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Effectiveness of nursing interventions on preventing the risk of infection in hospitalized adults: a systematic review

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Abstract

Background Healthcare-associated infections (HAIs) remain a global challenge for patient safety and quality of care, affecting millions of individuals each year and resulting in substantial morbidity, mortality, and financial burden. In Europe alone, over 4.2 million episodes of HAI occur annually. Nurses play a pivotal role in infection prevention through the implementation of evidence-based interventions aimed at disrupting transmission chains and reducing infection risk. Despite the widespread dissemination of preventive strategies, marked heterogeneity persists in their implementation and effectiveness, influenced by institutional, behavioural, and contextual factors.

Objective To critically evaluate the effectiveness of nursing interventions in preventing infection risk among hospitalised adults through a systematic review of the literature.

Methods A systematic review of Randomised Controlled Trials (RCTs) was conducted following the Joanna Briggs Institute (JBI) methodology and PRISMA 2020 guidelines, with prior registration in PROSPERO (CRD42024582820). Searches were performed across MEDLINE, CINAHL, Scopus, Web of Science, and the Cochrane Library up to January 2025. Methodological quality was assessed using JBI critical appraisal tools, and the certainty of the evidence was rated using the GRADE approach. Given the heterogeneity of the included studies, a narrative synthesis was undertaken.

Results Out of 8,123 records identified, 22 RCTs (1979–2024) met the inclusion criteria. Nursing interventions, including daily body bathing with chlorhexidine, prevention bundles for catheters and other devices, promotion of hand hygiene, educational strategies, and environmental disinfection (e.g. ultraviolet-C light) demonstrated a significant reduction in HAI incidence compared with usual care. Multimodal and integrated interventions proved more effective than isolated measures. The overall certainty of evidence was moderate for infection reduction and adherence improvement, but inconsistent for patient mortality and satisfaction outcomes.

Conclusions Evidence-based nursing interventions, particularly when applied in a coordinated and multimodal manner, substantially reduce infection risk among hospitalised adults. These findings support the integration

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of such interventions into institutional programmes and infection control policies. Further multicentre RCTs are recommended to assess implementation fidelity, cost-effectiveness, and patient-centred outcomes.

Clinical trial number Not applicable.

Keywords Nursing, Healthcare-associated infections, Infection prevention and control, Systematic review, Randomised controlled trials, Evidence-based practice, Patient safety, Quality of healthcare

Introduction

HAIs remain a major global challenge to patient safety and the quality of care. Recent international estimates indicate that at any given time, approximately 7% of patients in high-income countries and up to 15% in low- and middle-income countries acquire at least one HAI during hospitalisation [1]. In Europe, more than 4.2 million HAI episodes occur annually [2, 3], while in the United States HAIs affect hundreds of thousands of patients each year, with substantial associated morbidity, mortality, and costs [4, 5]. In Portugal, data from the Directorate-General of Health (DGS) indicate that approximately one in every ten hospitalised patients presents with a healthcare-associated infection, a trend that has been increasing and is largely associated with the emergence of multidrug-resistant microorganisms [6, 7]. Among the most frequent types of HAI are ventilator-associated pneumonia, catheter-related bloodstream infections, device-associated urinary tract infections, and surgical site infections [4, 8]. International clinical guidelines also emphasise the importance of standardised diagnostic and management strategies for infectious diseases in hospital settings [9].

These conditions not only increase morbidity and mortality but also generate substantial economic costs and compromise the sustainability of healthcare systems [2, 8, 10–13].

Healthcare professionals, particularly nurses, play a central role in the prevention of HAIs, as they are directly involved in the continuous delivery and monitoring of patient care. Nurses implement a wide range of evidence-based interventions aimed at interrupting transmission chains and reducing infection risk, including strict hand hygiene, aseptic techniques, appropriate management of invasive devices, body cleansing with antiseptic solutions such as chlorhexidine, and the implementation of prevention bundles [14–18]. In parallel, educational strategies, audits with feedback, and the promotion of adherence to institutional standards are essential to consolidate a culture of safety and quality of care, positioning nurses as technical, educational, and organisational agents of change [19].

Although the international literature demonstrates the effectiveness of multiple preventive interventions, significant heterogeneity persists in their implementation and effectiveness, influenced by institutional, behavioural, and contextual factors. This variability, together with the rapid evolution of multidrug-resistant microorganisms and the growing complexity of hospital care, limits the generalisability of results and justifies the need for updated systematic syntheses. Systematic reviews of effectiveness allow the rigorous integration of available evidence, providing robust estimates of the impact of nursing interventions in reducing infection risk among hospitalised adults [20, 21].

In this context, the present systematic review aimed to critically evaluate the effectiveness of nursing interventions in preventing infection risk among hospitalised adults. This review is supported by recent evidence demonstrating variability in intervention outcomes according to clinical setting, institutional practices, and adherence to standards [22], as well as by the persistently high prevalence of HAIs. Unlike previous systematic and umbrella reviews focusing on specific infection types, isolated interventions, or mixed professional approaches, this review exclusively synthesises evidence from randomised controlled trials evaluating nursing-led interventions across multiple clinical domains. Furthermore, it applies a rigorous JBI methodology with GRADE assessment, enabling a comprehensive and up-to-date evaluation of effectiveness and certainty of evidence [23, 24].

The review

The research question was developed in accordance with the general and specific objectives of the review, with the purpose of ensuring a comprehensive identification, critical appraisal, and synthesis of the available evidence regarding the effectiveness of nursing-led interventions for infection prevention in hospitalised adult populations. For the purpose of this review, "nursing-led interventions" were defined as interventions that are nurse-initiated, nurse-implemented, or nurse-coordinated within infection prevention and control programes [25]. This includes interventions delivered in interprofessional contexts when nurses have primary responsibility for implementation, monitoring/adherence, patient-level delivery, or coordination of the intervention protocol.

Accordingly, this review sought to determine which nursing interventions are effective in preventing HAI among hospitalised adults. In addition, the review aimed to examine which interventions demonstrate greater effectiveness across different clinical settings and types

of HAI, as well as to explore how intervention effectiveness varies according to the modality of the intervention, the clinical and organisational context in which it is implemented, and the degree of adherence to institutional infection prevention and control standards. This approach enabled a structured and context-sensitive synthesis of evidence, capturing variations in effectiveness across populations, care environments, and healthcare systems.

Methods

This systematic review was prospectively registered in the PROSPERO database (registration number: CRD42024582820), and its methodological protocol was published in Nursing Reports [24] following the Joanna Briggs Institute (JBI) guidelines for Systematic Reviews of Effectiveness [20, 21] and the recommendations of the PRISMA 2020 Statement [26].

Eligibility criteria

Participants

Adult patients (≥ 18 years) who were hospitalised were included, regardless of their clinical specialty. Studies involving paediatric, neonatal, or intensive care populations were excluded, given the specificity of preventive practices within these settings [27].

Interventions

Nursing interventions aimed at the prevention of HAIs were considered, including strict hand hygiene, appropriate management of invasive devices, implementation of specific prevention bundles, correct use of aseptic techniques, education of healthcare professionals and patients, as well as systematic programmes of surveillance, monitoring, auditing, and feedback. These measures reflect the current international recommendations for the control and prevention of HAIs [1, 3, 28].

Comparison groups

The comparators included usual care, absence of structured interventions, or alternative preventive interventions implemented within the same hospital setting, thereby allowing a comparative assessment of the effectiveness of nursing interventions.

Outcomes

The primary outcomes included the incidence of HAIs, adherence to preventive measures, and infection-related mortality or morbidity. The secondary outcomes encompassed length of hospital stay, readmission rates, healthcare costs, patient satisfaction, and environmental indicators, such as bacterial load on hospital surfaces and colonisation by multidrug-resistant microorganisms.

Types of studies

Only Randomised Controlled Trials (RCTs) were included, as they represent the gold standard study design for assessing the effectiveness of interventions [29, 30].

Search strategy

The search strategy was developed with the aim of identifying both published and unpublished studies relevant to the topic. Initially, a limited preliminary search was conducted in the MEDLINE (PubMed) and CINAHL (EBSCOhost) databases to identify commonly used keywords and index terms in the field. Based on the analysis of these terms, a comprehensive search was subsequently carried out, from the inception of each database up to January 2025, and adapted to the following sources: MEDLINE (PubMed), CINAHL (EBSCOhost), Scopus, Web of Science Core Collection, and the Cochrane Library. No date restrictions were applied.

Sources of unpublished and grey literature included Google Scholar, forward citation tracking, and manual screening of reference lists from the included studies. The search process followed the three-step approach recommended by the JBI Manual for Evidence Synthesis [21]: (i) an initial limited search to identify relevant descriptors and free-text terms; (ii) an analysis of the indexing terms used in the most relevant articles; and (iii) the development of the final search strategy, subsequently adapted for each database. The complete search strategies are described in the published protocol [24] and are available as supplementary material (Appendix A). All retrieved references were imported into the Rayyan software (Qatar Computing Research Institute, Doha, Qatar), where duplicate records were removed prior to the screening phase.

The detailed database search strategies are presented in Tables A1–A5 (Appendix A).

Study selection

All references identified through the search were imported into the Rayyan software (Qatar Computing Research Institute, Doha, Qatar) for screening and reference management [31]. The screening process was conducted in several stages. In the first phase, two independent reviewers (LTB and EM) screened titles and abstracts according to the predefined eligibility criteria, with any discrepancies resolved by a third reviewer (MD). Prior to full-scale screening, a pilot test was conducted on an initial sample of studies to ensure consistency in the application of criteria. Methodological alignment meetings were also held, in accordance with the JBI recommendations [32].

Potentially relevant studies were retrieved in full text. At this stage, eighty-eight articles were assessed, of which

three could not be obtained, despite attempts to contact academic institutions and the respective authors. Data extraction was performed by two independent reviewers (LTB and MD), with disagreements resolved by consensus. In total, 8,123 records were identified, of which, after successive exclusions, 81 articles met the eligibility criteria. The analysis was subsequently restricted to 22 randomised controlled trials (RCTs). The overall process is described in the PRISMA 2020 flow diagram (Appendix B).

Assessment of methodological quality

The eligible studies were critically appraised for methodological quality by six independent reviewers (LTB, EM, AS, RM, HC, JC), using the standardised JBI critical appraisal tool for randomised controlled trials (RCTs). This instrument comprises 13 assessment criteria, each rated as *"yes"*, *"no"*, *"unclear"*, or *"not applicable"*. For each criterion rated as *"yes"*, one point was assigned, and the total score for each study was obtained by summing these values. The overall result of the instrument ranged from 0 to 13 points. Discrepancies between reviewers were resolved by consensus following discussion.

Data extraction

Data extraction was performed by two independent reviewers (LTB and MD) using a standardised form created in Google Forms, following the JBI guidelines. Data were collected on study identification (author, year, country, and clinical setting), population characteristics, description of interventions and comparators, primary and secondary outcomes, statistical data, as well as the main findings and reported limitations. Disagreements between reviewers were resolved by consensus. Whenever missing data were identified, the authors of the original studies were contacted, but no responses were received. No statistical imputation was performed, and studies lacking essential information were excluded from the quantitative synthesis. In accordance with the JBI (2024) recommendations, data were analysed qualitatively and presented in the form of a narrative synthesis.

Data synthesis

The data synthesis was conducted according to the JBI methodology for systematic reviews of effectiveness. A formal meta-analysis was not performed due to the clinical and methodological heterogeneity among the included studies, the diversity of interventions and comparators, and the variation in reported outcomes. Consequently, the results were integrated through narrative synthesis, emphasising the direction and consistency of effects across each intervention domain. Where appropriate, relevant contextual factors were considered, including healthcare professionals' adherence, the fidelity of intervention implementation, and the microbial colonisation pressure.

Additional supporting data are provided in Supplementary Tables S1 and S2.

Assessing certainty in the findings

The certainty of evidence was assessed according to the Grading of Recommendations, Assessment, Development, and Evaluation (GRADE) approach [33]. Two independent reviewers (LTB and MD) conducted the assessment, with disagreements resolved through discussion and consensus. A Summary of Findings (SoF) table was developed using the GRADEpro GDT software (McMaster University, Hamilton, ON, Canada). The SoF table presents, where applicable, the quality rating of evidence for each primary and secondary outcome, based on the GRADE domains: risk of bias, imprecision, inconsistency, indirectness, and publication bias. All predefined outcomes of interest, including incidence of HAI, adherence to preventive measures, infection-related mortality and morbidity, length of hospital stay, hospital readmission rates, healthcare costs, patient satisfaction, and environmental indicators such as bacterial load on surfaces and colonisation by multidrug-resistant microorganisms, were reported in the SoF table. Due to the limited number of studies per comparison, no formal statistical tests for publication bias detection were conducted. However, this potential bias was qualitatively addressed in the limitations section of the review.

Results

Additional supporting data are provided in Supplementary Tables S1, S2 and S3.

Study inclusion

The search initially identified 8,123 records across the selected databases. After the removal of 872 duplicates and screening of titles and abstracts, 81 full-text articles were assessed, of which 59 met the eligibility criteria. Considering only RCTs, 22 studies were included in the final synthesis, in accordance with the PRISMA 2020 recommendations to ensure transparency and methodological rigour throughout the selection process [26].

The detailed flow of the identification, screening, and inclusion process is illustrated in the PRISMA 2020 flow diagram (Appendix C).

Methodological quality

Methodological quality was assessed using the Joanna Briggs Institute Critical Appraisal Checklist for Randomised Controlled Trials [20]. Two independent reviewers conducted the appraisal, with disagreements resolved through discussion or consultation with a third reviewer.

The methodological quality of the 22 included RCTs was assessed by six independent reviewers using the JBI critical appraisal tools specific to this study design. The scores assigned ranged from 7/13 to 11/13 positively rated criteria ("yes"), with no study meeting all evaluated items. In terms of distribution, three studies scored 7 points, five studies scored 8 points, seven studies scored 9 points, four studies scored 10 points, and three studies scored 11 points.

According to the JBI recommendations, there is no universal minimum cut-off score established for inclusion in systematic reviews. Inclusion depends on the predefined eligibility criteria outlined in the review protocol, with the critical appraisal serving to identify potential risks of bias and to support the interpretation of findings. Accordingly, in this review, all studies meeting the inclusion criteria were critically appraised and included, regardless of their total JBI score [34].

The most frequent limitations were related to the lack of blinding of participants (Q4) and of the health professionals responsible for the intervention (Q5) — predictable aspects given the nature of nursing interventions. Allocation concealment (Q2) was adequately described in only eight studies (36%). Blinding of outcome assessors (Q6) also represented a recurrent weakness, increasing the risk of detection bias. Furthermore, only 14 studies (64%) ensured adequate follow-up balance between groups (Q8), and 13 studies (59%) demonstrated a robust RCT methodological design (Q13).

The certainty of evidence, assessed using the GRADE approach, ranged from moderate (for the incidence of HAIs and adherence to preventive measures) to low or very low (for mortality, morbidity, and secondary outcomes such as length of hospital stay or healthcare costs). The Summary of Findings (SoF) tables systematically present the quality of evidence, justifications for any limitations, and the main results of this review (Appendix C).

Characteristics of included studies

This systematic review included 22 RCTs published between 1979 and 2024, conducted across various geographical regions, including Europe (United Kingdom, France, Germany, Spain), North America (United States and Canada), Asia (Japan, Singapore, Thailand), and Australia. The sample sizes varied considerably, ranging from fewer than 100 participants [35, 36] to more than 1,000 participants, depending on the type of intervention and clinical setting [14, 37]. The mean age of participants was predominantly above 50 years, reflecting the prevalence of adult and older hospitalised patients. The characteristics of the included studies are presented in Table 1.

The nursing interventions tested encompassed classical infection prevention measures, such as programmes promoting hand hygiene [17, 38], management of invasive devices, and prevention bundles for central venous and urinary catheters [39, 40], as well as skin and nasal decolonisation protocols using chlorhexidine and mupirocin [14, 41], and daily or preoperative body bathing with antiseptic solutions [42, 43]. Other studies explored educational interventions targeting healthcare professionals or patients, incorporating audit, monitoring, and feedback strategies [17, 44], as well as environmental interventions, including enhanced cleaning protocols and technologies such as ultraviolet light or hydrogen peroxide disinfection [37, 45, 46].

Regarding the comparators, most studies compared the interventions with usual care or the absence of a structured intervention [36, 47, 48]. In some cases, two alternative preventive strategies were compared, such as isolated versus combined decolonisation approaches [41].

The outcomes assessed focused primarily on the incidence of HAIs [14, 43], colonisation by multidrug-resistant microorganisms, such as MRSA and VRE [49, 50], adherence to preventive measures [17, 38], and mortality/morbidity [39, 40]. Secondary outcomes included the length of hospital stay [37], hospital readmissions [44], healthcare costs [46], environmental contamination [45, 51] and patient satisfaction [44].

Synthesis of results

Overall, nursing interventions showed a consistent trend towards reducing HAIs when compared with usual care. As summarised in Table 2, the most robust effects were observed for daily body bathing with chlorhexidine and device-related prevention bundles, which reduced bloodstream infections and intravascular device-related infections, respectively. Educational strategies and hand hygiene interventions significantly improved adherence to preventive measures, while environmental disinfection technologies reduced hospital colonisation by multidrug-resistant organisms. Multimodal strategies combining these components were more effective than isolated interventions [37, 46].

The main findings of the included RCTs are summarised in Table 2.

Risk of bias in studies

The mean methodological quality score of the included RCTs was 8.9 out of 13 (SD 1.2; range: 7–11), as assessed using the JBI critical appraisal tool for randomised controlled trials. The most frequent limitations were related to blinding: the item *"Q4. Were participants blinded to treatment assignment?"* was reported in only one study, while *"Q5. Were those delivering treatment blinded?"* and *"Q6. Were outcome assessors blinded?"* were rarely or never reported, reflecting the practical challenges of blinding in nursing interventions. Allocation concealment (Q2) was adequately described in only eight studies

Table 1 Characteristics of randomised controlled trials (RCTs) in the systematic review

Author/Year	Country	*n*	Main Intervention	Comparator	Primary Outcome	Result
Cadogan et al., 2021	Canada	412	Scheduled curtain cleaning	Routine cleaning	Bacterial load on surfaces	Significant reduction
Lorente et al., 2004	Spain	1,078	Scheduled circuit replacement	Routine replacement	Ventilator-associated pneumonia	Significant reduction
Climo et al., 2013	USA	7,727	Daily chlorhexidine bathing	Routine bathing	Bloodstream infections	Significant reduction
Rai et al., 2019	USA	376	Hand hygiene education	Standard education	Adherence / colonisation	Marked improvement
Kline et al., 2018	USA	1,240	Nasal mupirocin + chlorhexidine	Regular soap	Surgical S. aureus infection	Significant reduction
Anderson et al., 2018	USA	2,600	Prevention bundle / decolonisation	Standard care	Healthcare-associated infections	Significant reduction
Mertz et al., 2010	Canada	1,007	Decolonisation protocol	Standard care	MRSA colonisation	Significant reduction
Ho et al., 2015	Singapore	1,043	Daily chlorhexidine bathing	Routine bathing	MRSA/VRE colonisation	Significant reduction
Buxton et al., 1979	USA	120	Hand hygiene campaign	No campaign	Hospital infections	Significant reduction
Maechler et al., 2020	Germany	600	Decolonisation + education	Standard care	MRSA acquisition	Significant reduction
White et al., 2020	Australia	350	Hygiene education	Standard care	Adherence to preventive measures	Marked improvement
Ray et al., 2017	USA	1,500	UV-C disinfection	Standard cleaning	Environmental contamination	Significant reduction
Anderson et al., 2017	USA	2,445	UV-C environmental disinfection	Standard cleaning	HAIs (C. difficile, MRSA, VRE)	Significant reduction
Hall et al., 2016	Australia	415	Structured nursing training	Standard care	Protocol adherence	Marked improvement
Barbut et al., 2009	France	320	Environmental cleaning protocol	Standard care	C. difficile contamination	Significant reduction
Curran et al., 2008	United Kingdom	500	Hand hygiene intervention	Standard education	Hand hygiene adherence	Marked improvement
Darouiche et al., 2006	USA	1,650	Central venous catheter bundle	Standard care	Catheter-related infections	Significant reduction
Taweesuk et al., 2023	Thailand	280	Education + prevention bundle	Standard care	HAIs	Significant reduction
Kundrapu et al., 2012	USA	245	Environmental decontamination	Standard cleaning	MRSA/VRE transmission	Significant reduction
Murray et al., 2011	USA	310	Hand hygiene + feedback	Standard care	Hospital infections	Significant reduction
Takeda et al., 2024	Japan	430	Daily chlorhexidine bathing	Routine bathing	HAIs	Significant reduction
Morgan et al., 2023	USA	950	Multicentre UV-C intervention	Standard cleaning	Hospital infections	Significant reduction

Characteristics of the included studies ($N = 22$ RCTs)

(36%). Losses to follow-up were explicitly reported in 14 studies (64%), whereas in the remaining studies the information was not clearly described or quantified. Random sequence generation and baseline comparability between groups were sufficiently described in most cases. The criterion *"Q13. Was the study design appropriate, and were any deviations from the classical RCT model adequately justified?"* was rated positively in 13 studies (59%). All included studies addressed the core domains of internal validity, namely randomisation and baseline comparability, although many were judged to have unclear or high risk of bias regarding blinding and follow-up. Additional limitations were identified in relation to statistical analysis (Q12) and intervention implementation fidelity. Overall, none of the studies achieved the maximum score of 13. Most were classified as having moderate to high methodological quality, yet with potential performance and detection bias, mainly due to limited blinding and incomplete reporting. A summary of the methodological quality assessment using the JBI critical appraisal tool is presented in Table 3 (Summary of quality appraisal).

Adverse events and safety

The safety of nursing interventions was insufficiently reported in most of the included studies. Only five RCTs systematically described the occurrence of adverse events, reporting a low rate of complications associated with the interventions, such as transient skin irritation in participants exposed to chlorhexidine bathing, generally below 3% [14, 41]. No study reported serious adverse events or side effects that led to discontinuation of the intervention [42]. However, the absence of systematic monitoring and reporting limits robust conclusions regarding the safety profile of these interventions.

Heterogeneity of studies

Significant clinical and methodological heterogeneity was observed among the studies, particularly concerning the profile of the patients included (age, comorbidities),

Table 2 Summary of the main findings from the randomised controlled trials included, grouped by type of intervention, comparator, number of participants, direction of effect, certainty of evidence according to the GRADE approach, and methodological or contextual comments. The certainty rating summarises the level of confidence in the estimated effect, following the GRADE system. Results are presented as an overall trend interpreted from the narrative synthesis due to study heterogeneity

Intervention	Comparator	Participants (Studies)	Direction of Effect	Certainty of Evidence (GRADE)	Methodological Comments	Key References
Daily body bathing with chlorhexidine	Usual care (standard bathing)	~7,800 patients (8 RCTs)	Reduces bloodstream infections and MRSA/VRE colonisation	Moderate	Consistent effect, greater impact; minor adverse events; limitations: operational blinding	Climo et al., 2013; Ho et al., 2015; Takeda et al., 2024; Kline et al., 2018; Murray et al., 2011
Prevention bundles for catheters/devices	Usual care	~4,200 patients (6 RCTs)	Reduces intravascular device-related infections	High	Robust and consistent reduction; high plausibility; blinding difficult; implementation fidelity critical	Darouiche et al., 2006; Lorente et al., 2004; Anderson et al., 2018
Promotion of hand hygiene	Usual training/ no structured intervention	~3,500 professionals/patients (4 RCTs)	Improves adherence and reduces cross-colonisation	Moderate	Strong improvement; indirect effect on HAIs less consistent; sustainability depends on reinforcement/monitoring	Mertz et al., 2010; Rai et al., 2019; Buxton et al., 1979; Curran et al., 2008
Educational interventions for nursing teams	Usual training	~2,000 professionals (3 RCTs)	Increase protocol adherence and indirectly reduce HAIs	Low	Results dependent on organisational context; risk of performance bias; lack of blinding	Hall et al., 2016; Rosenthal et al., 2005
Environmental disinfection with UV-C/ hydrogen peroxide	Standard hospital cleaning	~5,000 patients (4 RCTs)	Reduces infections/ colonisation by C. difficile, MRSA, and VRE	Moderate	More evident effects in high-colonisation settings; dependent on operational adherence; variable reported cost-effectiveness	Anderson et al., 2017; Barbut et al., 2009; Ray et al., 2017; White et al., 2020; Kundrapu et al., 2012
Hospital mortality (all domains)	Usual care	~10,000 patients (10 RCTs)	No consistent differences in hospital mortality	Low	Mortality is multifactorial; infection prevention does not necessarily translate into reduced mortality	Darouiche et al., 2006; Lorente et al., 2004; Climo et al., 2013
Healthcare costs	Usual care	3 studies (~1,500 patients)	Trend towards reduced costs in enhanced environmental interventions	Low	Few studies with robust economic reporting; high heterogeneity	White et al., 2020; Anderson et al., 2017
Patient satisfaction	Usual care	2 studies (~600 patients)	No significant differences	Very low	Assessed in few studies; limited instruments and sample sizes	Curran et al., 2008; Rai et al., 2019
Adverse events (safety)	Usual care	5 studies	Rarely reported; low, mild, no serious events	Low	Lack of systematic reporting limits solid conclusions on safety	Climo et al., 2013; Kline et al., 2018; Murray et al., 2011

characteristics of clinical settings, intervention protocols (frequency, duration, and implementation), and outcome assessment criteria [37, 40]. This diversity justified the choice of a narrative synthesis rather than a formal meta-analysis [17].

Subgroup analysis

The available data did not allow predefined subgroup analyses due to the variability of reported variables and the lack of robust stratification in most studies. Nevertheless, qualitative reports suggest greater effectiveness of interventions such as chlorhexidine bathing and preventive bundles compared with other clinical contexts [14, 37, 40].

Secondary and complementary outcomes

Only seven studies evaluated the length of hospital stay, with inconsistent results that, when present, favoured the intervention [37, 46]. Healthcare costs were rarely assessed [46], indicating variable reductions depending on the context. Patient satisfaction was assessed in two studies, showing no statistically significant differences between groups [44, 47]. Environmental contamination was reported in five studies, all demonstrating a significant reduction in bacterial load on surfaces following enhanced environmental interventions [36, 45, 51].

Summary and Synthesis of the Main Outcomes Assessed.

Table 3 Summary of quality appraisal

Quality Criterion (JBI)	Number of Studies (*N* = 22)	Percentage (%)
Q1. Randomised design clearly described	22	100
Q2. Allocation concealment described	8	36
Q3. Groups comparable at baseline	18	82
Q4. Participants blinded	1	5
Q5. Healthcare professionals blinded	0	0
Q6. Outcome assessors blinded	3	14
Q7. Complete follow-up or losses < 20%	14	64
Q8. Intention-to-treat analysis performed	12	55
Q9. Appropriate statistical methods used	14	64
Q10. Primary outcomes clearly defined	21	95
Q11. Standardised and valid outcome measures	19	86
Q12. Adequate statistical analysis reported	13	59
Q13. Study design appropriate/deviation from standard justified	13	59

A summary of all primary and secondary outcomes assessed across studies is presented in Supplementary Table S3.

Publication bias

No formal statistical tests were conducted to detect publication bias due to the limited number of studies per comparison/intervention. However, this possibility was considered and discussed as a limitation of the synthesis.

Gaps in the evidence and general limitations

The main limitations identified across the included studies were the impossibility of blinding participants and professionals, substantial methodological heterogeneity, small sample sizes in some contexts, and incomplete reporting of secondary outcomes such as costs, long-term adherence, and quality of life [39, 40]. These aspects highlight the need for pragmatic multicentre RCTs with systematic reporting of safety, adherence, and cost-effectiveness outcomes.

Discussion

Summary of evidence

This systematic review of effectiveness, encompassing twenty-two randomised controlled trials published between 1979 and 2024 across multiple countries and continents, demonstrates that effective nursing interventions play a central role in preventing HAIs. Although several of the evaluated interventions (e.g., environmental disinfection, decolonization protocols, and prevention bundles) are inherently interprofessional, in all included studies nurses held a primary role in coordination, implementation, monitoring of adherence, or direct patient-level delivery, justifying their classification as nursing-led interventions in this review.

Although a formal meta-analysis was not feasible due to substantial clinical and methodological heterogeneity, important sources of heterogeneity can be addressed narratively. Most of the included randomised controlled trials were conducted in high-income countries and predominantly in acute hospital settings, where established infection prevention infrastructures, access to antiseptic agents, and structured surveillance systems are more common. These contextual characteristics likely contributed to the consistency and magnitude of the observed effects.

These findings suggest that nursing-led infection prevention is most effective when interventions target multiple dimensions of care, including technical practices, behavioural change, and environmental control. Organisational factors such as leadership style and patient safety culture have been shown to significantly influence nurses' adherence to safety practices [52].

From an implementation science perspective, the superior effectiveness of multimodal interventions may be explained by their capacity to simultaneously address behavioural, organisational, and environmental determinants of practice. In line with established implementation frameworks, such as the WHO multimodal strategy and Normalization Process Theory, isolated interventions often fail due to limited sustainability and suboptimal adherence, whereas integrated strategies combine technical components with educational, audit, and feedback mechanisms, fostering collective accountability, coherence, and long-term normalisation of safe practices within healthcare teams.

Beyond the impact on infection incidence, the results of this review demonstrate that multimodal interventions integrating educational components, bundles, and environmental control measures are more effective than isolated strategies. This aligns with high-level international recommendations advocating for the coordinated and systematic implementation of multiple preventive components. Recent guideline updates from the WHO and the CDC similarly emphasise the superiority of integrated approaches over single-measure interventions, particularly in complex hospital environments [1, 5]. Subgroup analyses suggest that these interventions exert a particularly strong effect in contexts with high bacterial colonisation pressure.

Although hospital mortality did not show statistically significant differences between groups in most included studies, the reduction of HAIs translates into substantial indirect benefits, including shorter hospital stays, lower healthcare costs, and fewer readmissions—findings also supported by recent international economic reviews and multicentre trials [46]. Nevertheless, some contemporary studies have reported heterogeneous effects on secondary outcomes such as length of stay and

cost-effectiveness, highlighting the influence of contextual and organisational factors on the magnitude of benefit achieved.

In the Portuguese context, the implementation of bundles and standardised educational strategies has been associated with reduced HAI incidence and improved adherence to preventive practices, although considerable variability between institutions persists, as reported in national surveillance data and official reports from the Portuguese Directorate-General of Health [53, 54]. These reports document persistent inter-hospital variability in HAI rates and adherence indicators, underscoring the challenges of standardised implementation at a national level.

The safety of the evaluated interventions also deserves emphasis, with adverse events reported as rare and predominantly mild (e.g., chlorhexidine-related skin irritation < 3%) and no serious effects observed in the analysed studies.

However, the clinical and methodological heterogeneity—including differences in populations, intervention fidelity and intensity, and outcome variability—together with limitations in blinding and incomplete reporting of secondary outcomes (costs, quality of life, satisfaction), warrant caution in generalising these findings. Similar limitations have been highlighted in recent international reviews, which stress the need for pragmatic multicentre trials with standardised outcome reporting and robust implementation evaluation frameworks [22, 28]. These weaknesses further underscore the need for pragmatic multicentre studies, particularly in low- and middle-income countries, as also recommended in recent CDC guidelines [5].

While several interventions evaluated in this review were embedded within multidisciplinary infection prevention and control programmes, nurses consistently played a primary and defining role in all included studies. Nursing leadership was evident through direct patient-level delivery of interventions, coordination of prevention bundles, monitoring of adherence, and implementation of educational strategies. This distinction highlights nursing as a central driver of implementation and sustainability of infection prevention strategies rather than merely a contributing discipline.

Contribution to nursing knowledge

This review contributes to nursing knowledge by providing, to our knowledge, the first systematic synthesis restricted to randomised controlled trials evaluating nursing-led interventions for infection prevention across multiple clinical domains. Unlike previous reviews focusing on single infection types, isolated interventions, or mixed professional approaches, this review clarifies the magnitude and certainty of effect attributable to nurse-coordinated strategies using a rigorous JBI methodology and GRADE assessment. By integrating classical preventive measures with emerging environmental technologies and adopting an implementation science perspective, this study strengthens the epistemological positioning of nursing as a central discipline in patient safety, infection prevention, and healthcare quality improvement.

Evidence regarding the direct costs associated with nursing-led infection prevention interventions was limited, and the certainty of evidence for economic outcomes was low. However, from an opportunity cost perspective, preventing healthcare-associated infections may generate indirect economic benefits through reduced length of hospital stay, avoidance of costly complications, fewer readmissions, and more efficient use of nursing time and institutional resources.

Limitations

Despite the methodological rigour of this review, the substantial clinical, organisational, and methodological heterogeneity among the included studies—in terms of populations, settings, intervention intensity and fidelity, and outcome reporting methods—precluded a formal meta-analysis and limits the direct extrapolation of results to all settings. Three potentially eligible articles could not be retrieved, increasing uncertainty regarding publication bias, an aspect similarly highlighted in international reviews.

The inherent difficulty of ensuring blinding among participants and professionals in behavioural or organisational interventions introduces performance bias in many RCTs, as documented in international methodological literature. The age of some studies, dating back to the 1980s, raises concerns about the immediate applicability of their results to contemporary practice, given that advances in institutional protocols and infection prevention may not be fully reflected in older trials.

From a reporting standpoint, systematic reporting of secondary outcomes—such as costs, long-term adherence, satisfaction, and quality of life—was insufficient in several studies, limiting conclusions on cost-effectiveness and long-term impact. Similarly, the assessment of adverse events was limited, hindering a comprehensive appraisal of the safety profile of the interventions evaluated.

The GRADE analysis indicated that the certainty of evidence ranged from moderate to low for many critical outcomes, reflecting methodological limitations, risk of bias, and incomplete reporting. This reinforces the need for cautious interpretation of findings and supports the recommendation for future pragmatic multicentre studies with standardised reporting according to international guidelines.

In contrast, the generalisability of these findings to low- and middle-income countries remains uncertain. Resource constraints, differences in staffing ratios, limited access to infection prevention technologies, and variability in baseline infection control practices may substantially influence both implementation fidelity and effectiveness. Consequently, the magnitude of benefit observed in this review should be interpreted cautiously when extrapolated to resource-limited settings.

Implications for practice and research

The findings of this review unequivocally reinforce the central role of evidence-based nursing interventions in preventing HAIs. The clinical and organisational impact of these interventions—including multidisciplinary bundles, rigorous hand hygiene, antiseptic use (e.g., chlorhexidine), invasive device prevention bundles, and environmental disinfection technologies—supports the systematic promotion of institutionally led nursing programmes aligned with the strategic priorities of the ECDC (2017) and World Health Organization (2016).

In practice, it is recommended that these preventive interventions become standard reference components within hospital plans, integrated into patient safety and quality policies, with structured monitoring of adherence and outcome indicators. The active participation of nurses as leaders and educators is essential to ensuring the sustainability and ongoing adaptation of preventive programs, consistent with the expanding body of international reviews and meta-analyses [15, 55].

From a research perspective, there remains a clear need for contemporary, pragmatic, multicentre randomised clinical trials conducted across diverse health systems, with a particular focus on low- and middle-income countries, high-colonisation regions, and resource-variable contexts. Future research should include not only clinical outcomes (HAI incidence, colonisation, mortality) but also implementation indicators, direct and indirect costs, quality of life, functionality, and patient satisfaction, dimensions that remain underexplored in current evidence.

The adoption of standardised reporting methodologies such as PRISMA (2020) [26], robust quality appraisal (GRADE), and consistent reporting of adverse events, costs, and patient-centred outcomes are essential to enhance the comparability and utility of evidence, guiding future guidelines and informing clinical and policy decision-making towards safer, more efficient, and person-centred nursing practice.

Conclusions

This systematic review evaluated the effectiveness of nursing interventions in reducing the risk of HAIs among hospitalised adults. The results demonstrate that strategies such as daily body bathing with chlorhexidine, implementation of preventive bundles, promotion of hand hygiene, and environmental disinfection using advanced technologies yield consistent and clinically relevant effects. Although no statistically significant differences in hospital mortality were observed, the reduction in infection incidence translates into substantial gains in patient safety, care quality, and healthcare system efficiency.

These findings highlight the relevance of integrating evidence-based nursing interventions into institutional infection prevention and control programmes, in accordance with international recommendations. Future research should prioritise pragmatic, multicentre clinical trials conducted in diverse contexts and healthcare systems, to assess not only effectiveness but also cost-effectiveness and patient-centred outcomes, contributing to more robust and sustainable infection prevention policies.

Abbreviations

HAI	Healthcare-associated infection
MRSA	Methicillin-resistant Staphylococcus aureus
VRE	Vancomycin-resistant Enterococcus
RCT	Randomised controlled trial
JBI	Joanna Briggs Institute
GRADE	Grading of Recommendations Assessment, Development and Evaluation
PRISMA	Preferred Reporting Items for Systematic Reviews and Meta-Analyses
UV-C	Ultraviolet-C

Supplementary Information

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Supplementary Material 1

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Author contributions

LFP-TB conceptualised the study, developed the protocol, coordinated the review process, performed study selection, data extraction, quality appraisal, data synthesis, and drafted the manuscript. ESFM and HMP-C contributed to study selection, data extraction, and critical appraisal. ARMS, ASFP, JAC, MACR, and MCM participated in data extraction, methodological quality assessment, and critical revision of the manuscript. All authors reviewed, revised, and approved the final version of the manuscript.

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Data availability

All data generated or analysed during this systematic review are included in this published article and its supplementary information files. The datasets used and/or analysed during the current study are available from the corresponding author on reasonable request.

Declarations

Ethics and consent to participate
Not applicable. This study is a systematic review of previously published data and did not involve human participants or primary data collection.

Consent for publication
Not applicable.

Competing interests
The authors declare no competing interests.

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