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Original Article

A Review of the Evidence on the Role of Floors and Shoes in the Dissemination of Pathogens in a Healthcare Setting

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Abstract

Background: It is generally accepted that shoes and floors are contaminated with pathogens including methicillin-resistant *Staphylococcus aureus* (MRSA), vancomycin-resistant enterococci (VRE), and *Clostridium difficile*, yet correlation to clinical infection is not well established. Because floors and shoes are low-touch surfaces, these are considered non-critical surfaces for cleaning and disinfection. The purpose of this review is to assess peer-reviewed literature inclusive of floors and shoe soles as contributors to the dissemination of infectious pathogens within healthcare settings.
Methods: Using the Preferred Reporting Items for Systematic Reviews (PRISMA) methodology, PubMed and Medline were searched for articles assessing the presence of pathogens on or the transmission of pathogens between or from floors or shoe soles/shoe covers. Inclusion criteria are the human population within healthcare or controlled experimental settings after 1999 and available in English.
Results: Four hundred eighteen articles were screened, and 18 articles documented recovery of bacterial and viral pathogens from both floors and shoes. Seventy-two percent (13/18) of these were published after 2015, showing increased consideration of the transfer of pathogens to high-touch surfaces from shoe soles or floors during patient care.
Conclusions: There is evidence that floors and shoes in healthcare settings are contaminated with several different species of health-care–associated pathogens including MRSA, VRE, and *Clostridium difficile*.

Keywords: health-care–associated infections; hospital floors; hospital transmission; shoes

Shoe soles are contaminated with a wide range of healthcare-associated pathogens including methicillin-resistant *Staphylococcus aureus* (MRSA), *Enterococcus faecalis*, *Clostridium difficile*, *Escherichia coli*, severe acute respiratory syndrome coronavirus-2 (SARS-CoV-2), and *Acinetobacter* spp.[1–3] Floors of healthcare facilities and shoe soles are contaminated with pathogens including MRSA, vancomycin-resistant enterococci (VRE), and *Clostridium difficile*.[4–6] Bacterial contamination of floors has been estimated to account for up to 15% of airborne colony forming units (CFU) as re-dispersal of these pathogens occurs during routine human activity such as walking.[7,8] During patient care, room doors are opened and closed frequently and bedside curtains are moved back and forth, which can lead to airborne dispersion of floor contaminants.[9,10]

Although floors are not often directly touched by hands, it has been observed that 41% of patient rooms have at least one high-touch object, such as personal belongings or medical

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devices, in direct contact with the hospital floor.[4] Additional studies have highlighted the role of high-touch objects such as portable medical equipment and wheelchairs in transferring pathogens from floors throughout the hospital setting.[11] Recent studies have called for a focus on the role of shoes as a reservoir for infectious pathogens.[12] One study cultured MRSA from 56% of samples from the soles of physicians' shoes prior to rounding and 65% after rounds,[13] whereas another estimated up to 40% of shoes in the community may carry *Clostridium difficile*.[14] Because these potential reservoirs are often considered non-critical surfaces as they do not come in direct contact with skin, expansion of standard infection prevention bundles with interventions targeted at floors and shoes are controversial.[15] The objective of this study is to systematically review the literature to assess the evidence surrounding the role of floors and shoe soles in the dissemination of infectious pathogens in the healthcare setting.

Methods

Guided by the Preferred Reporting Items for Systematic Reviews (PRISMA),[16] a review of the literature was conducted to assess the potential evidence that floors and the soles of shoes are reservoirs for pathogen transmission in the healthcare setting. We systematically searched articles indexed in Medline (Ovid) and Pubmed (NLM) using a broad set of keywords and Medical Subject Headings (MeSH) terms to maximize sensitivity; the date of the last search was October 24, 2023. Concepts that made up the search included shoe soles, shoe covers, floors, and infectious disease transmission. The full search strategy is outlined in Supplementary Table S1. The decision to include shoe covers as a key term was made to ensure a comprehensive review of the potential relation between floors and shoes in the spread of pathogens because this would have a mechanism similar to shoe soles. Bibliographies of identified articles were also searched for potentially relevant studies not identified through databases.

The eligibility for inclusion required that studies examined the pathogenic contamination of floors, shoe soles, or shoe covers or the transfer of pathogens between or from floors, shoe soles, or shoe covers. Studies were excluded if they were not related to floors, shoe soles, or shoe covers in the context of micro-organism contamination or transmission; were not human studies; did not occur in either a healthcare setting or controlled environment. Given the pace of acquisition of new knowledge and the ever-changing environment of healthcare, studies were limited to those published in the year 2000 or later. All included articles were available in English and contained original research.

All eligible articles were reviewed in two phases: abstract review and full-text review. All abstracts and full-text articles were independently reviewed by two authors and any discrepancies were resolved by consensus. Quality assessment or each article was assessed based on JBI Critical appraisal tools. A custom Microsoft Excel workbook (Microsoft Corp, Redmond, WA) for systematic reviews was designed to screen articles. Details including author, year of publication, study objective, setting, study design, key methods, primary outcomes, and findings were extracted during full-text review.

Quality control during the screening process was accomplished by database search conducted by an experienced author; independent screening of all abstracts and titles by two authors; independent review of all full-text articles by two authors. Additionally, during full-text review, each article was assessed for appropriate methodology and conclusions related to the stated objectives to ensure scientific quality of included studies. Of note, although the focus of this review was on the potential role of both floors and shoes in the spread of pathogens in the hospital setting, many of the articles included specifically discussed the effectiveness of cleaning and disinfection protocols. To provide a comprehensive assessment of this review, these findings are also presented. A series of database searches combined with reference search and review of articles cataloged by the study team identified 410 articles. This initiative did not involve human subjects and was therefore not reviewed by an Institutional Review Board.

Results

After removing 118 duplicates, 292 titles and abstracts were screened of which 267 were excluded because of lack of focus on floors, shoe soles, or shoe covers; scope outside of a human population; or a setting other than a healthcare environment or controlled study environment. Additionally, articles that were not original research or that were unable to be accessed by the investigators were removed (Fig. 1). Review of 25 full texts identified 18 articles for inclusion in the construction of the evidence table (Table 1).

Among the studies included in the review:

- Twelve (67%) used environmental point-prevalence assessments to quantify contamination of the hospital environment including floors, shoes, and high-touch objects.[1,2,4,5,17–24]
- Two studies (11%) used a before-and-after design to assess the effectiveness of shoe covers to prevent infection in an intensive care unit (ICU) setting[25] and reduce microbial burden on floors and in the air.[26]
- Three studies (17%) used a controlled experimental design to quantify contamination of shoe covers after five minutes of floor contact in an environment using routine floor cleaning,[3] measure the spread of a non-pathogenic virus placed on the floor of a patient room throughout high-touch surfaces,[27] and determine the effectiveness of ultraviolet C (UVC) disinfectant of shoe soles on pathogenic contamination of floors and high-touch surface.[6]
- Finally, one study used a controlled laboratory environment to compare floor decontamination and cleaning approaches as well as assess aerosolization during cleaning of a floor inoculated with a sample pathogen.[32]

The majority of included studies (72%; 13 articles) were published after 2015.[2–6,19–24,27,28]

Discussion

Floor contamination with health-care–associated pathogens

A number of studies have brought attention to floors in healthcare facilities as an underappreciated factor in transmission of pathogens.[3,4,6,22,24,27] Point-prevalence surveys using clinical cultures have repeatedly demonstrated that

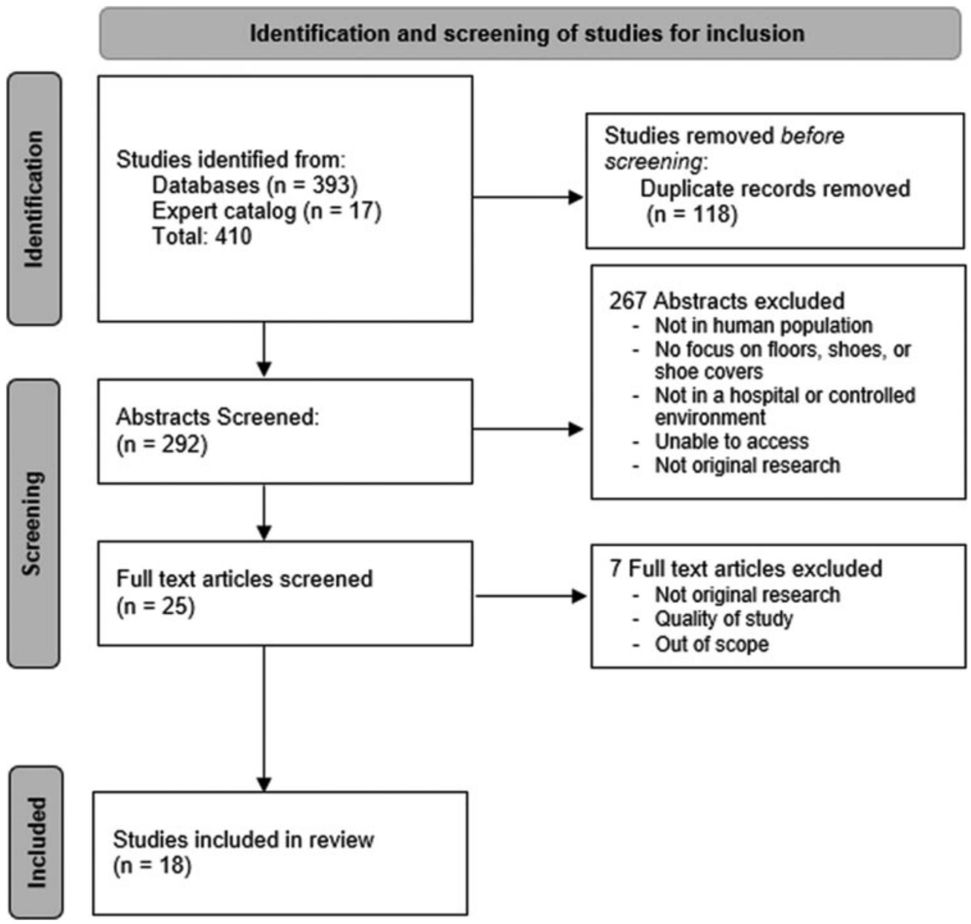

FIG. 1. Identification and screening of studies for inclusion.

floors are contaminated with pathogens responsible for health-care–associated infections (HAIs) including multi-drug–resistant organisms (MDROs) such as MRSA, VRE, and *Clostridium difficile*.[4–6,24,26] *Candida* spp., including *Candida parapsilosis, Candida metapsilosis*, *Candida orthopsilosis*, *Candida glabrata*, and *Candida albicans* were found on 36.4% of hospital floors in one study.[20]

Atata et al.[18] demonstrated high levels of bacterial contamination in operating rooms and surgical wards during every month of the year (1.3×10^3 CFU/m^2 to 5.23×10^3 CFU/m^2). Although levels of contamination detected in both floor and air samples were below infectious doses, these bacteria were shown to be the same strain found in patient wounds.[18] Deshpande et al.[4] found *Clostridium difficile* was equally present on floors in the rooms of patients with and without *Clostridium difficile* infection on the same unit ($p = 0.60$). These findings occurred during the use of daily bleach cleaning of high-touch surfaces and floor cleaning between patients, which is a common cleaning protocol.

Evidence has recently demonstrated the presence of SARS-CoV-2, the virus responsible for coronavirus disease 2019 (COVID-19), on hospital floors. A point-prevalence survey conducted in an ICU and general ward, both caring for patients with COVID-19, detected the virus on floors in 70% of ICU samples, 15.4% of general ward samples, 100% of samples from the medication room, and 37.5% of samples from staff dressing rooms.[19] Contamination of the medication room and staff dressing room floors with SARS-CoV-2, where patients are not present, suggests transfer throughout the area through medical staff movement.[19] Similarly, Seif et al.[2] detected SARS-CoV-2 on floors across clinical (i.e., ICU, neurology ward, emergency triage) and non-clinical areas (i.e., hallway floors, hospital kitchen). It should be noted that studies focused primarily on detection of viral RNA may not represent culturable virus. Publications in this review were more frequent after 2015, indicating a potential shift in recent thinking around the role of floors and shoes in HAIs.

Contamination of high-touch surfaces via floors

Although it is well accepted that high-touch surfaces are often contaminated with pathogens and are an important link in the transmission of HAIs, the hospital floor may be an overlooked source of contamination of these objects through both direct and indirect contact.[4] Koganti et al.[27] used a non-pathogenic marker to inoculate part of the floor in rooms of 10 patients on contact precautions. Patients were not informed about the location of the inoculation and healthcare providers were not aware of the study.[27] Rapid dissemination to the hands of patients (40%) and high-touch surfaces (100% in patient rooms) was demonstrated at one day after inoculation.[27] Virus was also detected on high-touch surfaces in the adjacent rooms, nursing station, and on portable equipment.[27] In a study by Deshpande et al.,[4] observations of 100 occupied patient rooms in five hospitals observed 41% had

Table 1. Summary of the Evidence from Articles Included in the Systematic Literature Review

Authors (Year)	*Objective*	*Setting*	*Design*	*Methods*	*Findings*
Seif et al. (2021)[22]	To quantify the presence of SARS-CoV-2 on environmental surfaces throughout a hospital caring for patients with COVID-19	Hospital	Environmental point-prevalence study	Environmental surface samples obtained in clinical wards (with and without COVID-19 cases) and throughout surrounding hospital areas.	SARS-CoV-2 was detected on the floors of ICUs, inpatient floors, emergency triage, the respiratory clinic, and the hospital kitchen.
Guo et al. (2020)[19]	To quantify the presence of SARS-CoV-2 in air samples and on surfaces	Hospital (ICU and general Floor caring for patients with COVID-19)	Environmental point-prevalence study	Samples collected from high-touch surfaces, floors, indoor air, and air outlets	Floors and objects in the ICU had greater positivity rate for presence of SARS-CoV-2 than those in the general ward. 100% of floor swabs in the pharmacy led to conclusion virus was being transmitted through medical staff movement. 50% of shoe soles were positive for the virus among ICU staff.
Redmond et al. (2021)[23]	To measure contamination of surfaces in an ICU and floor caring for patients with COVID-19	Hospital (ICU and floor caring for patients with COVID-19)	Environmental point-prevalence study	Three point-prevalence surveys conducted over five weeks in patient rooms included floors, socks, and high-touch surfaces	SARS-CoV-2 was detected on all floors ($n = 5$). Iterative improvement in disinfection protocols was implemented between each survey and found effectiveness in reducing contamination of all sampled areas.
Ciofi-Silva et al. (2019)[28]	To assess the presence of norovirus on floors and in air samples after various floor decontamination procedures	Controlled experiment	Experimental laboratory study	Floors were contaminated with infected sample and then cleaned with 1% hypochlorite solution or UVC.	Cleaning combined with disinfection was more effective at removing detectable virus from floors. Norovirus was shown to be aerosolized from floors during wet mopping.
Kanwar et al. (2019)[5]	To determine if personal clothing to be worn home after a shift is contaminated with MRSA, *Clostridum difficile*, VRE, or carbapenem-resistant gram-negative bacilli	Hospital (acute care)	Environmental Point-prevalence study combined with direct observation	Cultures of hands, clothing, and shoes were taken at the end of each day between January 2018 and May 2018 in a convenience sample of staff. Medical staff were directly observed to identify opportunities for contamination of personal clothing.	Among 41 participants, 44% were contaminated with one or more organisms of which 20% was on clothing and 29% was on shoes. Opportunities for contamination were observed for personal clothing but not observed for shoes.

(*continued*)

TABLE 1. (CONTINUED)

Authors (Year)	*Objective*	*Setting*	*Design*	*Methods*	*Findings*
Kumar et al. (2019)[20]	To quantify the presence of *Candida* species on surfaces in hospitals	Six hospitals (occupied isolation and non-isolation patient rooms)	Environmental Point-prevalence study	Cultures were collected using cellulose sponges from surfaces $\leq$ 3 feet from the patient, >3 feet from the patient, and in the patient bathroom. Only 1 of the 6 hospital sites collected floor samples from 20 x 20 cm sites adjacent to the patient bed, trash can, and in the bathroom.	*Candida* spp. were detected on 36.4% of hospital room floors, 23.5% of sink drains, and 4.8% of high touch surfaces. Species recovered from floors included *Candida parapsilosis, Candida metapsilosis, Candida orthopsilosis, Candida glabrata,* and *Candida albicans.*
Welle et al. (2019)[24]	To examine the transfer of bacteria from floors to bed linens through the soles of non-skid slipper socks of patients.	Two hospitals	Environmental point-prevalence study	132 samples were collected from the floor, bottom of socks, and bed linens in rooms and adjacent hallways, post-discharge, of patients with no known infection on admission or discharge.	Pathogen transfer from floor to bed linens via socks was detected with the majority of isolates resistant to two or more antibiotics. 54 isolates were detected from the floor, 34 from socks exposed to the floor, and 34 from bed linens exposed to socks.
Mustapha et al. (2018)[22]	To assess the effectiveness of manual cleaning and adjunct use of UVC decontamination on removal of MRSA, *Clostridium difficile*, and *Candida* species from hospital floors.	Hospital (floors of rooms housing patients under contact precautions for MRSA colonization or infection.)	Environmental point-prevalence study	A convenience sample (81 sites from 27 rooms) was used to culture floors before and after post-discharge manual cleaning with mops changed in between rooms. Cultures were taken again after adjunctive UVC decontamination.	Among the 27 rooms cultured, 33% were positive for MRSA, 30% for *Candida* spp., and 33% for *Clostridium difficile*. Manual cleaning significantly reduced presence of all pathogens ($p < 0.01$) and all detectable *Candida* spp. and *Clostridium difficile*. However, 9% of rooms cultured MRSA after manual cleaning. UVC reduced MRSA detection to 1% although non-statistically significant ($p > 0.05$).
Deshpande et al. (2017)[4]	To quantify contamination of patient room floors with pathogens and examine potential transfer from floors to objects and thus hands	Five hospitals	Environmental point-prevalence study	318 floor sites sampled in 159 patient rooms of patients with and without *Clostridium difficile* infection either during the patient stay or after post-discharge cleaning.	Among 100 occupied rooms surveyed, 41% had one or more high-touch objects (personal items, medical devices, linens) in contact with the floor. 31 cultures of hands or gloves collected after touching high-touch objects found MRSA (18%), VRE (6%) or *Clostridium difficile* (3%).

(*continued*)

TABLE 1. (CONTINUED)

Authors (Year)	*Objective*	*Setting*	*Design*	*Methods*	*Findings*
Galvin et al. (2016)[3]	To determine if patient shoe covers transfer bacteria from the floor to bedsheets	Hospital OR	Controlled clinical experiment & Experimental Laboratory study	*Clinical experiment:* Disposable shoe covers (n = 40) were worn over sterile bags and followed a planned path walking across hospital floors. Covers were swabbed after walking at 5 & 10 min in various settings. Shoe covers were then rubbed onto bed sheets and evaluated for presence of colony forming units.	Despite floors being cleaned daily and appearing to be clean, shoe covers became contaminated after 5 min of floor contact. The experimental laboratory confirmed pathogenic bacteria can be transferred from disposable shoe covers to bedsheets.
Koganti et al. (2016)[27]	To examine the potential for dissemination of microorganisms from floors to high-touch surfaces and hands of patients	Hospital (patient rooms on contact precautions)	Controlled experiment	A non-pathogenic virus was placed on the floor next to the bed of 10 patients in contact precautions for *Clostridium difficile* or MRSA. Patients did not know the exact location and hospital workers were unaware of the study. Samples were taken in the environment, on patients' hands, and soles of shoes daily for 3 d.	Nonpathogenic virus inoculated onto floors was detected on 100% of footwear, 40% of hands, and high touch surfaces within 3 feet (58%) of the bed, and greater than 3 feet (40%) of the bed after 1 d. Contamination was common on high-touch surfaces in adjacent rooms and on portable equipment.
Mahida et al. (2016)[21]	To evaluate the transfer of multi-drug–resistant organisms from floors to non-skid slipper socks of patients	Two hospitals (seven units total)	Environmental point-prevalence study	On each unit, patient socks were anonymously collected and transported to the laboratory. Additionally, five floor areas were sampled in each unit. A total of 54 pairs of socks and 35 floor samples were tested.	Of the 54 pairs of socks, 84% were contaminated with VRE, 9% with MRSA, and 0% with *Clostridium difficile*. Across 35 floor samples, 69% had detectable levels of VRE, 15% MRSA, and 0% *Clostridium difficile*.
Rashid et al. (2017)[6]	To assess the efficacy of a UVC device in reducing pathogen contamination of shoe soles	Controlled environment, simulated patient room	Controlled experiment	Shoe soles were inoculated with pathogens and randomly exposed to a UVC disinfectant device. Shoes then came into contact with floors either through purposeful rubbing for 1 min or through a clinical simulation of a 20-min patient encounter. Swabs were taken at each step. 240 samples were collected during clinical simulation.	Significant reduction in contamination with all pathogens tested was seen on the soles of shoes treated with UVC compared with control shoes during the controlled experiment ($p < 0.01$) and clinical simulation ($p < 0.001$).

(*continued*)

TABLE 1. (CONTINUED)

Authors (Year)	*Objective*	*Setting*	*Design*	*Methods*	*Findings*
Ali et al. (2014)[25]	To measure the effectiveness of shoe covers on rate of infection, mortality, and length of ICU stay	Hospital (medical and surgical ICU)	Before and After study	All patients (n = 1151) on the ICU during no shoe cover use (January to March 2012) and during enforced shoe cover use (May to July 2012) were observed for infections, length of stay in the ICU, and mortality.	No benefit was found from wearing shoe covers. Infections were higher in patients during the shoe cover intervention (4.0% vs. 2.6%, $p = 0.004$) as was length of stay greater than three days ($p = 0.038$). Mortality between groups was non-significant.
Atata et al. (2010)[18]	To examine the relationship between bacterial isolates from the hospital environment and those isolated from patient surgical sites	Hospital (surgical suites)	Environmental point-prevalence study	During an operation, samples were collected from the air and floor. Upon wound closure, the site was swabbed. Next, air and floor samples were taken in patient rooms post-surgery.	Bacterial load was detected on the floor and air of both OR and patient rooms, although at levels below infectious dose.
Amirfeyz et al. (2007)[1]	To compare bacterial contamination of outdoor shoes to dedicated OR theater shoes	Elective orthopedic surgery center	Environmental point-prevalence study	100 shoes were randomly selected from the OR changing room and soles were swabbed at the beginning and end of a work day. 50% were dedicated theater boots and 50% were outdoor shoes.	Pathogenic bacteria was present on 98% of outdoor shoes and 68% of morning theater shoes ($p < 0.001$). 56% of theatre shoes were contaminated at the end of the day.
Gupta et al. (2007)[26]	To measure the impact of protective footwear on floor contamination in an ICU	Hospital (ICU)	Before-and-after study	384 floor samples were taken at defined times throughout the day (and after daily mopping) during 2 wks of required shoe cover use and 2 wks of optional shoe cover use among staff and visitors. 192 air samples were collected twice daily at defined times.	Floor culture samples and air samples showed no significant difference during shoe cover use and a period without shoe cover use.
Agarwal et al. (2002)[17]	To quantify the presence of both blood and bacterial contamination of shoes dedicated to the OR	Hospital (surgical suites)	Environmental point-prevalence study	54 dedicated OR shoes were examined and swabbed, without notice, after routine OR cleaning.	44% of OR shoes were contaminated with blood and the majority of both the upper shoe and soles of staff were contaminated with significant bacterial burden. Nearly all shoes of surgeons, across specialties, were contaminated.

ICU = intensive care unit; SARS-CoV-2 = severe acute respiratory syndrome coronavirus 2; COVID-19 = ; coronavirus disease 2019; UVC = ultraviolet-C; MRSA = methicillin-resistant *Staphylococcus aureus*; VRE = vancomycin-resistant enterococci; OR = operating room.

one or more high-touch objects including personal clothing, telephone chargers, blood pressure cuffs, or bed linens touching the floor. This study also demonstrated that pathogens were frequently transferred to the hands of those who touched these items, highlighting the pathway of potential pathogen transfer from floors to hands.[4]

The ability of pathogens to be re-dispersed from the floor during routine activities, such as walking, has been demonstrated in a number of historical studies.[7] In this review, a simulated experiment testing the effectiveness of cleaning protocols on removal of norovirus from a hospital floor, Ciofi-Silva et al.[28] demonstrated that wet mopping resulted in aerosolization of the virus from the floor.

Shoes as a reservoir in the chain of infection transmission

Shoe soles were found to be contaminated with a wide range of health-care–associated pathogens including MRSA, *Enterococcus faecalis*, *Clostridium difficile*, *Escherichia coli*, SARS-CoV-2, and *Acinetobacter* species.[1–3] Two primary concerns regarding contamination of shoe soles are the introduction of pathogens into the hospital setting from the community and dissemination of pathogenic microorganisms throughout the healthcare setting.[1,3,19] Amirfeyz et al.[1] found 98% of outdoor shoes brought into an orthopedic center were contaminated with bacteria, 88% of which had at least two bacterial species. Some evidence suggests that dedicated shoes, such as dedicated operating room shoes, may control bacterial contamination because they have less presence of pathogenic bacteria when compared with outdoor shoes (68% vs. 98%; $p < 0.001$).[1]

The transfer of pathogens from shoes to floors has been demonstrated in existing literature, and the contamination of shoes from hospital floors—even those that appear to be clean—has also been demonstrated.[1,3] Studies in this review identified SARS-Cov-2 on the shoes of healthcare personnel as well as on the floors of non-patient care areas in the hospital, suggesting transfer from patient rooms throughout the hospital via shoes.[2,23] Welle et al.[24] showed pathogen transfer from floors to bed linens via non-skid socks distributed to patients. Mahida et al.[21] found 84% of non-skid socks distributed to patients were contaminated with VRE, 9% with MRSA, and 0% with *Clostridium difficile.* During this time, floor samples were tested for contamination with VRE (69%), MRSA (15%), and *Clostridium difficile* (0%) while the hospital documented three confirmed cases of VRE, two cases of MRSA, and four confirmed cases of *Clostridium difficile*.[21]

These findings suggest a relation between contamination of the soles of footwear and exposure to contaminated hospital floors, rather than contamination of soles of footwear solely from infected individuals wearing them. This prompted consideration of a chain of infection originating from floors and shoe soles acting as vectors. As a result, the authors present a proposed tool to frame a mechanism by which floors and shoes may contribute to the dissemination of infectious pathogens in the healthcare environment (Fig. 2). In summary, because healthcare personnel, visitors, and patients walk on contaminated floors, infectious pathogens are transferred to the bottoms of shoes, socks, or shoe covers. These pathogens are then spread to floors in other patient care and non-clinical areas of the hospital. Re-dispersal of floor pathogens, known to occur during walking and mopping, can result in either aerosolized particles at heights and

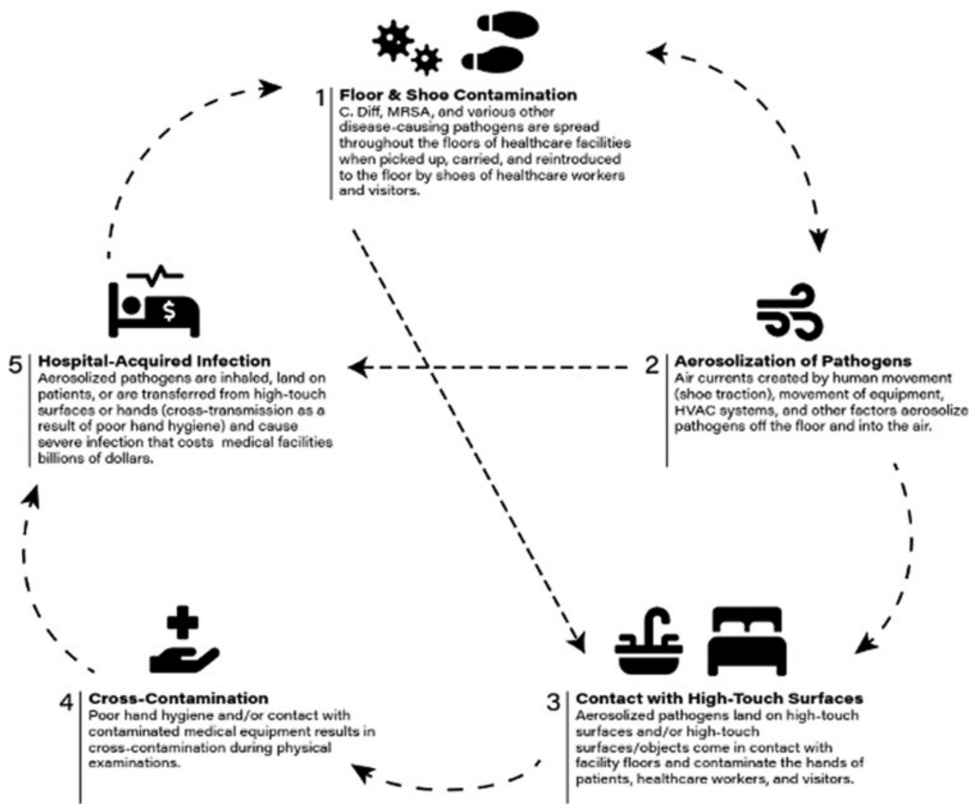

FIG. 2. Proposed mechanism for bacterial contamination originating from floors and shoes into the healthcare environment.

concentrations capable of inhalation or contamination of high-touch surfaces and floors as particles land.

Additionally, because high-contact objects such as bed linens and personal items are frequently in direct contact with floors or footwear, pathogens can be transferred directly from the floor. Healthcare personnel or patients then touch these high-touch objects, contaminating their hands and uniforms. This theoretical tool is based on the assumption that colonization can lead to infection.

Shoe covers as an infection control strategy

Protective footwear, such as disposable shoe covers, in the hospital and surgical setting is required personal protective equipment during occupational exposure to blood-borne pathogens as well as exposure to contact, droplet, and airborne-transmissible diseases.[29] Studies that met inclusion criteria for this review suggest a non-significant impact of shoe covers on infection rates, although historical studies have found conflicting results on the effectiveness of shoe covers.[26] Ali et al.[25] found no benefit of shoe covers in a before-and-after study enforcing the use of shoe covers among all providers, staff, and visitors on a medical and surgical ICU. In fact, infections were higher among patients cared for during the shoe cover intervention (4.0% vs. 2.6%; $p = 0.004$) as was length of stay greater than three days ($p = 0.038$).[25] In another study, the transfer of pathogens onto clean shoe covers was demonstrated to occur in just five minutes on a surgical unit with daily floor cleaning.[3]

Disinfection of floors and shoes

Disinfectants are well understood to be more effective at reducing microbial load found on hospital floors than detergents; however, this has not been translated to differences in HAIs. This may partially be explained by studies demonstrating that microbial presence returns to pre-disinfectant levels after a few hours because colony counts from floors increase with time since last mopping.[26] Additionally, complete inactivation of certain pathogens, such as MRSA, is difficult as they can be resistant to disinfectants.[22]

Manual cleaning with a quaternary ammonium-based disinfectant, with mop heads changed between rooms, has been found to reduce *Candida* spp. and *Clostridium difficile* to non-detectable levels via culture.[22] However, this same procedure did not result in a statistically significant reduction of positive cultures for MRSA.[22]

Decontamination of floors using UVC radiation has been shown to be effective at removing pathogens from floors, including MRSA, and is often used in addition to manual cleaning in hospitals.[22] Adjunct use of UVC decontamination to shoe soles using a germicidal UV light designed to sanitize shoes has demonstrated a statistically significant decrease in presence of *Escherichia coli*, *Staphylococcus aureus*, *Enterococcus faecalis*, and *Clostridium difficile* ($p < 0.001$ for each species) on shoes and subsequently floors ($p < 0.001$ for each species).[6] These pathogens were present on high-touch surfaces in 96% to 100% of samples taken where control shoes had entered the patient room compared with 5% to 8% of samples from rooms entered by shoes treated with UVC.[6]

Evidence included in this review calls into question the utility of the currently utilized strategy of using disposable shoe covers.[25,26] The idea of disinfecting floors and shoe soles is not novel and has been previously recommended.[13,19] Presence of SARS-CoV-2 on hospital floors, even in non-patient care areas, combined with a 50% positivity rate from swabbed shoe soles of medical providers led investigators to ''highly recommend that persons disinfect shoe soles before walking out of wards containing COVID-19 patients.''[19] Paduszyńska et al.[13] demonstrated the importance of shoes in transmission of disease and recommended cleaning floors more frequently in addition to daily sterilization of shoes.

The strengths of this review include the use of a number of quality control approaches to ensure a systematic approach. The limitations of this review include search strategies limited to Ovid Medline and PubMed, leaving potential for articles indexed in other databases to be missed. There are currently no studies that directly show the impact of disinfecting floors and shoes are associated with lower rates of HAIs. However, the highly nuanced variables that contribute to the development of an HAI will make it challenging to quantify this impact.

Conclusions

Although historically floors and shoes have been considered non-critical surfaces, this review highlights potential mechanisms by which they may play a role in the dissemination of infectious pathogens including direct contact of high-touch objects with floors and contamination of floors in non-patient care areas. Peer-reviewed literature that met inclusion criteria of this review demonstrated contamination of healthcare facility floors and shoe soles with several different species of healthcare-associated pathogens including MRSA, VRE, SARS-CoV-2, and *Clostridium difficile*. The fact that 72% of articles identified in this review were published since 2015 indicate growing consideration of floors and shoes in the development of HAIs.

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Authors' Contributions

Methodology: Limper, Sier. *Validation:* Limper, Sier, Warye, Spencer, Graves, Edmiston. *Writing—original draft:* Limper, Sier. *Writing—review and editing:* Warye, Spencer, Graves, Edmiston. *Supervision:* Limper, Warye, *Conceptualization:* Warye.

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Authors Disclosure Statement

All authors declare they have no competing interests to disclose. The corresponding author had full access to all the data in the study and had final responsibility for the decision to submit for publication, as well as how to present the results.

Supplementary Material

Supplementary Table S1

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