Reporting**: fully reported • **Scale**: surface > 1 cm^2 • **Range**: 0-infinity • **Unit of measure**: patch • **Direction**: lower is better • **Data value**: endpoint *Ease of use and comfort* • **Outcome type**: dichotomous outcome • **Reporting**: partially reported • **Scale**: low, high, medium • **Direction**: higher is better • **Data value**: endpoint
Notes	**Outcomes** For the WHO attire there were 4 large patches of contamination, for the North Caroline PPE 2, for the CDC PPE 1 small patch and for the Health Canada PPE there was 1 small patch of contamination

Risk of bias

Bias	Authors' judgement	Support for judgement
Random sequence generation (selection bias)	Unclear risk	Quote: "randomly assigned to use 3 different PPE protocols." Judgement comment: insufficient information provided
Allocation concealment (selection bias)	Unclear risk	No information provided
Blinding of participants and personnel (performance bias) All outcomes	Unclear risk	Quote: "Participants did not have any training in PPE. They were provided with the relevant protocol for donning/doffing, and procedures were examined by a study investigator using a checklist. The study investigator read out the donning and doffing steps, and participants followed the instructions. Videos were shown if available for each protocol that was tested." Judgement comment: no blinding possible but participants and personnel were not aware which protocol would be better, we felt that it is unclear if performance bias is likely

Chughtai 2018 *(Continued)*

Blinding of outcome assessment (detection bias) All outcomes	High risk	Judgement comment: procedures were examined by the study investigator who was aware of the PPE protocol.
Incomplete outcome data (attrition bias) All outcomes	Low risk	Judgement comment: data for all participants provided
Selective reporting (reporting bias)	Low risk	Judgement comment: there was no protocol reported in the paper for this study. However, the outcomes of interest were listed in the methods and appear reasonable for the study.
Other bias	Low risk	Judgement comment: no other bias detected

Curtis 2018

Study characteristics	
Methods	RCT with parallel groups *How was the simulation performed?* Participants had to demonstrate skills in donning PPE, working with PPE and doffing PPE in a simulated practice setting where they were observed. At Station 1, participants were asked to don Level C PPE. At Station 2, the participants were asked to demonstrate the proper technique for administration of the Duodote auto-injector to a simulated victim of nerve agent poisoning. Participants were then asked to use the Simple Triage and Rapid Treatment triage system for 6 different disaster scenarios that were described on cards attached to inflatable training manikins. At Station 3, participants were asked to decontaminate inflatable training manikins simulating contaminated victims of a hazardous materials incident. Following completion of the 3rd station, the participants doffed their Level C PPE and were asked to complete the post-exercise comfort survey.
Participants	N = 30 volunteers. Emergency Medicine residents were randomised, results of 26 are reported. The study was conducted at an urban, academic, tertiary referral centre that provides training to Emergency Medicine residents in a 4-year programme. All Emergency Medicine residents who attended the weekly educational conference were recruited for this study. As there were not any more residents available to participate at this single-site study, the number needed to study for significance was not determined. *Intervention*: n = 13 (53% female), *Control*: n = 13 (46% female)
Interventions	Intervention: training: video-based learning (VBL) A training video about specific content for the training modules was watched prior to completing a knowledge quiz and the practical exercises. An Emergency Medicine resident in the residency programme's disaster medicine specialty track wrote, directed, and edited the video. The VBL modality was setup and viewed without faculty interaction. Both educational modalities contained identical educational content Control: traditional lecture (TL) A PowerPoint presentation that covered the same information as the video was presented prior to completing a knowledge quiz and the practical exercises.
Outcomes	Primary outcome: performance scores on proper donning of PPE on the practical exercises evaluated by a blinded trained evaluator

Curtis 2018 *(Continued)*

Notes	Location: USA; no funding or conflict of interest reported

Risk of bias

Bias	Authors' judgement	Support for judgement
Random sequence generation (selection bias)	Unclear risk	Quote: "department research division consultant conducted a stratified randomisation of residents by post-graduate year class level and assigned them to either the experimental (VBL) group or the control (TL)"
Allocation concealment (selection bias)	Unclear risk	Quote: "Study participants identified themselves on all study tests and surveys using employee identification numbers rather than their names"
Blinding of participants and personnel (performance bias) All outcomes	Low risk	Study could not be blinded but unlikely that participants could have influenced the outcome because they knew to which group they belonged
Blinding of outcome assessment (detection bias) All outcomes	Low risk	Quote: "All evaluators were blinded as to which study participants had participated in the TL modality and which participated in the VBL modality."
Incomplete outcome data (attrition bias) All outcomes	Low risk	Data available for 13 out of 15 participants in both groups. Missing data were not related to the intervention.
Selective reporting (reporting bias)	Unclear risk	No study protocol provided. Probably all outcomes reported
Other bias	Unclear risk	No other bias detected

Drews 2019

Study characteristics

Methods	Design: a 2 (task) x 2 (gown) nested, repeated-measurements design Group: cross-over For simulation study: what was used for the exposure (virus, fluorescent fluid etc): no exposure was used only simulated tasks. Exposure simulation: all participants reviewed a brief presentation and were given an opportunity to ask questions on the design, attributes, and use of the redesigned gown. They were then introduced to the simulator and given patient information along with a brief description of the task they were to perform. The simulated patients were in isolation precautions with signage posted outside the patient room indicating the required PPE. Participants performed 2 scenarios, with a different gown (standard or re-designed) made available prior to the start of each scenario.
Participants	Male %: not reported Age (m ± SD): not reported Occupations: nurses (50%) and nurses' aides Employment duration: not reported

Drews 2019 *(Continued)*

Interventions	*Intervention*: *modified PPE: redesigned gown*: gown redesign considerations focused on improving the closure mechanism, providing visual cues to demarcate the contaminated outer from the clean inner surfaces, weighing down the gown material for better coverage, and making gown removal easier by adding perforations to the tie. A closure mechanism using an asymmetrical closure approach was favoured, with the gown secured by pulling a single strap from the back to front. An adhesive strip covered by red tape was placed at the end of the strap. Pulling the tape off the adhesive strip allowed for strap securement to the front of the gown *Control*: standard gown
Outcomes	1. Non-adherence to proper use of PPE during donning, measured as: if and how gown was closed 2. Non-adherence of proper use of PPE during doffing, measured as: pulling gown from waist, balling up gown) 3. Non-adherence of proper use of PPE during performance: measured as: exposure while squatting, tie or gown touches floor
Notes	Sponsorship source: This work was supported by the CDC (grant number P50 CA098252). The article appears as part of the supplement "Personal Protective Equipment for Preventing Contact Transmission of Pathogens: Innovations from CDC's Prevention Epicenters Program," sponsored by the CDC's Prevention Epicenters Program. Country: USA Setting Simulation learning center Authors name: Frank A. Drews Institution: Department of Psychology, and Division of Epidemiology, Department of Internal Medicine, University of Utah, Salt Lake City, US Email drews@psych.utah.edu Address: University of Utah, Department of Psychology, 380S 1530E BEH, Rm 502, Salt Lake City, UT 84112, US

Risk of bias

Bias	Authors' judgement	Support for judgement
Confounding NRS	Low risk	Confounders: 1. prior experience with PPE- none of HCW had 2. healthcare qualification or education of HCW - yes (nurses or nurses' aides) 3. age - no information 4. sex - no information 5. ambient temperatures - no difference, restricted to 1 centre) 6. stressful activities - no difference (all performed similar tasks)
Selection Bias NRS	Unclear risk	No details of participants mentioned
Blinding of participants and personnel (performance bias) All outcomes	High risk	Personnel and participants could not be blinded and likely that the redesigned gown can have influenced behaviour
Blinding of outcome assessment (detection bias) All outcomes	High risk	No blinding of outcome assessors mentioned. Adherance is a rather subjective evaluation

Drews 2019 *(Continued)*

Incomplete outcome data (attrition bias) All outcomes	Low risk	All data reported
Selective reporting (reporting bias)	Unclear risk	No protocol mentioned and unclear if all outcomes reported
Other bias	Unclear risk	There was no washout period and it is unclear if the order of the experiments was random. It is only reported as counter balanced

Gleser 2018

Study characteristics	
Methods	Simulation study, quasi-randomised study based on alternation *How was the simulation performed?* A volunteer HCW donned appropriate sized glove and then wetted each hand with fluorescent solution and distributed this solution equally on the glove's surfaces to simulate an external glove contamination. Immediately thereafter, the volunteer removed their gloves, and their hands were then examined using a UV Box (Hand Hygeine Teaching Box "Sharing Expertise; B. Braun, Melsungen, Germany) *How was the exposure simulated?* 5 mL of a fluorescent solution (Schülke Optics Training fluorescent lotion; Schülke & Mayr GmbH, Vienna, Austria) on each hand
Participants	N = 317 (~70% female) volunteer HCWs on 35 hospital wards in a tertiary care university hospital *Intervention*: N = 146 (104 nurses, 53 physicians) *Control*: N = 171 (118 nurses, 53 physicians)
Interventions	Intervention: modified PPE: tabs on gloves Doffy Glove, modified nitrile gloves with a textured small flap (doffing aid) above the thumb area positioned laterally on the wrist when worn that can be gripped during glove removal Control: standard nitrile medical examination gloves made according to the same material formulation and manufacturing process by the same company on behalf of IP Gloves GmbH
Outcomes	Contamination: any visible fluorescence on the volunteer's skin
Notes	Location: Germany; no funding or conflict of interest reported, however first author is also CEO of the start-up that developed and market the new types of gloves.

Risk of bias		
Bias	**Authors' judgement**	**Support for judgement**
Random sequence generation (selection bias)	High risk	Quote: "Participants were randomised for the use of either standard gloves or Doffy Gloves on an alternate daily basis" Judgement comment: quasi-randomisation; big difference in number in intervention or control group

Gleser 2018 *(Continued)*

Allocation concealment (selection bias)	Unclear risk	No description provided
Blinding of participants and personnel (performance bias) All outcomes	Low risk	Study could not be blinded but unlikely that participants could have influenced the outcome, which was assessed by observers
Blinding of outcome assessment (detection bias) All outcomes	High risk	Assessors of contamination were aware of which glove was used and subjective assessment
Incomplete outcome data (attrition bias) All outcomes	Low risk	No missing data reported
Selective reporting (reporting bias)	High risk	No study protocol provided
Other bias	High risk	Study authors have a big financial interest in a positive evaluation of their new product

Guo 2014

Study characteristics	
Methods	Randomised, multiple arm, cross-over, simulation study
Participants	N = 50; voluntary HCW who gave informed consent; excluded were those who were allergic to the fluorescent marker; 34/50 female, 20/50 nurses, 10/50 doctors, 15/50 support staff, 5/50 allied health workers; age 32.9 ± 5.7 years average; working experience 10.9 ± 5.1 years Location: Hong Kong, China
Interventions	*Intervention*: *different types of PPE compared* *Intervention 1*: N = 50 participants. 3 types of protective clothing: 1. Disposable, water-resistant, non-woven gown, 2. Reusable, woven cotton gown, 3. Disposable, non-woven plastic apron; and 2 different removal methods: individually determined or CDC-recommended. Each of the 50 participants was required to test the 3 different types of PPE followed by 1 of 2 different removal methods. *Intervention 2*: first the participant should doff according to their own views (individual method), then a CDC instruction video was shown and participants were asked to perform the donning or doffing method for gowns that was recommended by CDC in 2007: gown front and sleeves are contaminated! Unfasten neck, then waist ties. Remove gown using a peeling motion; pull gown from each shoulder toward the same hand. Gown will turn inside out. Hold removed gown away from body, roll into a bundle and discard into waste or linen receptacle. *Control*: cross-over N = 50 participants. 3 types of protective clothing were compared against each other.
Outcomes	1. Small patches of fluorescence < 1 cm^2 2. Large patches of fluorescence > 1 cm^2 3. Patches on the hands 4. Patches on the shoes 5. Underwear patches

Guo 2014 *(Continued)*

	6. Patches in the environment A fluorescent powder (GloGermCo,Moab,UT) especially developed for determining hand hygiene compliance was used in this study. The Glo Germ powder was mixed with light olive oil and water to resemble human aerosol as closely as possible. The study authors used repeated measures analysis to take into account the cross-over design of the study
Notes	Funding Hong Kong Polytechnic University; no conflict of interest declared

Risk of bias

Bias	Authors' judgement	Support for judgement
Random sequence generation (selection bias)	Unclear risk	Interventions were offered "in random order"; study authors asked for clarification
Allocation concealment (selection bias)	Unclear risk	Not reported
Blinding of participants and personnel (performance bias) All outcomes	Low risk	No blinding possible, but no performance bias expected as participants would not have an interest with any intervention
Blinding of outcome assessment (detection bias) All outcomes	Unclear risk	Not reported
Incomplete outcome data (attrition bias) All outcomes	Low risk	No loss to follow-up
Selective reporting (reporting bias)	Low risk	All data reported
Other bias	Low risk	Not detected

Hajar 2019

Study characteristics

Methods	**Study design:** RCT **Study grouping:** cross-over **Exposure (virus, fluorescent fluid etc)**: fluorescent solution (Super Blue Invisible Ink, Black Light World) **Exposure simulation**: participants donned the gowns and nitrile gloves (DenvilleScientific, Holliston, MA) in their usual manner. The gloved hands were inoculated with 0.5 mL of fluorescent solution (Super Blue Invisible Ink, Black Light World) that was rubbed over the gloved hands until dry (~15 s). The participants removed their PPE in their usual manner; no education was provided.
Participants	**Baseline characteristics** Overall

Hajar 2019 *(Continued)*

- *Male %*: not reported
- *Age (m ± SD)*: not reported
- *Occupations*: not reported
- *Employment duration*: not reported

Included criteria: not reported (HCW)

Excluded criteria: not reported

Interventions

Intervention characteristics: modified PPE

Increased-coverage gown

- *Intervention aim*: a modified cover gown with further improvements in hand and wrist skin coverage would reduce contamination during PPE removal
- *Content of the intervention*: the alternative-design gown was a modified version of the Assure Wear Versa Gown with Flexneck technology (AMD Ritmed,Tonawanda, NY); the gown includes an elastic band at the wrist for snug fit and was modified to provide a substantial increase in skin coverage including the entire wrist and the palms and dorsum of the hands to just above the fingers.

Standard gown

- *Intervention aim*: prevent contamination
- *Content of the intervention*: the standard gown, the Safety Plus polyethylene gown (TIDIProducts, Neenah, WI), was the gown used routinely in our facility

Increased coverage gown plus education

- *Intervention aim*: see above
- *Intervention duration per session*: 5 min education
- *Provider of the intervention*: researchers
- *Content of the intervention*: the education consisted of a 5-min session that included review of a poster providing instruction on the 1-step technique recommended by the CDC for PPE removal.

Standard gown plus education

- *Intervention aim*: see above
- *Intervention duration per session*: 5 min education
- *Provider of the intervention*: researchers
- *Content of the intervention*: the education consisted of a 5-min session that included review of a poster providing instruction on the 1-step technique recommended by the CDC for PPE removal.

Outcomes

Contamination outcome assessment: contamination of the hands and wrists was assessed using a black light, and the sites of contamination were recorded. After a washout period of at least 5 min, an additional simulation was conducted with cross-over to the alternate gown.

People with contamination

- **Outcome type**: dichotomous outcome
- **Reporting**: fully reported
- **Scale**: proportion
- **Unit of measure**: person
- **Direction**: lower is better
- **Data value**: endpoint

People with protocol deviation

- **Outcome type**: dichotomous outcome
- **Reporting**: fully reported
- **Unit of measure**: person

Hajar 2019 *(Continued)*

- **Direction**: lower is better
- **Data value**: endpoint

Notes	

Risk of bias

Bias	Authors' judgement	Support for judgement
Random sequence generation (selection bias)	Unclear risk	Quote: "personnel were randomized" Judgement comment: no reporting of random number generation
Allocation concealment (selection bias)	Unclear risk	Judgement comment: no reporting of allocation concealment
Blinding of participants and personnel (performance bias) All outcomes	High risk	Quote: "We conducted 2 non-blinded cross-over trials to compare contamination of personnel during simulations of contaminated PPE removal with the standard versus the alternative design cover gown." Judgement comment: study authors stated they were non-blinded. 1 gown was routinely used in the facility and participants may have had a biased preference for it.
Blinding of outcome assessment (detection bias) All outcomes	Unclear risk	Judgement comment: no mentioning of blinding of outcome assessors. Probably not blinded
Incomplete outcome data (attrition bias) All outcomes	Low risk	Quote: "total, 6 participants were excluded from the analysis because they did not complete the second assessment because they were unavailable or unable to be located after the initial assessment." Judgement comment: attrition was even in both trials, with 4 dropping out (2 each group) in trial 1 and 2 dropping out (1 each group) in trial 2. All data were reported for those analysed
Selective reporting (reporting bias)	Unclear risk	Judgement comment: no compliance data provided for second trial
Other bias	Unclear risk	Judgement comment: washout period very short and unclear if all contaminant was cleared away

Hall 2018

Study characteristics

Methods	Simulation study, non-randomised cross-over study *How was the simulation performed?* Prior to donning PPE volunteers were screened using Fluorescence Interactive Video Exposure System (FIVES) to ensure that there was no pre-existing contamination on their skin or scrubs from the environment, previous tests or background fluorescence. Over disposable scrubs volunteers then donned the PPE ensembles under supervision by a buddy, and they were screened again prior to beginning the simulation exercise. After completing the exercise, volunteers were screened front and back using the FIVES system to qualitatively record contamination resulting from the simulation. PPE was then removed according to protocol under the supervision of a buddy, and screening was repeated to detect any post-doffing contamination.

Hall 2018 *(Continued)*

	How was the exposure simulated? 'Violet' (Visualising Infection with Optimised Light for Education and Training) was a medical training manikin adapted to deliver simulants of 4 fluorochrome-tagged body fluids during a scenario based on a doctor and nurse undertaking clinical procedures with a suspected-case patient.
Participants	N = 11 (7 nurses, 4 doctors) Volunteer healthcare providers were recruited via calling notices at the participating Infectious Disease (ID) units, gave informed consent and were free to withdraw at any time. 11 volunteers completed the simulation exercise up to 10 times depending on their availability. 5 volunteers (including 1 further doctor and nurse) acted as 'buddies' to assist with doffing. All volunteers were experienced in using the PPE ensembles adopted by their respective ID units, but if they used an ensemble from another unit, they had to undergo training to practice donning and doffing 10 times or until deemed competent by a staff trainer. Limiting the number of volunteers reduced user attributable variation.
Interventions	Intervention: different types of PPE compared 5 'suspected case' PPE ensembles used in different infectious disease units around the UK. All models met the guidance of the Advisory Committee on Dangerous Pathogens endorsed by Public Health England. PPE components met their relevant material standards. All were donned and dry-doffed according to the specific protocol relevant to the ensemble. The PPE ensembles varied but could broadly be grouped as a 'gown model' or a 'coverall model' but each had slight differences (e.g. use of hood vs surgical cap, boots vs boot covers, and different glove lengths and number of pairs). Control: basic-level PPE (surgical mask, standard length apron, 1 pair short gloves, no standard footwear, scrubs and no buddy used for doffing)
Outcomes	Contamination: fluorescent areas seen on skin or scrubs of the volunteer post-doffing
Notes	Location: UK; no conflict of interested reported; funding was provided by Health and Safety Executive (HSE); Bozena Poller was funded by the Healthcare Infection Society's Graham Ayliffe Training Fellowship

Risk of bias

Bias	Authors' judgement	Support for judgement
Confounding NRS	Low risk	Differences related to: 1. prior experience with PPE - no 2. healthcare qualification or education of HCW - yes (nurses or physicians) 3. age - no information 4. sex - no information 5. ambient temperatures - no (restricted to 1 centre) 6. stressful activities - no (all performed similar tasks)
Selection Bias NRS	Low risk	Cross-over trial; 11 participants did the simulation up to 10 times
Blinding of participants and personnel (performance bias) All outcomes	Low risk	Participants knew which PPE they had on but it is unlikely that they could have influenced the outcome, which was an objective assessment by an observer.
Blinding of outcome assessment (detection bias) All outcomes	Unclear risk	The judgement of the contamination is subjective and the assessors were aware of the type of equipment but it is unclear if this could have influenced the outcome assessment
Incomplete outcome data (attrition bias)	Unclear risk	Quote: "This resulted in a non-trained volunteer participating in the role of the nurse for 1 simulation; their data were excluded from the final analysis, but

Hall 2018 *(Continued)*

All outcomes		their participation allowed data to be captured for their doctor partner. In total, 19, suspected case simulations captured 37 volunteers."
Selective reporting (reporting bias)	Unclear risk	No protocol provided
Other bias	Low risk	No other biases detected

Houlihan 2017

Study characteristics	
Methods	Retrospective cohort study Invitations to participate were sent to individuals known to the study authors, and through organisations supporting EMT deployment involving UK-based staff, including non-governmental organisations (NGOs), UK government-affiliated institutions, and the London School of Hygiene and Tropical Medicine (LSHTM). The participants filled in a questionnaire with information about PPE use. They then underwent a blood test to assess their antibody status. The researchers assessed the participants' risk of being exposed to EVD based on an independent algorithm.
Participants	N = 300 individuals who returned to the UK or Ireland after responding to the West African EVD epidemic completed the survey. Of these, N = 268 returned material for IgG assessment (median age 36 years range 30-45; 57% female; 35% lab staff, 26% physicians, 20% nurses, 19% other) In addition, there were N = 53 non-exposed control participants included who had not left the UK (median age 35 years range 31-40; 66% female)
Interventions	Intervention: doffing with extra sanitation; doffing with extra instructions There were 2 interventions that were of interest. (1) PPE removal with or without chlorine spray, (2) PPE removal with and without assistance. However, almost all clinical staff had used both interventions as compared to laboratory staff who had not used them. Because there was also a big difference in the likelihood of exposure between these 2 occupational groups, the effect of protection of these measures could therefore not be analysed.
Outcomes	Level of IgG antibody against Ebola Virus as an indicator of infection
Notes	Country: UK; funding by Wellcome Trust: Enhancing Research Activity in Epidemic Situations. The funders had no role in study design, data collection and analysis, decision to publish or preparation of the manuscript; 1 study author received funding from the Wellcome Trust via the University of Liverpool and also received non-financial support from NHSBT, as part of the Convalescent Plasma Study.

Risk of bias

Bias	**Authors' judgement**	**Support for judgement**
Confounding NRS	Low risk	Differences related to: 1. prior experience with PPE - no 2. healthcare qualification or education of HCW - no (clinical, lab or other role) 3. age - no 4. sex - no 5. ambient temperatures - no (all restricted to Africa) 6. stressful activities - yes (work roles varied depending on qualifications)

Houlihan 2017 *(Continued)*

Selection Bias NRS	High risk	Sample based on snowball sampling
Blinding of participants and personnel (performance bias) All outcomes	Low risk	Participants were not aware of exposure status when they reported their exposures.
Blinding of outcome assessment (detection bias) All outcomes	Low risk	Researchers knew who was rated as 'high risk' but objective outcome measure. Therefore unlikely that it was influenced
Incomplete outcome data (attrition bias) All outcomes	Unclear risk	Convenience sample; from sample 10.7% did not react
Selective reporting (reporting bias)	Unclear risk	No protocol provided
Other bias	Low risk	No other sources of bias detected

Hung 2015

Study characteristics	
Methods	RCT, 2 parallel groups, 2 training variants
Participants	Intervention group: N = 25, age 44% < 31 years, healthcare assistant 56%, nurse 44%, work experience < 6 years 44%, no gender reported Control group: N = 25, age 28% < 31 years, healthcare assistant 56%, nurse 44%, work experience < 6 years 48%, no gender reported All HCW of an outpatient department of a private hospital handling infectious patients before admission; able to read English, basic computer skills
Interventions	*Intervention: training:* extra computer simulation All participants were asked to don and doff N95 respirator, face shield, cap, gown, gloves for "precautions against airborne danger". External observers rated the procedures for errors. All participants then attended a PPE-training consisting of a 15-min demonstration of donning and doffing by an "infection control link nurse". After 1 week the intervention group got the interactive computer simulation programme and again after 1 week was assessed for compliance with the donning and doffing procedures. *Control:* the control group was assessed for compliance with donning and doffing procedures 1 week after PPE training. The group did not get the computer simulation training.
Outcomes	**Primary outcome:** score on 16-item checklist for donning and 20-item checklist for doffing. Secondary outcome: IBM computer system usability questionnaire (CSUQ) consisting of 19 items with a 7-point Likert response scale
Notes	Hong Kong China; funding: Hong Komg Research Grant Council; no conflict of interest reported
Risk of bias	

Bias	**Authors' judgement**	**Support for judgement**

Hung 2015 *(Continued)*

Random sequence generation (selection bias)	Unclear risk	Quote: "The subjects were randomly assigned to the control and experimental group of the same size", page 53
Allocation concealment (selection bias)	Unclear risk	Not reported
Blinding of participants and personnel (performance bias) All outcomes	Low risk	Not possible to blind participants or providers but outcome objectively assessed by observers, unlikely that this was influenced
Blinding of outcome assessment (detection bias) All outcomes	Low risk	Nurse assessing PPE compliance "was blinded about the research", page 53
Incomplete outcome data (attrition bias) All outcomes	Unclear risk	Not reported if all participants contributed data
Selective reporting (reporting bias)	High risk	Results of computer usability questionnaire not fully reported
Other bias	Low risk	No other biases assessed

Kpadeh Rogers 2019

Study characteristics	
Methods	**Study design:** non-RCT **Study grouping:** n/a **Simulation of the exposure (virus, fluorescent fluid etc)**: for each experiment, the top gloves on both hands were directly inoculated with 50 µL of bacterial suspension and 50 µL of GloGerm Mist liquid fluorescent marker (GloGerm, Moab, UT) to give a final concentration of 108 CFU of bacteria. A high inoculum was used based on our pilot observations that organism recovery from gloves was reduced by 1–2 logs from the original inoculum. Fluorescent marker was added to visually trace bacterial transfer throughout all experiments. **Exposure simulation**: participants were asked to rub the bacteria/fluorescent marker on their hands in a standardised way. A research team member provided verbal instructions to ensure that doffing steps were performed per CDC protocols. Alcohol-based hand rub, 63% alcohol (Steris Corp, Mentor, OH) and 2 US Environmental Protection Agency–registered hospital disinfectants, dispatch bleach disinfecting wipes (Clorox Healthcare, Oakland, CA) and Sani-Cloth AF3 quaternary ammonium (“quat”) disinfecting wipes (PDI Healthcare, Montvale, NJ), were used for decontamination. Volunteers were asked to decontaminate in a manner that ensured they covered all parts of the glove surface including between all fingers. Using a single pump of the alcohol-based hand rub, volunteers rubbed both gloved hands together, similar to routine hand hygiene in the hospital, until the gloves were completely dry. For wipe-based decontamination, the volunteer used a single wipe to decontaminate both gloves with continuous wiping for at least 1 min. We ensured a total manufacturer-recommended dwell or contact time, that is, time for which the glove surface remained visibly wet, of 3 min for quat and 1 min for bleach.
Participants	**Baseline characteristics** 10 participants were enrolled, 10 per organism Overall

Kpadeh Rogers 2019 *(Continued)*

- *Male %*: not reported
- *Age (m ± SD)*: not reported
- *Occupations*: healthcare providers
- *Employment duration*: not reported

Included criteria: volunteers were asked to don 2 pairs of gloves and a gown, with the under gloves representing HCW hands and the top gloves representing the actual gloves worn for patient care. In total, 20 HCW (10 per organism) were enrolled.

Excluded criteria: not reported

Pretreatment: cross-over trial. All participants used all 3 disinfectants and no disinfectant

Interventions	**Intervention characteristics: doffing with extra sanitation** Alcohol-based glove decontamination • *Intervention aim*: disinfecting outer gloves before doffing • *Content of the intervention*: alcohol-based hand rub, 63% alcohol (Steris Corp, Mentor, OH) Quat-based glove decontamination • *Intervention aim*: disinfecting outer gloves before doffing • *Content of the intervention*: Sani-Cloth AF3 quaternary ammonium ("quat") disinfecting wipes (PDI Healthcare, Montvale, NJ) Bleach-based glove decontamination • *Intervention aim*: disinfecting outer gloves before doffing • *Content of the intervention*: dispatch bleach disinfecting wipes (Clorox Healthcare, Oakland, CA) No glove decontamination • *Intervention aim*: no disinfection of outer gloves • *Content of the intervention*: no intervention
Outcomes	**Outcome assessment for simulation study**: at the end of the experiment, gloves were sampled using a 3M sponge-stick with 10 mL neutralising buffer (St. Paul, MN) in a standardised manner to ensure sampling of all surfaces. Sponge-sticks were processed using previously described methods. From the eluent, successive 1/10 dilutions were made and plated on tryptic soy agar (Becton Dickinson, Sparks, MD) in triplicate for quantitative culturing. Plates were incubated overnight, and the number of CFUs of *Klebsiella pneumoniae* and Methicillin-sensitive *Staphylococcus aureus* (MSSA) were calculated. The eluent was also enriched in gram-negative broth (Becton Dickinson) for *K. pneumoniae* and tryptic soy broth with salt (Remel, Lenexa, KS) for MSSA, incubated overnight, and plated onto MacConkey agar and blood agar, respectively. *Bacterial contamination (combined Staphylococcus and Klebsiella)* • **Outcome type**: continuous outcome • **Reporting**: fully reported • **Unit of measure**: CFU • **Direction**: lower is better • **Data value**: endpoint *Bacterial contamination* • **Outcome type**: dichotomous outcome • **Reporting**: fully reported • **Unit of measure**: participant • **Direction**: lower is better

Kpadeh Rogers 2019 *(Continued)*

- **Data value**: endpoint

Notes	

Risk of bias

Bias	Authors' judgement	Support for judgement
Confounding NRS	Unclear risk	Judgement comment: differences related to: 1. prior experience with PPE - yes (direct patient care experience) 2. healthcare qualification or education of HCW - no information 3. age - no information 4. sex - no information 5. ambient temperatures - no (restricted to 1 centre) 6. stressful activities - no (all performed similar tasks)
Selection Bias NRS	High risk	Judgement comment: 10 HCW performed the trial with 1 type of bacteria and another 10 HCW performed the trial with the second type of bacteria.
Blinding of participants and personnel (performance bias) All outcomes	Low risk	Judgement comment: participants knew which disinfectant they used, but it is unlikely that they could have influenced the outcome, which was an objective assessment by an observer.
Blinding of outcome assessment (detection bias) All outcomes	Low risk	Judgement comment: outcome assessors unblinded but outcome fairly objective. Unlikely that they influenced the outcome measurement
Incomplete outcome data (attrition bias) All outcomes	Unclear risk	Judgement comment: apparently data from all experiments reported
Selective reporting (reporting bias)	Low risk	No protocol but apparently all outcomes reported
Other bias	Low risk	Judgement comment: no other sources of bias detected

Mana 2018

Study characteristics

Methods	Simulation study, randomised cross-over study *How was the simulation performed?* Participants were instructed to don intervention or control gown and gloves in their usual manner. A lotion containing both exposures was rubbed onto the gloves and then the participants rubbed gloved hands on the front area of the gown to simulate contamination. Participants doffed the PPE again in their usual manner. *How was the exposure simulated?* Exposure to contamination was simulated by a lotion containing 0.5 mL of phosphate-buffered saline containing 108 PFU of the enveloped virus bacteriophage Phi X174 (American Type Culture Collection (ATCC) 13706-B1), and 0.5 mL of fluorescent lotion

Mana 2018 *(Continued)*

Participants	N = 31 11 physicians (36%), 6 nurses (19%), 14 allied health personnel (45%) 31 paired simulations
Interventions	*Intervention*: modified PPE: gown easy doffing Assure Wear Gown with Flexneck technology (AMD Ritmed, Tonawanda, NY) designed to allow easy removal at the neck and with increased skin coverage and snugness of fit at the wrist. The gown has a double elastic neck closure system to aid in removal, thumb loops with smaller holes and provides more palm coverage and elastic band around wrist to improve snugness of gown *Control*: Standard Safety Plus polyethylene gown (TIDI Products, Neenah, WI). Problems can occur with hand and wrist contamination due to skin exposure at the gown–glove interface despite the presence of a thumb loop intended to keep the gown in proximity to the gloves. A loose fit at the wrist and minimal coverage of the upper palm contributes to the potential for contamination. Contamination of the neck region often occurs when gowns do not easily come apart at the posterior neck, resulting in tearing of gown material.
Outcomes	UV contamination: a black light (Ultra LightUV1 by Grizzly Gear, SCS Direct, Trumball, CT) was used to look for the fluorescent tracer on the hands, wrist, neck and chest. Bacteriophage contamination: the participants' hands and wrist were swabbed with gauze to collect potential bacteriophage. Alcohol based hand sanitiser was used for hand hygiene and sterile gloves were donned prior to the participant swabbing their neck and chest, including their clothing to collect other potential contamination.
Notes	Location: USA; financial support: this work was supported by a Merit Review grant (no. 1 I01 BX002944-01A1) from the Department of Veterans Affairs to C.J.D. AMD Ritmed provided the Assure Wear VersaGowns with Flexneck technology for testing, but they had no role in study design, analysis or interpretation of the data, or writing of the manuscript. Potential conflicts of interest: C.J.D. received research grants from Clorox, Merck, AvidBiotics, and GOJO, and has served on scientific advisory boards for 3M and Seres Health. All other study authors reported no conflicts of interest relevant to this article.

Risk of bias

Bias	Authors' judgement	Support for judgement
Random sequence generation (selection bias)	Low risk	Quote: "Healthcare personnel were randomised to perform simulations of contaminated glove and gown removal using either the standard or alternative design gown." Additional info from study authors: the random sequence was generated have used a List Randomizer from the web-site: www.random.org/lists/, which provided a random listing of which gown will be used first for each participant.
Allocation concealment (selection bias)	Low risk	Additional info received from study authors: the allocation was irrevocable
Blinding of participants and personnel (performance bias) All outcomes	Low risk	Participants could not be blinded but this is unlikely to have an effect on the outcome because this was assessed by observers
Blinding of outcome assessment (detection bias) All outcomes	Low risk	Additional information from authors: it was not possible to blind outcome evaluators for the fluorescence evaluation because the gowns are visibly different. However, the outcome evaluators for the assessment of bacteriophage Phi X174 contamination were blinded to the identity of the study groups.

Mana 2018 *(Continued)*

Incomplete outcome data (attrition bias) All outcomes	Low risk	Additional information from study authors: there were no missing data
Selective reporting (reporting bias)	Unclear risk	Additional information from study authors: we did not register the study protocol
Other bias	Low risk	No indication of other biases

Osei-Bonsu 2019

Study characteristics	
Methods	Simulation study, randomised *How was the simulation performed?* 1. Glo Germ fluorescent powder (Glo Germ Company, Moab, UT) 2. 1 mL of *Staphylococcus epidermidis* in a 0.5 McFarland suspension (1.5 10 8 CFU/mL). The *S epidermidis* was genetically engineered to stably express a green fluorescent protein that is visible under a black light in bacterial cultures *How was the exposure simulated?* In order to simulate PPE contamination, after donning PPE, study assistants (KO, NM, and MD) used a wedge foam paint brush to liberally coat participants with Glo Germfluorescent powder (Glo Germ Company, Moab, UT) on both arms, hands, and the abdomen. The brush was dipped back into the powder after coating each arm or abdomen. These areas were thought most likely to be contaminated in the course of patient care activities at the bedside. Participants were then also coated with *S Epidermidis* in the same distribution on the body. The solution was applied by dripping droplets over the PPE with a 1000 uL pipette by the study staff. After the opportunity to review the assigned procedure and ask questions, participants were then asked to doff PPE under guided observation by the study investigators. There was no training or practice of the doffing techniques prior to the simulation. Prompts were given as needed to ensure the participants followed the assigned procedure.
Participants	*Inclusion criteria*: clinical providers and microbiology laboratory personnel as well as life safety administrators. Laboratory personnel and life safety administrators do not use PPE in the context of patient care, but do use it as occupational PPE (i.e. gowns, gloves, masks, and goggles) in the laboratory or to train other staff on proper PPEusage. *Exclusion criteria:* individuals < 18 years of age or > 65 years of age; pregnancy or breastfeeding; history of joint replacements or other prosthetic medical devices; and active inflammatory skin conditions or open wounds. Differences between intervention groups in HCW profession type and duration of work experience Occupation: 18% MD, 67% RN, 16% non-clinician Work experience average 5.2 years
Interventions	Interventions: different doffing procedures; Doffing with extra sanitation; Doffing with double gloves; Doffing 1 step 1. *CDC standard doffing procedure* (Control intervention): prescribed procedure for doffing in the following order: gloves, goggles/face shield, gown, mask/respirator, hand hygiene 2. *CDC* 1 *step*: similar to CDC procedure but gloves and gown are doffed in 1 go. *3.CDC plus extra hand hygiene:* CDC plus extra disinfection of gloves with alcohol-based hand rub

Osei-Bonsu 2019 *(Continued)*

	4. *CDC plus double gloves*: similar to CDC procedure but 2 pairs of gloves used and the first pair is doffed first and the second pair last
Outcomes	1. Fluorescent contamination: number of people contaminated 2. Bacterial contamination: number of people contaminated 3. Usability: score on questionnaire of 5 questions
Notes	Location: USA Corresponce: Michelle Doll: Michelle.Doll@vcuhealth.org. Address: Michelle Doll, MD, MPH, Virginia Commonwealth University Health System, 1300 E Marshall St, North Hospital, 2nd Fl, Rm 2-100, PO Box 980019, Richmond, VA 23298

Risk of bias

Bias	Authors' judgement	Support for judgement
Random sequence generation (selection bias)	Low risk	Quote: "participants were assigned a procedure by having them pick a doffing procedure at random from a closed envelope." Judgement: likely to be random
Allocation concealment (selection bias)	Low risk	Quote: "Participants were assigned a procedure by having them pick a doffing procedure at random from a closed envelope." Judgement: unlikely that participants or researchers could change assigned group
Blinding of participants and personnel (performance bias) All outcomes	Low risk	Judgement: personnel and participants could not be blinded, however unlikely that they could have an influence on the outcome which is fairly objective
Blinding of outcome assessment (detection bias) All outcomes	Low risk	Judgement: no information. However both outcomes fairly objective and unlikely that this changed the outcome assessment
Incomplete outcome data (attrition bias) All outcomes	Low risk	Judgement: no information, apparently all data available
Selective reporting (reporting bias)	High risk	Not all outcomes fully reported: main outcome usability only reported as not significant
Other bias	Low risk	No other biases detected

Shigayeva 2007

Study characteristics

Methods	Retrospective cohort study
Participants	HCW who provided care or entered the room of a Toronto SARS patient who required intubation, during the 24 h before and 4 h after intubation

Shigayeva 2007 *(Continued)*

	Eligible N = 879, analysed N = 795; age (median) = 41 years (range 21-67 years); employment in current occupation (median) = 12 years (range 0-43 years); 46% nurses, 14% physicians, 14% respiratory therapists, 10% imaging staff and 16% other; 1055 exposure episodes or shifts Active training intervention: N = 511 episodes (= 385 people), Passive training intervention: N = 236 episodes (= 178 people), Comparison no active training: N = 308 episodes (= 323 people) Location: Canada
Interventions	*Intervention*: t*raining* *Intervention 1*: active training: participants answered that they had received any individual or group face-to-face training sessions *Intervention 2*: passive training: participants watched a video or got written information. *Comparison:* no training reported Other predictors of PPE studied in a multivariate generalised estimating equation logistic regression analysis in addition to training for both outcomes: phase of epidemic, occupation, work experience, hospital type, location of care, number of times patient's room entered, SARS diagnosis recognised, Apache II score of patient.
Outcomes	1. Consistent adherences as proportion of exposure episodes. Participants were interviewed based on a questionnaire 0.2-10 months after the exposure. Interviewers asked about consistent use of PPE: masks, gowns, gloves and eye protection and possible predictors of their use, including training. Consistent adherence was defined as always wearing gloves, a gown, a mask, and eye protection. Consistent adherence was reported in 817/1055 (77%) exposure episodes. Eye protection was least with 13.5% consistent and no PPE in 23 episodes (2.2%). PPE use increased during epidemic from 34.6% at start to 97.4% in the end. 2. Doffing as proportion of exposure episodes (safe, at some risk, or at risk). Participants were asked about their sequence of doffing PPE. Safe was defined as the sequence of removing gown and gloves, hand hygiene, mask, goggles, or safety glasses, hand hygiene. At some risk was considered if hand hygiene was performed only once. At risk if no hand hygiene was performed or hands touched potentially contaminated face. Doffing description was available for 810/1055 (77%) of exposure episodes; 15.4% qualified as safe, 63% as at some risk, and 22% as at risk.
Notes	Units of analysis used in studies: exposure episodes not people exposed, based on work schedules, patient assignments and health records. There were 65 intubations of SARS patients of which 7 were not recognised as such at the time of intubation. Funding Ontario Ministery of Health and Long term Care; no conflict of Interest reported

Risk of bias

Bias	Authors' judgement	Support for judgement
Confounding NRS	Low risk	Adjustment in multiple regression analysis for education, work experience, and presumably for age and sex
Selection Bias NRS	Low risk	Whole cohort assessed that was working during the epidemic. Exposure to SARS patients clearly defined
Blinding of participants and personnel (performance bias) All outcomes	Low risk	Both the intervention and the outcome were assessed at the same time

Shigayeva 2007 *(Continued)*

Blinding of outcome assessment (detection bias) All outcomes	High risk	Both the intervention and the outcome were assessed with the same questionnaire at the same time
Incomplete outcome data (attrition bias) All outcomes	Low risk	90% HCW participated for adherence and for 77% of shifts more or less reliable info about doffing available
Selective reporting (reporting bias)	Unclear risk	Not clear which predictors of adherence or safe doffing were tested and negative
Other bias	Low risk	No indication of other bias

Strauch 2016

Study characteristics	
Methods	Simulation study, cross-over RCT *How was the simulation performed?* 2 different simulations of contamination of the Filtering Facepiece Respirator (FFR) were performed: 1 in which the FFR was contaminated but not the hands and another one in which the hands were contaminated but not the FFR 1. Contamination of the FFR and clean hands: 20 participants performed 3 trials of FFR with removal tabs (tab+) and tab- masks each in random order 2. Clean FFR and contamination of hands: 20 participants performed 1 tab+ trial and 1 tab- trial *How was the exposure simulated?* To contaminate the FFR, 7 mL of fluorescent tracer was brushed onto the entire outer surface of the test FFRs. As only the outer surface of the FFR was contaminated with the fluorescent tracer, transfer from the FFR to the hands would only occur if the FFR was doffed improperly by grasping the contaminated surface. 2. For the hand contamination test, 1 mL of fluorescent tracer was applied and rubbed into the hands of the test participant before removal of a clean FFR with or without tabs. The fluorescent tracer was prepared by suspending 1 g of GloGerm (GloGerm Company; Moab,UT) powder suspended in 25 mL of mineral oil.
Participants	N = 20 aged 18-60 HCW Volunteers employed as HCW, that were enrolled in a respiratory protection programme and experienced in wearing FFRs were preferred, but a potential participant was not excluded if all of the qualities were not met. Volunteers were excluded if they had a history of skin cancer, sensitivity to UV light, or burns from a black light Country: USA
Interventions	Intervention: modified PPE: masks with tabs Mask with tabs; N-95 mask with 4 red foam tabs attached to straps to assist in mask removal Control: mask with out tabs
Outcomes	Contamination of the hands resulting from exposure to a contaminated mask Contamination of the head resulting from exposure to contaminated hands: the participant's head, face and hair were photographed under UVA light for contamination with fluorescent tracer.

Strauch 2016 *(Continued)*

Notes	Location: USA; funding source and conflict of interest were not published; reported on Lumens as a measure of contaminate but the written results did not match those presented in figure.

Risk of bias

Bias	Authors' judgement	Support for judgement
Random sequence generation (selection bias)	Unclear risk	Quote: "each subject doffed one randomly assigned FFR" Unclear how randomisation was performed
Allocation concealment (selection bias)	Unclear risk	Unclear if allocation was irrevocable
Blinding of participants and personnel (performance bias) All outcomes	Low risk	Not reported but unlikely to have influenced the outcome that was assessed by observers
Blinding of outcome assessment (detection bias) All outcomes	Unclear risk	Not reported
Incomplete outcome data (attrition bias) All outcomes	Unclear risk	Unclear if there were missing data
Selective reporting (reporting bias)	Unclear risk	No protocol available
Other bias	Low risk	No other biases detected

Suen 2018

Study characteristics

Methods	**Study design:** RCT **Study grouping:** **Simulation exposure (virus, fluorescent fluid etc)**: fluorescent solution (UV GERM Hygiene Spray, Glow Tec Ltd., London, England) that mimics contaminated bodily fluids or secretions spread via contact route. **Exposure simulation**: fluorescent solution was sprayed onto the face shield, 2 upper limb/gloves and anterior surfaces of the gown at a distance of 60 cm from the participants, which represents the length of a stethoscope, simulating the usual working distance between a patient and an HCW, with an average of 1.99 g fluorescent solution/per stroke. This value was determined using an electronic analytical balance with a precision of 0.1 g (NJW-3000, Xiangxin, Taipei, Taiwan) via obtaining the average of 20 trial cases. A standard of 3 strokes was sprayed on each body part with a total of 12 strokes made for each case. The weight of the splash in 1 stroke was 1.99 g in this study when the density of the solution was assumed as 1. **How was the simulation performed?:** on the testing day, the participants watched a video about donning and doffing of the PPE ensembles to familiarise themselves with the procedures. The experiment was sequentially conducted in 3 areas. Area A was the 'clean zone', where the participants donned the working clothes and clean PPE ensemble in front of a mirror. Area B was the 'preparation zone', where

Suen 2018 *(Continued)*

	the PPE of the participants was contaminated with a fluorescent solution. Area C was the 'de-gown and test-zone', wherein the participants were required to doff the PPE.
Participants	**Baseline characteristics** Overall • *Male %*: 42% • *Age range*: between 20 and 60 years • *Occupations*: all nurses and 48% from departments with high infectious disease exposure • *Employment duration*: not reported **Included criteria:** HCWs that were willing to participate **Excluded criteria**: pregnant women and participants suffering from upper respiratory tract infection and respiratory diseases requiring treatment were excluded. **Pretreatment**: all participants tested the 3 PPE types
Interventions	**Intervention characteristics: different types of PPE compared** PPE1 • C*ontent of the intervention*: HA standard Ebola PPE set is a neck-to-ankle overall with an overlying water-resistant gown (Halyard, AAMI Level 4 Liquid Barrier Standard), double and long nitrate gloves, boots, hood, disposable face shield and N95 respirator. A bow was tied at the lateral of the waist to minimise the risk of front contamination. PPE2 • *Content of the intervention*: DuPon Tyvek,Model 1422A is commonly adopted in clinical settings to prevent Ebola transmission in countries, such as the USA and South Korea. Its protective clothing is also fluid resistant, but the design is a 1-piece head-to-ankle overall with a zipper on the front. The whole outfit includes double gloves, boots, disposable face shield and an N95 respirator. A plastic apron was used to cover up the front zipper before use. PPE3 • *Content of the intervention*: PPE3 is an isolation gown (Medicom) for routine patient care and performing aerosol-generating procedures. PPE3 was selected as the reference PPE in the present study. A commercially available pure cotton surgical scrub suit (upper and lower working clothes) was worn inside the individual PPE ensembles during testing. Participants were free to select the appropriate size of gowns and gloves and the known best-fitted respirator model (3 M 1860, 1860s and 1870)
Outcomes	*How was the outcome measured:* 1. Areas in contamination were counted, measured, and categorised as small- (medium- (1 cm^2 to < 3 cm^2), large- (≥ 3 cm^2 to 5 cm^2) or extra-large patch (≥ 5 cm^2)The presence of fluorescent solution using UV lamp (CheckPoint, 220-240 V / 50 Hz; Glow Tec Ltd., London, England) under a dim light. The participants' hair and head, face, anterior/posterior neck, left/right arms, hands or wrists, upper/lower working clothes and shoes, along with the surrounding environment (rubbish bin cover, chair, faucet (tap), and sink). 2. Deviation rate is mean of 11 issues 10 issues and 9 issues resp for donning and same for doffing *Overall small contamination sites* • **Outcome type**: dichotomous outcome • **Unit of measure**: median number of small contamination sit *Overall extra-large contamination sites* • **Outcome type**: dichotomous outcome

Suen 2018 *(Continued)*

- **Unit of measure**: median number of extra-large contamination sites

Overall deviation rate of donning PPE

- **Outcome type**: dichotomous outcome
- **Unit of measure:** mean percentage errors of all items on a checklist

Overall deviation rate of doffing PPE

- **Outcome type**: dichotomous outcome
- **Unit of measure:** mean percentage errors of all items on a checklist

Time of donning PPE

- **Outcome type**: continuous outcome
- **Scale**: mean time
- **Unit of measure**: min
- **Direction**: lower is better

Time of doffing PPE

- **Outcome type**: continuous outcome
- **Reporting**: fully reported
- **Scale**: mean time
- **Unit of measure**: min

Notes

Risk of bias

Bias	Authors' judgement	Support for judgement
Random sequence generation (selection bias)	Low risk	Quote: "random order as decided by a computer-generated randomised table
Allocation concealment (selection bias)	Unclear risk	Not reported
Blinding of participants and personnel (performance bias) All outcomes	Low risk	Judgement comment: not possible to blind but outcome objective and difficult to influence by providers and participants
Blinding of outcome assessment (detection bias) All outcomes	Unclear risk	Judgement comment: not reported
Incomplete outcome data (attrition bias) All outcomes	Low risk	Judgement comment: data for all participants reported
Selective reporting (reporting bias)	Low risk	Judgement comment: no protocol provided but apparently all outcomes reported
Other bias	Low risk	Judgement comment: no other biases detected

Tomas 2016

Study characteristics	
Methods	Simulation study, RCT, parallel groups *How was the simulation performed?* Participants removed improved gowns and gloves in their usual manner. *How was the exposure simulated?* Gloved hands were inoculated with 0.5 mL phosphate-buffered saline (PBS) containing 10^10 PFUs of MS2 and 0.5 mL fluorescent lotion and the solutions were rubbed over the gloved hands until dry. Bacteriophage MS2 was of the type 15597-B1 (American Type Culture Collection,VA).
Participants	N = 30 HCW; no other information provided; asked study authors for more information
Interventions	*Intervention*: modified PPE: seamless gown-glove interface A seamless PPE prototype in which adhesive material on the outer sleeve of the gown at the wrist attaches to the inner cuff of the gloves, providing continuous coverage of the wrist and hand. This design prevents exposure of skin and requires that gloves be peeled off as the gown is removed. The prototype seamless PPE consisted of polyethylene contact isolation gowns (SafetyPlus Polyethylene Gown, TIDI Products, Neenah, WI) and nitrile gloves (Denville Scientific, South Plainfield, NJ). Permanent contact bond adhesive (DAP Weldwood Contact Cement, DAP Products, Baltimore, MD) was applied circumferentially to the outer gown at the level of the wrist. Gloves were pressed to the gowns for 15 min and allowed to air dry for 24 h. *Control*: only described as standard PPE and assumed as gloves and gown
Outcomes	1. Outcome assessment fluorescent: hand and wrist skin contamination with the fluorescent lotion was assessed using a black light (Ultra Light UV1 by Grizzly Gear, SCS Direct,Trumball, CT). 2. Outcome assessment bacteriophage: participants then wiped both hands and wrists with a sterile, pre-moistened 4 x 4 gauze pad that was placed into a sterile container containing 10 mL PBS and mixed in a vortex mixer for 1 min to elute the bacteriophage. Aliquots of each elutant were serially diluted and cultured to quantify virus particles.
Notes	Location: USA; funding was provided by the Department of Veteran Affairs; 1 author, C.J.D. had previously received research grants from Clorox, Merck, AvidBiotics and GOJO and the same author also served on scientific advisory boards for 3M and Seres Health.

Risk of bias

Bias	**Authors' judgement**	**Support for judgement**
Random sequence generation (selection bias)	Unclear risk	Quote: "Healthcare personnel were randomized to perform simulations of contaminated glove removal" We asked study authors for method of generation
Allocation concealment (selection bias)	Unclear risk	Unclear if irrevocable
Blinding of participants and personnel (performance bias) All outcomes	Low risk	Not blinded but objectively measured outcome
Blinding of outcome assessment (detection bias)	Unclear risk	No information provided

Tomas 2016 *(Continued)*

All outcomes		
Incomplete outcome data (attrition bias) All outcomes	Unclear risk	No information on missing data provided
Selective reporting (reporting bias)	Unclear risk	No protocol published
Other bias	Low risk	No other biases detected

Wong 2004

Study characteristics	
Methods	Randomised, multiple-arm, parallel-group, simulation study
Participants	Nursing students volunteering; N = 100 nursing students who had given written consent, 82% female, age 21 ± 1.2 years, 60% completed > 1 study year, all had been taught PPE use, none had been involved with SARS patients
Interventions	*Intervention*: d*ifferent types of PPE compared* 10 different brands and types of PPE at the time of the study in use in Hong Kong hospitals; 1 type was a surgical gown and 1 the brand Barrierman, probably Tyvek by DuPont, the others were denoted as White A, White, Green, Y-HR-9, Yellow, Blue, Blue-9, B-NHK-9, B-HR-9. These were categorised into 4 categories: A: good water repellency and penetration resistance but poor air permeability; B good water repellency and air permeability but poor water penetration resistance; C: surgical gown with poor water repellency and penetration resistance and fair air permeability; D Barrierman, with good water repellency, poor air permeability and fair water penetration resistance. Types A,B, C, and D were compared against each other
Outcomes	1. Usability rated by the users as the mean of 5-point scales for: instructions, comfort, ease of donning and doffing, and satisfaction 2. Donning and doffing time/durations in min 3. Contamination after spraying fluorescent marker on the trunk and doffing of PPE, measured as mean number of contaminated spots that light up in UV-light
Notes	Hong Kong, China; funded by Hong Kong Infection Control Nurses' Association, Hong Kong Polytechnic University; no conflict of interest is reported in the article

Risk of bias

Bias	**Authors' judgement**	**Support for judgement**
Random sequence generation (selection bias)	Low risk	Participantss were allocated a PPE using a random table page 91
Allocation concealment (selection bias)	Unclear risk	Not reported and information asked from study authors did not lead to a higher confidence in allocation concealment
Blinding of participants and personnel (performance bias)	Unclear risk	Not blinded; page 91 and discussion page 95 indicates that they knew what they were wearing, obviously, as PPE Type D was a 1-piece construct, and they were asked to read manual for wearing.

Wong 2004 *(Continued)*

All outcomes		
Blinding of outcome assessment (detection bias) All outcomes	Unclear risk	Not reported
Incomplete outcome data (attrition bias) All outcomes	Unclear risk	Not reported if any data were missing
Selective reporting (reporting bias)	Unclear risk	Apparently all data reported
Other bias	Low risk	No indication of other bias

Zamora 2006

Study characteristics	
Methods	Randomised, 2-arm, cross-over, simulation study
Participants	Clincians from Queen's Hospital, Kingston, ON, Canada volunteering to participate. N = 50; PAPR-first N = 27, age 34.3 ± 8.7 years, height 171.8 ± 8.1, weight 76.3 ± 16.7, male 16/27, anaesthetists 19/27, prior PAPR training 15/27 Enhanced respiratory and contact precautions (E-RCP) first N = 23, age 36.8 ± 9.8, height 172.3 ± 7.6, male 11/23, anaesthetist 10/23, prior PAPR training 18/23 Location: Canada
Interventions	*Intervention: different types of PPE compared: PAPR versus mask* PPE with PAPR, consisting of Tyvek hood (3M), Bouffant hair cover, Spartan economy impact goggle, 3M air-mate breathing tube, 3M HEPA filter unit, N95 mask, 3 pairs of gloves, Tyvek coverall with hood, 2 Tyvek boot covers, Astound impervious surgical gown. Doffing order: first gloves, turbo unit hose, hood, gown, second gloves, belt and battery, shoe covers, third gloves, wash hands, new gloves, coverall, second shoe covers, gloves, new gloves, goggles, hair cover, gloves, wash hands, new mask. Comparison: E-RCP consisting of Bouffant hair cover, Spartan economy impact goggle, face shield (Splash shield), N95 mask, 2 pairs of gloves, Astound impervious gown. Doffing order: outer gloves, gown, inner gloves, wash hands, new gloves, face shield, hair cover, goggles, mask, gloves, wash hands.
Outcomes	1. Number of participants with presence of contamination on base layer of clothes or skin. Contamination measured with fluorescein solution (5 mL in front of face shield and torso) plus invisible detection paste on forearms and palms of the hands; assessment after removing of outer layer by unblinded assessor with UV lamp; blinded evaluator then inspected all skin and clothes and measured area of contamination. Secondary outcomes were: contamination of inner layers of PAPR system, area size of contamination, number of donning or doffing violations; time required for donning and doffing. 2. Number of participants with donning or removal violation was defined as out of sequence removal, touching or tearing item of clothing, touching body part before hand washing. Used the Mainland-Gart test for the analysis of cross-over studies
Notes	Funding: Physicians' Services Incorporated Foundation and Clinical Teachers' Association of Queen's University; no Conflict of Interest declared

Zamora 2006 *(Continued)*

Risk of bias

Bias	Authors' judgement	Support for judgement
Random sequence generation (selection bias)	Low risk	Participants randomised by coin tossing
Allocation concealment (selection bias)	Unclear risk	Once started, order was known, but unclear if participants could still change groups and if there would be an interest to do so.
Blinding of participants and personnel (performance bias) All outcomes	Unclear risk	Participants knew attire
Blinding of outcome assessment (detection bias) All outcomes	Low risk	Evaluators blind for attire
Incomplete outcome data (attrition bias) All outcomes	Low risk	Apparently all data collected and usable
Selective reporting (reporting bias)	Unclear risk	Apparently all outcomes reported
Other bias	Low risk	No indication of other bias

CDC: Center for Disease Control and Prevention; **CFU:** colony-forming unit; **ECDC:** European Centre for Disease Prevention and Control; **EMT:** emergency medical technician; **EVD:** Ebola virus disease; **HCW:** healthcare worker; **IgG:** immunoglobulin G; **IQR:** interquartile range; **LED:** light-emitting diode; **MD:** Doctor of Medicine; **MPN:** most probable number; **MSF:** Médecins Sans Frontières; n/a: not applicable; **PAPR:** powered, air-purifying respirator; **PFU:** plaque-forming unit; **PLS:** polystyrene latex beads; **PPE:** personal protection equipment; **RCT:** randomised controlled trial; **RN:** Registered Nurse; **SARS:** severe acute respiratory syndrome; **SD:** standard deviation; **UV:** ultraviolet **WHO:** World Health Organization

Characteristics of excluded studies *[ordered by study ID]*

Study	Reason for exclusion
Abrahamson 2006	Uncontrolled study; 1 type of training only
Abualenain 2018	No comparison group
Alraddadi 2016	No comparison group
Anderson 2017	No highly infectious disease exposure
Beam 2011	No control group with an active intervention
Beam 2014	Uncontrolled study; only 1 type of training in donning and doffing studied with video recordings
Beam 2016a	Not an empirical study
Beam 2016b	Not an empirical study

Study	Reason for exclusion
Bearman 2007	Trial of universal gloving, not as part of full-body PPE
Bischoff 2019	No highly infectious disease exposure
Borchert 2007	Description of use of PPE in MHF outbreak, not a case-control or cohort study
Bosc 2016	Wrong comparator
Buianov 1991	Study compares 2 types of PPE for highly infectious diseases but does not measure contamination or infection as outcome, only physiological parameters (native speaker assessment AP)
Butt 2016	Wrong comparator
Casanova 2008	Not a comparative study; only studied 1 method of doffing
Casanova 2018	No comparison group
Castle 2009	Outcome only performance with PPE and not infection rate or adherence
Chandramohan 2018	No comparison group
Christian 2004	Investigation of cluster of SARS infected HCW; not a case-control or cohort study
Chughtai 2013	Overview focusing on mask use only, not part of full-body PPE
Clay 2015	Simulation study; military HCWs; no control group
Coates 2000	Outcome performance only not infection rates or adherence
Coca 2015	Wrong type of participants, thermal manikin study
Coca 2017	Secondary outcomes only
Colebunders 2004	Description of MHF outbreak; not a case-control or cohort study
Cooper 2005	Simulation study, but of facial protection only, no full-body PPE involved
Delaney 2016	No comparison group
Doll 2017a	No comparison group
Doll 2017b	No comparison group
Doshi 2016	No comparison group
Drew 2016	No comparison group
DuBose 2018	Wrong study design
Dunn 2015	Case study of spread of infection in 1 hospital; used in discussion section
Elcin 2016	No comparison group
Fischer 2015	Not a primary study, literature review

Study	Reason for exclusion
Fogel 2017	Wrong study design
Foote 2017	Wrong intervention
Franklin 2016	Not an empirical study
Garibaldi 2019	Secondary outcomes only
Gozel 2013	Description of use of PPE among HCW exposed to CCHF; not case-control or cohort study
Grélot 2015	Measurement of thermal strain, no infection or contamination or compliance measured
Grélot 2016	Measurement of thermal strain, no infection or contamination or compliance measured
Hendler 2000	PPE versus no PPE; outcome performance only
Herlihey 2016	No comparison group
Herlihey 2017	No comparison group
Hersi 2015	Not a primary study, rapid review
Ho 2003	Descriptive study of SARS outbreak and HCWs use of PPE; not a case-control or cohort study
Ho 2004	Compares consistent versus inconsistent use of PPE, not 2 different types
Hon 2008	Evaluation of on-line PPE training; uncontrolled study, no comparison training
Hormbrey 1996	Description of introduction of new clothing; no infection or adherence outcome
Huh 2020	No comparison group
Jacob 2018	Not empirical study
Jaffe 2019	No personal contamination outcome
Jaques 2016	Report contains no data
Jeffs 2007	Description of control of MHF outbreak; not a case-control or cohort study
Jinadatha 2015	Wrong type of participants, investigation of disinfection on different PPE fabrics and components
Jones 2020	Not empirical study
Kahveci 2019	Participants not HCWs
Kang 2017	Wrong study design
Kang 2017a	No comparison group
Kappes Ramirez 2018	Wrong outcomes
Keane 1977	Description of risk of HCW only; no evaluation of PPE safety
Kerstiens 1999	Desription of Ebola outbreak; not case-control or cohort study

Study	Reason for exclusion
Kilinc-Balci 2016	Not an empirical study
Kilinc-Balci 2015	Report contains no data
Kim 2015	No control group, HCWs infected with MERS CoV
Ko 2004	Description of risk of EMT staff; no evaluation of PPE safety
Kogutt 2019	No comparison group
Kratz 2017	Report contains no data
Kwon 2016	No comparison group
Kwon 2017	No comparison group
Lai 2005	Study of SARS IgG prevalence in HCWs who did not become sick, no PPE use measured
Lai 2011	No personal contamination measured only environmental contamination
Lange 2005	Letter to the editor; not primary study
Lau 2004	Compares consistent versus inconsistent use of PPE, not 2 different types
Le 2004	Compares consistent versus inconsistent use of PPE, not 2 different types
Lee 2017	Report contains no data
Lindsley 2012	Test respiratory protection only; not part of full-body PPE
Lindsley 2014	Tests respiratory protection only; not part of full-body PPE
Liu 2009	Compares consistent versus inconsistent use of PPE, not 2 different types
Loeb 2004	Compares consistent versus inconsistent use of PPE, not 2 different types
Low 2005	A review of SARS and HCW; not a primary study
Lowe 2014	Description of PPE use only; no adherence or infection outcomes
Lu 2006	Comparison of viral load in patients infected outside and inside hospital; comparison is with no PPE
Lu 2020	No Intervention
Luo 2011	Simulation study of 1 Tyvek® (duPont) suit only, no comparison suit or no comparison doffing method
Ma 2004	Retrospective case-control study about PPE for SARS, compares consistent versus inconsistent use not 2 types
Makovicka 2018	No highly infectious disease exposure
Malik 2006	Participants not exposed to highly infectious diseases

Study	Reason for exclusion
Marklund 2002	Description of Ebola patient transportation; not an intervention study
Matanock 2014	Description of risk of infection of HCW compared to general population; no evaluation of PPE
McLaws 2016	Not an empirical study
Mehtar 2015	No control group, 2 infection prevention and control training courses
Minnich 2003	Description of ambulance adaptation for transport of highly infected patients; not evaluation or intervention study
Mollura 2015	Review; EVD within radiology wards and on imaging equipment
Moore 2005	Review not intervention study
Morgan 2009	Review of adverse effects of contact precautions
Mumma 2018	No comparison group
Mumma 2019	No Intervention
Muyembe-Tamfum 1999	Description of Ebola outbreak; not case-control or cohort study
Nikiforuk 2017	Wrong patient population
Nishiura 2005	Compares consistent versus inconsistent use of PPE, not 2 different types
Northington 2007	No comparison group; only 1 type of education with follow-up
Novosad 2016	No comparison group
Nyenswah 2015	Case study of EVD cluster including HCWs, but insufficient information on PPE to draw any conclusions
Ofner 2003	SARS case series only; no healthy controls; not case control or cohort study
Ofner-Agostini 2006	SARS case series only; no healthy controls; not case control or cohort study
Ogendo 2008	Eye protection only; not part of full-body PPE
Ong 2013	No exposure to highly infectious diseases
Park 2004	Compares consistent versus inconsistent use of PPE, not 2 different types
Parveen 2018	No comparison group
Pei 2006	Compares consistent versus inconsistent use of PPE, not 2 different types
Phan 2018	Wrong intervention
Phrampus 2016	No comparison group
Porteous 2018	No personal contamination outcome
Quinn 2018	Wrong outcomes

Study	Reason for exclusion
Ragazzoni 2015	No control group, virtual reality simulation training study
Ransjo 1979	No exposure to highly infectious diseases
Reynolds 2006	Case-control study evaluating SARS risk in HCWs in Vietnam but no inclusion of PPE use
Rosenberg 2016	Report of publication of Tomas 2015
Russell 2015	No control group, no outcome, before/after summary card
Scales 2003	Compares consistent versus inconsistent use of PPE, not 2 different types
Schumacher 2010	Comparison is no PPE; outcome is performance time only
Scott Taylor 2017	Wrong outcomes
Seto 2003	Compares consistent versus inconsistent use of PPE, not 2 different types
Shao 2015	Not a primary study, Chinese review
Sorensen 2008	No exposure to highly infectious diseases
Su 2017	No comparison group
Suen 2017	No highly infectious disease exposure
Tartari 2015	No control group, infection control readiness checklist (from 45 countries), no outcome
Teleman 2004	Compares consistent versus inconsistent use of PPE, not 2 different types
Tomas 2015	No comparison used only description of contamination in a simulation study
Tomas 2016a	Wrong intervention
Torres 2015	Not a primary study, literature review
Visnovsky 2019	No personal contamination outcome
Weber 2018	No comparison group
Weber 2019	No Intervention
West 2014	Not a primary study but a commentary
Williams 2019	No comparison group
Xi 2016	No comparison group
Yin 2004	Case-control study of use of PPE for SARS, not comparing 2 different types of PPE
Yuan 2018	Not empirical study
Zellmer 2015	No control group, checklist for removing PPE

Study	Reason for exclusion
Zhou 2003	Follow-up of HCWs exposed to SARS and their PPE and protection measures, not comparative study

CCHF: Crimean-Congo haemorrhagic fever; **EMT:** emergency medical technician; **EVD:** Ebola virsu disease; **HCW:** healthcare worker; **IgG:** immunoglobulin G; **MERS CoV;** Middle East respiratory syndrome coronavirus; **MHF:** Marburg haemorrhagic fever; **PPE:** personal protective equipment; **SARS:** severe acute respiratory syndrome

Characteristics of ongoing studies *[ordered by study ID]*

ChiCTR2000029900

Study name	Renmin Hospital of Wuhan University
Methods	Unclear
Participants	HCWs exposed to COVID-19
Interventions	Infection and prevention strategies
Outcomes	Infection
Starting date	Not reported
Contact information	Chinese trial register
Notes	

ChiCTR2000030317

Study name	West China Hospital of Sichuan University
Methods	RCT
Participants	HCWs exposed to COVID-19
Interventions	Self-made mask
Outcomes	Infection rate
Starting date	Not reported
Contact information	Chinese trials register
Notes	

ChiCTR2000030834

Study name	Tongji Hospital Tongji Medical College Huazhong University Wuhan China -a
Methods	Unclear

ChiCTR2000030834 *(Continued)*

Participants	HCWs exposed to COVID-19
Interventions	Infection prevention and control
Outcomes	Infection
Starting date	Not reported
Contact information	Chinese trials register
Notes	

ChiCTR2000030895

Study name	Tongji Hospital Tongji Medical College Huazhong University Wuhan China -b
Methods	Not reported
Participants	HCWs
Interventions	Infection prevention and control
Outcomes	Infection
Starting date	Not reported
Contact information	Chinese trials register
Notes	

HCW: healthcare worker

DATA AND ANALYSES

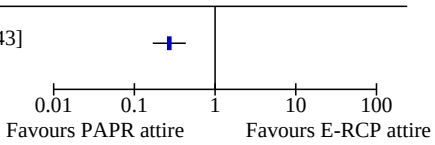
Comparison 1. PAPR versus E-RCP Attire

Outcome or subgroup title	No. of studies	No. of participants	Statistical method	Effect size
1.1 Any contamination	1		Risk Ratio (M-H, Random, 95% CI)	Totals not selected
1.2 Contamination > 1 cm	1		Risk Ratio (M-H, Random, 95% CI)	Totals not selected
1.3 Contamination area	1		Mean Difference (IV, Fixed, 95% CI)	Totals not selected
1.4 Donning noncompliance	1		Risk Ratio (M-H, Random, 95% CI)	Totals not selected
1.5 Doffing noncompliance	1		Risk Ratio (M-H, Random, 95% CI)	Totals not selected
1.6 Donning time	1	100	Mean Difference (IV, Fixed, 95% CI)	Not estimable

Outcome or subgroup title	No. of studies	No. of partici-pants	Statistical method	Effect size
1.7 Doffing time	1	100	Mean Difference (IV, Fixed, 95% CI)	Not estimable

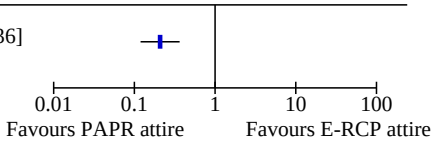
Analysis 1.1. Comparison 1: PAPR versus E-RCP Attire, Outcome 1: Any contamination

Study or Subgroup	PAPR attire Events	Total	E-RCP attire Events	Total	Risk Ratio M-H, Random, 95% CI
Zamora 2006	13	50	48	50	0.27 [0.17 , 0.43]



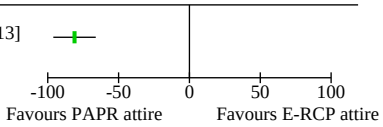
Analysis 1.2. Comparison 1: PAPR versus E-RCP Attire, Outcome 2: Contamination > 1 cm

Study or Subgroup	PAPR attire Events	Total	E-RCP attire Events	Total	Risk Ratio M-H, Random, 95% CI
Zamora 2006	10	50	48	50	0.21 [0.12 , 0.36]



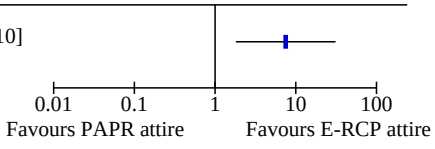
Analysis 1.3. Comparison 1: PAPR versus E-RCP Attire, Outcome 3: Contamination area

Study or Subgroup	PAPR Mean	SD	Total	E-RCP Mean	SD	Total	Mean Difference IV, Fixed, 95% CI
Zamora 2006	1.7	1.5	50	82.8	54	50	-81.10 [-96.07 , -66.13]



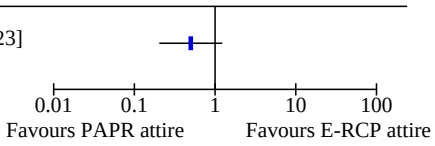
Analysis 1.4. Comparison 1: PAPR versus E-RCP Attire, Outcome 4: Donning noncompliance

Study or Subgroup	PAPR attire Events	Total	E-RCP attire Events	Total	Risk Ratio M-H, Random, 95% CI
Zamora 2006	15	50	2	50	7.50 [1.81 , 31.10]



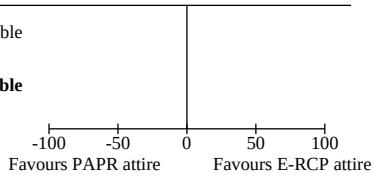
Analysis 1.5. Comparison 1: PAPR versus E-RCP Attire, Outcome 5: Doffing noncompliance

Study or Subgroup	PAPR attire Events	PAPR attire Total	E-RCP attire Events	E-RCP attire Total	Risk Ratio M-H, Random, 95% CI
Zamora 2006	6	50	12	50	0.50 [0.20 , 1.23]



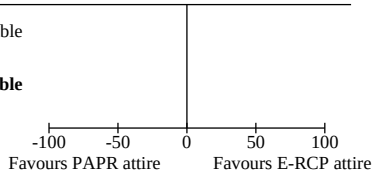
Analysis 1.6. Comparison 1: PAPR versus E-RCP Attire, Outcome 6: Donning time

Study or Subgroup	PAPR Mean	PAPR SD	PAPR Total	E-RCP Mean	E-RCP SD	E-RCP Total	Weight	Mean Difference IV, Fixed, 95% CI
Zamora 2006	377	0	50	118	0	50		Not estimable
Total (95% CI)			**50**			**50**		**Not estimable**
Heterogeneity: Not applicable								
Test for overall effect: Not applicable								
Test for subgroup differences: Not applicable								



Analysis 1.7. Comparison 1: PAPR versus E-RCP Attire, Outcome 7: Doffing time

Study or Subgroup	PAPR Mean	PAPR SD	PAPR Total	E-RCP Mean	E-RCP SD	E-RCP Total	Weight	Mean Difference IV, Fixed, 95% CI
Zamora 2006	472	0	50	135	0	50		Not estimable
Total (95% CI)			**50**			**50**		**Not estimable**
Heterogeneity: Not applicable								
Test for overall effect: Not applicable								
Test for subgroup differences: Not applicable								



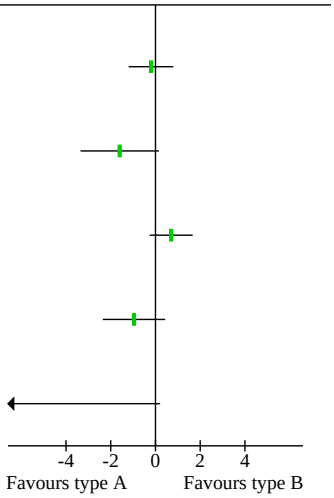
Comparison 2. Four types of PPE attire compared

Outcome or subgroup title	No. of studies	No. of partici-pants	Statistical method	Effect size
2.1 A vs B Contamination, mean number of spots	1		Mean Difference (IV, Fixed, 95% CI)	Totals not selected
2.1.1 Face type A vs type B	1		Mean Difference (IV, Fixed, 95% CI)	Totals not selected
2.1.2 Trunk type A vs type B	1		Mean Difference (IV, Fixed, 95% CI)	Totals not selected
2.1.3 Neck type A vs type B	1		Mean Difference (IV, Fixed, 95% CI)	Totals not selected
2.1.4 Foot type A vs type B	1		Mean Difference (IV, Fixed, 95% CI)	Totals not selected

Outcome or subgroup title	No. of studies	No. of partici-pants	Statistical method	Effect size
2.1.5 Palm type A vs type B	1		Mean Difference (IV, Fixed, 95% CI)	Totals not selected
2.2 A vs B Usability score (1-5)	1		Mean Difference (IV, Fixed, 95% CI)	Totals not selected
2.3 A vs B Donning time	1		Mean Difference (IV, Fixed, 95% CI)	Totals not selected
2.4 A vs B Doffing time	1		Mean Difference (IV, Fixed, 95% CI)	Totals not selected
2.5 A vs D Contamination, mean number of spots	1		Mean Difference (IV, Fixed, 95% CI)	Totals not selected
2.5.1 Face type A vs type D	1		Mean Difference (IV, Fixed, 95% CI)	Totals not selected
2.5.2 Trunk type A vs type D	1		Mean Difference (IV, Fixed, 95% CI)	Totals not selected
2.5.3 Neck type A vs type D	1		Mean Difference (IV, Fixed, 95% CI)	Totals not selected
2.5.4 Foot type A vs type D	1		Mean Difference (IV, Fixed, 95% CI)	Totals not selected
2.5.5 Palm type A vs type D	1		Mean Difference (IV, Fixed, 95% CI)	Totals not selected
2.6 A vs D Usability score (1-5)	1		Mean Difference (IV, Fixed, 95% CI)	Totals not selected
2.7 A vs D Donning time	1		Mean Difference (IV, Fixed, 95% CI)	Totals not selected
2.8 A vs D Doffing time	1		Mean Difference (IV, Fixed, 95% CI)	Totals not selected

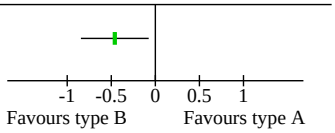
Analysis 2.1. Comparison 2: Four types of PPE attire compared, Outcome 1: A vs B Contamination, mean number of spots

Study or Subgroup	A, not perm not breath Mean	SD	Total	B, permeable but breath Mean	SD	Total	Mean Difference IV, Fixed, 95% CI
2.1.1 Face type A vs type B							
Wong 2004	2.36	1.19	25	2.56	2.25	25	-0.20 [-1.20 , 0.80]
2.1.2 Trunk type A vs type B							
Wong 2004	0.02	0.01	25	1.62	4.47	25	-1.60 [-3.35 , 0.15]
2.1.3 Neck type A vs type B							
Wong 2004	0.82	2.43	25	0.12	0.36	25	0.70 [-0.26 , 1.66]
2.1.4 Foot type A vs type B							
Wong 2004	0.86	2.11	25	1.82	2.86	25	-0.96 [-2.35 , 0.43]
2.1.5 Palm type A vs type B							
Wong 2004	4.2	9.54	25	11.92	17.83	25	-7.72 [-15.65 , 0.21]



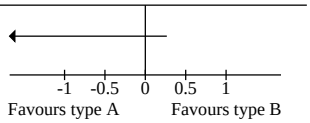
Analysis 2.2. Comparison 2: Four types of PPE attire compared, Outcome 2: A vs B Usability score (1-5)

Study or Subgroup	A, not perm not breath Mean	SD	Total	B, permeable but breath Mean	SD	Total	Mean Difference IV, Fixed, 95% CI
Wong 2004	3.56	0.76	25	4.02	0.62	25	-0.46 [-0.84 , -0.08]



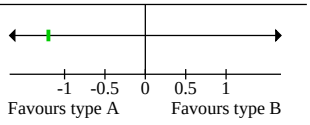
Analysis 2.3. Comparison 2: Four types of PPE attire compared, Outcome 3: A vs B Donning time

Study or Subgroup	A, not perm not breath Mean [Sec]	SD [Sec]	Total	B, permeable but breath Mean [Sec]	SD [Sec]	Total	Mean Difference IV, Fixed, 95% CI [Sec]
Wong 2004	48.84	10.84	25	55.53	14.05	25	-6.69 [-13.65 , 0.27]



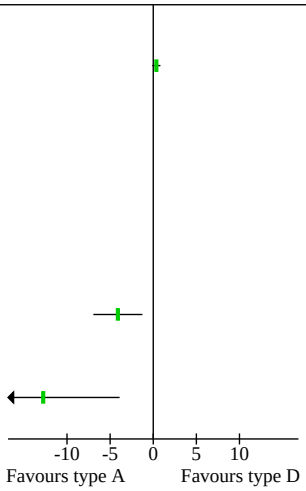
Analysis 2.4. Comparison 2: Four types of PPE attire compared, Outcome 4: A vs B Doffing time

Study or Subgroup	A, not perm not breath Mean [Sec]	SD [Sec]	Total	B, permeable but breath Mean [Sec]	SD [Sec]	Total	Mean Difference IV, Fixed, 95% CI [Sec]
Wong 2004	20.05	5.67	25	21.25	10.64	25	-1.20 [-5.93 , 3.53]



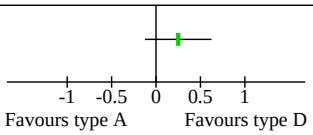
Analysis 2.5. Comparison 2: Four types of PPE attire compared, Outcome 5: A vs D Contamination, mean number of spots

Study or Subgroup	A, not perm not breath Mean	SD	Total	D, fairly perm not breath Mean	SD	Total	Mean Difference IV, Fixed, 95% CI
2.5.1 Face type A vs type D							
Wong 2004	2.36	1.19	25	2	0.14	25	0.36 [-0.11 , 0.83]
2.5.2 Trunk type A vs type D							
Wong 2004	0.02	0.01	25	0	0	25	Not estimable
2.5.3 Neck type A vs type D							
Wong 2004	0.82	2.43	25	0	0	25	Not estimable
2.5.4 Foot type A vs type D							
Wong 2004	0.86	2.11	25	4.96	6.94	25	-4.10 [-6.94 , -1.26]
2.5.5 Palm type A vs type D							
Wong 2004	4.2	9.54	25	16.96	20.49	25	-12.76 [-21.62 , -3.90]



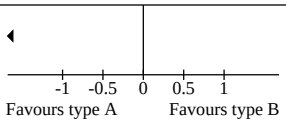
Analysis 2.6. Comparison 2: Four types of PPE attire compared, Outcome 6: A vs D Usability score (1-5)

Study or Subgroup	A, not perm not breath Mean	SD	Total	D, fairly perm not breath Mean	SD	Total	Mean Difference IV, Fixed, 95% CI
Wong 2004	3.56	0.76	25	3.31	0.58	25	0.25 [-0.12 , 0.62]



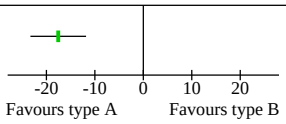
Analysis 2.7. Comparison 2: Four types of PPE attire compared, Outcome 7: A vs D Donning time

Study or Subgroup	A, not perm not breath Mean [Sec]	SD [Sec]	Total	B, permeable but breath Mean [Sec]	SD [Sec]	Total	Mean Difference IV, Fixed, 95% CI [Sec]
Wong 2004	48.84	10.84	25	82.67	22.09	25	-33.83 [-43.48 , -24.18]



Analysis 2.8. Comparison 2: Four types of PPE attire compared, Outcome 8: A vs D Doffing time

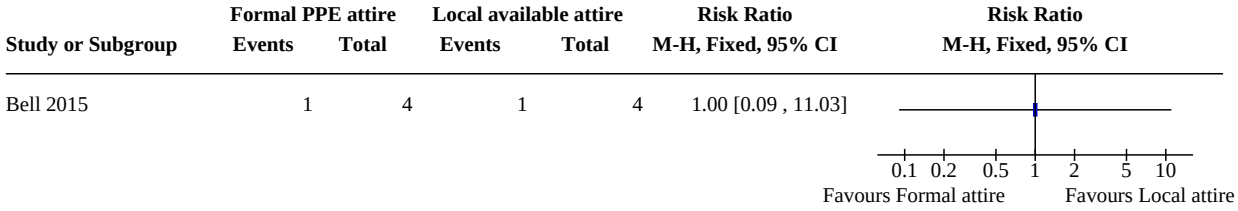
Study or Subgroup	A, not perm not breath Mean [Sec]	SD [Sec]	Total	B, permeable but breath Mean [Sec]	SD [Sec]	Total	Mean Difference IV, Fixed, 95% CI [Sec]
Wong 2004	20.05	5.67	25	37.61	13.5	25	-17.56 [-23.30 , -11.82]



Comparison 3. Formal versus local available attire

Outcome or subgroup title	No. of studies	No. of participants	Statistical method	Effect size
3.1 Contamination	1		Risk Ratio (M-H, Fixed, 95% CI)	Totals not selected

Analysis 3.1. Comparison 3: Formal versus local available attire, Outcome 1: Contamination

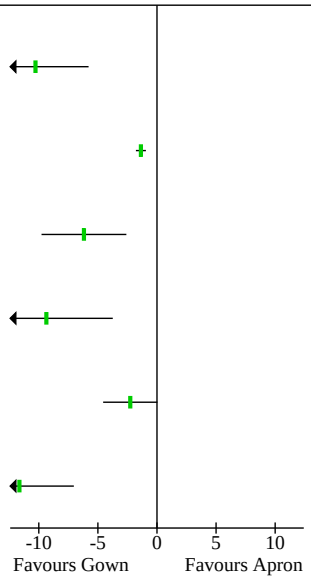


Comparison 4. Gown versus apron

Outcome or subgroup title	No. of studies	No. of participants	Statistical method	Effect size
4.1 Contamination with marker; individual doffing	1		Mean Difference (IV, Fixed, 95% CI)	Totals not selected
4.1.1 small patches	1		Mean Difference (IV, Fixed, 95% CI)	Totals not selected
4.1.2 large patches	1		Mean Difference (IV, Fixed, 95% CI)	Totals not selected
4.1.3 hand	1		Mean Difference (IV, Fixed, 95% CI)	Totals not selected
4.1.4 shoe	1		Mean Difference (IV, Fixed, 95% CI)	Totals not selected
4.1.5 underwear	1		Mean Difference (IV, Fixed, 95% CI)	Totals not selected
4.1.6 environment	1		Mean Difference (IV, Fixed, 95% CI)	Totals not selected
4.2 Contamination with marker; CDC doffing	1		Mean Difference (IV, Fixed, 95% CI)	Totals not selected
4.2.1 small patches	1		Mean Difference (IV, Fixed, 95% CI)	Totals not selected
4.2.2 large patches	1		Mean Difference (IV, Fixed, 95% CI)	Totals not selected
4.2.3 hand	1		Mean Difference (IV, Fixed, 95% CI)	Totals not selected
4.2.4 shoe	1		Mean Difference (IV, Fixed, 95% CI)	Totals not selected
4.2.5 underwear	1		Mean Difference (IV, Fixed, 95% CI)	Totals not selected
4.2.6 environment	1		Mean Difference (IV, Fixed, 95% CI)	Totals not selected

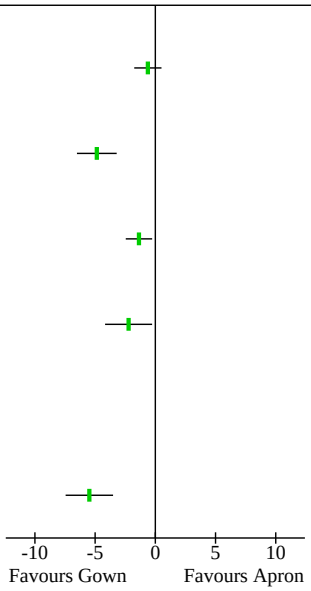
Analysis 4.1. Comparison 4: Gown versus apron, Outcome 1: Contamination with marker; individual doffing

Study or Subgroup	Gown Mean	Gown SD	Gown Total	Apron Mean	Apron SD	Apron Total	Mean Difference IV, Fixed, 95% CI
4.1.1 small patches							
Guo 2014	6.7	6.1518	50	16.98	14.9907	50	-10.28 [-14.77 , -5.79]
4.1.2 large patches							
Guo 2014	0.26	0.5657	50	1.62	1.4142	50	-1.36 [-1.78 , -0.94]
4.1.3 hand							
Guo 2014	2.38	4.2426	50	8.56	12.2329	50	-6.18 [-9.77 , -2.59]
4.1.4 shoe							
Guo 2014	1.08	2.192	50	10.44	20.1525	50	-9.36 [-14.98 , -3.74]
4.1.5 underwear							
Guo 2014	0.06	0.2828	50	2.32	8.2731	50	-2.26 [-4.55 , 0.03]
4.1.6 environment							
Guo 2014	6.96	6.364	50	18.6	15.3442	50	-11.64 [-16.24 , -7.04]



Analysis 4.2. Comparison 4: Gown versus apron, Outcome 2: Contamination with marker; CDC doffing

Study or Subgroup	Gown Mean	Gown SD	Gown Total	Apron Mean	Apron SD	Apron Total	Mean Difference IV, Fixed, 95% CI
4.2.1 small patches							
Guo 2014	1.26	3.677	50	1.88	1.7678	50	-0.62 [-1.75 , 0.51]
4.2.2 large patches							
Guo 2014	0.14	0.3536	50	5	5.9397	50	-4.86 [-6.51 , -3.21]
4.2.3 hand							
Guo 2014	1.82	2.687	50	3.18	2.8991	50	-1.36 [-2.46 , -0.26]
4.2.4 shoe							
Guo 2014	1.26	2.3335	50	3.48	6.6468	50	-2.22 [-4.17 , -0.27]
4.2.5 underwear							
Guo 2014	0	0	50	0.36	1.4849	50	Not estimable
4.2.6 environment							
Guo 2014	1.4	3.677	50	6.88	6.0811	50	-5.48 [-7.45 , -3.51]

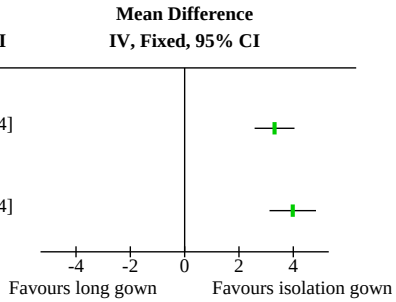


Comparison 5. Three types of PPE compared

Outcome or subgroup title	No. of studies	No. of participants	Statistical method	Effect size
5.1 Time for donning	1		Mean Difference (IV, Fixed, 95% CI)	Totals not selected
5.1.1 PPE 1 vs PPE 3	1		Mean Difference (IV, Fixed, 95% CI)	Totals not selected
5.1.2 PPE 2 vs PPE 3	1		Mean Difference (IV, Fixed, 95% CI)	Totals not selected
5.2 Time for doffing	1		Mean Difference (IV, Fixed, 95% CI)	Totals not selected
5.2.1 PPE 2 vs PPE 3	1		Mean Difference (IV, Fixed, 95% CI)	Totals not selected
5.2.2 PPE 2 vs PPE 3	1		Mean Difference (IV, Fixed, 95% CI)	Totals not selected

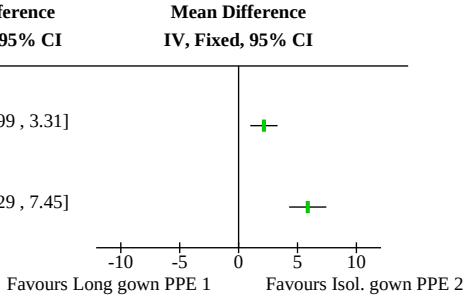
Analysis 5.1. Comparison 5: Three types of PPE compared, Outcome 1: Time for donning

Study or Subgroup	PPE 1 long gown Mean	SD	Total	PPE 3 isolation gown Mean	SD	Total	Mean Difference IV, Fixed, 95% CI
5.1.1 PPE 1 vs PPE 3							
Suen 2018	6.59	1.67	29	3.28	1.15	30	3.31 [2.58 , 4.04]
5.1.2 PPE 2 vs PPE 3							
Suen 2018	7.26	2.06	29	3.28	1.15	30	3.98 [3.12 , 4.84]



Analysis 5.2. Comparison 5: Three types of PPE compared, Outcome 2: Time for doffing

Study or Subgroup	PPE 1 long gown Mean	SD	Total	PPE 3 isolation gown Mean	SD	Total	Mean Difference IV, Fixed, 95% CI
5.2.1 PPE 2 vs PPE 3							
Suen 2018	6.59	2.59	29	4.44	1.87	30	2.15 [0.99 , 3.31]
5.2.2 PPE 2 vs PPE 3							
Suen 2018	10.31	3.93	29	4.44	1.87	30	5.87 [4.29 , 7.45]

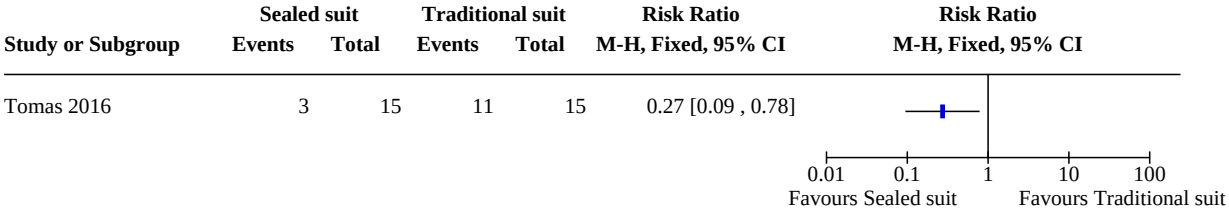


Comparison 6. Gown sealed gloves versus standard gown

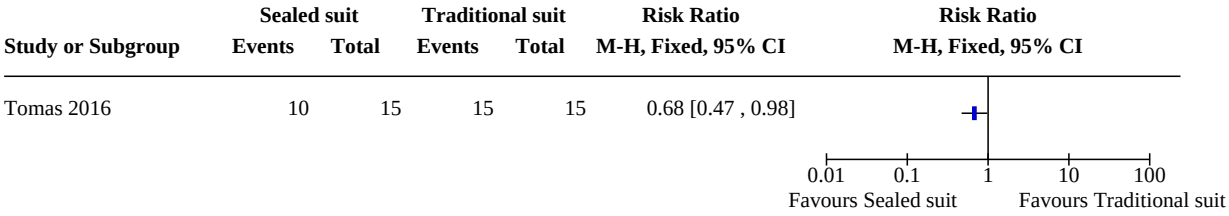
Outcome or subgroup title	No. of studies	No. of participants	Statistical method	Effect size
6.1 Contamination fluorescent lotion	1		Risk Ratio (M-H, Fixed, 95% CI)	Totals not selected

Outcome or subgroup title	No. of studies	No. of partici-pants	Statistical method	Effect size
6.2 Contamination MS2	1		Risk Ratio (M-H, Fixed, 95% CI)	Totals not selected

Analysis 6.1. Comparison 6: Gown sealed gloves versus standard gown, Outcome 1: Contamination fluorescent lotion



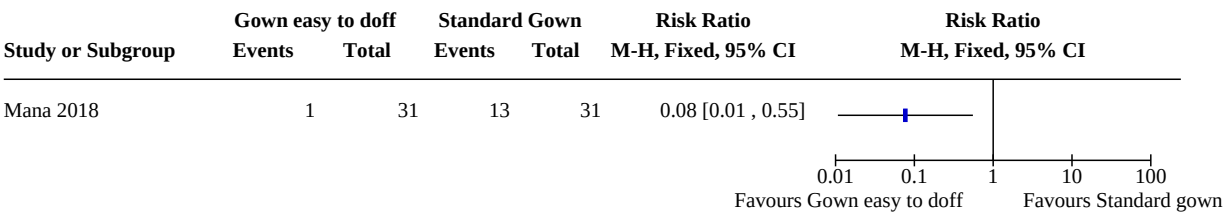
Analysis 6.2. Comparison 6: Gown sealed gloves versus standard gown, Outcome 2: Contamination MS2



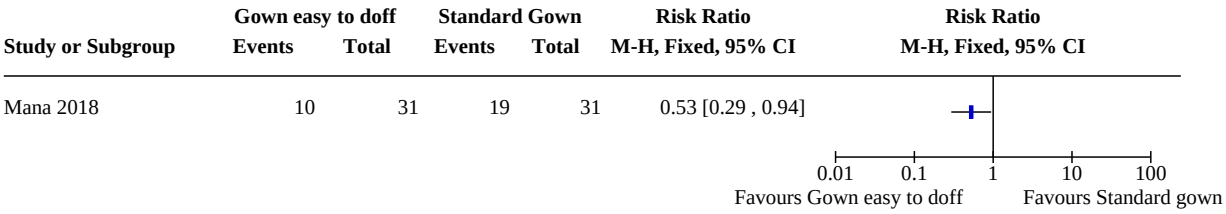
Comparison 7. Gown easy to doff versus standard gown

Outcome or subgroup title	No. of studies	No. of partici-pants	Statistical method	Effect size
7.1 Contamination with fluorescent marker	1		Risk Ratio (M-H, Fixed, 95% CI)	Totals not selected
7.2 Contamination with bacteriophage	1		Risk Ratio (M-H, Fixed, 95% CI)	Totals not selected

Analysis 7.1. Comparison 7: Gown easy to doff versus standard gown, Outcome 1: Contamination with fluorescent marker



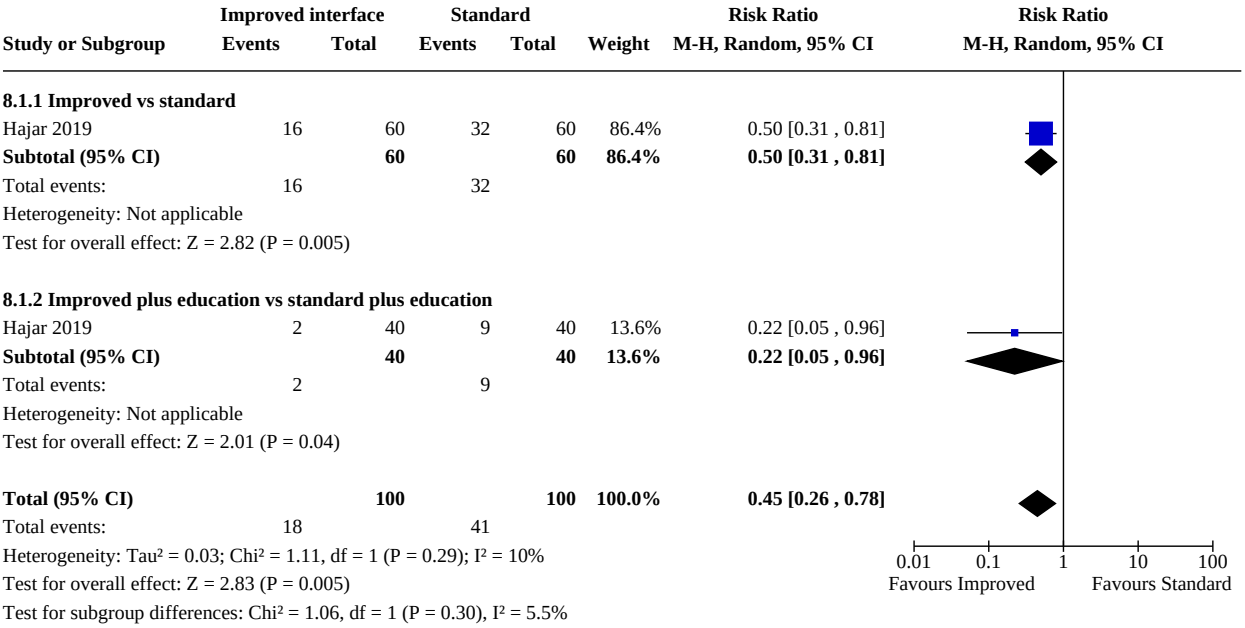
Analysis 7.2. Comparison 7: Gown easy to doff versus standard gown, Outcome 2: Contamination with bacteriophage



Comparison 8. Gown with gown-glove improvement vs standard gown-gloves

Outcome or subgroup title	No. of studies	No. of participants	Statistical method	Effect size
8.1 People with contamination	1	200	Risk Ratio (M-H, Random, 95% CI)	0.45 [0.26, 0.78]
8.1.1 Improved vs standard	1	120	Risk Ratio (M-H, Random, 95% CI)	0.50 [0.31, 0.81]
8.1.2 Improved plus education vs standard plus education	1	80	Risk Ratio (M-H, Random, 95% CI)	0.22 [0.05, 0.96]

Analysis 8.1. Comparison 8: Gown with gown-glove improvement vs standard gown-gloves, Outcome 1: People with contamination

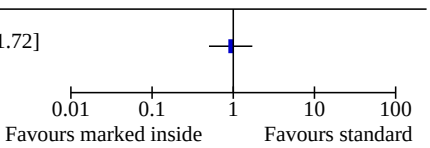


Comparison 9. Gown with marked inside versus standard gown

Outcome or subgroup title	No. of studies	No. of participants	Statistical method	Effect size
9.1 Noncompliance donning: people with errors	1		Risk Ratio (M-H, Fixed, 95% CI)	Totals not selected
9.2 Noncompliance: errors during performance	1		Mean Difference (IV, Fixed, 95% CI)	Totals not selected
9.3 Noncompliance doffing: people with errors	1		Odds Ratio (M-H, Fixed, 95% CI)	Totals not selected

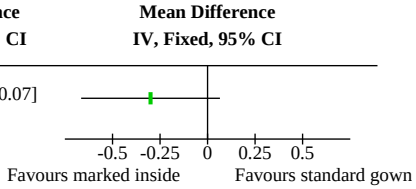
Analysis 9.1. Comparison 9: Gown with marked inside versus standard gown, Outcome 1: Noncompliance donning: people with errors

Study or Subgroup	Gown marked inside Events	Total	Standard gown Events	Total	Risk Ratio M-H, Fixed, 95% CI
Drews 2019	13	40	14	40	0.93 [0.50 , 1.72]



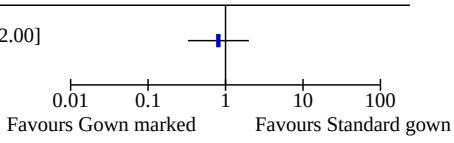
Analysis 9.2. Comparison 9: Gown with marked inside versus standard gown, Outcome 2: Noncompliance: errors during performance

Study or Subgroup	Gown marked inside Mean	SD	Total	Standard gown Mean	SD	Total	Mean Difference IV, Fixed, 95% CI
Drews 2019	0.9	0.9	40	1.2	0.76	40	-0.30 [-0.67 , 0.07]



Analysis 9.3. Comparison 9: Gown with marked inside versus standard gown, Outcome 3: Noncompliance doffing: people with errors

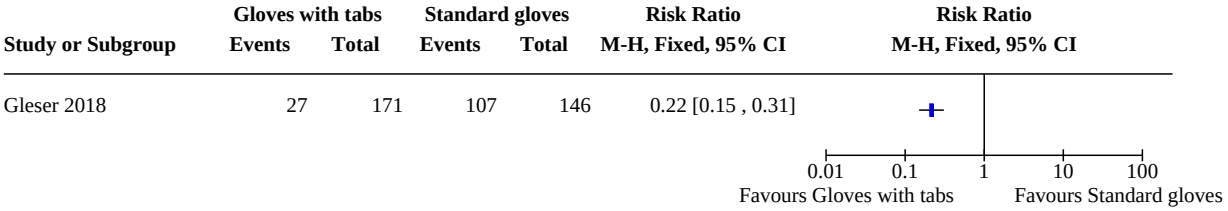
Study or Subgroup	Gown marked inside Events	Total	Standard gown Events	Total	Odds Ratio M-H, Fixed, 95% CI
Drews 2019	14	40	16	40	0.81 [0.33 , 2.00]



Comparison 10. Gloves with tab versus standard gloves

Outcome or subgroup title	No. of studies	No. of participants	Statistical method	Effect size
10.1 Any contamination of hands	1		Risk Ratio (M-H, Fixed, 95% CI)	Totals not selected

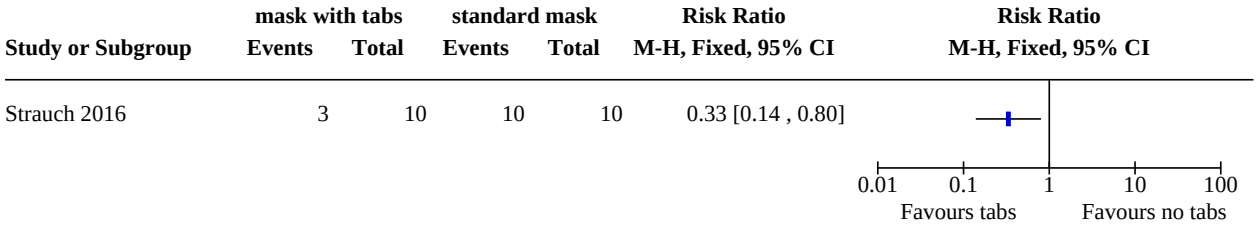
Analysis 10.1. Comparison 10: Gloves with tab versus standard gloves, Outcome 1: Any contamination of hands



Comparison 11. Mask with tabs versus no mask tabs

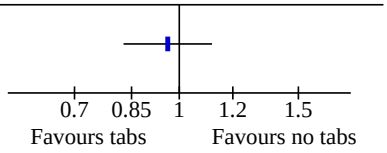
Outcome or subgroup title	No. of studies	No. of participants	Statistical method	Effect size
11.1 Contamination of head from hands	1		Risk Ratio (M-H, Fixed, 95% CI)	Totals not selected
11.2 Contamination of hands from mask	1		Risk Ratio (M-H, Fixed, 95% CI)	Totals not selected

Analysis 11.1. Comparison 11: Mask with tabs versus no mask tabs, Outcome 1: Contamination of head from hands



Analysis 11.2. Comparison 11: Mask with tabs versus no mask tabs, Outcome 2: Contamination of hands from mask

Study or Subgroup	mask with tabs Events	Total	standard mask Events	Total	Risk Ratio M-H, Fixed, 95% CI
Strauch 2016	50	60	52	60	0.96 [0.83 , 1.12]

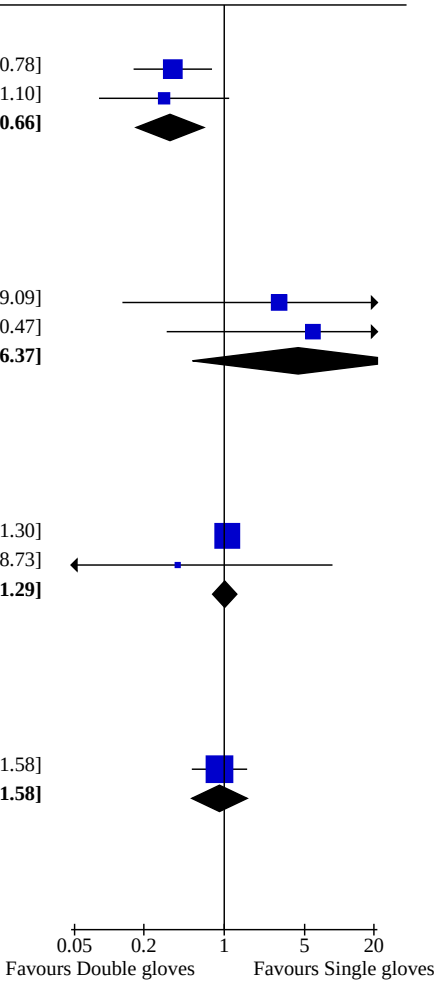


Comparison 12. Doffing with double gloves versus doffing with single gloves

Outcome or subgroup title	No. of studies	No. of participants	Statistical method	Effect size
12.1 Contamination: virus detected	2		Risk Ratio (M-H, Fixed, 95% CI)	Subtotals only
12.1.1 All body parts	2	58	Risk Ratio (M-H, Fixed, 95% CI)	0.34 [0.17, 0.66]
12.1.2 Face	2	58	Risk Ratio (M-H, Fixed, 95% CI)	4.39 [0.53, 36.37]
12.1.3 Shirt	2	58	Risk Ratio (M-H, Fixed, 95% CI)	1.01 [0.79, 1.29]
12.1.4 Pants	1	36	Risk Ratio (M-H, Fixed, 95% CI)	0.91 [0.52, 1.58]
12.2 Contamination: virus quantity	1		Mean Difference (IV, Fixed, 95% CI)	Totals not selected
12.2.1 Dominant hand	1		Mean Difference (IV, Fixed, 95% CI)	Totals not selected
12.2.2 Non-dominant hand	1		Mean Difference (IV, Fixed, 95% CI)	Totals not selected
12.2.3 Face	1		Mean Difference (IV, Fixed, 95% CI)	Totals not selected
12.2.4 Shirt	1		Mean Difference (IV, Fixed, 95% CI)	Totals not selected
12.2.5 Pants	1		Mean Difference (IV, Fixed, 95% CI)	Totals not selected
12.3 Non-compliance: any error	1		Risk Ratio (M-H, Fixed, 95% CI)	Totals not selected
12.4 Contamination with fluorescent	1		Risk Ratio (M-H, Random, 95% CI)	Totals not selected

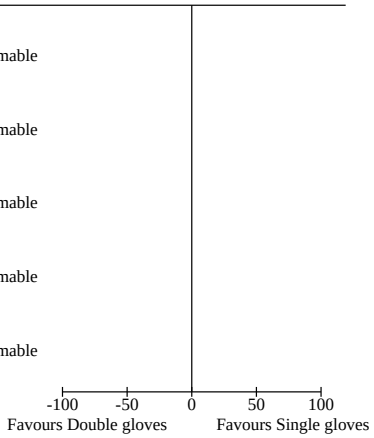
Analysis 12.1. Comparison 12: Doffing with double gloves versus doffing with single gloves, Outcome 1: Contamination: virus detected

Study or Subgroup	Double gloves Events	Total	Single gloves Events	Total	Weight	Risk Ratio M-H, Fixed, 95% CI
12.1.1 All body parts						
Casanova 2012	5	18	14	18	65.8%	0.36 [0.16 , 0.78]
Osei-Bonsu 2019	2	10	8	12	34.2%	0.30 [0.08 , 1.10]
Subtotal (95% CI)		**28**		**30**	**100.0%**	**0.34 [0.17 , 0.66]**
Total events:	7		22			
Heterogeneity: Chi² = 0.05, df = 1 (P = 0.82); I² = 0%						
Test for overall effect: Z = 3.14 (P = 0.002)						
12.1.2 Face						
Casanova 2012	1	18	0	18	52.2%	3.00 [0.13 , 69.09]
Osei-Bonsu 2019	2	10	0	12	47.8%	5.91 [0.32 , 110.47]
Subtotal (95% CI)		**28**		**30**	**100.0%**	**4.39 [0.53 , 36.37]**
Total events:	3		0			
Heterogeneity: Chi² = 0.10, df = 1 (P = 0.76); I² = 0%						
Test for overall effect: Z = 1.37 (P = 0.17)						
12.1.3 Shirt						
Casanova 2012	17	18	16	18	92.1%	1.06 [0.87 , 1.30]
Osei-Bonsu 2019	0	10	1	12	7.9%	0.39 [0.02 , 8.73]
Subtotal (95% CI)		**28**		**30**	**100.0%**	**1.01 [0.79 , 1.29]**
Total events:	17		17			
Heterogeneity: Chi² = 0.61, df = 1 (P = 0.43); I² = 0%						
Test for overall effect: Z = 0.08 (P = 0.94)						
12.1.4 Pants						
Casanova 2012	10	18	11	18	100.0%	0.91 [0.52 , 1.58]
Subtotal (95% CI)		**18**		**18**	**100.0%**	**0.91 [0.52 , 1.58]**
Total events:	10		11			
Heterogeneity: Not applicable						
Test for overall effect: Z = 0.34 (P = 0.74)						
Test for subgroup differences: Chi² = 11.08, df = 3 (P = 0.01), I² = 72.9%						



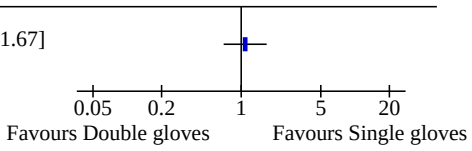
Analysis 12.2. Comparison 12: Doffing with double gloves versus doffing with single gloves, Outcome 2: Contamination: virus quantity

Study or Subgroup	Double gloves Mean [PFU]	SD [PFU]	Total	Single gloves Mean [PFU]	SD [PFU]	Total	Mean Difference IV, Fixed, 95% CI [PFU]
12.2.1 Dominant hand							
Casanova 2012	0.36	0	18	1.44	0	18	Not estimable
12.2.2 Non-dominant hand							
Casanova 2012	0.28	0	18	0.65	0	18	Not estimable
12.2.3 Face							
Casanova 2012	0	0	18	0.11	0	18	Not estimable
12.2.4 Shirt							
Casanova 2012	2.33	0	18	1.93	0	18	Not estimable
12.2.5 Pants							
Casanova 2012	1.05	0	18	0.97	0	18	Not estimable



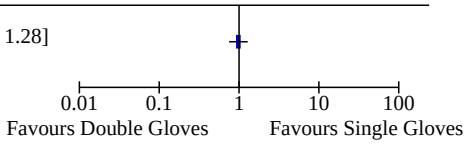
Analysis 12.3. Comparison 12: Doffing with double gloves versus doffing with single gloves, Outcome 3: Non-compliance: any error

Study or Subgroup	Double gloves Events	Total	Single gloves Events	Total	Risk Ratio M-H, Fixed, 95% CI
Casanova 2012	13	18	12	18	1.08 [0.70 , 1.67]



Analysis 12.4. Comparison 12: Doffing with double gloves versus doffing with single gloves, Outcome 4: Contamination with fluorescent

Study or Subgroup	Double gloves Events	Total	Single gloves Events	Total	Risk Ratio M-H, Random, 95% CI
Osei-Bonsu 2019	9	10	11	12	0.98 [0.75 , 1.28]



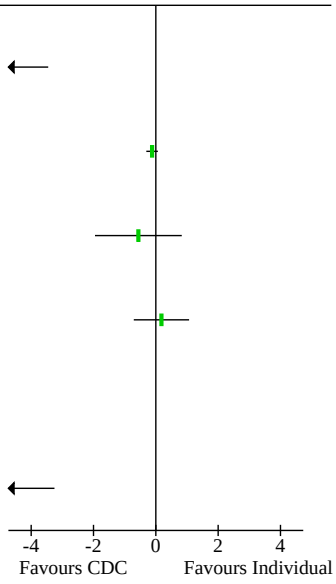
Comparison 13. CDC versus individual doffing

Outcome or subgroup title	No. of studies	No. of participants	Statistical method	Effect size
13.1 Gown: contamination with fluor marker	1		Mean Difference (IV, Fixed, 95% CI)	Totals not selected
13.1.1 small patch	1		Mean Difference (IV, Fixed, 95% CI)	Totals not selected

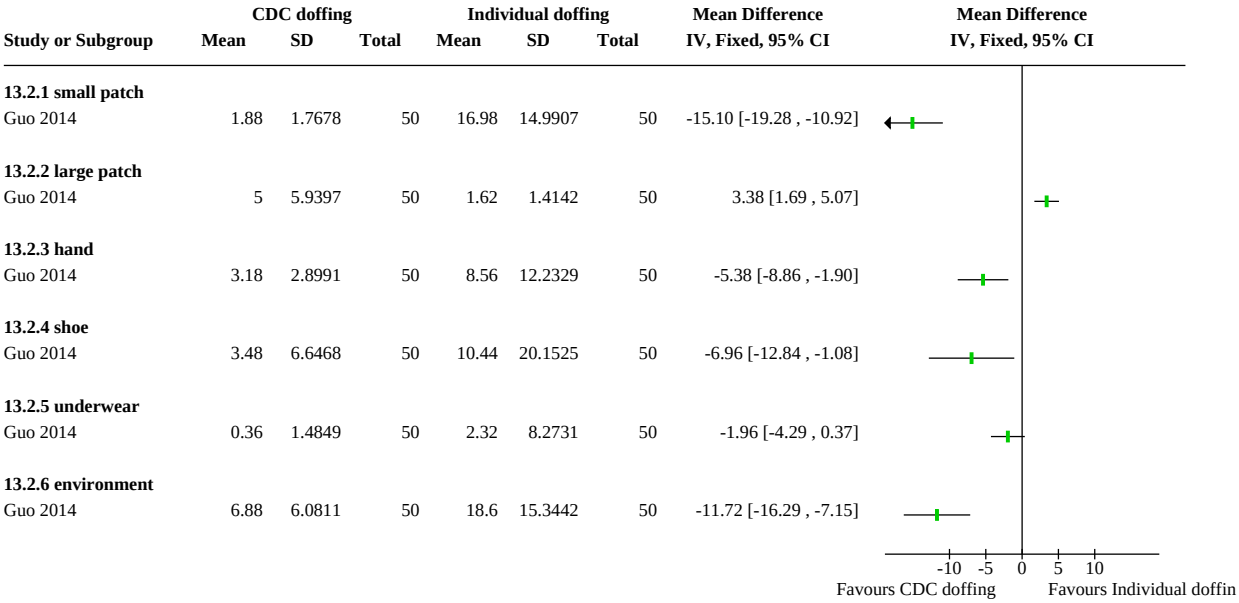
Outcome or subgroup title	No. of studies	No. of participants	Statistical method	Effect size
13.1.2 large patch	1		Mean Difference (IV, Fixed, 95% CI)	Totals not selected
13.1.3 hand	1		Mean Difference (IV, Fixed, 95% CI)	Totals not selected
13.1.4 shoe	1		Mean Difference (IV, Fixed, 95% CI)	Totals not selected
13.1.5 underwear	1		Mean Difference (IV, Fixed, 95% CI)	Totals not selected
13.1.6 environment	1		Mean Difference (IV, Fixed, 95% CI)	Totals not selected
13.2 Apron: contamination with fluor marker	1		Mean Difference (IV, Fixed, 95% CI)	Totals not selected
13.2.1 small patch	1		Mean Difference (IV, Fixed, 95% CI)	Totals not selected
13.2.2 large patch	1		Mean Difference (IV, Fixed, 95% CI)	Totals not selected
13.2.3 hand	1		Mean Difference (IV, Fixed, 95% CI)	Totals not selected
13.2.4 shoe	1		Mean Difference (IV, Fixed, 95% CI)	Totals not selected
13.2.5 underwear	1		Mean Difference (IV, Fixed, 95% CI)	Totals not selected
13.2.6 environment	1		Mean Difference (IV, Fixed, 95% CI)	Totals not selected

Analysis 13.1. Comparison 13: CDC versus individual doffing, Outcome 1: Gown: contamination with fluor marker

Study or Subgroup	CDC Mean	CDC SD	CDC Total	Individual Mean	Individual SD	Individual Total	Mean Difference IV, Fixed, 95% CI
13.1.1 small patch							
Guo 2014	1.26	3.677	50	6.7	6.1518	50	-5.44 [-7.43 , -3.45]
13.1.2 large patch							
Guo 2014	0.14	0.3536	50	0.26	0.5657	50	-0.12 [-0.30 , 0.06]
13.1.3 hand							
Guo 2014	1.82	2.687	50	2.38	4.2426	50	-0.56 [-1.95 , 0.83]
13.1.4 shoe							
Guo 2014	1.26	2.3335	50	1.08	2.192	50	0.18 [-0.71 , 1.07]
13.1.5 underwear							
Guo 2014	0	0	50	0.06	0.2828	50	Not estimable
13.1.6 environment							
Guo 2014	1.4	3.677	50	6.69	6.364	50	-5.29 [-7.33 , -3.25]



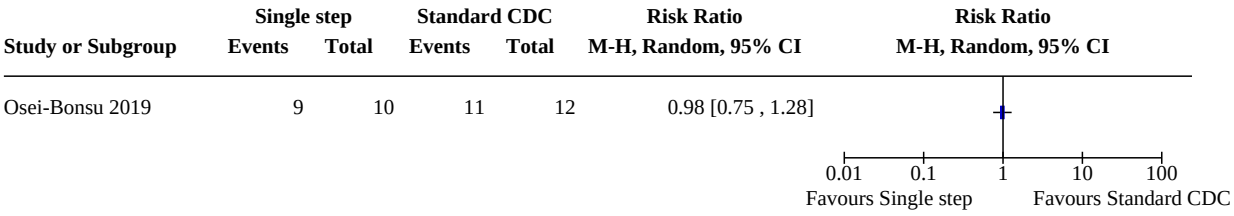
Analysis 13.2. Comparison 13: CDC versus individual doffing, Outcome 2: Apron: contamination with fluor marker



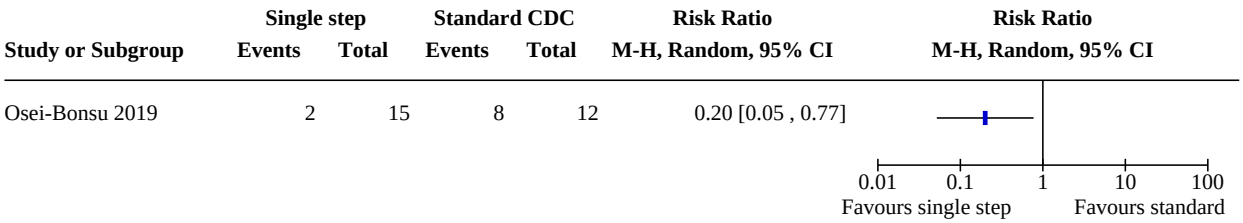
Comparison 14. Single-step doffing vs CDC standard

Outcome or subgroup title	No. of studies	No. of partici-pants	Statistical method	Effect size
14.1 Fluorescent contamination	1		Risk Ratio (M-H, Random, 95% CI)	Totals not selected
14.2 Bacterial contamination	1		Risk Ratio (M-H, Random, 95% CI)	Totals not selected

Analysis 14.1. Comparison 14: Single-step doffing vs CDC standard, Outcome 1: Fluorescent contamination



Analysis 14.2. Comparison 14: Single-step doffing vs CDC standard, Outcome 2: Bacterial contamination



Comparison 15. Doffing with extra sanitation of gloves versus standard no sanitation

Outcome or subgroup title	No. of studies	No. of participants	Statistical method	Effect size
15.1 Bacterial contamination	1		Risk Ratio (M-H, Random, 95% CI)	Totals not selected
15.1.1 Alcohol-based hand rub	1		Risk Ratio (M-H, Random, 95% CI)	Totals not selected

Analysis 15.1. Comparison 15: Doffing with extra sanitation of gloves versus standard no sanitation, Outcome 1: Bacterial contamination

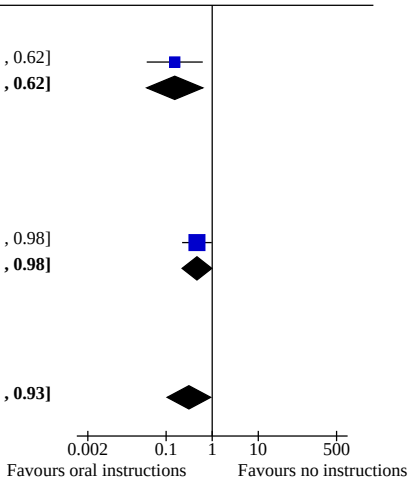
Comparison 16. Donning and doffing with instructions versus without instructions

Outcome or subgroup title	No. of studies	No. of participants	Statistical method	Effect size
16.1 People with one or more errors	1	120	Risk Ratio (M-H, Random, 95% CI)	0.31 [0.11, 0.93]
16.1.1 Basic PPE	1	60	Risk Ratio (M-H, Random, 95% CI)	0.15 [0.04, 0.62]
16.1.2 Enhanced PPE	1	60	Risk Ratio (M-H, Random, 95% CI)	0.47 [0.22, 0.98]
16.2 Non-compliance: mean errors	1	120	Mean Difference (IV, Random, 95% CI)	-0.89 [-1.36, -0.41]
16.2.1 Basic PPE	1	60	Mean Difference (IV, Random, 95% CI)	-0.70 [-1.15, -0.25]
16.2.2 Enhanced PPE	1	60	Mean Difference (IV, Random, 95% CI)	-1.20 [-1.87, -0.53]

Outcome or subgroup title	No. of studies	No. of partici-pants	Statistical method	Effect size
16.3 Fluorescence contamination	1		Mean Difference (IV, Random, 95% CI)	Totals not selected

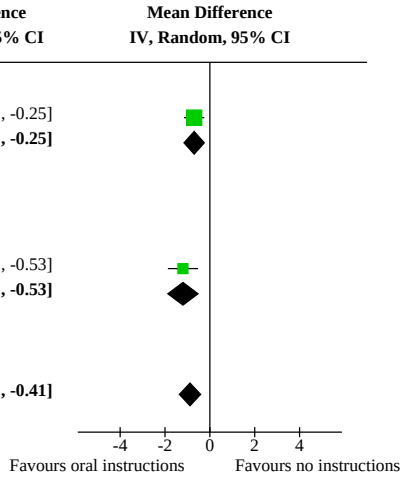
Analysis 16.1. Comparison 16: Donning and doffing with instructions versus without instructions, Outcome 1: People with one or more errors

Study or Subgroup	Spoken instructions Events	Total	No spoken instructions Events	Total	Weight	Risk Ratio M-H, Random, 95% CI
16.1.1 Basic PPE						
Casalino 2015	2	30	13	30	36.2%	0.15 [0.04 , 0.62]
Subtotal (95% CI)		**30**		**30**	**36.2%**	**0.15 [0.04 , 0.62]**
Total events:	2		13			
Heterogeneity: Not applicable						
Test for overall effect: Z = 2.62 (P = 0.009)						
16.1.2 Enhanced PPE						
Casalino 2015	7	30	15	30	63.8%	0.47 [0.22 , 0.98]
Subtotal (95% CI)		**30**		**30**	**63.8%**	**0.47 [0.22 , 0.98]**
Total events:	7		15			
Heterogeneity: Not applicable						
Test for overall effect: Z = 2.02 (P = 0.04)						
Total (95% CI)		**60**		**60**	**100.0%**	**0.31 [0.11 , 0.93]**
Total events:	9		28			
Heterogeneity: Tau² = 0.34; Chi² = 2.04, df = 1 (P = 0.15); I² = 51%						
Test for overall effect: Z = 2.10 (P = 0.04)						
Test for subgroup differences: Chi² = 1.89, df = 1 (P = 0.17), I² = 47.0%						

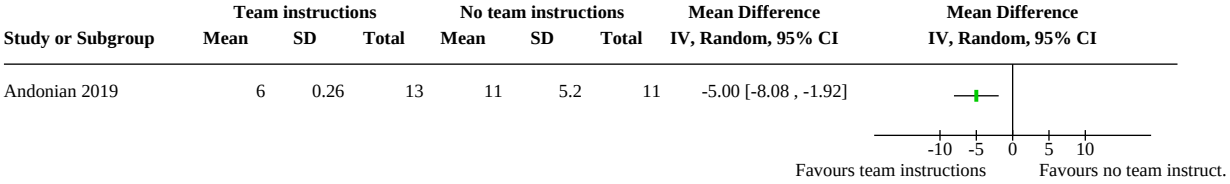


Analysis 16.2. Comparison 16: Donning and doffing with instructions versus without instructions, Outcome 2: Non-compliance: mean errors

Study or Subgroup	Spoken instructions Mean	SD	Total	No spoken instructions Mean	SD	Total	Weight	Mean Difference IV, Random, 95% CI
16.2.1 Basic PPE								
Casalino 2015	0.1	0.4	30	0.8	1.2	30	62.9%	-0.70 [-1.15 , -0.25]
Subtotal (95% CI)			**30**			**30**	**62.9%**	**-0.70 [-1.15 , -0.25]**
Heterogeneity: Not applicable								
Test for overall effect: Z = 3.03 (P = 0.002)								
16.2.2 Enhanced PPE								
Casalino 2015	0.3	0.8	30	1.5	1.7	30	37.1%	-1.20 [-1.87 , -0.53]
Subtotal (95% CI)			**30**			**30**	**37.1%**	**-1.20 [-1.87 , -0.53]**
Heterogeneity: Not applicable								
Test for overall effect: Z = 3.50 (P = 0.0005)								
Total (95% CI)			**60**			**60**	**100.0%**	**-0.89 [-1.36 , -0.41]**
Heterogeneity: Tau² = 0.04; Chi² = 1.46, df = 1 (P = 0.23); I² = 32%								
Test for overall effect: Z = 3.67 (P = 0.0002)								
Test for subgroup differences: Chi² = 1.46, df = 1 (P = 0.23), I² = 31.6%								



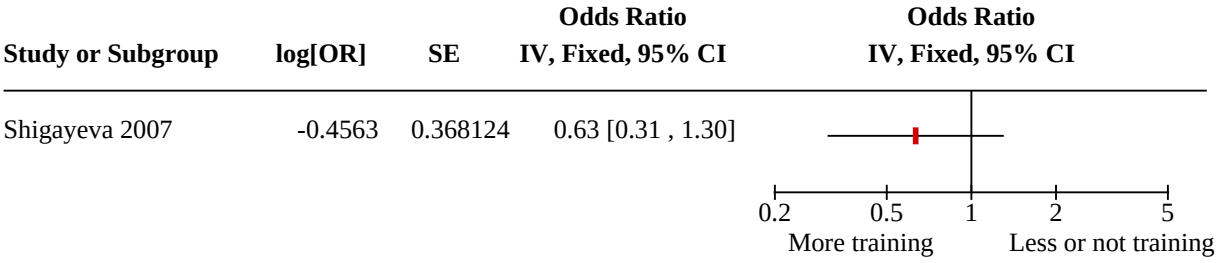
Analysis 16.3. Comparison 16: Donning and doffing with instructions versus without instructions, Outcome 3: Fluorescence contamination



Comparison 17. Active training in PPE use versus passive training

Outcome or subgroup title	No. of studies	No. of participants	Statistical method	Effect size
17.1 Noncompliance with PPE	1		Odds Ratio (IV, Fixed, 95% CI)	Totals not selected

Analysis 17.1. Comparison 17: Active training in PPE use versus passive training, Outcome 1: Noncompliance with PPE

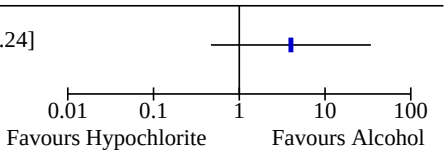


Comparison 18. Doffing with hypochlorite versus doffing with alcohol-based glove sanitiser

Outcome or subgroup title	No. of studies	No. of participants	Statistical method	Effect size
18.1 Contamination MS2	1		Risk Ratio (M-H, Fixed, 95% CI)	Totals not selected
18.2 Contamination Ph6	1	15	Odds Ratio (M-H, Fixed, 95% CI)	Not estimable

Analysis 18.1. Comparison 18: Doffing with hypochlorite versus doffing with alcohol-based glove sanitiser, Outcome 1: Contamination MS2

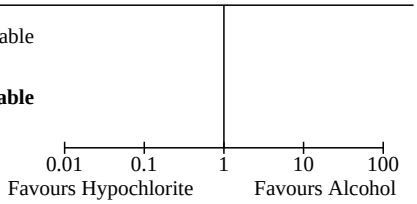
Study or Subgroup	Hypochlorite Events	Hypochlorite Total	Alcohol Events	Alcohol Total	Risk Ratio M-H, Fixed, 95% CI
Casanova 2016	2	5	1	10	4.00 [0.47 , 34.24]



Analysis 18.2. Comparison 18: Doffing with hypochlorite versus doffing with alcohol-based glove sanitiser, Outcome 2: Contamination Ph6

Study or Subgroup	Hypochlorite Events	Hypochlorite Total	Alcohol Events	Alcohol Total	Weight	Odds Ratio M-H, Fixed, 95% CI
Casanova 2016	0	5	0	10		Not estimable
Total (95% CI)		**5**		**10**		**Not estimable**
Total events:	0		0			

Heterogeneity: Not applicable
Test for overall effect: Not applicable
Test for subgroup differences: Not applicable

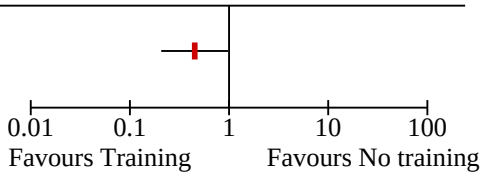


Comparison 19. Active training in PPE doffing versus passive training

Outcome or subgroup title	No. of studies	No. of participants	Statistical method	Effect size
19.1 Noncompliance doffing protocol	1		Odds Ratio (IV, Fixed, 95% CI)	Totals not selected

Analysis 19.1. Comparison 19: Active training in PPE doffing versus passive training, Outcome 1: Noncompliance doffing protocol

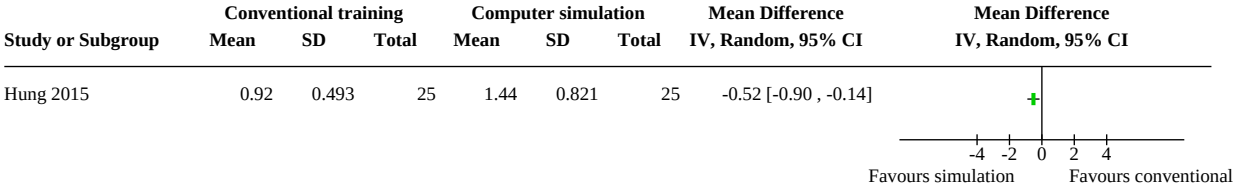
Study or Subgroup	log[OR]	SE	Odds Ratio IV, Fixed, 95% CI
Shigayeva 2007	-0.79694	0.397	0.45 [0.21 , 0.98]



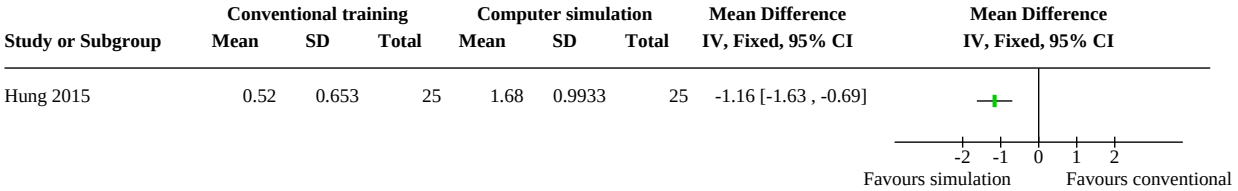
Comparison 20. Computer simulation versus no simulation

Outcome or subgroup title	No. of studies	No. of participants	Statistical method	Effect size
20.1 Number of errors while donning	1		Mean Difference (IV, Random, 95% CI)	Totals not selected
20.2 Number of errors while doffing	1		Mean Difference (IV, Fixed, 95% CI)	Totals not selected

Analysis 20.1. Comparison 20: Computer simulation versus no simulation, Outcome 1: Number of errors while donning



Analysis 20.2. Comparison 20: Computer simulation versus no simulation, Outcome 2: Number of errors while doffing



Comparison 21. Video-based learning versus traditional lecture

Outcome or subgroup title	No. of studies	No. of participants	Statistical method	Effect size
21.1 Skills in PPE donning	1		Mean Difference (IV, Fixed, 95% CI)	Totals not selected

Analysis 21.1. Comparison 21: Video-based learning versus traditional lecture, Outcome 1: Skills in PPE donning

ADDITIONAL TABLES

Table 1. Exposure and outcome in simulation studies

Study ID	Exposure						Outcome		
	Agent	Name	Solution	Amount	Additions	Exposure method	Detection	Photographs	Measure
Andonian 2019	Fluorescent fluid/microbeads	Powder (Glitter Bug)/fluorescent 2-µm polystyrene latex bead (PLSs)	Grapeseed oil and water (1:6 oil-to-water ratio)/in aerosol	75 mg/mL	-	Pesticide hand sprayer: 5 sweeping passes of sprayer from head to feet on the front and back of the HCW/4 min of continuous aerosol generation while the HCW turned 90° every 60 s	UV-light/PLS detection was performed by counting via epifluorescent microscopy	No	Number of body sites with fluorescent marker/with PLS
Bell 2015	Fluorescent	Glogerm, Tide, Bright Dyes Orange Dye	Water	100 mL	Oatmeal, chocolate powder, crushed cereal	100 mL splashed on the front torso of their garment	UV LED black light, Chauvet	Yes	Contaminated yes/no
Buianov 2004	Microbes	?	10^8 CFU/m^3	?	?	?	?	?	?
Casanova 2012	Virus	MS2	10^5 PFU/5 muL	25 muL	?	Shoulder, respirator, eye protection, hand 5 drops of 5 muL	Swabs of face and hands; extraction gloves, scrubs	n/a	Any contamination yes/no; mean Log10 PFU recovered
Casanova 2016	Virus	MS2, Phi6	10^8 MS2, 10^7 Phi6/5 muL	25 muL	?	Hand, shoulder, face-shield, boot	Swabs of face and hands; extraction gloves, scrubs	n/a	Any contamination yes/no
Chughtai 2018	Fluorescent	Fluorescent spray: Glitter Bug	?	0.5 mL	?	Rubbed over hands; sprayed on front and	UV light	No	People with contaminated patches

Table 1. Exposure and outcome in simulation studies *(Continued)*

						sides from 1 m distance			
Gleser 2018	Fluorescent	Schulke	?	5 mL	No	Distributed equally on the gloves	UV box	No	Hand contamination (yes/no)
Guo 2014	Fluorescent	Glogerm	Oil and water	?	No	Sprayed 3.8 g of the lotion onto the upper body of the subject at a distance of 60 cm from the participant	UV scan	No	Number of stains
Hajar 2019	Fluorescent	Fluorescent solution (Super Blue Invisible Ink, Black Light World)	?	0.5 mL	?	Rubbed over gloved hands appr 15 s	Black light	no	Sites per person/people with contamination
Hall 2018	Fluorescent	VIOLET-tool	Water, glycerol	800 mL (blue UV)	Flour, salt	Manikin vomited, produced diarrhoea, sweat and cough	UV-A strip lights	Yes	Yes/no and location (n = 12)
Kpadeh Rogers 2019	Bacteria	Bacterial suspension of MSSA/GloGerm Mist liquid	?	50 muL each	?	Rubbed the bacteria/fluorescent marker on their hands	Plated on tryptic soy agar for quantitative culturing. Plates were incubated overnight.	No	Number of CFUs of *K pneumoniae* and MSSA were calculated
Mana 2018	Fluorescent	?	?	0.5 mL	No	Rubbed over gloved hands; then contaminated front of the gown	Ultra light UV1	No	Any contamination yes/no
	Virus	Phi X174	10^8 PFU/0.5 mL	0.5 mL	?	Rubbed over degloved hands for 10 sec	Swabs of hands and wrist; swabs of neck and chest	n/a	Any contamination yes/no; mean Log10 PFU recovered
Osei-Bonsu 2019	Fluorescent/ bacteria	Glo Germ fluorescent powder/*Staphylo-*	?	1 mL of *S epidermidis* in a 0.5	?	Wedge foam paint brush to coat participants with Glo Germflu-	Black light/areas of apparent powder transfer were documented and cultured using cotton swabs, inoc-	No	Number of people with contamination

Table 1. Exposure and outcome in simulation studies *(Continued)*

		coccus epidermidis		McFarland suspension (1.5 10^8 CFU/mL)		orescent powder on both arms, hands, and the abdomen/dripping droplets over the PPE with a 1000 uL pipette	ulated onto blood agar plates, and incubated for 48 h.		
Suen 2018	Fluorescent	Fluorescent solution (UV GERM Hygiene Spray, Glow TecLtd	?	12 times 1.99 g	?	Solution was sprayed onto the face shield, 2 upper limb/gloves and anterior surfaces of the gown	UV lamp (CheckPoint, 220–240 V/50 Hz; Glow Tec Ltd., London, England) under dim light	No	Overall average of contaminated body sites
Strauch 2016	Fluorescent	Glogerm	Oil	25 mL	No	1. brushed on masks 2. 1 mL on the hands	UV-A light	Yes	Contaminated yes/no; intensity of UV light reflection
Tomas 2016	Fluorescent	?	?	0.5 mL	No	Rubbed over gloved hands	Ultra light UV1	No	Contaminated hands/wrist yes/no
	Virus	MS2	10^10 PFU /0.5 mL	0.5 mL	?	Gloved hands were inoculated	Swabs of hands and wrist	n/a	Contaminated hands/wrist yes/no; mean log10 PFU recovered
Wong 2004	Fluorescent	?	Water	100 mL	No	Sprayed the exposed part with an atomiser (participants were blindfolded during this process)	UV scan	Yes	Number of stains
Zamora 2006	Fluorescent	Detection paste	?	100 mL	No	Paste on forearms and palms of the hands	UV lamp	No	Areas measured

CFU: colony forming units; **HCW:** healthcare worker; ***K pneumonia:*** *Klebsiella pneumoniae;* **LED:** light-emitting diode; **MS2:** harmless virus; **MSSA:** methicillin-sensitive *Staphylococcus aureus;* **mL:** millilitre; **muL:** microlitre; **n/a:** not applicable; **PFU:** plaque forming units; **Phi6:** harmless virus; **PLS:** polystyrene latex bead; **UV:** ultraviolet

APPENDICES

Appendix 1. Effects of wearing personal protective equipment (PPE) consistently on the risk of SARS infection

Wearing PPE consistently versus wearing PPE inconsistently

During and just after the SARS epidemic a number of studies evaluated the impact of the use of PPE on SARS infection rates. Six of these studies were case-control studies and five were retrospective cohort studies. Since information in these studies was collected in the same retrospective way by questionnaires and/or interviews we combined the results of these studies.

There were two studies (Le 2004; Park 2004), one in a single hospital in Vietnam and the other in multiple hospitals in the USA, that reported no cases in spite of sufficient exposure to SARS patients. The Vietnamese study claimed that this was because of the almost universal use of N95 masks later during the epidemic. The US study could not find an explanation because the use of PPE was not optimal in many cases. We could find no reasons to explain this result because these studies were similar to the other studies included. Also, in another hospital near the one in the Vietnamese study, SARS cases did occur among healthcare workers but this was more at the beginning of the epidemic and it was unclear how well PPE had been used (Reynolds 2006).

1 Consistent mask use versus inconsistent use

We were able to combine six studies (Liu 2009; Loeb 2004; Nishiura 2005; Scales 2003; Seto 2003; Teleman 2004), in a meta-analysis that showed a beneficial effect of consistent mask use as part of PPE both in a fixed-effect (OR 0.28, 95% CI 0.17 to 0.46, I^2 = 42%) and in a random-effects meta-analysis model (OR 0.27, 95% CI 0.13 to 0.53).

2 Consistent gown/suit use versus inconsistent use

Four studies (Loeb 2004; Nishiura 2005; Pei 2006; Teleman 2004), could be combined and showed that consistent gown use had a preventive effect on SARS infection both in a fixed- and random-effects analysis (OR 0.22, 95% 0.10 to 0.50, I^2 = 53%). The data in Teleman 2004 were reported as OR 0.5, 95% CI 0.4 to 6.9 P = 0.6). However, this is an apparent mistake as the confidence interval does not fit with the OR nor with the P value. We corrected this to OR 0.5, 95% CI 0.04 to 6.9 which makes the results consistent.

3 Consistent glove use versus inconsistent use

Also consistent glove use in six studies (Loeb 2004; Nishiura 2005; Pei 2006; Scales 2003; Seto 2003; Teleman 2004), led to a decrease in the risk of SARS infection both in fixed-effect meta-analysis (OR 0.54 95% CI 0.33 to 0.89, I^2 = 0%) and in a random-effects analysis (OR 0.53, 95% CI 0.28 to 1.01) but this was not statistically significant.

4 Consistent use of more than one PPE part versus inconsistent use

Ho 2004, Lau 2004, and Scales 2003 measured consistent use of more than one PPE part compared to no use at all. The combination of more than one PPE had a similar effect on SARS infection risk but this was not statistically significant, neither in the fixed-effect analysis (OR 0.36, 95% CI 0.09 to 1.39, I^2 = 35%) nor in the random-effects analysis (OR 0.37, 95% CI 0.07 to 1.98).

Appendix 2. MEDLINE search strategy 15 July 2019

#1

"Protective Clothing"[Mesh] OR gown*[tw] OR coverall*[tw] OR "protective layer"[tw] OR "protective layers"[tw] OR "surgical toga"[tw] OR apron*[tw] OR "smock"[tw] OR "smocks"[tw] OR "hazmat suit"[tw] OR (hazmat[tw] AND suit[tw]) OR "Gloves, Protective"[Mesh] OR "glove"[tw] OR "gloves"[tw] OR "Respiratory Protective Devices"[Mesh] OR "Masks"[Mesh] OR "mask"[tw] OR "masks"[tw] OR "air-purifying respirator"[tw] OR "PAPR"[tw] OR "enhanced respiratory and contact precautions" OR "E-RCP"[tw] OR "respiratory protection"[tw] OR "transparent panel"[tw] OR "surgical mask"[tw] OR "surgical masks"[tw] OR "filtering face piece"[tw] OR "filtering facepiece"[tw] OR "Eye Protective Devices"[Mesh] OR goggle*[tw] OR "visor"[tw] OR "facial protection equipment"[tw] OR "safety glass"[tw] OR "safety glasses"[tw] OR "safety spectacles"[tw] OR "personal protective equipment"[tw] OR "PPE"[tw] OR "protective equipment"[tw] OR overshoe*[tw] OR "shoe cover"[tw] OR "shoe covers"[tw] OR "rubber boot"[tw] OR "rubber boots"[tw] OR "head cover"[tw] OR "head covering"[tw] OR "face shield"[tw] OR "face shields"[tw] OR "surgical hood"[tw] OR "hood"[tw] OR "Equipment Contamination/prevention and control"[Mesh] OR "Infection Control"[Mesh] OR "infection control"[tiab] OR "gloving"[tw] OR "donning"[tw] OR "doffing"[tw]

#2

"Communicable Diseases"[Mesh] OR "infectious disease"[tiab] OR "infectious diseases"[tiab] OR "Disease Transmission, Infectious"[Mesh] OR "disease transmission"[tw] OR "Infectious Disease Transmission, Patient-to-Professional"[Mesh] OR "infection control precautions"[tw] OR "human-to-human transmission"[tw] OR "parenteral transmission"[tw] OR "Virus Diseases/prevention and control"[Mesh] OR "viral disease"[tw] OR "viral diseases"[tw] OR "Bacterial Infections/prevention and control"[Mesh] OR "bacterial infection"[tw] OR "filovirus"[tw] OR "Ebolavirus"[Mesh] OR "Hemorrhagic Fever, Ebola"[Mesh] OR "Ebola"[tw] OR "Marburg virus"[tw] OR "Lassa virus"[tw] OR "haemorrhagic fever"[tw] OR "HIV Infections/prevention and control"[Mesh] OR "HIV"[ti] OR "hiv infection"[tiab] OR "hiv transmission"[tw]

OR "Influenza, Human/prevention and control"[Mesh] OR "SARS Virus"[Mesh] OR "Severe Acute Respiratory Syndrome Virus"[tw] OR "SARS"[tw] OR "MERS"[tw] OR "respiratory infection"[tw] OR "Influenza, Human/prevention and control"[Mesh] OR "influenza"[tiab] OR "Tuberculosis/prevention and control"[Mesh] OR "tuberculosis"[tiab] OR "Hepatitis A"[Mesh] OR "hepatitis a"[ti] OR "Hepatitis B/prevention and control"[Mesh] OR "hepatitis b"[ti] OR "Hepatitis C/transmission"[Mesh] OR "hepatitis c"[ti] OR "bioterrorism"[tw] OR "aerosol-generating procedure"[tw] OR "Cross Infection"[Mesh] OR "bacterial contamination"[tw] OR "microbial contamination"[tw] OR "self-contamination"[tw] OR "decontamination"[tw] OR "surface decontamination"[tw] OR "skin decontamination"[tw]

#3

"Health Personnel"[Mesh] OR "Personnel, Hospital"[Mesh] OR "health care worker"[tw] OR "health care workers"[tw] OR "health care personnel"[tw] OR "health personnel"[tw] OR "health-personnel"[tw] OR "health provider"[tw] OR "health providers"[tw] OR "health care provider"[tw] OR "health care providers"[tw] OR "medical staff"[tw] OR "medical personnel"[tw]OR "medical professional"[tw] OR "medical worker"[tw] OR "medical workers"[tw] OR "dental personnel"[tw] OR "dental staff"[tw] OR "Dentists"[Mesh] OR "dentist"[tw] OR "dentists"[tw] OR "dental assistant"[tw] OR "dental assistants"[tw] OR "Dental Assistants"[Mesh] OR "nursing staff"[tw] OR "Nurses"[Mesh] OR "nurse"[tw] OR "nurses"[tw] OR "nursing assistant"[tw] OR "nursing assistants"[tw] OR "Nurses' Aides"[Mesh] OR "Nurse Midwives"[Mesh] OR "midwife"[tw] OR "midwives"[tw] OR "military-medical personnel"[tw] OR "Physicians"[Mesh] OR "physician"[tw] OR "physicians"[tw] OR "emergency medical services"[tw] OR "Emergency Medical Services"[MeSH] OR "transporting patients"[tw] OR "patient transport"[tw] OR "Ambulances"[Mesh] OR "Allied Health Personnel"[Mesh] OR paramedic[tw] OR paramedics[tw] OR paramedical personnel[tw] OR "Burial"[Mesh] OR burial staff OR cleaning workers[tw] OR cleaner work OR cleaner[tw] OR cleaners[tw]

#4

(#1 AND #2 AND #3)

Appendix 3. CENTRAL search strategy 20 March 2020

#1 MeSH descriptor: [Personal Protective Equipment] explode all trees

#2 MeSH descriptor: [Protective Clothing] explode all trees

#3 MeSH descriptor: [Respiratory Protective Devices] explode all trees

#4 MeSH descriptor: [Masks] explode all trees

#5 MeSH descriptor: [Eye Protective Devices] explode all trees

#6 MeSH descriptor: [Equipment Contamination] explode all trees

#7 MeSH descriptor: [Infection Control] explode all trees and with qualifier(s): [methods - MT]

#8 (glove* or gloving):ti,ab,kw

#9 (gown* or coverall* or (protective NEXT layer*) or (surgical NEXT toga*) or apron* or smock* or (hazmat NEXT suit*)):ti,ab,kw

#10 (mask* or (air NEXT purifying NEXT respirator*) or PAPR or "enhanced respiratory and contact precautions" or ERCP or "respiratory protection" or (transparent NEXT panel*) or (filtering NEXT face NEXT piece*) or (filtering NEXT facepiece*)):ti,ab,kw

#11 (goggle* or visor* or (safety NEXT glass*) or "safety spectacles" or overshoe* or (shoe NEXT cover*) or (rubber NEXT boot*) or (head NEXT cover*) or (face NEXT shield*) or hood* or "protective equipment" or PPE or donning or doffing):ti,ab,kw

#12 "infection control":ti,ab,kw

#13 {or #1-#12}

#14 MeSH descriptor: [Health Personnel] explode all trees

#15 MeSH descriptor: [Personnel, Hospital] explode all trees

#16 ((health NEXT care NEXT worker*) or (healthcare NEXT worker*) or "health care personnel" or "healthcare personnel" or "health personnel" or (health NEXT provider*) or (health NEXT care NEXT provider*) or "medical staff" or "medical personnel" or (medical NEXT professional*) or (medical NEXT worker*) or "military-medical personnel" or "military medical personnel"):ti,ab,kw

#17 MeSH descriptor: [Dentists] explode all trees

#18 MeSH descriptor: [Dental Assistants] explode all trees

#19 ("dental personnel" or "dental staff" or dentist* or (dental NEXT assistant*)):ti,ab,kw

#20 MeSH descriptor: [Nurses] explode all trees

#21 MeSH descriptor: [Nursing Assistants] explode all trees

#22 MeSH descriptor: [Nurse Midwives] explode all trees

#23 MeSH descriptor: [Nursing Staff] explode all trees

#24 (nurse or nurses or nursing or midwife OR midwives):ti,ab,kw

#25 MeSH descriptor: [Physicians] explode all trees

#26 physician*:ti,ab,kw

#27 MeSH descriptor: [Emergency Medical Services] explode all trees

#28 MeSH descriptor: [Ambulances] explode all trees

#29 ("emergency medical services" or "transporting patients" or "patient transport" or paramedic* or (ambulance NEXT worker*)):ti,ab,kw

#30 MeSH descriptor: [Allied Health Personnel] explode all trees

#31 MeSH descriptor: [Burial] explode all trees

#32 "burial staff":ti,ab,kw

#33 ("cleaning workers" or cleaner* or janitor*):ti,ab,kw

#34 {or #14-#33}

#35 MeSH descriptor: [Communicable Diseases] explode all trees

#36 MeSH descriptor: [Disease Transmission, Infectious] explode all trees

#37 MeSH descriptor: [Virus Diseases] explode all trees and with qualifier(s): [prevention & control - PC, transmission - TM]

#38 MeSH descriptor: [Bacterial Infections] explode all trees and with qualifier(s): [prevention & control - PC, transmission - TM]

#39 MeSH descriptor: [Ebolavirus] explode all trees

#40 MeSH descriptor: [Hemorrhagic Fever, Ebola] explode all trees

#41 MeSH descriptor: [Marburg Virus Disease] explode all trees

#42 MeSH descriptor: [Lassa virus] explode all trees

#43 MeSH descriptor: [Influenza, Human] explode all trees and with qualifier(s): [prevention & control - PC, transmission - TM]

#44 MeSH descriptor: [SARS Virus] explode all trees

#45 MeSH descriptor: [Severe Acute Respiratory Syndrome] explode all trees

#46 MeSH descriptor: [Middle East Respiratory Syndrome Coronavirus] explode all trees

#47 MeSH descriptor: [HIV Infections] explode all trees and with qualifier(s): [prevention & control - PC, transmission - TM]

#48 MeSH descriptor: [Tuberculosis] explode all trees and with qualifier(s): [prevention & control - PC]

#49 MeSH descriptor: [Hepatitis A] explode all trees and with qualifier(s): [prevention & control - PC, transmission - TM]

#50 MeSH descriptor: [Hepatitis B] explode all trees and with qualifier(s): [prevention & control - PC, transmission - TM]

#51 MeSH descriptor: [Cross Infection] explode all trees

#52 ((infectious NEXT disease*) or "disease transmission" or "infection control precautions" or "human-to-human transmission" or "human transmission" or "parenteral transmission"):ti,ab,kw

#53 ((viral NEXT disease*) or (bacterial NEXT infection*) or filovirus or ebola or "Marburg virus" or "Lassa virus" or "haemorrhagic fever" or "hemorrhagic fever" or (HIV NEAR/3 infection*) or "Severe Acute Respiratory Syndrome Virus" or SARS or "Middle East Respiratory

Syndrome" or MERS or coronavirus* or (corona NEXT virus*) or COVID or "COVID 19" or “severe acute respiratory syndrome coronavirus 2” or "SARS CoV 2" or (SARS NEXT CoV*)):ti,ab,kw

#54 ("surface decontamination" or "skin decontamination" or "self contamination" or self-contamination):ti,ab,kw

#55 {or #35-#54}

Appendix 4. Medline OVID search strategy 20 March 2020

1 exp Personal Protective Equipment/

2 exp Protective Clothing/

3 exp Respiratory Protective Devices/

4 exp Masks/

5 exp Eye Protective Devices/

6 exp Equipment Contamination/

7 exp Infection Control/mt [Methods]

8 (glove* or gloving).ti,ab.

9 (gown* or coverall* or protective layer* or surgical toga* or apron* or smock* or hazmat suit*).ti,ab.

10 (mask or masks or air purifying respirator* or PAPR or "enhanced respiratory and contact precautions" or ERCP or "respiratory protection" or transparent panel* or filtering face piece* or filtering facepiece*).ti,ab.

11 (goggle* or visor* or facial protection equipment or safety glass* or safety spectacles or overshoe* or shoe cover* or rubber boot* or head cover* or face shield* or hood* or protective equipment or PPE or donning or doffing).ti,ab.

12 infection control.ti.

13 or/1-12

14 exp Health Personnel/

15 exp Personnel, Hospital/

16 (health care worker* or healthcare worker* or health care personnel or health personnel or health care provider* or health provider* or medical staff or medical personnel or medical professional* or medical worker* or military medical personnel).ti,ab.

17 exp Dentists/

18 exp Dental Assistants/

19 (dental personnel or dental staff or dentist* or dental assistant*).ti,ab.

20 exp Nurses/

21 exp Nursing Assistants/

22 exp Nurse Midwives/

23 exp Nursing Staff/

24 (nurse or nurses or nursing or midwife or midwives).ti,ab.

25 exp Physicians/

26 physician*.ti,ab.

27 exp Emergency Medical Services/

28 exp Ambulances/

29 (emergency medical services or transporting patients or patient transport or paramedic* or ambulance worker*).ti,ab.

30 exp Allied Health Personnel/

31 exp Burial/

32 burial staff.ti,ab.

33 (cleaning worker* or cleaner* or janitor*).ti,ab.

34 or/14-33

35 exp Communicable Diseases/

36 exp Disease Transmission, Infectious/

37 exp Virus Diseases/

38 exp Bacterial Infections/

39 exp Ebolavirus/

40 exp Hemorrhagic Fever, Ebola/

41 exp Marburg Virus Disease/

42 exp Lassa virus/

43 exp Influenza, Human/

44 exp SARS Virus/

45 exp Severe Acute Respiratory Syndrome/

46 exp Middle East Respiratory Syndrome Coronavirus/

47 exp HIV Infections/pc, tm [Prevention & Control, Transmission]

48 exp Tuberculosis/pc, tm [Prevention & Control, Transmission]

49 exp Hepatitis A/pc, tm [Prevention & Control, Transmission]

50 exp Hepatitis B/pc, tm [Prevention & Control, Transmission]

51 exp Cross Infection/

52 (infectious disease* or disease transmission or infection control precautions or (human* adj3 transmission) or parenteral transmission).ti,ab.

53 (viral disease* or viral infection* or bacterial infection* or filovirus or ebola* or Marburg virus or Lassa virus or h?emorrhagic fever or (HIV adj3 infection*) or Severe Acute Respiratory Syndrome Virus or SARS or Middle East Respiratory Syndrome or MERS or coronavirus* or corona virus* or COVID or severe acute respiratory syndrome coronavirus or SARS CoV 2 or SARS-CoV-2).ti,ab.

54 (skin decontamination or surface decontamination or self contamination).ti,ab.

55 or/35-54

56 13 and 34 and 55

57 exp animals/ not humans.sh.

Appendix 5. Embase OVID search strategy 20 March 2020

1 exp protective equipment/

2 exp protective clothing/

3 exp mask/

4 exp eye protective device/

5 exp medical device contamination/

6 infection control/pc [Prevention]

7 (glove* or gloving).ti,ab.

8 (gown* or coverall* or protective layer* or surgical toga* or apron* or smock* or hazmat suit*).ti,ab.

9 (mask or masks or air purifying respirator* or PAPR or "enhanced respiratory and contact precautions" or ERCP or "respiratory protection" or transparent panel* or filtering face piece* or filtering facepiece*).ti,ab.

10 (goggle* or visor* or facial protection equipment or safety glass* or safety spectacles or overshoe* or shoe cover* or rubber boot* or head cover* or face shield* or hood* or protective equipment or PPE or donning or doffing).ti,ab.

11 infection control.ti.

12 or/1-11

13 exp health care personnel/

14 exp hospital personnel/

15 (health care worker* or healthcare worker* or health care personnel or health personnel or health care provider* or health provider* or medical staff or medical personnel or medical professional* or medical worker* or military medical personnel).ti,ab.

16 exp dentist/

17 exp dental assistant/

18 (dental personnel or dental staff or dentist* or dental assistant*).ti,ab.

19 exp nurse/

20 exp nursing assistant/

21 exp nurse midwife/

22 exp nursing staff/

23 (nurse or nurses or nursing or midwife or midwives).ti,ab.

24 exp physician/

25 physician*.ti,ab.

26 exp emergency health service/

27 exp ambulance/

28 (emergency medical services or transporting patients or patient transport or paramedic* or ambulance worker*).ti,ab.

29 exp paramedical personnel/

30 exp burial/

31 burial staff.ti,ab.

32 (cleaning worker* or cleaner* or janitor*).ti,ab.

33 or/13-32

34 exp communicable disease/

35 exp disease transmission/

36 exp virus infection/

37 exp bacterial infection/

38 exp ebolavirus/

39 exp Ebola hemorrhagic fever/

40 exp Marburg hemorrhagic fever/

41 exp Lassa virus/

42 exp filovirus infection/

43 exp influenza/

44 exp SARS coronavirus/

45 exp severe acute respiratory syndrome/

46 exp Middle East respiratory syndrome coronavirus/

47 exp Human immunodeficiency virus infection/pc [Prevention]

48 exp tuberculosis/pc [Prevention]

49 exp hepatitis/pc [Prevention]

50 exp cross infection/

51 (infectious disease* or disease transmission or infection control precautions or (human* adj3 transmission) or parenteral transmission).ti,ab.

52 (viral disease* or viral infection* or bacterial infection* or filovirus or ebola* or Marburg virus or Lassa virus or h?emorrhagic fever or (HIV adj3 infection*) or Severe Acute Respiratory Syndrome Virus or SARS or Middle East Respiratory Syndrome or MERS or coronavirus* or corona virus* or COVID or severe acute respiratory syndrome coronavirus or SARS CoV 2 or SARS-CoV-2).ti,ab.

53 (skin decontamination or surface decontamination or self contamination).ti,ab.

54 or/34-53

55 12 and 33 and 54

56 exp experimental organism/

57 animal tissue/

58 exp animal disease/

59 exp carnivore disease/

60 exp bird/

61 exp experimental animal welfare/

62 exp animal husbandry/

63 animal behavior/

64 exp animal cell culture/

65 exp mammalian disease/

66 exp mammal/

67 exp marine species/

68 nonhuman/

69 animal.hw.

70 or/56-69

71 70 not human/

72 55 not 71

Appendix 6. Scopus search strategy 18 June 2019

#1

"protective clothing" OR gown* OR coverall* OR "protective layer" OR "protective layers" OR "surgical toga" OR apron* OR smock OR smocks OR "hazmat suit" OR glove OR gloves OR "respiratory protective devices" OR mask OR "air-purifying respirator" OR "PAPR" OR "enhanced respiratory and contact precautions" OR "E-RCP" OR "respiratory protection" OR "transparent panel" OR "surgical mask" OR "surgical masks" OR "filtering face piece" OR "filtering facepiece" OR "eye protective device" OR goggle* OR visor OR "facial protection equipment" OR "safety glass" OR "safety glasses" OR "safety spectacles" OR "personal protective equipment" OR "PPE" OR "protective equipment" OR overshoe* OR "shoe cover" OR "shoe covers" OR "rubber boot" OR "rubber boots" OR "head cover" OR "head covering" OR "face shield" OR "face shields" OR "surgical hood" OR hood OR gloving OR donning OR doffing)

#2

"health care personnel" OR "hospital personnel" OR "health care worker" OR "health care workers" OR "health care personnel" OR "health personnel" OR "health-personnel" OR "health provider" OR "health providers" OR "health care provider" OR "health care providers" OR "medical staff" OR "medical personnel" OR "medical professional" OR "medical worker" OR "medical workers" OR "dental personnel" OR "dental staff" OR "dentist" OR "dentists" OR "dental assistant" OR "dental assistants" OR "nursing staff" OR "nurse" OR "nurses" OR "nursing assistant" OR "nursing assistants" OR "midwife" OR "midwives" OR "military-medical personnel" OR "physician" OR "physicians" OR "emergency medical services" OR "transporting patients" OR "patient transport" OR "ambulance" OR "paramedical personnel" OR paramedic OR paramedics OR "burial staff" OR "cleaning workers" OR cleaner OR cleaners

#3

"virus infection" OR "viral disease" OR "filovirus" OR "ebola" OR "marburg virus" OR "lassa virus" OR "haemorrhagic fever" OR "Severe Acute Respiratory Syndrome Virus" OR "SARS" OR "MERS" OR "bioterrorism" OR "bacterial contamination" OR "microbial contamination" OR "self-contamination" OR "decontamination" OR "surface decontamination" OR "skin decontamination"

#4

LIMIT-TO (PUBYEAR, 2018)

#5

#1 AND #2 AND #3 AND #4

Appendix 7. Embase search strategy embase.com 15 July 2016

#7

#6 NOT [medline]/lim) (646)

#6

#5 AND [embase]/lim (2,227)

#5

#4 AND [humans]/lim (5,270)

#4

#1 AND #2 AND #3 (5,675)

#3

'communicable disease'/de OR "infectious disease":ab,ti OR 'disease transmission'/de OR "disease transmission" OR "infection control precautions" OR "human-to-human transmission" OR "parenteral transmission" OR 'virus infection'/de OR "viral disease":ab,ti OR 'bacterial infection'/de OR "bacterial infection":ab,ti OR "filovirus" OR 'ebola virus'/de OR 'hemorrhagic fever ebola'/de OR "ebola" OR "marburg virus" OR "lassa virus" OR "haemorrhagic fever" OR 'sars coronavirus'/de OR "Severe Acute Respiratory Syndrome Virus" OR "SARS" OR "MERS" OR "bioterrorism" OR 'cross infection'/de OR "bacterial contamination" OR "microbial contamination" OR "self-contamination" OR "decontamination" OR "surface decontamination" OR "skin decontamination" (323,524)

#2

'health care personnel'/de OR 'hospital personnel'/de OR "health care worker" OR "health care workers" OR "health care personnel" OR "health personnel" OR "health-personnel" OR "health provider" OR "health providers" OR "health care provider" OR "health care providers" OR "medical staff" OR "medical personnel" OR "medical professional" OR "medical worker" OR "medical workers" OR “dental personnel” OR “dental staff” OR "dentist" OR "dentists" OR "dental assistant" OR "dental assistants" OR "nursing staff" OR 'nurses'/de OR "nurse" OR "nurses" OR "nursing assistant" OR "nursing assistants" OR 'nursing assistant'/de OR 'nurse midwife'/de OR "midwife" OR "midwives" OR "military-medical personnel" OR 'physician'/de OR "physician" OR "physicians" OR "emergency medical services" OR “transporting patients” OR “patient transport” OR 'ambulance'/de OR 'paramedical personnel'/de OR "paramedical personnel" OR paramedic OR paramedics OR 'posthumous care'/de OR "burial staff" OR "cleaning workers" OR "cleaner work" OR cleaner OR cleaners (1,287,399)

#1

'protective clothing'/de OR gown* OR coverall* OR "protective layer" OR "protective layers" OR "surgical toga" OR apron* OR smock OR smocks OR "hazmat suit" OR (hazmat AND suit) OR glove OR gloves OR 'respiratory protective devices'/de OR 'mask'/de OR mask OR "air-purifying respirator" OR "PAPR" OR "enhanced respiratory and contact precautions" OR "E-RCP" OR “respiratory protection” OR "transparent panel" OR "surgical mask" OR "surgical masks" OR "filtering face piece" OR "filtering facepiece" OR 'eye protective device'/de OR goggle* OR visor OR "facial protection equipment" OR "safety glass" OR "safety glasses" OR "safety spectacles" OR "personal protective equipment" OR "PPE" OR "protective equipment" OR overshoe* OR "shoe cover" OR "shoe covers" OR "rubber boot" OR "rubber boots" OR "head cover" OR "head covering" OR "face shield" OR "face shields" OR "surgical hood" OR hood OR 'medical device contamination'/de OR 'infection control'/de OR 'infection control':ab,ti OR gloving OR donning OR doffing (160,118)

Appendix 8. CINAHL EBSCO search strategy 20 March 2020

S51 S10 AND S32 AND S50

S50 S33 OR S34 OR S35 OR S36 OR S37 OR S38 OR S39 OR S40 OR S41 OR S42 OR S43 OR S44 OR S45 OR S46 OR S47 OR S48 OR S49

S49 TI ("surface decontamination" OR "skin decontamination") OR AB ("surface decontamination" OR "skin decontamination")

S48 AB (“viral disease” OR “viral diseases” OR “viral infection” OR “viral infections” OR “bacterial infection” OR “bacterial infections” OR filovirus OR ebola* OR “Marburg virus” OR “Lassa virus” OR “haemorrhagic fever” OR “hemorrhagic fever” OR “HIV infection” OR “HIV infections” OR “Severe Acute Respiratory Syndrome Virus” OR SARS OR “Middle East Respiratory Syndrome” OR MERS OR coronavirus* OR “corona virus” OR “corona viruses” OR COVID OR “severe acute respiratory syndrome coronavirus” OR “SARS CoV 2” OR “SARS-CoV-2”)

S47 TI (“viral disease” OR “viral diseases” OR “viral infection” OR “viral infections” OR “bacterial infection” OR “bacterial infections” OR filovirus OR ebola* OR “Marburg virus” OR “Lassa virus” OR “haemorrhagic fever” OR “hemorrhagic fever” OR “HIV infection” OR “HIV infections” OR “Severe Acute Respiratory Syndrome Virus” OR SARS OR “Middle East Respiratory Syndrome” OR MERS OR coronavirus* OR “corona virus” OR “corona viruses” OR COVID OR “severe acute respiratory syndrome coronavirus” OR “SARS CoV 2” OR “SARS-CoV-2”)

S46 TI (“infectious disease” OR “infectious diseases” OR “disease transmission” OR “infection control precautions” OR “human-to-human transmission” OR “parenteral transmission”) OR AB (“infectious disease” OR “infectious diseases” OR “disease transmission” OR “infection control precautions” OR “human-to-human transmission” OR “parenteral transmission”)

S45 (MH "Cross Infection+")

S44 (MH "Hepatitis B+/PC/TM")

S43 (MH "Hepatitis A/PC/TM")

S42 (MH "Tuberculosis+/PC/TM")

S41 (MH "HIV Infections+/TM/PC")

S40 (MH "Middle East Respiratory Syndrome") OR (MH "Middle East Respiratory Syndrome Coronavirus")

S39 (MH "SARS Virus") OR (MH "Severe Acute Respiratory Syndrome")

S38 (MH "Influenza, Human+")

S37 (MH "Hemorrhagic Fever, Ebola") OR (MH "Ebola Virus")

S36 (MH "Bacterial Infections+")

S35 (MH "Virus Diseases+")

S34 (MH "Disease Transmission, Patient-to-Professional") OR (MH "Disease Transmission, Professional-to-Patient")

S33 (MH "Communicable Diseases+")

S32 S11 OR S12 OR S13 OR S14 OR S15 OR S16 OR S17 OR S18 OR S19 OR S20 OR S21 OR S22 OR S23 OR S24 OR S25 OR S26 OR S27 OR S28 OR S29 OR S30 OR S31

S31 TI ("cleaning worker" OR "cleaning workers" OR cleaner* or janitor*) OR AB ("cleaning worker" OR "cleaning workers" OR cleaner* or janitor*)

S30 (TI burial) or (AB burial)

S29 (MH "Allied Health Personnel+")

S28 TI (“emergency medical services” OR “transporting patients” OR “patient transport” OR paramedic* OR “ambulance worker” OR “ambulance workers”) OR AB (“emergency medical services” OR “transporting patients” OR “patient transport” OR paramedic* OR “ambulance worker” OR “ambulance workers”)

S27 (MH "Ambulances")

S26 (MH "Emergency Medical Services+")

S25 (TI physician*) OR (AB physician*)

S24 (MH "Physicians+")

S23 AB (nurse OR nurses OR nursing OR midwife OR midwives)

S22 TI (nurse OR nurses OR nursing OR midwife OR midwives)

S21 (MH "Nurse Midwives")

S20 (MH "Nursing Assistants")

S19 (MH "Nurses+")

S18 AB ("dental personnel" OR "dental staff" OR dentist* OR "dental assistant" OR "dental assistants")

S17 TI ("dental personnel" OR "dental staff" OR dentist* OR "dental assistant" OR "dental assistants")

S16 (MH "Dental Assistants")

S15 (MH "Dentists+")

S14 AB (“health care worker” OR “health care workers” OR “healthcare worker” OR “healthcare workers” OR “health care personnel” OR “health personnel” OR “health care provider” OR “health care providers” OR “health provider” OR “health providers” OR “medical staff” OR “medical personnel” OR “medical professional” OR “medical professionals” OR “medical worker” OR “medical workers” OR "military medical personnel")

S13 TI (“health care worker” OR “health care workers” OR “healthcare worker” OR “healthcare workers” OR “health care personnel” OR “health personnel” OR “health care provider” OR “health care providers” OR “health provider” OR “health providers” OR “medical staff” OR “medical personnel” OR “medical professional” OR “medical professionals” OR “medical worker” OR “medical workers” OR "military medical personnel")

S12 (MH "Personnel, Health Facility+")

S11 (MH "Health Personnel+")

S10 S1 OR S2 OR S3 OR S4 OR S5 OR S6 OR S7 OR S8 OR S9

S9 AB (glove* OR gloving OR gown* OR coverall* OR "protective layer" OR "protective layers" OR "surgical toga" OR apron* OR smock* OR "hazmat suit" OR “hazmat suits” OR mask* OR "air-purifying respirator" OR PAPR OR "enhanced respiratory and contact precautions" OR E-RCP OR ECPR OR "respiratory protection" OR "transparent panel" OR "surgical mask" OR "surgical masks" OR "filtering face piece" OR "filtering facepiece" OR goggle* OR visor* OR "facial protection equipment" OR "safety glass" OR "safety glasses" OR "safety spectacles" OR "personal protective equipment" OR PPE OR "protective equipment" OR overshoe* OR "shoe cover" OR "shoe covers" OR "rubber boot" OR "rubber boots" OR "head cover" OR "head covering" OR "face shield" OR "face shields" OR "surgical hood" OR "hood" OR "infection control OR donning OR doffing)

S8 TI (glove* OR gloving OR gown* OR coverall* OR "protective layer" OR "protective layers" OR "surgical toga" OR apron* OR smock* OR "hazmat suit" OR “hazmat suits” OR mask* OR "air-purifying respirator" OR PAPR OR "enhanced respiratory and contact precautions" OR E-RCP OR ECPR OR "respiratory protection" OR "transparent panel" OR "surgical mask" OR "surgical masks" OR "filtering face piece" OR "filtering facepiece" OR goggle* OR visor* OR "facial protection equipment" OR "safety glass" OR "safety glasses" OR "safety spectacles" OR "personal protective equipment" OR PPE OR "protective equipment" OR overshoe* OR "shoe cover" OR "shoe covers" OR "rubber boot" OR "rubber boots" OR "head cover" OR "head covering" OR "face shield" OR "face shields" OR "surgical hood" OR "hood" OR "infection control OR donning OR doffing)

S7 (MH "Infection Control+/PC")

S6 (MH "Equipment Contamination/PC")

S5 (MH "Respiratory Protective Devices")

S4 (MH "Gloves")

S3 (MH "Eye Protective Devices")

S2 (MH "Masks")

S1 (MH "Protective Clothing+")

Appendix 9. CINAHL search strategy 31 July 2018

S5 S4 MEDLINE records excluded (878)

S4 (S1 AND S2 AND S3) (2,584)

S3

(MH "Communicable Diseases") OR (TI "infectious disease") OR (AB "infectious disease") OR (MH "Disease Transmission) OR TX "disease transmission" OR (MH "Disease Transmission, Patient-to-Professional") OR TX "infection control precautions" OR TX "human-to-human transmission" OR TX "parenteral transmission" OR (MH "Virus Diseases/PC") OR TX "viral disease" OR TX "viral diseases" OR TX "bacterial infection" OR (MH "Bacterial infection/PC") OR TX "filovirus" OR TX "ebolavirus" OR (MH "Hemorrhagic Fever, Ebola") OR TX "ebola" OR TX "marburg virus" OR TX "lassa virus" OR TX "haemorrhagic fever" OR (MH "SARS Virus") OR TX "severe acute respiratory syndrome virus" OR TX "SARS" OR TX "MERS" OR TX "respiratory infection" OR TX "bioterrorism" OR TX "aerosol-generating procedure" OR (MH "Cross Infection") OR TX "bacterial contamination" OR TX "microbial contamination" OR TX "self-contamination" OR TX "decontamination" OR TX "surface decontamination" OR TX "skin decontamination" (37,937)

S2

(MH Protective Clothing) OR TX gown* OR TX coverall* OR TX "protective layer" OR TX "protective layers" OR TX "surgical toga" OR TX apron* OR TX "smock" OR TX "smocks" OR TX "hazmat suit" OR TX (hazmat AND suit) OR (MH "gloves protective") OR TX glove OR TX gloves OR (MH "Respiratory Protective Devices") OR (MH "Masks") OR TX mask OR TX masks OR TX "air-purifying respirator" OR TX "PAPR" OR TX "enhanced respiratory and contact precautions" OR TX "E-RCP" OR TX "respiratory protection" OR TX "transparent panel" OR TX "surgical mask" OR TX "surgical masks" OR TX "filtering face piece" OR TX "filtering facepiece" OR (MH "Eye Protective Devices") OR TX goggle* OR TX "visor" OR TX "facial protection equipment" OR TX "safety glass" OR TX "safety glasses" OR TX "safety spectacles" OR TX "personal protective equipment" OR TX "PPE" OR TX "protective equipment" OR TX overshoe* OR TX "shoe cover" OR TX "shoe covers" OR TX "rubber boot" OR TX "rubber boots" OR TX "head cover" OR TX "head covering" OR TX "face shield" OR TX "face shields" OR TX "surgical hood" OR TX "hood" OR (MH "Equipment Contamination/PC") OR (MH "Infection Control") OR (TI "infection control") OR (AB "infection control") OR TX "gloving" OR TX "donning" OR TX “doffing” (28,554)

S1

(MH "Health Personnel") OR TX health care workers OR TX health care personnel OR TX health personnel OR TX health-personnel OR TX health providers OR TX health care providers OR TX medical staff OR TX medical personnel OR TX medical professional OR TX medical workers OR TX dental personnel OR TX dental staff OR (MH "Dentists") OR TX dentist OR TX dental assistant OR TX nursing staff OR (MH "Nurses") OR TX nurse OR TX nursing assistant OR (MH "Allied Health Personnel" OR (MH "Midwives") OR TX nurse midwife OR TX nurse midwives OR TX military-medical personnel OR (MH “Physicians") OR TX physician OR TX emergency medical services OR (MH “Emergency Medical Services”) OR TX transporting patients OR TX patient transport OR (MH "Ambulance") OR (MH "Allied Health Personnel") OR TX paramedic OR TX paramedical personnel OR (MH "Burial") OR TX burial staff OR TX cleaning worker OR TX cleaner work OR TX cleaner OR TX cleaners (498,394)

Appendix 10. OSH-update search strategy

Step:	Hits:	Strategy:
#1	32657	GW{protective clothing OR gown* OR coverall* OR protective layer* OR surgical toga* OR apron* OR smock* OR hazmat suit* OR (hazmat AND suit) OR glove* OR respiratory protective device* OR mask OR masks OR air purifying respirator* OR 'PAPR' OR 'enhanced respiratory and contact precautions' OR 'E-RCP' OR respiratory protection OR transparent panel* OR surgical mask* OR filtering face piece OR eye protective device* OR goggle* OR visor OR facial protective equipment OR safety glass* OR safety spectacles OR personal protective equipment OR 'PPE' OR protective equipment OR overshoe* OR shoe cover* OR rubber boot* OR head cover* OR face shield* OR surgical hood OR hood OR equipment contamination OR infection control OR gloving OR donning OR doffing}
#2	11286	GW{communicable disease* OR infectious disease* OR disease transmission OR infection control precautions OR human-to-human transmission OR parenteral transmission OR viral disease* OR bacterial infection* OR filovirus OR Ebolavirus OR hemorrhagic fever OR Ebola OR Marburg virus OR Lassa virus OR SARS virus OR severe acute respiratory syndrome virus OR 'SARS' OR 'MERS' OR respiratory infection* OR bioterrorism OR aerosol-generating procedure OR cross infection* OR bacterial contamination OR microbial contamination OR self-contamination OR decontamination OR surface decontamination OR skin decontamination}
#3	32599	GW{health personnel OR health care worker* OR health care personnel OR health personnel OR health-personnel OR health provider* OR health care provider* OR medical staff OR medical personnel OR medical professional OR medical worker* OR dental personnel OR dental staff OR dentist* OR dental assistant* OR nursing staff OR nurse* OR nursing assistant* OR nurses' aides OR nurse midwife OR nurse midwives OR midwife OR midwives OR military-medical personnel OR physician* OR emergency medical services OR transporting patients OR patient transport OR ambulance* OR allied health personnel OR paramedic* OR paramedical personnel OR burial OR burial staff OR cleaning worker* OR cleaner work OR cleaner*}
#4	1250	#1 AND #2 AND #3
#5	742476	DC{OUBIB OR OUCISD OR OUHSEL OR OUISST OR OUNIOC OR OUNIOS OR OURILO}
#6	1103	#4 AND #5

FEEDBACK

Unified design for PPE, September 2019

Summary

We noted the timely and welcome update of the above review by Dr Verbeek and his team. As stated in the introduction, in epidemics of highly infectious diseases such as Ebola Virus Disease (EVD), healthcare workers (HCW) are at much greater risk of infection than the general population. Sadly the review comes at a time when this once again is being proved, with recent (20th July, 2019) data from the Democratic Republic of Congo (DRC) recording that since the beginning of the epidemic, the cumulative number of cases has been 2564 (2470 confirmed and 94 probable) with 1728 deaths (1634 confirmed and 94 probable cases). Of those, the cumulative number of confirmed/ probable cases among health workers is 138 (5% of all confirmed/probable cases) including 41 deaths (1). This comes shortly after the World Health Organization declared EVD in DRC a Public Health Emergency of International Concern (2). With the United Nations also recognising the seriousness of the emergency, by activating the Humanitarian System-wide Scale-Up to support the EVD response, this increases the possibility of HCW from around the globe being called upon to provide practical support in country, or travellers to affected countries returning with infection, and with it the need for personal protection from exposure to patients' contaminated body fluids.

We were pleased that data from our recent research (3) was included in the review. In our study, we compared five PPE ensembles used in different high consequence infectious disease (HCID) units around the UK for examination of a 'suspected case', using a medical training manikin to expose HCW wearing the PPE to four different body fluid simulants, each tagged with different colour fluorochromes, and UV light to visualise any cross-contamination during dry doffing. We note and accept the conclusions of the Review that "what is missing is a harmonised set of PPE standards and a unified design for PPE to be used when taking care of patients with highly infectious diseases", also that the quality of the evidence was low because conclusions were based on single studies or on small numbers of participants.

While resources did not allow us to address the 'small numbers' issue, we have addressed the 'unified design for PPE' in a paper which was published after the Review literature search cut-off date. In this follow-up work, we presented the outcome of the initial research to the HCID units and reached a consensus on a unified PPE ensemble for examination of a suspected HCID case. Again, using HCW volunteers, we tested the unified PPE ensemble with fluorochromes as before, the result being no cross contamination events from 20 volunteers (4). In subsequent HCW training for one HCID unit, a further 40 challenges using 35 volunteers tested the PPE ensemble with only one cross contamination event through a known deviation from the doffing protocol (unpublished data).Therefore, there were 60 challenges with 54 volunteers with one breach. Public Health England plan in the near future to make written and video guidance available to demonstrate safe use of this unified PPE ensemble, and similar guidance is already available through Health Protection Scotland (5).

While more is needed, we believe this adds to the body of evidence required to ensure HCW can conduct the important business of patient care with confidence that they will be protected from potential infection.

Brian Crook(a), Anne Tunbridge(b), Bozena Poller(b), Samantha Hall(a), Cariad Evans(c) on behalf of the High Consequence Infectious Diseases Project Working Group UK

(a) Health and Safety Executive, Harpur Hill, Buxton SK17 9JN UK, (b) Sheffield Teaching Hospitals NHS Foundation Trust, Department of Infectious Diseases, Royal Hallamshire Hospital, Glossop Road, Sheffield S10 2JF, UK, (c) Sheffield Teaching Hospitals NHS Foundation Trust, Department of Virology, Northern General Hospital, Herries Road, Sheffield, S5 7AU, UK

References

1. DRC Ministry of Health. Epidemiological situation report, Fri 20 Jul 2019. Available at: https://mailchi.mp/sante.gouv.cd/ebola_kivu_20juil19?e=77c16511ad

2. WHO news release 17th July, 2019. Available at: https://www.who.int/news-room/detail/17-07-2019-ebola-outbreak-in-the-democratic-republic-of-the-congo-declared-a-public-health-emergency-of-international-concern

3. Hall S, Poller B, Bailey C, Gregory S, Clark R, Roberts P, Tunbridge A, Poran V, Evans C, Crook B. Use of ultraviolet-fluorescence-based simulation in evaluation of personal protective equipment worn for first assessment and care of a patient with suspected high-consequence infectious disease. J Hosp Infect 2018;99: 218-228

4. Poller B, Tunbridge A, Hall S, Beadsworth M, Jacobs M, Peters E, Schmid ML, Sykes A, Poran V, Gent N, Evans C, Crook B on behalf of the High Consequence Infectious Diseases Project Working Group. A unified personal protective equipment ensemble for clinical response to possible high consequence infectious diseases: A consensus document on behalf of Public Health England and the Health and Safety Executive. Journal of Infection 2018;77:496–502

5. NHS Education for Scotland. Viral Haemorrhagic Fever- The correct order for donning and the safe order for removal and disposal of Personal Protection Equipment. Available at:https://www.nes.scot.nhs.uk/education-and-training/by-theme-initiative/public-health/health-protection/travel-and-international-health/viral-haemorrhagic-fever.aspx

Reply

Thank you for the comments and for supporting the conclusions of our review. It is great to see that the use of PPE for highly infectious diseases is becoming standardised in the UK. Compared to the current diversity in outfits this is certainly an improvement.

We believe that controlled studies form the best evidence in showing the protective capabilities of PPE against highly infectious diseases. We have no doubts that PPE helps in preventing infection. The question remains what the best possible PPE is. Given that infections still occur among health care workers and that users are not very satisfied with the PPE ensembles currently in use, improvement is still possible. Therefore, we included only controlled studies that compared newly designed PPE with existing PPE. The 20 test of one type of PPE by 17 volunteers in the Poller 2018 study were an uncontrolled experiment. Unfortunately, the paper did not provide data on the test of volunteers but only reported that there were no contaminations. Without knowing further details of this study, for example how many times the volunteers tested the new PPE ensemble, it is difficult to judge the significance of this result.

We also noticed that the agreed PPE ensemble currently does not include tags on gloves and masks or a sealed gown-glove combination. These are both aspects that are supported by some evidence in our updated Cochrane review, meaning that these may prevent contamination more than conventional PPE. Therefore, we think that the agreed PPE ensemble could still be improved. We also hope that the newly agreed ensemble, and any further improvements upon it, will be tested against the currently used ones in a sufficiently large randomised experiment of simulated exposure.

Contributors

Jos H Verbeek, Blair Rajamaki, Sharea Ijaz, Christina Tikka, Jani H Ruotsalainen, Riitta Sauni

Certainty of the evidence, November 2019

Summary

This is a large scale and important review. On the next update, the review may benefit from up-to-date application of GRADE. Authors should use the term 'certainty' rather than 'quality' of evidence. At present, the term 'certainty' features in GRADE tables, but 'quality' throughout the text. Although the authors GRADE all comparisons as very low certainty, in the abstract the authors present findings using the term 'may', for example: "may protect better". The accepted plain language for very low certainty evidence is 'we do not know', and the review may therefore over-represent the certainty of evidence. The authors should consider how best to ensure the very low certainty of evidence is adequately reflected for each result presented.

Paul Hine, Honorary research fellow, Cochrane Infectious Diseases Group

Reply

Thank you very much for your comments on our review and pointing out the inconsistency in using quality and certainty of the evidence. We will repair this throughout the review with the next update.

We don't think that the phrase 'may improve' instead of ‘we don't know’ over-represents the certainty of the evidence. At the beginning of the abstract we state: 'Evidence for all outcomes is based on single studies and is very low quality'. Recent GRADE guidance says that very low certainty evidence can be reported as 'may improve but the evidence is very uncertain'.[1] This is also the guidance in the latest version of the Cochrane Handbook (Table 15.6.b). We will add the additional "but the evidence is very uncertain" to the phrase 'may improve' in the review update in line with the most recent GRADE guidance.

[1] *Santesso N, Glenton C, Dahm P, Garner P, Akl E, Alper B, Brignardello-Petersen R, Carrasco-Labra A, De Beer H, Hultcrantz M, Kuijpers T, Meerpohl J, Morgan R, Mustafa R, Skoetz N, Sultan S, Wiysonge C, Guyatt G, Schünemann HJ, for the GRADE Working Group, GRADE guidelines 26: Informative statements to communicate the findings of systematic reviews of interventions, Journal of Clinical Epidemiology (2019)*

Contributors

Jos H Verbeek, Blair Rajamaki, Sharea Ijaz, Christina Tikka, Jani H Ruotsalainen, Riitta Sauni

Comparisons, April 2020

Summary

The comparison of PAPR and gown, vs N95 and gown is a poor comparison. And should not be used as a fair comparison and will likely give HCW the wrong impression. PAPR/CAPR and gown vs N95 and face shield with gown should be the equal comparison arms. Please consider this as this will give people the wrong messaging as we know face shields are an important component to PPE and we should do a real comparison as to determine whether one protection is better than another.

Michael Bolaris

Reply

Thank you for comments. We were already quite strict with including only studies that intended to evaluate full-body protection. We don't have control over the interventions and controls that have been evaluated in studies. This specific combination of intervention and control was evaluated in one trial as a result of the problems encountered with aerosol generating procedures during the SARS epidemic. We think that the results are still very useful for the current COVID-19 pandemic. The difference in contamination with the two types of PPE was especially caused by contamination of the neck in the PPE that consisted of mask and gown but where the gown did not cover the neck. We doubt that a face-shield would have made much difference here because it does not protect the neck. The current WHO COVIID-19 guidelines suggest the use of a gown with face mask and goggles as minimum PPE. This PPE ensemble leaves a part of the body uncovered and the trial mentioned above shows that this can easily lead to contamination

Contributors

Jos H Verbeek, Blair Rajamaki, Sharea Ijaz, Riitta Sauni, Elaine Toomey, Bronagh Blackwood, Christina Tikka, Jani H Ruotsalainen, F Selcen Kilinc Balci

WHAT'S NEW

Date	Event	Description
24 April 2020	Feedback has been incorporated	Feedback about comparisons and author response incorporated

HISTORY

Protocol first published: Issue 4, 2015
Review first published: Issue 4, 2016

Date	Event	Description
30 March 2020	New citation required and conclusions have changed	Seven new studies incorporated, revised to incorporate COVID-19 developments, conclusions changed.
30 March 2020	New search has been performed	All searches updated, new studies incorporated, categorisation of interventions slightly changed, background revised to incorporate COVID-19 developments, conclusions changed
5 December 2019	Feedback has been incorporated	Feedback about the certainty of the evidence and authors' response incorporated
13 September 2019	Amended	Feedback updated with more information from latest tests
9 September 2019	Feedback has been incorporated	Feedback and authors' response added
22 July 2019	Amended	In summary of findings tables we corrected the number of plusses for the quality of the evidence to match the very low quality evidence
20 June 2019	New citation required and conclusions have changed	We included eight new studies of which one is a field study and seven are simulation studies. This extended the evidence to other types of PPE.
18 June 2019	New search has been performed	Updated the databases:PubMed up to 15 July 2018, CENTRAL up to 18 June 2019, Scopus 18 June 2019, CINAHL 31 July 2018 and OSH-Update up to 31 December 2018

CONTRIBUTIONS OF AUTHORS

Conceiving the protocol: JV, SI, CT, JR, KN

Designing the protocol: JV, CT, JR, KN, ME, EM, RS

Coordinating the protocol and the review: JV, SI

Designing search strategies: KN

Data extraction: JV, BR, SI, CT, RS, BB, ET

Data analysis: JV

Writing the protocol and the review: JV, BR, FSKB, BB, ET

Providing general advice on the protocol and review: RS, FSKB

DECLARATIONS OF INTEREST

Jos Verbeek: none known

Blair Rajamaki: none known

Sharea Ijaz: none known

Christina Mischke: none known

Jani Ruotsalainen: none known

F Selcen Kilinc Balci: none known

Riitta Sauni: none known

Bronagh Blackwood: none known

Elaine Toomley: none known

SOURCES OF SUPPORT

Internal sources

- Cochrane Collaboration, UK

  Bursary to Sharea Ijaz
- Finnish Institute of Occupational Health, Finland

  Salary for Jos Verbeek, Christina Mischke, Jani Ruotsalainen, Erja Mäkelä and Kaisa Neuvonen
- National Institute for Occupational Safety and Health, USA

  Salary for F Selcen Kilinc Balci

External sources

- No sources of support supplied

DIFFERENCES BETWEEN PROTOCOL AND REVIEW

- We changed the title from 'Personal protective equipment for preventing highly infectious diseases due to contact with contaminated body fluids in health care staff' to 'Personal protective equipment for preventing highly infectious diseases due to exposure to contaminated body fluids in healthcare staff' to avoid confusion with the term 'contact precautions'.
- We replaced the statement in the methods section: "We will also include audit reports or case reports of PPE failure in which there are no comparisons. We will not use these for drawing conclusions but only to compare with findings produced by the above study types. For audit reports, we will examine any reports of failed PPE or audits of health care staff being infected or contaminated" with "We intended to also include uncontrolled audit reports or case reports of PPE failure for descriptive purposes, but we did not find any. If we find any such reports in future updates of this review, we will not use them for drawing conclusions, but only to compare with findings produced by the above study types".
- We added the following definition of PPE in the methods section because it was lacking: "We defined PPE as any of the above equipment designed or intended to protect healthcare staff from contamination with body fluids".
- We added an extra outcome "Time to don and doff the PPE" because we stated in our protocol that we would add outcomes that we had not defined in advance and that we considered important.
- We added a more detailed description of the specific resources that we searched in addition to the electronic databases, that is, the specific non-governmental organisations (Médicins Sans Frontierès and Save the Children), and specific manufacturers (DuPont, 3M, and Alpha Pro Tech). We could not foresee in advance which parties we would be contacting.
- When using the GRADE considerations to assess the certainty of the evidence, for non-randomised studies, we started at the 'low-certainty' level, rather than the 'moderate-certainty' level outlined in the protocol, as per the recommendations of the *Cochrane Handbook for Systematic Reviews of Interventions* (Schünemann 2017).

NOTES

Disclaimer. The findings and conclusions in this Cochrane systematic review are those of the authors and do not necessarily represent the official position of the National Institute for Occupational Safety and Health, Centers for Disease Control and Prevention. Mention of product names does not imply endorsement

INDEX TERMS

Medical Subject Headings (MeSH)

Body Fluids; Gloves, Protective; *Health Personnel; Hemorrhagic Fever, Ebola [prevention & control] [transmission]; Infectious Disease Transmission, Patient-to-Professional [*prevention & control]; *Personal Protective Equipment; Protective Clothing; Randomized Controlled Trials as Topic; Severe Acute Respiratory Syndrome [prevention & control] [transmission]

MeSH check words

Humans