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Systematic review

Multimodal strategies for the implementation of infection prevention and control interventions—update of a systematic review for the WHO guidelines on core components of infection prevention and control programmes at the facility level

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A B S T R A C T

Background: Health care-associated infections (HAIs) remain a significant challenge worldwide, and the use of multimodal strategies is recommended by the WHO to enhance infection prevention.
Objectives: To update the systematic review on facility level infection prevention and control interventions on the WHO core component of using multimodal strategies.
Methods: Data sources: Medline (by PubMed), EMBASE, CINAHL, and the Cochrane library.
Study eligibility criteria: Randomized controlled studies, interrupted time series, and before-after studies in acute care settings, from November 24, 2015 to June 30, 2023.
Participants: Both paediatric and adult populations.
Interventions: Infection prevention and control interventions implemented with at least three WHO multimodality elements.
Assessment of risk of bias: Effective practice and organisation of care and integrated quality criteria for review of multiple study designs tools. Methods of data synthesis: Descriptive data synthesis.
Results: Of 5678 identified titles and abstracts, 32 publications were eligible for data extraction and analysis. Five non-controlled before-after studies were excluded due to an insufficient integrated quality criteria for review of multiple study designs score. Of the remaining 27 studies, nine reported on the effect of multimodal strategies to reduce device-associated HAIs, four on surgical site infections, eight on infections due to antimicrobial resistance and six on hand hygiene (HH) compliance. Eleven were controlled studies (randomized controlled studies or controlled before-after studies), nine interrupted time series and seven non-controlled before-after studies. Twenty-two of the studies originated from high-income countries, and the overall quality was medium to low. Twenty studies showed either significant HAI reductions or HH improvement.
Conclusion: Most studies demonstrate a significant effect on HAI prevention and HH improvement after applying a multimodal strategy. However, the quality of evidence remains low to moderate, with few studies from low-income or middle-income countries. Future research should focus on higher quality studies in resource limited settings. **Ashlesha Sonpar, Clin Microbiol Infect 2025;31:948**

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Introduction

Health care-associated infections (HAIs) are among the most common adverse event in health care, with a significant impact on mortality and economy [1–3]. In 2010, the WHO estimated that in acute care hospitals, an average of 7% and 15% of patients acquire at least one HAI in high-income and low-income countries, respectively [1]. More recent studies found HAI prevalence of 12.5%, 27.0%, and 8.0% in Eastern Mediterranean, African, and European countries, respectively [4,5]. A significant proportion of HAIs could be averted by effective infection prevention and control (IPC) measures [6,7]. However, the implementation of such measures depends on various contextual factors, resulting in variable IPC standards across countries [7–10].

In 2016, WHO published a guideline with evidence-based recommendations on critical elements (eight core components) of IPC programmes at both the national and facility levels [6]. This guideline was followed by the publication of practical implementation manuals and a document defining the minimum requirements for IPC programmes [11,12]. One of the WHO core components recommends the use of multimodal strategies for the implementation of IPC interventions aiming to prevent HAI, reduce antimicrobial resistance (AMR), and improve hand hygiene (HH) compliance [6]. A number of studies showed that behavioural change with the aim to improve practice and prevent HAI can best be achieved by applying a multimodal implementation approach [6], which was also used by WHO in 2009 to promote HH globally [13]. The WHO concept of multimodality includes a set of five elements, such as (i) system change; (ii) education and training of health care workers; (iii) monitoring infrastructure, practices, processes, and outcomes and providing data feedback; (iv) reminders in the workplace/communications; and (v) culture change by strengthening the institutional safety climate. Multimodality is met when three or more elements are combined to facilitate an intervention [6,14].

The recommendations of multimodal improvement strategies, and all eight WHO core components, are based on evidence from two systematic reviews [7,10]. The first review was performed by the systematic review and evidence-based guidance on organization of hospital infection control programmes (SIGHT) study group and provides evidence-based guidance on the organisation of IPC in hospitals, including literature up to end of December 2012 [7]. Subsequently, SIGHT was updated, including literature up to November 23, 2015 [10]. The evidence for applying a multimodal strategy in HAI prevention came from 15 Cochrane Effective Practice and Organisation of Care (EPOC) studies of limited quality [15]. Further context on the subject was provided by 29 non-controlled and qualitative studies. Of the total of 44 studies, 40 were from high-income countries [10]. The aim of this systematic review was to update evidence on multimodal improvement strategies in interventions to reduce HAI and infections due to AMR pathogens, and to improve HH compliance. This updated evidence base, encompassing all three reviews, will in turn inform the WHO guidelines on the IPC core components. This review focuses on multimodal strategies, as a large number of studies using at least three of the five elements have been published since the last update.

Methods

Data sources

This systematic review was structured according to the Preferred Reporting Items for Systematic Review and Meta-Analysis guidelines [16]. We searched MEDLINE (via PubMed), the Excerpta Medica Database (EMBASE via embase.com), the Cumulative Index to Nursing and Allied Health Literature (CINAHL), and the Cochrane library for citations indexed from November 24, 2015 to June 30, 2023. We limited the search strategy to information regarding the use of multimodal strategies in the implementation of IPC programmes in acute care facilities (Table S1). The research protocol was registered at the International prospective registry of systematic reviews (PROSPERO: CRD42021289265).

Study eligibility criteria

Articles were eligible for inclusion based on the following criteria: (1) quantitative evaluation of multimodal or multifaceted strategies (including at least three of the five elements of the WHO definition of multimodal improvement strategies) on one of the primary outcomes; (2) implementation at the acute health care facility level; (3) study designs with a separate control group (randomized controlled trials [RCT] and controlled before-after [CBA] studies), interrupted time series (ITS) (as defined by the EPOC criteria) [15], or non-CBA (NCBA) when adjusted for relevant confounders (see definition in supplement); and (4) peer-reviewed publications in English, or in German, French, Spanish, Portuguese, and Chinese if title and abstract were available in English. If multiple publications referred to the same dataset, the report with the highest data representation was selected. An article had to meet all the criteria to be included.

Articles were excluded based on the following criteria: (1) outbreak reports, systematic reviews, scoping reviews, umbrella reviews, meta-analyses, editorials, letters, conference proceedings, comments, case studies, or qualitative studies; (2) outpatient care, emergency or ambulatory care, or same-day surgery; (3) studies where multimodal antimicrobial stewardship was the only strategy; (4) cost-effectiveness analyses; (5) studies on HAIs due to viruses; and (6) studies for which full text was unavailable for review.

Primary outcomes

Primary outcomes were change of HAI (nonspecified or total), central line-associated bloodstream infection (CLABSI), catheter-related bloodstream infection (CRBSI), ventilator-associated pneumonia (VAP), catheter-associated urinary tract infection (CAUTI), or surgical site infection (SSI) rates, HAI due to AMR pathogens or multidrug-resistant organisms (MDROs), *Clostridioides difficile* infection, colonization with AMR pathogens or MDROs, HH compliance, or consumption of alcohol-based hand rub (Table S1 for search terms used).

Study selection

Titles, abstracts, and full texts were screened independently by two researchers (J.W. and C.H. or A.S. and J.T.) against the inclusion and exclusion criteria using the web-based review tool Rayyan (www.rayyan.ai). Disagreements were resolved by consensus or by a third researcher (W.Z.).

Data extraction and risk of bias assessment

J.W., C.H., A.S., and J.T. independently extracted data using a predefined data extraction form, including first author, year of publication, country, study aim, study design, setting, population, intervention, elements of the multimodal strategy, study groups, and study outcome. Study origin was stratified by country income, as defined by the World Bank classification [17]. Risk of bias was independently assessed by two reviewers using the EPOC criteria [15]. The NCBA studies were assessed using the integrated quality criteria for review of multiple study designs tool [18]. The EPOC studies were rated low risk of bias when all the individual domains in the EPOC quality assessment scored at low risk; otherwise, they were rated either medium or high risk of bias (medium risk of bias if at least one domain was scored as unclear or some concerns but no domain was scored as high risk; high risk of bias if any one domain was rated as high risk or multiple (3 or more) domains were rated as unclear or some concerns). The NCBA studies were graded on the basis of an overall score (9–17 points = low quality evidence, 18–25 points = medium quality of evidence, 26–30 points = high quality of evidence) with a set of specific criteria. A paper had to have a minimum score of 22 and meet the four mandatory criteria to be included in the review [18].

Data analysis

Due to the wide range of outcomes and the large degree of heterogeneity between studies, it was not possible to perform a meta-analysis or formal evaluation of the overall body of evidence by GRADE (grading of recommendations assessment development) [19]. Data synthesis was descriptive, summarizing relevant information from data extraction related to the effectiveness of the multimodal improvement strategies on the outcomes of interest. The data were grouped by outcome, and studies listed more than once if more than one outcome of interest was reported.

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Results

A total of 5678 titles and abstracts were identified, of which 32 were eligible for data extraction and risk of bias assessment: six (cluster-) RCTs, five CBA-studies, nine ITS analyses, and 12 NCBA studies. Five NCBA studies [20–24] were excluded after quality review (Table S2). Fig. 1 shows the systematic review profile; the remaining 27 studies are summarized in Table 1 [25–51]. Twenty-two studies were conducted in high-income countries, three in upper-middle income countries, and two in lower-middle income countries. Twenty-one reports were single-centre studies and six were multicentre studies (Table S3). Of the 20 EPOC studies, seven and 13 had medium and high risk of bias, respectively (Table S2).

Healthcare-associated infections

Two studies investigated the effectiveness of multimodal strategies on HAI overall (Table 1). The NCBA study by Hagel et al. [25] evaluated a hospital-wide infection control programme, including HH-promotion and care bundles for VAP, CLABSI, CAUTI, and SSI. The intervention significantly reduced severe HAI (severe sepsis/septic shock or death) in the intensive care unit (ICU) department, whereas no effect was seen in general wards. It is unclear to what extent the results can be attributed to study interventions alone, as some bundled interventions were already implemented in ICUs before the study [25]. Using a stepped-wedge CBA design, Wolfensberger et al. [26] looked at the effect of a nonventilator associated hospital acquired pneumonia prevention bundle combined with several implementation strategies. The study identified significant nonventilator associated hospital acquired pneumonia-reductions and, additionally, measured determinants of the implementation success.

Surgical site infections

One CBA- and three NCBA studies investigated the effectiveness of multimodal strategies on SSI (Table 1) [27–30]. Calderwood et al. [28] demonstrated an effect of a large-scale multistate campaign on SSI-prevention in patients undergoing hip arthroplasty ($p < 0.01$). Allegranzi et al. [27] reported on overall SSI in four African countries, and showed that the implementation of a multimodal SSI-prevention strategy in low-resource settings improved infection prevention practices and reduced SSIs by 40% ($p < 0.001$). The two other studies by Dieplinger et al. [29] and Kawakita et al. [30] reported significant reductions of SSI in women undergoing caesarean delivery. All four studies applied an intervention incorporating surgical bundles, and three studies combined bundles with education and audit and feedback [27–29]. In addition, Allegranzi et al. [27] included element one, facilitating the local production of chlorohexidine-based disinfectant and the procurement of antimicrobials for surgical prophylaxis. The studies also focused on local-driven, multidisciplinary-driven, and resident-driven leadership.

Device-associated HAIs

Nine studies investigated the effectiveness of multimodal strategies to reduce CLABSI/CRBSI (n = 5), CAUTI (n = 1), and VAP (n = 3, Table 1) [31,33–35,37–39,49]. The stepped-wedge cluster-RCT by van der Kooi et al. [39] evaluated improved CVC-insertion practices and HH alone or combined to reduce CRBSI in 11 European countries. The three study arms applied the five elements of the WHO multimodal strategy [6]. After adjustment for an already decreasing baseline trend, the study found a significant effect on CRBSI in the HH-arm and the combined arm [39]. The CRBSI reduction was the result of improved practice as evidenced by measuring process indicators. Two studies reported on multimodal interventions to reduce CLABSI [31,35]. The ITS study by Bae et al. [31] analysed the effect of a multimodal strategy in the intervention of an automatic notification of catheter days as a reminder for the physician. Central line days were significantly reduced and there was a decreasing trend of the CLABSI rates. The CBA study by O'Neill et al. [35] addressed CLABSI prevention in the non-ICU setting. It found a nonsignificant decrease of the CLABSI-rate after the implementation of a multimodal catheter maintenance bundle.

Two ITS single-centre studies investigated the effectiveness of multimodal strategies on VAP. Su et al. [37] focused on a simple 3-element bundle, such as education, HH, and oral care. There was significant decrease of VAP, but also a rebound after withdrawal of education and oral care. Talbot et al. [38] showed decrease of VAP after implementing a VAP-bundle combined with a real-time computerized ventilator dashboard ($p < 0.001$). The effect was sustained over multiple years, which was attributed to the visual compliance reminders in the patient rooms. The single-centre NCBA study by Michelángelo et al. [34] focused on experimental learning strategies using games and role playing. A modest but significant improvement of monthly VAP-rates was observed.

The CBA study by Garcia et al. [33] investigated the effectiveness of a multimodal strategy on CAUTI, which included nurse CAUTI champions. Although CAUTI-rates remained unchanged in the control ward, there was decrease in the intervention wards (no p-value).

Healthcare-associated infections due to AMR pathogens or MDRO

Nine studies investigated the effectiveness of multimodal strategies on infection or colonisation with AMR pathogens or MDRO (Table 1) [40–48].

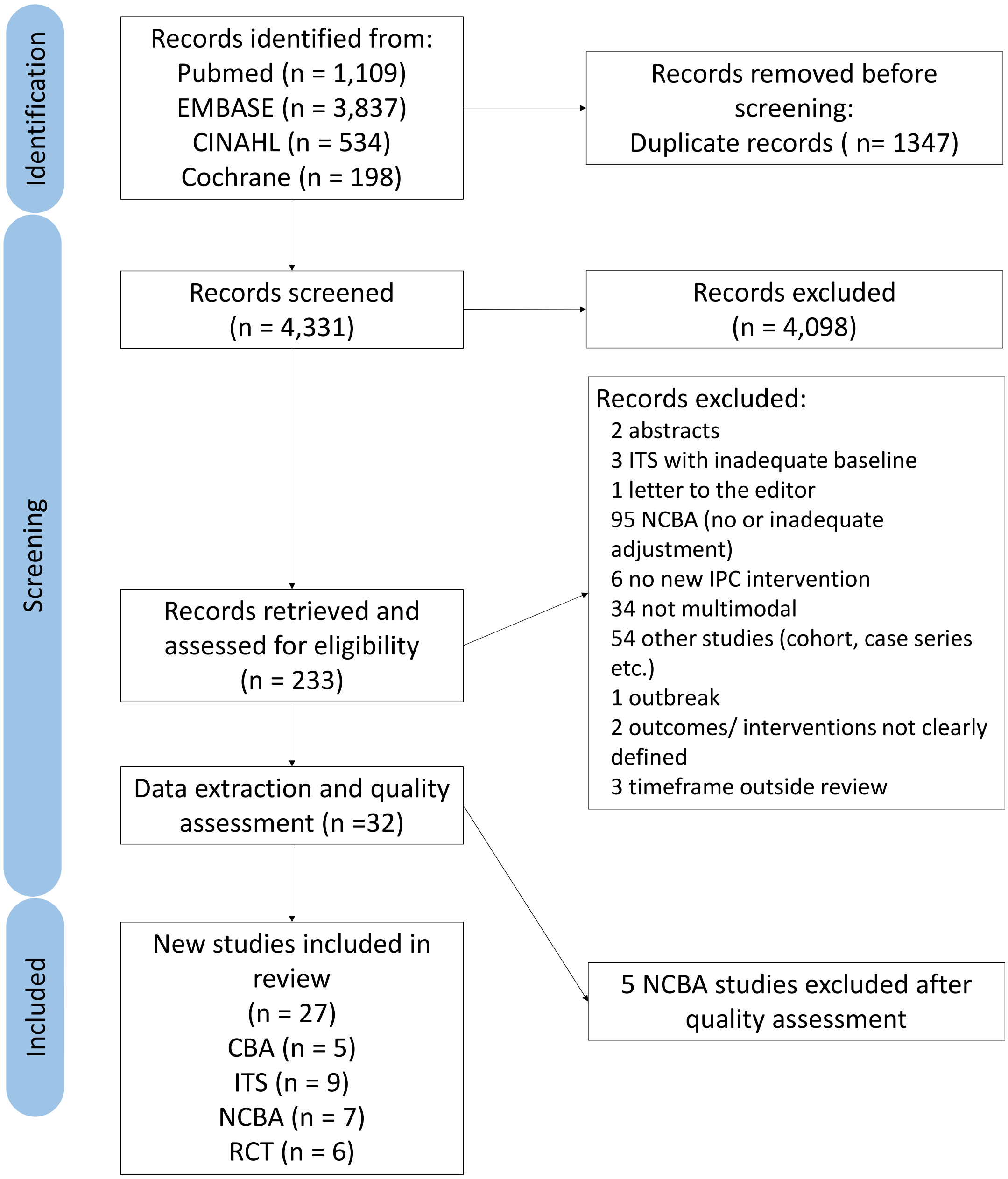

Fig. 1. Systematic review profile - systematic review of multimodal improvement strategies using WHO core components for effective infection prevention and control programs at the healthcare facility levels. Note: CBA: Controlled before-after study; EPOC: Cochrane Effective Practice and Organisation of Care; ITS: Interrupted time series study; NCBA: Non-controlled before and after study; NCC: Non-controlled cohort study; RCT: Randomized controlled trial. Flow chart created as per PRISMA 2020 guidelines [16].

Mitchell et al. [43] implemented an environmental cleaning bundle combined with training and feedback in a stepped-wedge randomized multicentre trial. Improved cleaning thoroughness significantly reduced vancomycin-resistant *Enterococci* infections. *Clostridioides difficile* infections did not change over the same period. The RCT of von Lengerke et al. [48] compared HH training with and without behaviour change techniques. Significant reductions of methicillin-resistant *Staphylococcus aureus* (MRSA), vancomycin-resistant *Enterococci* and multidrug-resistant gram negative bacteria were identified. However, the two arms did not perform differently. The RCT by Stewardson et al. [46] identified a slight decrease of MRSA and extended spectrum β-lactamase bacteria after a HH-intervention that focused on feedback and patient participation. Both studies report cross-contamination between the intervention and control wards as a possible explanation for the nonsignificant differences between arms with and without multimodal strategies [46,48].

Six single-centre ITS-studies investigated the effect of IPC interventions implemented using a multimodal strategy on infection or colonisation with MDRO [40–42,44,45,47]. The studies by Saharman et al. [44] and Valencia-Martín et al. [47] showed an effect on drug resistant *Acinetobacter baumannii* acquisition or infection. Li et al. [42] showed a reduction of ICU-acquired carbapenem-resistant *Klebsiella pneumoniae* after intensifying bundle components (more education and cleaning) despite new admissions of positive patients. Bundle compliance was not measured in this study. Spyridopoulou et al. [45] found a reduction of carbapenem-resistant *Klebsiella pneumoniae*-BSI after a bundled intervention including active surveillance cultures in a high endemic haematology setting. Chun et al. [40] showed a

Table 1
Summary of studies included in systematic review of multimodal improvement strategies using WHO core components for effective infection prevention and control programmes at the health care facility levels

Outcome	Study	Study design	Measure reported	Effect estimate (CI)[a]		Risk of bias/ICROMS assessment	Country/region
Health care associated infections	Hagel et al. [25], 2019	NCBA study; adjusted for confounders	aIRR of HAI	HAI rate: General wards: 1.29 (0.78–2.15) Severe HAIs: General wards: 0.86 (0.35–2.10)	 ICU: 0.59 (0.27–1.21) ICU: 0.13 (0.05–0.32)	Medium quality	Germany
	Wolfensberger et al. [26], 2023	CBA study	nvHAP incidence rate (per 1000 patient days) and aIRR	Baseline: 1.42 (1.27–1.58) Implementation: 0.99 (0.63–1.56) Intervention: 0.90 (0.73-1.10) aI RR: 0.69 (0.52-0.91)		High	Switzerland
Surgical site infections	Allegranzi et al. [27], 2018	NCBA study; adjusted for confounders	Cumulative incidence (per 100 surgical operations) and OR	Baseline: 8.0% (6.8–9.5) Follow-up 3.9% (3.0–4.8) OR: 0.40 (0.27–0.61)		High quality	Africa
	Calderwood et al. [28], 2019	CBA study	SSI incidence and OR	Hip arthroplasty Control states: Baseline: 2.18% Postintervention: 2.14% OR: 0.85 (0.75–0.96) Knee arthroplasty Control states: Baseline: 1.64% Postintervention: 1.45% OR: 0.88 (0.78–0.99)	 Intervention states: Baseline: 1.98% Postintervention: 1.64% Intervention states: Baseline: 1.65% Postintervention: 1.30%	High	United States
	Dieplinger et al. [29], 2020	NCBA study; adjusted for confounders	SSI incidence and OR	Preintervention: 1.50% Postintervention: 0.56% OR: 0.39 (0.17–0.89)		High quality	Austria
	Kawakita et al. [30], 2019	NCBA study; adjusted for confounders	SSI incidence and OR	Adjusted analysis Preimplementation: 4.1% Postimplementation: 1.9% OR: 0.46 (0.27–0.77)		High quality	United States
Device-associated health care-associated infections	Bae et al. [31], 2022	ITS	CLABSI incidence rate (per 1000 line days) and OR	Preintervention: Median: 3.1 (IQR: 2.3–3.9) Postintervention Median: 1.2 (IQR: 1.1–2.5) OR: 0.52 (0.28–0.94)		Medium	Korea
	Blanco-Mavillard et al. [32], 2021	RCT	Proportion of peripheral venous catheter failure related to BSI (secondary outcome)	Control Baseline: 0 12 months: 0.12% (SD 0.40)	Intervention Baseline: 0.65% (SD 1.28) 12 months: 0	High	Spain
	Garcia et al. [33], 2023	CBA	CAUTI incidence rate (per 1000 catheter days)	Control Baseline: 1.45 Follow-up: 1.7	Intervention Baseline: 1.29 Follow-up: 0.64	High	United States
	Michelángelo et al. [34], 2020	NCBA study; adjusted for confounders[b]	VAP incidence rate (per 1000 ventilation days)	Before intervention: 6.11 (5.82–6.40) After intervention: 3.55 (2.96–4.14)		Medium quality	Argentina

	O'Neil et al. [35], 2016	CBA	CLABSI incidence rate (per 1000 catheter days)	Control Baseline: 1.43 Intervention: 1.39	Intervention Baseline: 3.02 Intervention: 1.72	High	United States
	Savage et al. [36], 2018	NCBA study; adjusted for confounders[b]	Modelled mean CLABSI incidence rate (per 1000 line days)	Preintervention period: 3.80 (3.17–4.43) Peri-intervention period: 1.88 (1.28–2.48) Postintervention period: 0.42 (0–1.12)[c] Second peri-intervention period 0.45 (0–1.14)[c]		Medium quality	United States
	Su et al. [37], 2017	ITS	VAP incidence rate (per 1000 ventilator days) and IRR	Phase 1/preimplementation: 39.1 Phase 2/run in: 40.5 Phase 3/implementation: 15.9 Phase 4/post implementation: 20.4 IRR (phase 3 vs. 1): 0.41 (0.23–0.73)		Medium	Taiwan
	Talbot et al. [38], 2015	ITS	VAP incidence rate (per 1000 ventilator days)	Baseline: 19.5 Intervention: 9.2		Medium	United States
	van der Kooi et al. [39], 2018	RCT	CRBSI incidence rate (per 1000 line days)	Baseline: 2.4 Intervention: 0.9 Rate ratio: 0.39 (0.32–0.48)		High	Europe
Health care-associated infections due to antimicrobial-resistant pathogens or multidrug-resistant organisms	Chun et al. [40], 2016	ITS	Hospital onset MRSA BSI incidence rate (per 100 000 patient days)	Preintervention: Median: 12.11 (IQR: 11.79) Intervention: Median: 8.07 (IQR: 8.77)		High	Korea
	Kousouli et al. [41], 2018	ITS	CRKP, CRAB, CRPA BSI incidence rate (per 1000 patient days)	Preintervention: 2010: 21.03 2011: 19.63 Intervention: 2012: 17.32 2013: 14.45 2014: 22.85 2015: 25.02		High	Greece
	Li et al. [42], 2019	ITS	CRKP colonization/ infection incidence rate (per 1000 ICU patient-days)	Baseline: 10.08 (4.43–16.43) Follow-up: 2.84 (2.8–2.89)		Medium	China
	Mitchell et al. [43], 2019	RCT	VRE infection rate (per 10 000 occupied bed days) and RR	Baseline: 0.35 Intervention: 0.22 RR: 0.63 (0.41–0.97)		Medium	Australia
	Saharman et al. [44], 2021	ITS	CRKP-, CRAB- and CRPA acquisition rate (per 100 patient days at risk) and IRR	Phase 1: 2.1 (99% CI: 1.7–2.6) Phase 3: 2.3 (99% CI: 1.9–2.7) IRR: 0.343 (99% CI: 0.164–0.717)		High	Indonesia
	Spyridopoulou et al. [45], 2020	ITS	CRKP-BSI incidence rate (per 1000 patient days)	Baseline: 1.58 Follow-up: 0 Difference in slope: −0.332 (−0.502 to −0.162)		High	Greece

(continued on next page)

Table 1 (*continued*)

Outcome	Study	Study design	Measure reported	Effect estimate (CI)[a]			Risk of bias/ICROMS assessment	Country/region
	Stewardson et al. [46], 2016	RCT	IRR for MDRO acquisition (baseline vs. intervention)	Feedback + patient participation: MRSA: 0.79 (0.66–0.95) ESBL: 1.13 (0.84–1.52)	Feedback: MRSA: 0.82 (0.67–0.99) ESBL: 1.56 (1.11–2.19)	Control: MRSA: 0.92 (0.75–1.13) ESBL: 1.21 (0.86–1.71)	Medium	Switzerland
	Valencia-Martín et al. [47], 2019	ITS	MDR-AB incidence rate in clinical samples (per 1000 patient days)	Initial: 10.9 cases 60 weeks postintervention: 0 cases			Medium	Spain
	von Lengerke et al. [48], 2019	RCT	MDRO infection incidence rate (per 1000 patient days)	ASH (untailored) arm 2013: 0.691 2014: 0.605 2015: 0.669		Tailoring arm 2013: 0.845 2014: 0.585 2015: 0.348	High	Germany
Hand hygiene compliance and alcohol-based-hand rub use	Aghdassi et al. [49], 2020	RCT	HH compliance and OR	Control Baseline: 59% Follow-up: 60% OR:1.06 (0.84–1.35)		Intervention Baseline: 59% Follow-up: 61% OR: 1.08 (0.88–1.33)	High	Germany
	Al-Maani et al. [50], 2022	NCBA study; adjusted for confounders	HH compliance	Preintervention: 52.6% 3 months postintervention: 74.1% 15 months postintervention: 70.0%			Medium quality	Oman
	Chun et al. [40], 2016	ITS	Increase in ABHR procurement and HH compliance	Baseline: HH Compliance: 33.2% Intervention: HH compliance: 92.2% ABHR procurement increase: 134% (120%–149%)			High	Korea
	Ghorbanmovahhed et al. [51], 2023	CBA	HH compliance	Control[d] Pre-test: 16.48% Post-test:16.18%		Intervention[d] Pre-test: 18.80% Post-test: 37.32%	High	Iran
	Stewardson et al. [46], 2016	RCT	ABHR procurement (L per 1000 patient days) and HH compliance	Feedback + patient participation: ABHR Baseline: 27.9L (SD 5.1) Intervention: 30.5L (SD 2.8) HH Baseline: 66% (62–70) Intervention: 77% (74–80) Follow-up: 72% (69–76)	Feedback: ABHR Baseline: 30.4L (SD 4.6) Intervention: 29.8L (SD 2.9) HH Baseline: 65% (62–69) Intervention: 75% (72–77) Follow-up: 72% (68–75)	Control: ABHR Baseline: 31.8L (SD 7.4) Intervention: 27.8L (SD 2.6) HH Baseline: 66% (62–70) Intervention: 73% (70–77) Follow-up: 70% (66–75)	Medium	Switzerland
	von Lengerke et al. [48], 2019	RCT	ABHR use (mL per inpatient day) and HH compliance	ASH (untailored) arm ABHR 2013: 137 mL 2014: 157 mL 2015: 163 mL	 HH 55% 68% 64%	Tailoring arm ABHR HH 128 mL 54% 131 mL 64% 129 mL 70%	High	Germany

ABHR, alcohol based handrub; aIRR, adjusted incidence rate ratio; BSI, bloodstream infection; CAUTI, catheter-associated urinary tract infection; CBA, controlled before-after study; CLABSI, central line-associated bloodstream infection; CRAB, carbapenem-resistant *Acinetobacter baumannii*; CRBSI, catheter-related bloodstream infections; CRKP, carbapenem-resistant *Klebsiella pneumoniae*; CRPA, carbapenem-resistant *Pseudomonas aeruginosa;* ESBL, extended spectrum β-lactamase; HAI, health care-associated infections; HH, hand hygiene; ICROMS, integrated quality criteria for review of multiple study designs; ICU, intensive care unit; IRR, incidence rate ratio; ITS, interrupted time series; MDR-AB, multidrug-resistant *Acinetobacter baumannii*; MDRGN, multidrug-resistant gram negative bacteria, MDRO, multiple drug–resistant organism; MRSA, methicillin-resistant *Staphylococcus aureus*; NCBA, non-controlled before-after study; nvHAP, non-ventilator-associated pneumonia; OR, odds ratio; RCT, randomised controlled trial; RR, relative risk; SSI, surgical site infection; VAP, ventilator-associated pneumonia; VRE, vancomycin-resistant enterococci.

[a] 95% CI reported unless otherwise stated.

[b] ITS study design but evaluated as NCBA due to data analysis methodology.

[c] Reported as 0.42 ± 0.70 and 0.45 ± 0.69 in article and for consistency converted to a confidence interval here. Lower CI cut off at zero.

[d] Calculated from numbers provided in Table 4 of original article.

significant reduction of hospital-onset MRSA-BSI after performing a WHO HH campaign.

HH compliance and alcohol-based hand rub use

Six studies investigated the effectiveness of multimodal strategies on HH compliance (Table 1) [40,46,48–51]. The RCT by Stewardson et al. [46] compared enhanced feedback and patient participation with standard care and found an increase of HH compliance in both the intervention and control arms. The RCT by von Lengerke et al. [48] compared standard HH-education with education based on a psychological framework of behaviour change and found an effect in the intervention arm. The RCT by Aghdassi et al. [49] found no increase of overall HH compliance after a multimodal HH-intervention. However, compliance before aseptic procedures increased in the intervention group. The CBA study by Al-Maani et al. [50] and the NCBA study by Ghorbanmovahhed et al. [51] focused on link nurses and senior health care workers as role models. An effect of the intervention was seen in both studies. The one study that was conducted in a lower-income middle-income country showed remarkably lower baseline HH compliance compared with the studies performed in high-income countries [51]. Three studies investigated the effectiveness of multimodal strategies on alcohol-based handrub use (Table 1). The results were inconsistent with only the ITS by Chun et al. [40] showing increased use of handrub by the WHO HH improvement strategy [46,48].

Discussion

This systematic review identified 27 studies to update the evidence on multimodal improvement strategies for the implementation of IPC interventions and its effect on HAI, AMR, and HH since the last update until November 2015 [7]. The overall quality of the evidence has slightly increased, but the number of studies conducted in low-income countries remains very low. The findings support previous reports on multimodal improvement strategies in IPC, and mapped the results within the five WHO-recommended areas of multimodal strategies, such as system change, education and training, monitoring and feedback, communication, and institutional safety climate [6,7]. Our results confirm the effectiveness of multimodal strategies to reduce HAIs, and add evidence on AMR and MDROs, although results for these outcomes vary. Although this review focuses on acute health care facilities, optimal IPC practices are essential in any health care setting, and thus, the concept of multimodality for implementing best practice procedures may also apply in primary care and long-term care facilities.

Multimodal improvement strategy elements

System change is a vital element in a multimodal improvement strategy and ensures that health care facilities have the necessary infrastructure, supplies, and resources (including human) to implement IPC measures. Although in high-income countries, basic infrastructure is often established, human resources (i.e. dedicated IPC professionals) are a recurring problem in all countries, including those with higher resources for IPC [52]. In low-income and middle-income countries, deficiencies in basic infrastructure may be seriously hampering IPC practices implementation, and thus, may need to be addressed at an early stage [53,54]. This requires commitment from senior management to dedicate resources to IPC and underscores the importance of the fifth area of the multimodal strategy: culture change. Our review includes mainly studies conducted in high-income or upper-middle income countries. Although most studies in this review address the area of system change, it should be noted that this mainly includes small additions to existing structures, such as the installation of multidisciplinary teams [29,36] or providing material for defined bundle elements [39].

Education and training of health care workers in IPC as an essential area for improvement of IPC practices but unfortunately it has been documented as the most defective IPC core component and thus requires attention and learning from available evidence [52,55]. Providing training, including practical skills, when introducing system change is critical to ensure understanding and adoption of the new elements introduced. Once the general conditions for training are in place, such as a programme, protected time, and skilled trainers, activities should focus on sustainability. This includes checking on competence and reviewing and refreshing training. All studies in this review had an element of education and provide interesting insights on how to tackle this critical component; however, different training methods were used, such as presentations, bedside training, and e-learning [32,33,39]. To achieve sustainability, some studies developed innovative tools such as games and error analysis videos, or they tailored education based on psychological frameworks or behaviour change concepts [34,48].

Monitoring and feedback is a critical element to establish practices and areas requiring improvement and evaluate the impact of IPC interventions implementation. The majority of the studies in this review describe monitoring of outcome and process indicators. Different tools are used for this purpose, such as checklists or audits [29,31,36,37,43]. Feedback is essential to make monitoring meaningful, make key players aware of gaps and interventions' impact, and give health care workers the opportunity to learn from errors. The implementation of this element was found in about half of the studies [32,34,35,39–41,43–45,48,49]. Degree and organisation of feedback was different. Some studies had weekly (interdisciplinary) meetings to identify and discuss barriers [36,47], whereas others combined monitoring with immediate feedback [34,46].

Reminders and communication are important to remind health care workers about best practice procedures or the goals of an IPC intervention programme. Posters, pocket leaflets, but also screensavers or monitors, are often used for this purpose. Some studies introduced more technically advanced methods, such as a computerized ventilator dashboard in the patient room offering reminders when VAP interventions were due [38]. Reminders can also help sensitizing patients and visitors for best practice procedures and potential risks, and thus, make them participating in the care process [46].

Culture change to establish an institutional safety climate underpins all other strategy elements and is critical for success and sustainability. It includes giving champions or role models responsibility in the implementation of an IPC intervention [6]. Depending on the health care setting, champions or role models are identified in different professions and disciplines [30,36,49]. However, culture change is not confined to champions and role models, but includes any strategy to improve a culture of accountability and patient safety [27]. In hierarchical systems, a safety climate needs to be promoted and supported by management level; a number of studies mentioned hospital management involvement [25,39,48]. Frontline workers from different professions and disciplines need to practically collaborate with hospital managers and (board) directors to define and implement an IPC intervention programme. Multidisciplinary role playing and simulation scenarios also have been tested as part of a wider implementation strategy with the aim of improving the institutional safety climate [34].

Strengths and limitations

This systematic review confirms effectiveness of multimodal improvement strategies in IPC intervention programmes at the health care facility level. It provides more information related to the prevention of AMR pathogens and MDROs compared with the reviews by Zingg et al. [7] and Storr et al. [10]. Nevertheless, this study has limitations. First, according to an EPOC risk-of-bias assessment, the included studies all had a medium or high risk of bias. Second, due to the methodological heterogeneity of the interventions, comparability was limited and a formal meta-analysis was not possible. Third, many studies were conducted in high-income countries, limiting generalization of the findings to low-resource settings.

Conclusion and future research

Most studies demonstrate effectiveness of multimodal strategies on HAI prevention and HH improvement, confirming findings by previous reviews of the WHO core components [7,10]. Based on these findings and previous reviews, WHO continue to strongly recommend the use of multimodal improvement strategies as the best approach to implement IPC interventions. However, the quality of evidence remains limited and only a minority of studies are from low-income or middle-income countries. More high-quality studies may better take into account important types of bias, such as the Hawthorne effect and cross-contamination. It is important to distinguish implementation from intervention success and to infer causality rather than association. This could be achieved by combining outcome and process indicators. Finally, this review was focused on health care facilities only and therefore cannot be extrapolated to long-term care facilities or outpatient clinics.

Author contributions

A.T., B.A., J.W., C.H., and W.Z. established the study protocol. J.W., C.H., J.T., A.S., and S.K. performed literature search and data extraction. J.W., C.H., J.T., and A.S. did data verification and cross-checking. Data analysis was done by J.W., A.S., C.H., J.T. and A.T., B.A., J.W., W.Z. participated in discussions about results' interpretation. J.W., C.H., J.T., A.S., and W.Z. wrote the first draft of the manuscript. All authors reviewed and contributed to subsequent drafts and approved the final version.

Transparency declaration

Potential conflict of interest

The authors declare that they have no competing interests. The opinions expressed in this article are those of the authors and do not reflect the official position of WHO. WHO takes no responsibility for the information provided or the views expressed in this article.

Financial report

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Appendix A. Supplementary data

Supplementary data to this article can be found online at https://doi.org/10.1016/j.cmi.2025.01.011.

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