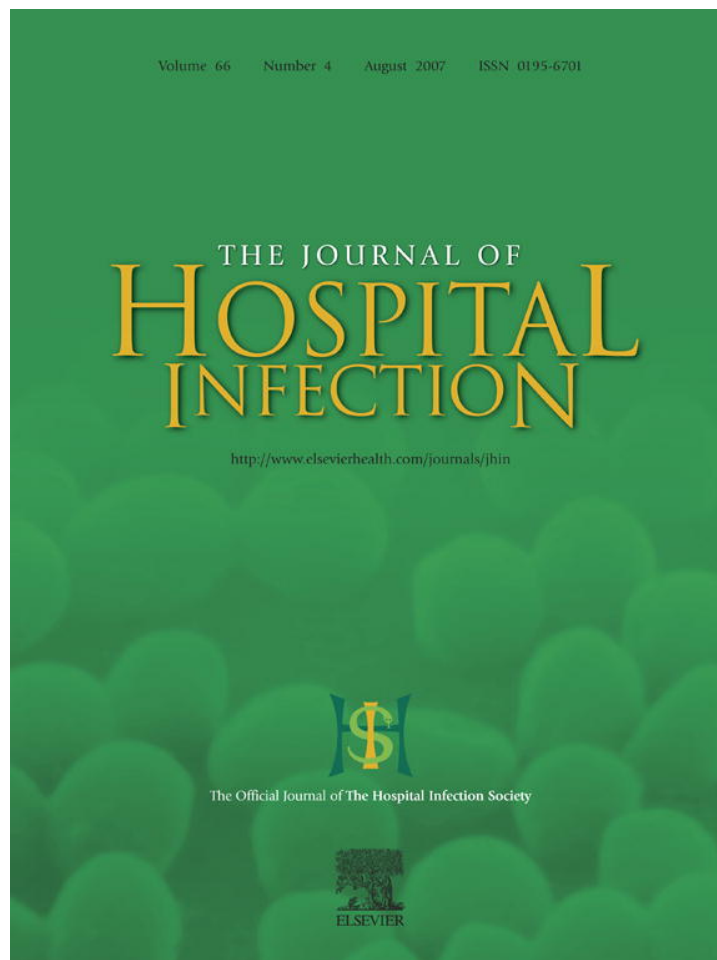


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REVIEW

Uniform: an evidence review of the microbiological significance of uniforms and uniform policy in the prevention and control of healthcare-associated infections. Report to the Department of Health (England)

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Domestic laundry of
uniforms

Summary A systematic search and quality assessment of published literature was conducted to establish current knowledge on the role of healthcare workers uniforms' as vehicles for the transfer of healthcare-associated infections. This review comprised a systematic search of national and international guidance, published literature and data on recent advances in laundry technology and processes. We found only a small number of relevant studies that provided limited evidence directly related to the decontamination of uniforms. Studies concerning domestic laundry processes are small scale and largely observational. Current practice and guidance for laundering uniforms is extrapolated from studies of industrial hospital linen processing. Healthcare workers' uniforms, including white coats, become progressively contaminated in use with bacteria of low pathogenicity from the wearer and of mixed pathogenicity from the clinical environment and patients. The hypothesis that uniforms/clothing could be a vehicle for the transmission of infections is not supported by existing evidence. All components of the laundering process contribute to the removal or killing of micro-organisms on fabric. There is no robust evidence of a difference in efficacy of decontamination of uniforms/clothing between

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industrial and domestic laundry processes, or that the home laundering of uniforms provides inadequate decontamination.

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Introduction

Public perception that healthcare professionals wearing uniforms to travel to and from work might contribute to the spread of healthcare-associated infections (HCAI) has become the focus of professional and media concern. A survey by the Royal College of Nursing showed that staff have limited numbers of uniforms and that few hospitals have changing facilities.¹ It is more common for healthcare staff to launder their uniforms at home than for Trusts to supply uniforms processed in an industrial laundry. However, evidence to support the perception that wearing uniforms in public spaces and home laundering pose an infection risk is rarely cited. Our review was commissioned and funded by the Department of Health (England) to inform policy development. We describe a systematic review of the literature related to healthcare workers' uniforms as a vehicle of transmission and the efficacy of different laundry practices.

Methods

A systematic search of electronic databases of national and international guidance, published literature and data on recent advances in laundry technology and processes was used to identify papers that would inform the evidence base. The questions used to focus the search strategy are shown in [Box 1](#).

Definition of terms

For the purposes of retrieving studies for this review, uniform was defined as clothing worn by healthcare practitioners for everyday practice in clinical environments and included:

- dresses, tunics and trousers;
- white coats and jackets;
- scrub suits worn outside the operating department;
- fabric gowns worn continuously for patient contact in specialist clinical settings, such as burns units, isolation units and special care baby units.

Box 1 Review questions

What is the evidence that:

1. Work clothing of healthcare practitioners becomes contaminated with micro-organisms?
2. Micro-organisms causing HCAI adhere more readily to some fabrics than others?
3. There is an epidemiological link between microbiological contaminants found on the work clothing of healthcare practitioners and cases of HCAI?
4. Some parts of the laundry cycle are more effective than others at reducing soil?
5. There is a difference in decontamination efficacy between domestic and industrial processes of laundering of work clothing?
6. Underpins current UK guidance on hospital laundry?

We did not include studies related to the wearing of clothing designated as protective equipment for either the patient or the person wearing it.

Data sources

Published literature available in English language was searched for in the National Research Register and six major databases available through the OVID interface: MEDLINE; EMBASE; Cumulative Index of Nursing and Allied Health Literature (CINAHL); Cochrane Clinical Trials Register; NHS Centre for Reviews and Dissemination, Database of Reviews of Effectiveness; and the Health Management Information Consortium Database.

The search strategy and medical subject headings (MeSH) terms were developed and refined in MEDLINE and adapted for use in EMBASE and CINAHL ([Box 2](#)). The period from 1966 to December 2005 was searched and 1781 relevant studies were identified for preliminary abstract appraisal. Additional studies of potential relevance were identified from reference lists of retrieved studies.

Abstract review

Search results were downloaded into a Reference Manager™ database and titles and abstracts

Box 2 MEDLINE MeSH terms

CLOTHING/
 TEXTILES/
 DETERGENTS/
 SOAPS/
 Household Products/
 Disinfection/
 Disinfectants/
 Decontamination/
 Hygiene/or Housekeeping, Hospital/
 Heat/
 Cell Survival/
 Water Microbiology/
 LAUNDERING/
 Hygiene/
 Laundry Service, Hospital/
 BACTERIA/
 VIRUSES/
 Infection Control/
 Cross Infection/
 Communicable Disease Control/

printed for preliminary review. Reviewers identified and retrieved all studies where the title or abstract addressed one or more of the study questions; identified primary research or systematically conducted secondary research; indicated a theoretical/clinical/in-use study. Limited resources meant that foreign language studies were excluded from the review.

This process resulted in 118 full-text studies being retrieved for preliminary appraisal. Two experienced reviewers appraised each study independently and identified 24 studies meeting the criteria for quality assessment (Box 3). Disagreement between reviewers was resolved through discussion.

Quality assessment and data extraction

The 24 studies were assessed and data extracted using a process adapted from the Scottish

Box 3 Appraisal inclusion criteria

1. The study addresses one or more of the review questions in a clear, focused way.
2. The intervention/investigation is clearly described and applicable to current practice.
3. The study outcomes are measured in a standard, valid and reliable way.
4. The microbiological techniques are applicable to current practice, standard, valid and reliable.

Intercollegiate Guideline Network (2005). Studies were not double-blind appraised; however, all studies were appraised and data extracted by one experienced reviewer and agreed by a second experienced reviewer.

Results**What is the evidence that the work clothing of healthcare practitioners becomes contaminated with micro-organisms?**

Seven studies were identified for quality assessment, all of which were small scale. These studies indicated that nurses' uniforms become contaminated with micro-organisms.^{2–8} However, approximately one-third of the micro-organisms recovered originate from the flora of the wearer.² Uniforms have been found to become frequently contaminated below the waist and heavily contaminated after procedures likely to involve exposure to pathogens, e.g. dressing wounds.² The use of plastic aprons significantly reduces microbial contamination of the front of the uniform.³ Meticillin-resistant *Staphylococcus aureus*, *Clostridium difficile*, and vancomycin-resistant enterococci have been recovered from staff uniforms, but many studies have reported the presence of pathogens rather than the degree of contamination or have not distinguished between pathogenic and non-pathogenic environmental or skin flora.^{4–6,8} In a study of uniforms worn by staff working in an isolation ward, *S. aureus* was recovered in small numbers (1–5 cfu/25 cm² contact plate) from 9–15% of in-use protective clothing and uniforms.³ Doctors' white coats have been shown to become contaminated progressively as they were worn, but the majority of organisms isolated were non-pathogenic environmental bacteria or skin commensals probably originating from the wearer.^{7,8}

What is the evidence of an epidemiological link between microbiological contaminants found on the work clothing of healthcare practitioners and cases of HCAI?

One study conducted in a burns unit demonstrated that it was possible to transfer *S. aureus* from nurses' gowns to patients and bed sheets.⁹ One report describing an epidemiological link between microbial contamination of work clothing and cases of HCAI occurred under very unusual circumstances. Lint from scrub suits heavily contaminated with *Bacillus cereus* was thought to have

settled into surgical wounds that were exposed for extended periods during surgery, subsequently causing wound infection.¹⁰ In this case the industrial laundry was the source of the contamination on work clothing rather than contamination acquired during use.¹¹

What is the evidence that indicates that micro-organisms causing HCAI adhere more readily to some fabrics than others?

Two studies were found that investigated the relationship between micro-organisms and properties of fabrics in a laboratory setting. However, neither study reflected the type of contamination encountered in clinical environments where micro-organisms on fabrics are more likely to be derived from skin scales or surface contact with body fluids.^{12,13}

Which part of the laundry cycle contributes the greatest reduction in soil?

The effect of dilution with water

Dilution is a key component of removing microbial contamination. In two studies the effect of dilution was tested in a wash process that used no detergent and cool water (<31 °C) and was found to achieve reductions in bacteria recovered in wash effluent of between 10^{1.5} and 10³.^{14,15} However, it is difficult to generalise the results of these studies since the dilution will depend on the number of washes and rinses and the volumes of water in each wash or rinse compared with the volume or weight of fabric. In addition, the effect of dilution is influenced by the presence of detergent suspending contamination from the fabric thus enabling it to be diluted.

The effect of water temperature

Temperature affects microbial reductions by both facilitating the detergent effect and by thermal disinfection when above a threshold level. There is evidence that the number of micro-organisms that survive the process decreases with increasing temperature; however, significant reductions are still achieved at relatively low temperatures of <40 °C.^{14–17} One study that compared the effect of washing in hot (66 °C) and cool (31 °C) water found no difference in bacterial reduction at these temperatures. However, both processes included the addition of bleach and therefore it was not possible to determine the independent effect of water temperature.¹⁴ Laboratory studies showed a reduction of 10⁵ in *S. aureus* on cloth swatches

on exposure to water at 55 °C for 5 min and elimination of the organisms after exposure to 61 °C for 5 min.¹⁸

Heat-resistant organisms such as enterococci have been eliminated from fabric swatches in a wash cycle that included holding at a temperature of 71 °C, although the use of swatches meant that the effect seen could have been due to dilution of the test organism throughout the load (Box 4).^{19,20} Another study showed the effects of thermal disinfection by sealing enterococci in capillary tubes to remove dilution effects and found that, although some strains were relatively resistant, all were reduced between 10² and 10³ at 65 °C for 10 min.²¹ Spore-forming environmental bacteria, such as *Bacillus* spp., have been found to survive the laundering process at high wash temperature; however, these bacteria are not generally associated with HCAI.^{11,10,15}

Box 4 Methods used to test the efficacy of laundry processes in eliminating micro-organisms

Swatches of cloth: Pieces of fabric are inoculated with known numbers of test organisms and processed, either alone or with a standard load. The main limitation of this method is that although processing with a load better simulates conditions in the machine, the redistribution of organisms from a small swatch to other fabric within the load would be sufficient to account for large reductions in the number of organisms on the swatch and therefore changes cannot be assumed to be due to the removal or destruction of micro-organisms during the process.

Impression plates: This method enables fabric from a standard load to be sampled without destroying the fabric. However, it probably only detects about 1% of the total number of micro-organisms present on damp fabric, and less than 0.5% from dry fabric.¹¹ It is therefore a relatively insensitive method of measuring the effect of the laundry process but will reliably detect high numbers of micro-organisms.

Sampling effluent water: This method is used to determine the number of micro-organisms removed from linen during sequential stages in the wash process. It can provide a good estimate of organisms being eluted from linen as it passes through the wash and rinse cycles. These can then be taken as representative of reductions on the linen load as a whole. This method can be used to investigate naturally contaminated linens.

Role of bleach

Bleach (as either sodium hypochlorite or hydrogen peroxide) has a disinfectant activity and is also used to remove stains. The effect of bleach depends on the concentration, contact time, water pH and temperature; in most of the studies examined, however, these parameters are not described. There are few studies that evaluate the effect of bleach independently from the wash temperature. One study found that the bacterial counts in rinse water fell by 10^2 – 10^3 3 min after bleach was added to a low-temperature wash to achieve a concentration of 125 mg/L.¹⁵ Another study demonstrated that more bacteria were eliminated from linen processed in a wash extractor as the concentration of bleach was increased from <50 to 250 mg/L.²²

The effect of drying

Microbicidal action in drying could occur either through dehydration or by thermal disinfection, which should be effective against all relevant hospital pathogens.

Although one early study did not demonstrate that tumble drying had an effect on microbial contamination, more recent studies have reported reductions in bacterial counts during tumble drying of up to 10^9 with a greater effect on Gram-negative than Gram-positive micro-organisms, which suggests a dehydration mechanism in addition to any thermal effect.^{15–17} Ironing without prior washing has been reported to reduce microbial counts by at least 10^7 .¹⁵ Tunnel drying, a process that included a jet of steam followed by dry heat at 85 °C for 5 min, was reported to virtually eliminate bacterial counts on patients' dresses.²³

Is there any evidence for a difference in efficacy between domestic and industrial processes of laundering of work clothing?

Concern has been expressed that domestic washing machines do not provide a sufficiently controlled environment in which to decontaminate staff uniforms. In particular, it has been suggested that if washed with other clothing, cross-contamination with hospital pathogens may occur. Early reports of automated washing machines suggested reductions of 10^4 in microbial contamination could be achieved, with additional reductions of 10^5 after tumble drying at 71 °C for 30 min.²⁴ Only a few, small-scale studies have investigated the efficacy of home laundering of staff uniforms.^{4,25,26} Although one of these studies suggests that home laundering did not remove microbial

contamination, it tested artificially contaminated clothing and did not report the level of initial contamination or the subsequent reduction in numbers of the contaminating pathogen achieved.⁴ Nor did it compare the effect with an industrial process.⁴ The only study that compared home laundering with an industrial process found no difference in their ability to remove microbial contamination. No pathogenic micro-organisms were recovered from home-laundered uniforms whether washed alone or together with household clothing and when washed in either hot or cool water.²⁵ Similarly, in another small-scale test of domestic washing machines using wash temperatures of 40 and 60 °C, *S. aureus* was eliminated from all test swatches. A mixture of environmental bacteria derived from the machine were recovered but these were all removed by tumble drying or ironing.²⁶

What is the evidence underpinning current UK guidance on hospital laundry?

In a hospital setting the work of the laundry is mostly focused on processing bed linen, some of which can be heavily soiled with patient-derived contamination. Concern about the risk of bed linen acting as a vehicle for the transmission of pathogens has led to the recommendation that processing of hospital linen should include thermal disinfection, and in some circumstances chemical disinfection.²⁷ Guidelines recommend the use of a disinfection cycle that maintains the load at 65 °C for at least 10 min or, preferably, 71 °C for not less than 3 min, with a time allowance to ensure heat penetration. The use of cooler washes with the addition of bleach to the penultimate rinse is recommended for fabrics which are unable to withstand these temperatures.²⁷ Source evidence underpinning these recommendations is not cited and they would appear to be based on thermal disinfection of vegetative micro-organisms rather than the effect of the laundry process as a whole. There is no specific guidance on the processing of staff uniforms. International guidance on the provision and laundering of work clothes is minimal and the evidence base is similarly unclear or not cited.^{28–31}

Discussion

The evidence directly related to the laundering of uniforms is limited and varies in method and design, making comparison difficult. Technological advances have resulted in changes in the fabrics used

for the manufacture of uniforms and work clothing, the detergents used in domestic laundering and increased ownership of domestic washing machines. It is essential that the findings from these studies are considered within context and not over-emphasised in the development of uniform policy.

There is a body of evidence from small-scale experimental and clinical studies that uniforms and white coats become progressively contaminated during clinical care and that this contamination reaches a level of saturation that then plateaus. Most microbial contamination originates from the wearer of the uniform rather than from the patient.²⁻⁹ This means that clean uniforms become contaminated by skin commensals from the wearer, and additional microorganisms from the environment and patients.

Although it has been hypothesised that contaminated uniforms are a potential vehicle for the transmission of pathogens, no studies demonstrated the transfer of micro-organisms from uniforms to patients in the clinical situation.²⁻⁹ Only one study showed an epidemiological link between contaminated clothing and HCAI, but this occurred when clothing became highly contaminated in an industrial laundry rather than as a result of clinical care.^{10,11} There is evidence that where protective clothing, such as aprons, is used for direct contact with patients, exogenous contamination of uniforms from patients or their environment can be minimised. Uniforms should not be considered as a substitute for protective clothing and the use of plastic aprons as a component of standard principles is currently recommended in national infection prevention guidelines.^{32,33}

It is unclear whether microbial adherence promotes or decreases the transmission potential of uniforms. Surfaces which more readily accumulate micro-organisms could be considered more likely to contribute to the transmission of HCAI. However, micro-organisms that have an enhanced ability to adhere to surfaces are less likely to be shed from fabric onto other surfaces and are thus less likely to contribute to transmission. In addition, the medium in which the microbe is suspended will affect both its adherence to surfaces and its ability to survive. The unpredictability of these effects means that the differences between fabrics in terms of microbial adherence and survival are unlikely to make a major contribution to the transmission of micro-organisms.

Current advice relating to the laundering of uniforms is derived from recommendations related to laundering patient linen. National guidance on the standards required for hospital laundries is directed at processing hospital linen that has far

greater patient contact than staff uniforms. It focuses on thermal disinfection rather than the complete laundry process in eliminating microbial contamination. Differences in both the level and type of contamination mean that the results of studies on patient linen may not be directly applicable to laundering healthcare uniforms. In addition, it is difficult to distinguish the effect that different components of the laundry process have on the reduction of soil because many studies use different machines; involve a wide range of process parameters; components cannot be tested in isolation from the whole process; and the methods used may not be comparable (see Box 4).

Industrial laundries process most linen by batch continuous washing machines ('tunnel washers') where it is thermally disinfected. Healthcare workers' uniforms tend to be washed industrially in washer-extractors and dried in tunnel driers (where hot air is blown at garments on hangers on a moving line as they travel through a semi-enclosed cabinet) rather than by batch continuous washing machine and tumble drying. Washer-extractor cycles are thought to give a substantially greater dilution of contamination than batch continuous washing machines. Studies concerning the effectiveness of laundry processes focus on industrial laundries and patient linen rather than uniforms.¹⁴⁻²³ They provide evidence that micro-organisms are both removed and killed during the laundering process and dilution during washing and rinsing is important in removing micro-organisms. Significant reductions in micro-organisms occur at the lower wash temperatures more commonly used in domestic washing machines, e.g. 40 °C. The effect of the type of machine, size of load and level of soil is likely to have as much impact on the cleanliness of the item at the end of the process as the combination of detergent, water, dilution and wash temperature. Ensuring an optimal ratio between fabric load and water volume is important in both industrial and domestic settings to facilitate the effect of agitation and dilution on removing contamination.

There is no strong scientific evidence to suggest that home laundering of uniforms is inferior to industrial processing as a means of decontaminating uniforms, or that laundering in domestic machines presents a hazard in terms of cross-contamination of other items in the wash-load with hospital pathogens. In normal circumstances staff uniforms are likely to be less contaminated with pathogens than other hospital linens that have more substantial contact with patients and their body fluids.

Our review has demonstrated that common assumptions about the microbiological significance

of healthcare workers' uniforms and the inadequacy of domestic laundering are not supported by robust evidence. Current national guidance for the prevention of HCAI recommends that standard principles for infection control are key to protecting patients and staff from cross-contamination with pathogenic micro-organisms.^{32,33} Therefore, uniforms and other work clothing should not be regarded as personal protective clothing and plastic aprons or other personal protective clothing must be used to protect uniform/work clothing from contamination during patient care activities. Uniform/clothing that becomes obviously contaminated with organic soil, such as blood or other body substances, must be changed for a clean uniform as soon as practicable; and uniforms/work clothing should be washed/cleaned according to the manufacturer's instructions. Where this is undertaken in a domestic washing machine, overloading should be avoided to ensure that adequate dilution is achieved during the washing process.

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