

Contextual data

KQ8. Should health workers using waterproof aprons to cover gowns or coveralls while providing direct or indirect care to patients with Ebola or Marburg virus disease, use disposable versus reusable versus biodegradable types of aprons?

We conducted a rapid review for KQ 8, especially updating the Hersi et al. 2015 rapid review and the Verbeek et al. 2020 systematic review with respect to the use of aprons.[1] [2] There is very limited data to support the choice among disposable, reusable or biodegradable types of aprons. The data gap on this key question identified in the WHO recommendation in 2014 remains an issue today. [3]

Table 1 summarizes PPE recommendations regarding apron use by the WHO, US CDC and European CDC. Both the WHO and US CDC recommend the use of apron. [3] [4] The European CDC technical report did not mention the use of apron. [5]

Reidy et al. report on PPE solution for UK military medical personnel working in an Ebola treatment unit in Sierra Leone. [6] Aprons were included within the PPE solution to increase protection to the front of the wearer, as this area was considered to be at high risk of splashes/spills of contaminated material and, in addition, the coverall zip was set into permeable material. The properties stipulated were: length (below knee), plastic and lightweight design (minimum 16-mm thickness, so it would stay in place but could be torn off deliberately as part of the removal process), fluid repellent and disposable. The apron chosen was adjustable, and so could cover the zip completely, irrespective of body shape, and helped to minimize heat stress whilst giving the necessary protection. The recommendation was to change aprons and gloves between patients in order to reduce the risk of cross-contamination between patients.

With respect to the extraction of contextual data, the key findings are as follows (Table 2).

- *Disposable* (single-use) isolation gowns are designed to be discarded after a single use and are typically constructed of nonwoven materials alone or in combination with materials that offer increased protection from liquid penetration, such as plastic films. They can be produced using a variety of nonwoven fiber-bonding technologies (thermal, chemical, or mechanical) to provide integrity and strength rather than the interlocking geometries associated with woven and knitted materials. The basic raw materials typically used for disposable isolation gowns are various forms of synthetic fibers (e.g. polypropylene, polyester, polyethylene). Fabrics can be engineered to achieve desired properties by using particular fiber types, bonding processes, and fabric finishes (chemical or physical treatments). [7]
- *Reusable* (multi-use) gowns are laundered after each use. Reusable isolation gowns are typically made of 100% cotton, 100% polyester, or polyester/cotton blends. These fabrics are tightly woven plain weave fabrics that are chemically finished and may be pressed through rollers to enhance the liquid barrier properties. Reusable garments generally can be used for 50 or more washing and drying cycles. The number of laundering/drying cycles is suggested by the manufacturer. According to a guidance by the Association for the Advancement of Medical Instrumentation, a verifiable tracking system, such as a manual check off, bar code, or radio frequency chip, a verifiable tracking system, must be in place. [7]
- According to the setup of a simulation study, personal protective clothing PPC2 was composed of absorbent cotton fabric (zero value for water repellency and liquid penetration pressure) with the greatest thickness. [8] PPC1 and PPC3 had grades 4 and 5 of water repellency, high resistance to liquid water penetration, and thinner fabric. PPC2 carried the lowest contaminative hazards to the hands, shoes, and surroundings compared with PPC1 and PPC3. Cotton through its material and

properties can absorb droplet contaminants and thereby reduce opportunities for such contaminants to spread to the environment. However, the absorbent fabric likewise increased underwear contamination by liquid crossing outerwear.

- Plastic apron (PPC3) had a higher chance of contaminating the environment than PPC1 and PPC2. Because plastic had the lowest water-absorbing properties, the droplets that cannot be absorbed by the surface of the plastic might then drop to the floor or spread to the surrounding area, which especially increased contamination with large patches. The plastic apron had a smaller covered area, which also caused heavier underwear contamination (or the contamination of the next layer of the PPE ensemble). [8]
- The results of this simulation study indicate that the traditional cotton surgical gown (woven gown) can absorb liquid contaminants and thus reduces environmental contamination. The other gown (nonwoven gown) can resist the absorption of liquid contaminants when the covered area is sufficient and thus provides better physical barrier protection than the woven gown. However, the nonwoven gown has weak liquid absorption ability. The liquid contaminant may easily drop to the floor or splash to the surrounding environment during movement. More important, an extra force added to the movement, such as by pulling off the isolation gown without unfastening the ties, tearing off the plastic apron, or removing the gown or apron forcefully, spreads droplet contaminants that can splash not only to the surrounding environment but also to nearby patients. [8]
- The present results suggest that double gowns with outer absorbent cotton reduce the spread of contaminants to the environment, whereas inner water repellency gowns can resist contaminants and prevent them from penetrating into underwear and even the skin, providing better protection than a single gown in preventing HW from coming into contact with patients' blood and body fluids during splashing procedures. [8]
- Lee et al. 2021 assessed PPE needs for health workers by surveying a convenient sample of 200 HWs in the US. [9] PPE design features were assessed on a five-point Likert-type scale, ranging from "strongly disagree" (1) to "strongly agree" (5). The mean values of PPE were higher than 3 (on the 1-5 scale) for fit (mean = 3.45, SD = 0.56), comfort (M = 3.38, SD = 0.72), mobility (M = 3.44, SD = 0.69), and donning and doffing (M = 3.71, SD = 0.87), suggesting that HWs think that current PPE (scrubs, gowns, coveralls, and apron) for body protection meet their needs of fit, comfort, mobility, and donning and doffing.
- With respect to body protection, 31% of the participants considered comfortability as the biggest challenge when wearing PPE, followed by sizing and fit (27%), donning and doffing (14%), movement (12%), material durability (12%), and others (3%) such as easy to use and PPE weight. HWs are more likely "Strongly agree" than "Strongly disagree" to accept PPE based on the donning and doffing feature, odds ratio = 2.37, 95% confidence interval [0.48, 11.61], which means that the donning and doffing feature plays a vital role on HWs' overall PPE acceptance. [9]
- Poller et al 2018 conducted a simulation study and organized a consensus panel to identify a unified PPE ensemble for clinical response to possible high consequence infectious diseases in the United Kingdom. [10] The consensus ensemble provided full protection against contamination in the simulation study. This ensemble included wide, extra-long medium thickness plastic apron (such as those worn for endoscopy). A higher fit to protect the upper chest is desired and no such apron existed. Tearing the neck loop in the middle so both the neck and waist areas were tied was deemed an acceptable and simple modification, which significantly improved protection. Details regarding doffing assistance, instructions and training for the use of the PPE ensemble are captured in Table 2. [10]
- Kilinc-Balci et al. 2015 tested 22 commercial single-use isolation gowns for barrier and strength properties using American Society of Testing and Materials International ASTM (D5034, D5733,

D1683, F1671) and American Association of Textile Chemists and Colorists (AATCC 42 and 127) test methods and the Association for the Advancement of Medical Instrumentation (AAMI) PB70 liquid barrier classification standard requirements. [11] Testing results demonstrated that there is a large variation in the barrier and strength properties of existing isolation gowns in the marketplace. It was also found that nine (41%) of the 22 tested isolation gowns failed to meet the AAMI PB70 requirements for the liquid barrier performance at the level specified by the manufacturer. The results support the use of aprons for additional protection.

Simulation studies are needed to clarify apron choices - they are simple to do at a usability lab, may require few participants (e.g., 40), [12] and can be conducted at a reasonably low cost. The WHO may consider commissioning a simulation study with an experimental design to test the choices of aprons, as well as other PPE elements in KQ4 and KQ7. For example, the methods section of Drew et al. 2019 provides an example for the planning of such commission, and simulation platforms exist for training and evaluating how HWs use PPE.[13, 14]

References

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Table 1: Summary of PPE recommendations regarding apron use by WHO, US CDC and European CDC

Source	Apron use
WHO [3]	
Recommendation 8	<p>Compared with other forms of protective body wear, the choice of PPE for covering clothing should be either a disposable gown and apron, or a disposable coverall and apron; the gown and the coverall should be made of fabric that is tested for resistance to penetration by blood or body fluids or to blood-borne pathogens.</p> <p><i>Conditional recommendation, very low quality evidence comparing effectiveness of gowns and coveralls</i></p>
Recommendation 9	<p>The choice of apron should be, in order of preference:</p> <ul style="list-style-type: none"> <input type="checkbox"/> Disposable, waterproof apron <input type="checkbox"/> If disposable aprons are not available, heavy duty, reusable waterproof aprons can be used if appropriate cleaning and disinfection between patients is performed. <p><i>Strong recommendation, very low quality evidence comparing effectiveness of disposable and reusable apron</i></p> <p><u>Rationale and remarks:</u> An apron should be worn over the gown or coveralls; it is easier to remove a soiled apron compared to gowns and coveralls. An apron is generally worn for the entire time the health worker is in the treatment area. If the apron is visibly soiled, a disposable apron should be removed and changed. Feasibility issues, such as availability of new aprons and waste disposal within isolation areas, must be addressed. Health workers wearing a reusable apron should leave the ward to clean, disinfect and remove the apron.</p>
US CDC [4]	<p>Single-use (disposable) apron that covers the torso to the level of the mid-calf should be used over the gown or coveralls if patients with Ebola are vomiting or have diarrhea, and should be used routinely if the facility is using a coverall that has an exposed, unprotected zipper in the front. An apron provides additional protection, reducing the contamination of gowns or coveralls by body fluids and providing a way to quickly remove a soiled outer layer during patient care. Select an apron with a neck strap that can be easily broken or untied to avoid having to pull the strap over the head, which makes it easier to remove without self-contamination when exchanging a soiled apron during care or when removing the apron during the doffing procedure.</p>
European CDC [5]	No mention of apron, the focus was on impermeable gown.

Table 2. Summary of contextual data

Author	Year	Study methods	Method details, measures or findings relevant to the extraction of contextual data	Data type	Contextual data
Guo [8]	2014	Simulation study with 50 participants	Simulation study aimed to examine the body contamination rates and environmental contamination levels during the removal of 3 types of personal protective clothing (PPC) by the individual accustomed removal method (IARM) and gown removal methods recommended by the Centers for Disease Control and Prevention (CDC).	Usability	Personal protective clothing PPC2 was composed of absorbent cotton fabric (zero value for water repellency and liquid penetration pressure) with the greatest thickness. PPC1 and PPC3 had grades 4 and 5 of water repellency, high resistance to liquid water penetration, and thinner fabric. PPC2 carried the lowest contaminative hazards to the hands, shoes, and surroundings compared with PPC1 and PPC3. Cotton through its material and properties can absorb droplet contaminants and thereby reduce opportunities for such contaminants to spread to the environment. However, the absorbent fabric likewise increased underwear contamination by liquid crossing underwear.
		Simulation study with 50 participants	as above	Usability	Plastic apron (PPC3) had a higher chance of contaminating the environment than PPC1 and PPC2. Because plastic had the lowest water-absorbing properties, the droplets that cannot be absorbed by the surface of the plastic might then drop to the floor or spread to the surrounding area, which especially increased contamination with large patches. The plastic apron had a smaller covered area, which also caused heavier underwear contamination.
Guo	2014	Simulation study with 50 participants	as above		The results of this study and those of Wong et al indicate that the traditional cotton surgical gown (woven gown) can absorb liquid contaminants and thus reduces environmental contamination. The other gown (nonwoven gown) can resist the absorption of liquid contaminants when the covered area is sufficient and thus provides better physical barrier protection than the woven gown. However, the nonwoven gown has weak liquid absorption ability. The liquid contaminant may easily drop to the floor or splash to the surrounding environment during movement. More important, an extra force added to the movement, such as by pulling off the isolation gown without unfastening the ties, tearing off the plastic apron, or removing the gown or apron forcefully, spreads droplet contaminants that can splash not only to the surrounding environment but also to nearby patients.
Guo	2014	Simulation study with 50 participants	as above	Implementation	The present results suggest that double gowns with outer absorbent cotton reduce the spread of contaminants to the environment, whereas inner water repellency gowns can resist contaminants and prevent them from penetrating into underwear and even the skin, providing better protection than a single gown in preventing HW from coming into contact with patients' blood and body fluids during surgery and other splashing procedures.
Lee [9]	2021	Assessing PPE needs for health workers by surveying a convenient sample of 200 HWs in the US	This study showed the need for current PPE improvement in terms of fit, comfort, mobility, and donning and doffing for HCWs' safety and health. Donning and doffing plays an important role in HCWs' overall acceptance of PPE for body protection.	Usage	For body protection, 83% were using gowns, followed by 80.5% of scrubs including tops and pants, 31% of disposable aprons, 18.5% of coveralls, and 13.5% of reusable aprons.
Lee	2021	as above	PPE design features including 13 items of fit, 10 items of mobility, 6 items of comfort, 2 items of donning and doffing, and 2 items of aesthetic, and 1 item related to overall PPE acceptability. All measures were measured on a five-point Likert-type scale, ranging from "strongly disagree" (1) to "strongly agree" (5).	Usability	The study assessed the current PPE design features for body protection, including fit, mobility, comfort, donning and doffing, and aesthetic. The mean values of PPE were higher than 3 (on the 1-5 scale) for fit (mean = 3.45, SD = 0.56), comfort (M = 3.38, SD = 0.72), mobility (M = 3.44, SD = 0.69), and donning and doffing (M = 3.71, SD = 0.87), suggesting that HWs think that current PPE (scrubs, gowns, coveralls, and apron) for body protection meet their needs of fit, comfort, mobility, and donning and doffing.

Lee	2021	as above	PPE design features were also assessed using open-ended questions. Qualitative data were analyzed to identify thematic content.	Usability	With respect to body protection, 31% of the participants considered comfortability as the biggest challenge when wearing PPE, followed by sizing and fit (27%), donning and doffing (14%), movement (12%), material durability (12%), and others (3%) such as easy to use and PPE weight.
Lee	2021	as above	A categorical logit model was used to examine the effect of PPE design features (fit, mobility, comfort, donning and doffing, and aesthetic) and years of work experiences on overall PPE acceptability.	Acceptability	HCWs are more likely “Strongly agree” than “Strongly disagree” to accept PPE based on the donning and doffing feature, OR = 2.37, 95% CI [0.48, 11.61], which means that the donning and doffing feature plays a vital role on HCWs' overall PPE acceptance.
Lee	2021	as above		Implementation	This study also reveals that most HCWs dispose of their PPE in a trash can in a healthcare unit, and non-disposed PPE is laundered at home, which may expose family members to a health risk if a proper precaution is not followed.
Kilinc [7]	2015	Expert review	This paper reviews isolation gowns in healthcare settings, including the fabrics used, gown design and interfaces, as well as critical parameters that affect microorganism and liquid transmission through fabrics.	Implementation	Disposable (single-use) isolation gowns are designed to be discarded after a single use and are typically constructed of nonwoven materials alone or in combination with materials that offer increased protection from liquid penetration, such as plastic films. They can be produced using a variety of nonwoven fiber-bonding technologies (thermal, chemical, or mechanical) to provide integrity and strength rather than the interlocking geometries associated with woven and knitted materials. The basic raw materials typically used for disposable isolation gowns are various forms of synthetic fibers (e.g. polypropylene, polyester, polyethylene). Fabrics can be engineered to achieve desired properties by using particular fiber types, bonding processes, and fabric finishes (chemical or physical treatments).
Kilinc	2015	as above	as above	Implementation	Reusable (multi-use) gowns are laundered after each use. Reusable isolation gowns are typically made of 100% cotton, 100% polyester, or polyester/cotton blends. These fabrics are tightly woven plain weave fabrics that are chemically finished and may be pressed through rollers to enhance the liquid barrier properties. Reusable garments generally can be used for 50 or more washing and drying cycles. The number of laundering/drying cycles is suggested by the manufacturer. According to a guidance by the Association for the Advancement of Medical Instrumentation, a verifiable tracking system, such as a manual check off, bar code, or radio frequency chip, a verifiable tracking system, must be in place.
Poller [10]	2018	Simulation study and consensus panel to identify a unified PPE ensemble for clinical response to possible high consequence infectious diseases in the United Kingdom	A simulation-based exercise was developed to assess the safety of PPE ensembles in use in the UK during first assessment of a patient with a possible HCID. A mannequin was adapted to expose volunteer HCWs to synthetic bodily fluids (vomit, sweat, diarrhea and cough), each with a different colored fluorescent tracer, invisible other than under ultraviolet (UV) light. After exposure, HCWs were examined under UV lights to locate fluorescent contamination, and were screened again after removing PPE (doffing) to detect any personal contamination. The exercise was videoed, allowing retrospective analysis of contamination events and user errors.	Implementation	The simulation testing identified significant HCW contamination events after doffing, related to protocol failure or complications in PPE doffing, providing conclusive evidence that improvements could be made.
Poller	2018	as above	At a workshop with an expert stakeholder group, the data were examined and a unified PPE ensemble agreed.	Implementation	This ensemble was then tested in the same simulation exercise and no evidence of any HCW contamination was seen after doffing. Following further review by the working group, a consensus agreement has been reached and a unified ‘HCID assessment PPE’ ensemble, with accompanying donning and doffing protocols, is identified.
Poller	2018	as above		Implementation	Wide, extra-long medium thickness plastic apron (such as worn for endoscopy): although agreed that ideally PPE items should not be modified, a higher fit to protect the upper chest was desired and no such apron existed. Tearing the neck loop in the middle so both the neck and waist areas were tied was deemed an acceptable and simple modification, which significantly improved protection.

Poller	2018	as above		Implementation	Doffing assistance: A ‘hands off’ doffing buddy is essential to support staffing safe removal of PPE and to avoid buddy contamination. The buddy should talk the HW slowly through each step, instructing and mirroring each action face to face. This also allows the buddy to identify any slip of PPE, such as the mask or hood moving on the face, which ensures the person doffing avoids inadvertent contamination.
Poller	2018	as above		Implementation	Instructions and signage: Instruction posters (donning and doffing cards) for the new PPE ensemble are made. It is recommended that they are clearly visible in the donning and doffing area, but should not replace the support of a ‘doffing buddy’ to ensure all stages are followed safely. Clear zone demarcations are recommended, and can be reinforced visually at the zone boundaries by laminated cards stating the area (e.g. ‘Red area: you are entering the dirty zone’, ‘Amber area: you are entering the doffing zone’, ‘Green area: you are entering a clean area’). Doffing areas should be sufficiently spacious to allow the HW to move freely without touching surfaces or walls.
Poller	2018	as above		Implementation	Training: In order to ensure familiarity of this PPE and sustain competency in its use, it is advised that a regular mandatory training program be in place.
Boon [15]	2014	Survey 44 frontline physicians and nurses deployed to West Africa between March and September of 2014.	To understand frontline physicians’ and nurses’ perspectives about personal protective equipment (PPE) use during the 2014-2016 EVD outbreak in West Africa and to incorporate these findings into the development process of a WHO rapid advice guideline.	Implementation	Both gowns and coveralls were associated with significant heat stress and dehydration. Heat and dehydration also were a significant or major issue for the majority of individuals using a gown (n=11, 73%) or coverall (n=26, 87%); however, there was no significant difference between the two groups (p=0.41). Another survey participant commented: “ <i>The coverall would probably be better tolerated if we could breathe easier and see without problems</i> ”. Our study demonstrated that it was possible to incorporate primary data on end-users’ preferences into a rapid advice guideline for a public health emergency in difficult field conditions. Health workers perceived a balance between transmission protection and ability to care for patients effectively while wearing PPE.
Kilinc-Balci [11]	2015	Evaluation of the Performance of Isolation Gowns	American Society of Testing and Materials International’s (ASTM) F23 Committee started a work item in collaboration with the National Personal Protective Technology Laboratory to develop minimum performance and design criteria for isolation gowns to assist end users in correct isolation gown selection, assuring higher levels of protection than currently provided.	Implementation	Consumer complaints about strength properties of isolation gowns highlighted the need for a new standard that specifies minimum performance requirements.
Kilinc-Balci	2015	as above	Twenty two single-use isolation gowns were evaluated for barrier and strength properties using ASTM (D5034, D5733, D1683, F1671) and American Association of Textile Chemists and Colorists (AATCC 42 and 127) test methods and Association for the Advancement of Medical Instrumentation (AAMI) PB70 liquid barrier classification standard requirements.	Implementation	Testing results demonstrated that there is a large variation in the barrier and strength properties of existing isolation gowns in the marketplace. It was also found that nine (41%) of the 22 tested isolation gowns failed to meet the AAMI PB70 requirements for the liquid barrier performance at the level specified by the manufacturer.
Reidy [6]	2017	Narrative report	In September 2014, specialists from Public Health England, the National Ambulance Resilience Unit and the Ministry of Defence (MoD) worked together to identify the combination of PPE and donning and doffing protocols for PPE worn by military medical personnel working in a 12-bedded ETU in Kerry Town, Sierra Leone. Medical workers were protected by the combination of PPE, donning and doffing procedures, and working practices used within the facility.	Implementation	Aprons were included within the PPE solution to increase protection to the front of the wearer, as this area was considered to be at high risk of splashes/spills of contaminated material and, in addition, the coverall zip was set into permeable material. The properties stipulated were: length (below knee), plastic and lightweight design (minimum 16-mm thickness, so it would stay in place but could be torn off deliberately as part of the removal process), fluid repellent and disposable. The apron chosen was adjustable, and so could cover the zip completely, irrespective of body shape, and helped to minimize heat stress whilst giving the necessary protection. The recommendation was to change aprons and gloves between patients in order to reduce the risk of crosscontamination between patients.

Fischer [16]	2015	Expert commentary	Articles pertaining to filovirus transmission and PPE in filovirus outbreaks were reviewed and findings are presented.	Implementation	The use of a waterproof or impermeable apron worn over the gown/coverall is recommended to provide further protection against infectious body fluids. Both the CDC and the WHO recommend using a disposable apron if feasible because a reusable one will require decontamination after each use.
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