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Review

Effectiveness and core components of infection prevention and control programmes in long-term care facilities: a systematic review

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SUMMARY

Background: Infection prevention and control (IPC) is a measure to prevent healthcare-associated infections in healthcare settings. There is limited evidence of the effectiveness of IPC programmes in long-term care facilities (LTCFs).

Aim: To review and analyse the effectiveness and the components of IPC programmes in LTCFs for older adults.

Methods: Electronic databases (PubMed, EMBASE, CINAHL and Cochrane CENTRAL) were searched systematically for English-language articles assessing IPC interventions in LTCFs, published over the last decade (2007–2016). The components of IPC programmes were analysed based on the World Health Organization (WHO) manuals for improving IPC activities. Two reviewers independently assessed the quality of studies using the Cochrane risk-of-bias tool and the risk-of-bias assessment tool for non-randomized studies.

Findings: Seventeen studies met the eligibility criteria; 10 studies were randomized trials (58.8%) and the others were non-randomized trials to examine the impact of IPC programmes on infection and/or performance outcomes of healthcare workers. None of the included studies implemented all of the WHO core components. Behavioural change strategies using education, monitoring and feedback were reported to be successful interventions for reducing the threat of healthcare-associated infections. Generally, studies using four or more elements of the WHO multi-modal strategy reported significant reductions in infection rates.

Conclusions: There is some evidence for the effectiveness of IPC interventions using education, monitoring, feedback and four or more elements of the WHO multi-modal strategy to control healthcare-associated infections in LTCFs.

Introduction

Healthcare-associated infections (HAIs) constitute a critical health problem which contributes to the morbidity and mortality of residents in long-term care facilities (LTCFs). Older adult residents in LTCFs are susceptible to infection

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due to many host and facility factors, such as comorbidities, immuno-senescence, grouped-living status including sharing of sanitary rooms, and frequent close contact with healthcare workers (HCWs) [1]. Herzig *et al.* [2] estimated that 1.13–2.68 million infections occurred during 2013 in US nursing homes. Based on the results of point prevalence surveillance, the European Centre for Disease Prevention and Control (ECDC) estimated that 116,416 residents had at least one HAI, and 4.2 million infections occurred each year in European LTCFs [3]. Thus, multi-lateral approaches and strategies have been implemented to prevent and control HAIs in LTCFs by the ECDC and the US Centers for Disease Control and Prevention.

The risk of HAIs can be reduced by implementing infection prevention and control (IPC) processes. IPC programmes are essential and important measures to improve health outcomes and the safety of both elderly residents and HCWs in healthcare settings [4]. There is abundant evidence indicating the effectiveness of IPC programmes in acute care facilities [5,6]. However, evidence to support the benefit of programmes for LTCFs is limited. The risk factors of infection, the environmental nature, and the resources available differ between acute care hospitals and LTCFs [7]. LTCFs have fewer resources such as infection control experts, HCWs, and diagnostic equipment or systems [8]. These factors may affect the types, planning, implementation and evaluation of IPC programmes. Thus, it is useful to analyse IPC programmes in these settings to ensure the effectiveness of such programmes.

The World Health Organization (WHO) developed a practical manual to guide effective implementation of IPC programmes. According to the manual, eight core components including multi-modal strategies are necessary to improve IPC practices [9]. However, LTCFs may face difficulties in implementing all of the core components for IPC programmes with the limited resources available. To the authors' knowledge, no systematic reviews to date have examined the effectiveness of the WHO core components of IPC programmes in LTCFs. In consideration of this reason, it is necessary to understand the influence of inclusion of WHO core components in IPC programmes on outcomes in LTCFs.

Objective

The objective of this systematic review was to identify the effectiveness of the WHO core components of IPC programmes for older adult residents and HCWs in LTCFs by synthesizing previous literature.

Methods

This review is reported according to the Preferred Reporting Items for Systematic Reviews and Meta-analyses (PRISMA) statement [10].

Table I
Search terms for database searches

Database	Search terms
PubMed	((((infection[Title/Abstract] OR infections[Title/Abstract])) AND ('nursing home*'[Title/Abstract] OR 'skilled nursing*'[Title/Abstract] OR 'long-term care'[Title/Abstract])) AND (practice[Title/Abstract] OR control*[Title/Abstract] OR measur*[Title/Abstract] OR evaluat*[Title/Abstract] OR effect*[Title/Abstract] OR prevent*[Title/Abstract] OR program*[Title/Abstract] OR intervention*[Title/Abstract] OR outcome*[Title/Abstract])) NOT (surgery[Title/Abstract] OR cancer[Title/Abstract] OR 'neoplasm'[Title/Abstract] OR 'intensive care unit'[Title/Abstract] OR child[Title/Abstract] OR children[Title/Abstract] OR 'operative'[Title/Abstract])
EMBASE	('infection':ab,ti OR 'infections':ab,ti) AND ('nursing home*':ab,ti OR 'skilled nursing*':ab,ti OR 'nursing home patient':ab,ti) AND ('practice':ab,ti OR 'control*':ab,ti OR 'measur*':ab,ti OR 'evaluat*':ab,ti OR 'effect*':ab,ti OR 'prevent*':ab,ti OR 'program*':ab,ti OR 'intervention*':ab,ti OR 'outcome*':ab,ti) NOT ('surgery':ab,ti OR 'cancer':ab,ti OR 'neoplasm':ab,ti OR 'intensive care unit':ab,ti OR 'child':ab,ti OR 'children':ab,ti OR 'operative':ab,ti)
CINAHL	TI (infection OR infections) AND TI ('nursing home*' OR 'skilled nursing*' OR 'long-term care') AND TI (practice OR control* OR measur* OR evaluat* OR effect* OR prevent* OR program* OR intervention* OR outcome*) NOT TI (surgery OR cancer OR 'neoplasm' or 'intensive care unit' OR child OR children OR 'operative') AB (infection OR infections) AND AB ('nursing home*' OR 'skilled nursing*' OR 'long-term care') AND AB (practice OR control* OR measur* OR evaluat* OR effect* OR prevent* OR program* OR intervention* OR outcome*) NOT AB (surgery OR cancer OR 'neoplasm' or 'intensive care unit' OR child OR children OR 'operative')
Cochrane CENTRAL	infection OR infections in Title, Abstract, Keywords, AND 'nursing home*' OR 'skilled nursing*' OR 'long-term care' in Title, Abstract, Keywords, AND practice OR control* OR measur* OR evaluat* OR effect* OR prevent* OR program* OR intervention* OR outcome* in Title, Abstract, Keywords, NOT surgery OR cancer OR 'neoplasm' or 'intensive care unit' OR child OR children OR 'operative' in Title, Abstract, Keywords, Publication Year from 2007 to 2016 in Trials

EMBASE, Excerpta Medica Database; CINAHL, Cumulative Index for Nursing and Allied Health Literature.

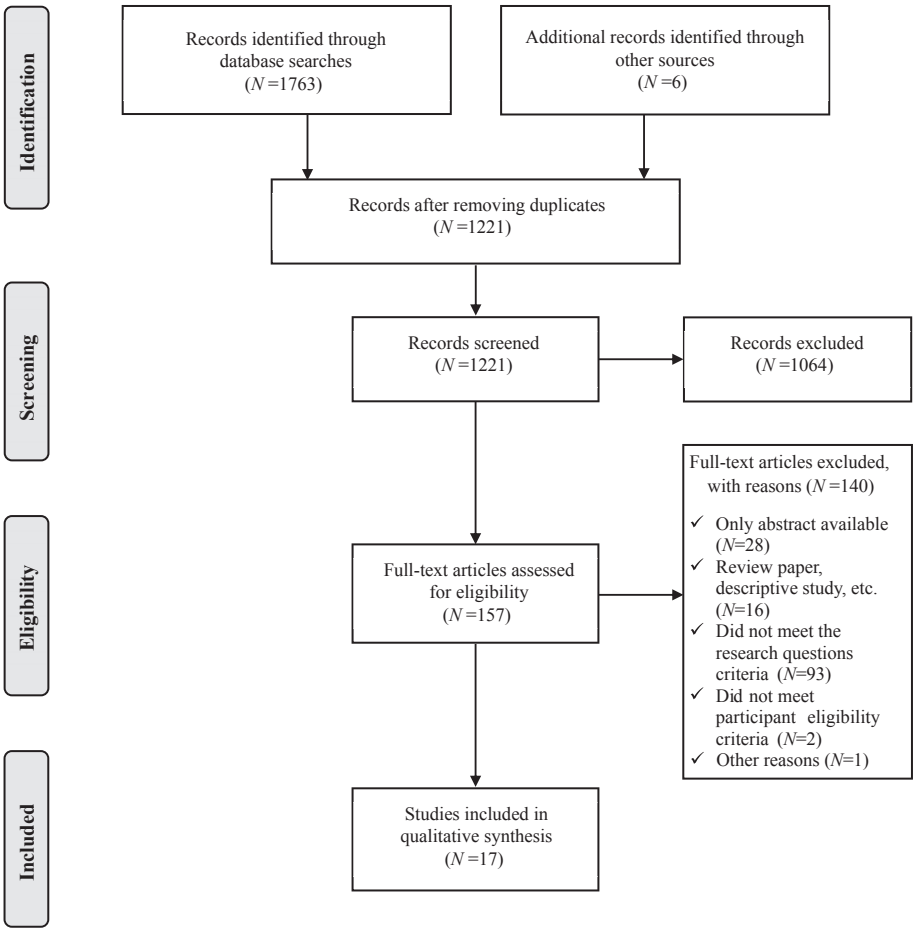

Figure 1. PRISMA flow diagram. Source: Moher D, Liberati A, Tetzlaff J, Altman DG; The PRISMA Group. Preferred Reporting Items for Systematic Reviews and Meta-Analyses: the PRISMA statement. PLoS Med 2009:6:e1000097.

Research question

1. How effective are IPC programmes at preventing infectious diseases in LTCFs?
2. What components of IPC programmes, individually or in combination with other components, are appropriate to prevent infectious diseases in older adult residents in LTCFs?

PICOS statement

Population (setting/place): older adult residents and HCWs in LTCFs including nursing homes and skilled nursing facilities.

Intervention: infection prevention and control programme.

Comparison: no restrictions.

Outcomes: all outcome measures related to infection control.

Study design: no restrictions.

Search strategy

PubMed, Excerpta Medica Database (EMBASE), Cumulative Index for Nursing and Allied Health Literature (CINAHL) and Cochrane CENTRAL were searched. The search terms were determined using the PICOS statement and combinations of terms therein, using Boolean operators (Table I). In addition, a manual search of the reference lists of reviewed studies was undertaken, and the results were combined.

Eligibility criteria

Studies published in the English language within the past 10 years (2007–2016) were included in this review if they evaluated IPC programmes in LTCFs. Studies concerning antibiotic-related topics (for example, antibiotic stewardship) and complementary and alternative therapy were excluded. Publication types such as letters, editorials, conference papers, review papers, case reports and qualitative design studies were also excluded.

Study selection

Two reviewers (MHL and GAL) screened the results of the search independently. A primary screening was conducted using the titles and abstracts of the studies considered for inclusion. The full text of each study selected in primary screening was reviewed if the title and abstract met the eligibility criteria, or if it was unclear whether it met the exclusion criteria. Any disagreement was discussed and consensus

was reached. The results of the study selection process are shown in Figure 1.

Data extraction

Data were extracted from the studies by MHL and GAL; data pertaining to study design, participants, description of intervention, outcomes, effectiveness and results were extracted. Any disagreements were resolved by discussion between the reviewers or by consultation with YHP if necessary.

Intervention categories

The components of the interventions were categorized in accordance with the WHO IPC manual [9]. The eight core components for IPC improvement are: IPC programmes; IPC guidelines; education and training; surveillance; multi-modal strategies; monitoring, audit and feedback; work load, staffing and bed occupancy; and built environment, materials and equipment [9]. The IPC guidelines encompass policies, protocols or standards in IPC implementation [9]. For this systematic review, the IPC guidelines were regarded as strategies for intervention in the included studies. Thus, the interventions presented in the included studies were categorized using seven of the core components, excluding those pertaining to the IPC guidelines.

Quality assessment

Two reviewers (MHL and GAL) independently assessed the quality of studies using the Cochrane risk-of-bias instrument for randomized trials [11] and the risk-of-bias assessment tool for non-randomized studies [12]. The criteria for outcome measurement were assessed by focusing on the primary outcome of the studies. If the judgement in all key domains was 'low risk of bias', the summary risk of bias was determined to be low. If the judgement in one or more key domains was 'unclear risk of bias', the summary of risk of bias was deemed to be unclear. If the study was considered to be at high risk of bias in one or more key domains, the summary risk of bias was designated as high. All discrepancies were resolved by discussion between two reviewers, and, if necessary, with the corresponding author.

A qualitative synthesis was conducted due to the heterogeneity of methodologies and outcomes in the included studies. Effect size parameters of the included studies are expressed as risk ratios, odds ratios or rate ratios, as possible.

Results

Study characteristics

In total, 1769 studies were identified from four databases and manual searches of the reference lists of included studies. After removal of duplicates (N=548), 1221 studies were screened by title and abstract, and 157 studies were assessed for eligibility using the full text. Finally, 17 studies were included in this systematic review (Figure 1).

The majority of the 17 studies (N=12) had been published in the last five years (2012–2016). Seven studies were performed in the USA and the others were performed in Asia (N=6) or Europe (N=4). Ten studies used a randomized trial format, and seven studies used a non-randomized design to examine the effectiveness of the IPC interventions. Five of seven non-randomized trials used a before–after design without a control group.

Most studies (N=12) evaluated multi-faceted interventions and the others employed a single intervention. Eligible studies reported infection rates, compliance and knowledge of infection control among HCWs as the outcome. The majority of studies (N=12) measured infection rates as the primary outcome; most studies reported the incidence rates of multi-drug-resistant-organism (MDRO)-related infections or respiratory tract infections. Studies (N=6) measuring compliance frequently used hand hygiene adherence data to evaluate the effect of the interventions. Only six of the reviewed studies evaluated both infection-related outcomes (patient-based data) and performance indicators of HCWs (knowledge, compliance, etc.) [13–18] (Table II).

Risk of bias in included studies

The results of the quality assessment of included studies are shown in Figures 2 and 3.

Table II
Characteristics of included studies (N=17)

Characteristics	N (%)
Publication year	
2008–2009	1 (5.88)
2010–2011	4 (23.53)
2012–2013	4 (23.53)
2014–2015	5 (29.41)
2016	3 (17.65)
Location	
USA	7 (41.18)
Europe	4 (23.53)
Asia	6 (35.29)
Design	
Randomized trial	10 (58.82)
Non-randomized trial (before–after study with control group)	2 (11.76)
Non-randomized trial (before–after study without control group)	5 (29.41)
No. of interventions	
Single	5 (29.41)
Multiple	12 (70.59)
Outcome	
Infection rate	
Multi-drug-resistant organism	5 (14.29)
Respiratory tract infection	4 (11.43)
Urinary tract infection	1 (2.86)
Skin and soft tissue infection	2 (5.71)
Gastrointestinal infection	2 (5.71)
Device-associated infection	1 (2.86)
Overall infection	2 (5.71)
Other	4 (11.43)
HAI-related indicator (colonization rate, no. of admissions, etc.)	5 (14.29)
Compliance with practice	6 (17.14)
Knowledge	3 (8.57)

HAI, healthcare-associated infection.

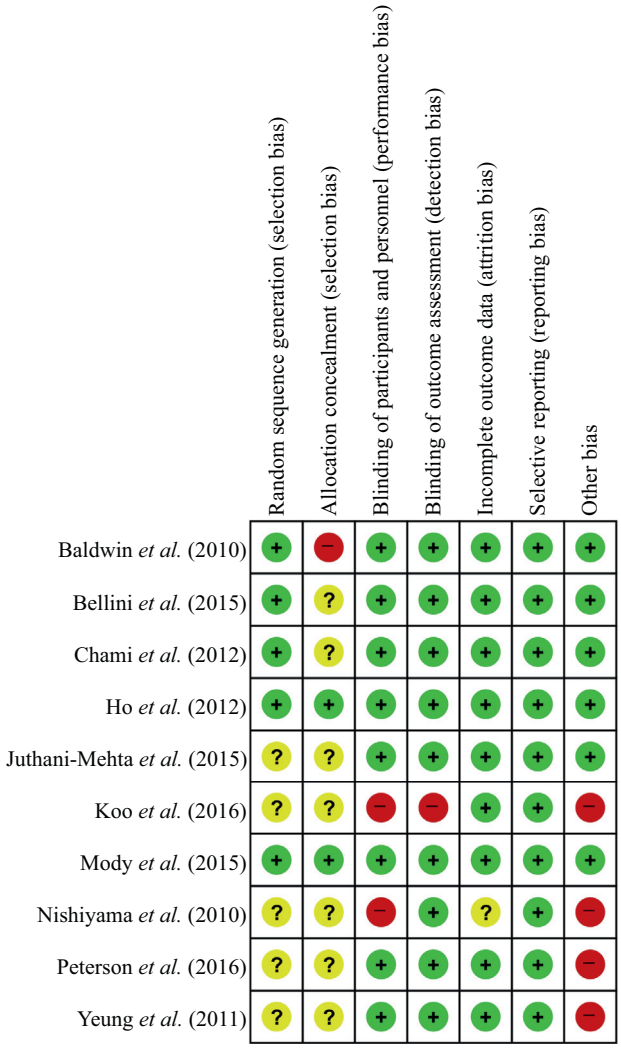

Figure 2. Risk-of-bias summary in randomized trials (Revman 5.3), representing low (+), unclear (?) and high (-) risk of bias.

Randomized trials

The risk of bias for randomized trials was assessed using the Cochrane risk-of-bias tool [11], including assessment of random sequence generation, allocation concealment, blinding of participants and personnel, blinding of outcome assessment, incomplete outcome data, selective reporting and other bias. While two studies were at low risk for all criteria [15,19], another study was at high risk for three criteria [20]. None of the 10 randomized trials were at high risk of bias pertaining to random sequence generation, although the risk of bias in this aspect was unclear for five studies due to of lack of relevant information [13,16,20–22]. The majority of randomized studies (N=7) were unclear in terms of allocation concealment criteria due to lack of detailed descriptions [13,16,20–24]. All randomized studies were at low risk of reporting bias. Four studies were at high risk for other types of bias due to potential threats such as baseline imbalances and contamination issues.

Non-randomized trials

Risk of bias for non-randomized trials was assessed using the risk-of-bias assessment tool for non-randomized study [12]. Three studies were at low risk for all criteria [18,25,26]. One

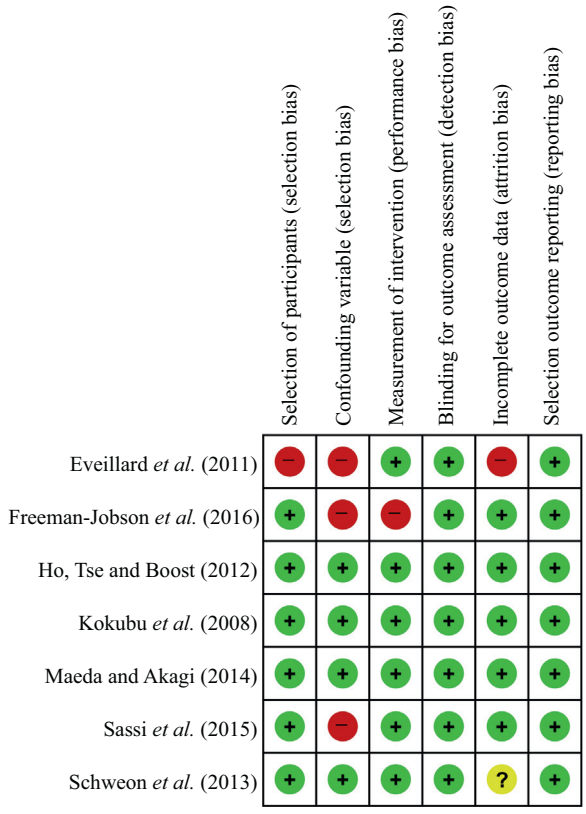

Figure 3. Risk-of-bias summary in non-randomized trials (Revman 5.3), representing low (+), unclear (?) and high (-) risk of bias.

study was at high risk for three criteria [27]. Lack of consideration of confounding variables created a high risk of bias in three of the seven non-randomized trials [27–29]. All non-randomized studies were at low risk for detection and reporting bias.

Characteristics of the interventions

Table III summarizes the characteristics of interventions and the findings of included studies. Five studies implemented interventions focused on MDROs [14,19–21,23]. Four studies used a specific oral care protocol and measures for preventing respiratory tract infections such as pneumonia [13,22,25,26]. Although most of the included studies involved hand hygiene as part of the intervention, four studies were primarily focused on improving hand hygiene [15–17,27]. In the other studies, the intervention topics were general infection control [24], hygiene [29], enteral feeding [18] and urinary tract infections [28].

The sample size was relatively large in 11 studies which involved multiple facilities. The other studies were conducted with a small number of participants in single facilities. The study period was over one year in eight studies, while the other studies took between two weeks to several months to complete.

Components and effectiveness of the interventions

None of the eligible studies included all of the WHO core components in the interventions (Table IV). Only five studies were determined to have a low risk of bias based on the

Table III
Studies of infection prevention and control (IPC) interventions in long-term care facilities (LTCFs)

Author	Design	Setting	Residents' characteristics	Sample size	Description of intervention	Duration	Outcome	Effectiveness	Results
Randomized trials									
Peterson *et al.* (2016) - USA	Cluster randomized controlled trial	12 nursing units at three LTCFs	NR	1. Year 1 intervention: six units, control: six units. 2. Year 2 intervention: 12 units	1. Universal decolonization for MRSA 2. Active surveillance (all admissions) 3. Annual instruction on HH 4. Enhanced cleaning of surfaces (every 4 months)	2 years	1. MRSA infection rate per 10,000 patient-days 2. MRSA colonization rate *Based on the results in Year 1	1. Rate ratio: 1.989 (95% CI 0.861−4.594, P=0.108) 2. Intervention: 16.64 →11.61%, control: 16.64 →17.85%	1. In Year 1, there was a non-significant reduction in MRSA infection rate. 2. In Year 1, the rate difference of the intervention group compared with the control group was significant (P=0.001).
Koo *et al.* (2016) - USA	Cluster randomized controlled trial	12 NHs	NR	Intervention: six NHs. Control: six NHs	1. Pre-emptive barrier precautions with gloves and gown 2. Monthly MDRO and infection surveillance with feedback 3. NH staff education Control: own IPC practices and given knowledge tests	3 years (30 min, 10 modules)	Knowledge about IPC topics	1. The average post-knowledge scores for intervention group were significantly higher than pre-test scores (average 8.5%, P<0.001).	1. HCW knowledge score improvement was highest for topics such as HH, urinary catheter care and MDROs.
Mody *et al.* (2015) - USA	Stratified-cluster randomized controlled trial	12 NHs	Intervention: 74.4 years ± 12.4, male 46.8%. Control: 72.5 years ± 13.2, male 57.2%	Intervention: six NHs. Control: six NHs	1. Pre-emptive barrier precaution 2. Active surveillance for MDROs and infections with	3 years (30 min, 10 modules)	1. Overall MDRO prevalence 2. Risk of new MDRO acquisition per 1000 device-days 3. Incidence of	1. Rate ratio for all MDROs: 0.77 (95% CI 0.62 −0.94, P<0.05) 2. Hazard ratio for new MRSA acquisition:	1. Intervention group had a significant decrease in overall MDRO prevalence. 2. The rate of

					feedback 3. NH staff education on IPC practices and HH promotion Control: own IPC practices		device-associated infections per 1000 device-days	0.78 (95% CI 0.65—0.95, P=0.01) 3. Hazard ratio for first new CAUTI: 0.54 (95% CI 0.30—0.97, P=0.04)	MRSA acquisition and first new CAUTI were lower in the intervention group than in the control group.
Juthani-Mehta *et al*. (2015) - USA	Stratified-cluster randomized controlled trial	36 NHs	Intervention: 86.5 years ± 8.0, female 75.8%. Control: 86.1 years ± 8.3, female 76.7%	Intervention: 18 NHs (434 participants). Control: 18 NHs (400 participants)	1. Manual tooth/gum brushing plus 0.12% chlorhexidine oral rinse twice daily 2. Upright positioning during feeding Control: usual care	2.5 years	1. Development of first pneumonia (per person-year) 2. Development of first LRTI 3. Compliance	1. Intervention: 0.28, control: 0.26, hazard ratio: 1.12 (95% CI 0.84—1.50, P=0.44) 2. Intervention: 0.29, control: 0.27, hazard ratio: 1.07 (95% CI 0.79—1.46, P=0.65) 3. Chlorhexidine: 87.9%, toothpaste: 75.0%, upright position: 100.0%	1. There was no significant difference in the incidence of first pneumonia and LRTI between intervention and control.
Bellini *et al*. (2015) - Switzerland	Cluster randomized controlled trial	104 NHs	Intervention: 83.7 years ± 8.1, female 72%. Control: 83.4 years ± 5.4, female 73%	Intervention: 53 NHs (2338 residents). Control: 51 NHs (2412 residents)	1. Universal MRSA screening 2. Topical decolonization of carriers 3. Disinfection of environment, standard precautions and training sessions Control: standard precautions alone	12 months	1. Change in prevalence of MRSA carriers 2. OR of being an MRSA carrier	1. Intervention: 8.9→ 5.8%, control: 8.9→ 6.6% (P=0.66), OR 0.871 (95% CI 0.69—1.10, P=0.254) 2. OR 0.72 (P=0.17)	1. There was no significant reduction in prevalence of MRSA carrier.

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Table III (*continued*)

Author	Design	Setting	Residents' characteristics	Sample size	Description of intervention	Duration	Outcome	Effectiveness	Results
Baldwin *et al.* (2010) - Northern Ireland	Cluster randomized controlled trial	32 NHs	Intervention: 84 years ± 9. Control: 82 years ± 10	Intervention: 16 NHs. Control: 16 NHs	1. Education: 2-h session at baseline, and at 3 and 6 months 2. Audit: assessment of compliance with good practice and feedback Control: usual practice	12 months	1. MRSA prevalence 2. Change in infection control audit scores	1. Relative risk: 0.81 (95% CI 0.51−1.30, P=0.39) for all residents recruited at baseline and during the study 2. Intervention: 82%, control: 64% at 12 months (P=0.0001)	1. MRSA prevalence was not significantly different between intervention and control groups. 2. Infection control audit scores were significantly higher in intervention group compared with control group at 12 months.
Nishiyama *et al.* (2010) - Japan	Randomized trial	One NH	76.1 years ± 7.8, female 76%	Intervention: 26 residents. Control: 24 residents	1. All subjects performed daily oral care two to three times per day 2. Professional care: 20 min per week 3. Mucosal care: 1 min, with sponge brush Control: professional care without mucosal care	12 months	1. Numbers of mutant streptococci 2. Numbers of subjects with *Candida* spp. infections	1. Only significant difference at 6 months in tongue samples (P=0.043) 2. Significant difference in saliva at 12 months (P<0.05) and in plaque at 3 and 12 months (P<0.01)	1. Professional dental care with mucosal care had no effect on mutant streptococci colonization in saliva or plaque. 2. Mucosal care had little effect on opportunistic infections with *Candida* spp.
Ho *et al.* (2012) - Hong Kong	Cluster randomized controlled trial	18 LTCFs	Aged from 62 to 112 years	Intervention 1: six LTCFs (248 staff, 767 residents). Intervention 2: six LTCFs (331 staff, 929 residents).	WHO multi-modal HH interventions: ABHR, gloves, posters, reminders, video clips and performance	2009.11—2010.07	1. HH compliance 2. Respiratory outbreaks requiring hospitalization 3. MRSA infections	1. Before/after — Intervention 1: 27.0%/60.6% (P<0.001). Intervention 2: 22.2%/48.6% (P<0.001).	1. HH compliance was increased after intervention in intervention groups. 2. The risks of respiratory

				Control: six LTCFs (231 staff, 711 residents)	feedback Intervention 1: slightly powdered gloves Intervention 2: powderless gloves Control: a 2-h health talk		requiring hospitalization	Control: 19.5%/ 21.6% (P=0.851). Intervention vs control: OR 4.44 (95% CI 3.80—5.18, P<0.001) 2. Rate ratio 0.12 (95% CI 0.01—0.93, P=0.04) 3. Rate ratio 0.61 (95% CI 0.38—0.97, P=0.04)	outbreaks and MRSA infections requiring hospitalization were reduced in the intervention group.
Yeung *et al.* (2011) - Hong Kong	Stratified cluster randomized controlled trial	Six LTCFs	Disabilities (mild to moderate) — intervention: 79.2%, control: 88.3%	Intervention: three LTCFs (73 staff, 244 residents). Control: three LTCFs (115 staff, 379 residents)	A multi-faceted HH programme: pocket-sized containers of ABHR, a 2-h seminar, reminder materials and posters Control: basic life support education and workshops and usual HH practices	2 weeks	1. HH adherence 2. Incidence of infection	1. Intervention vs control: 33.3% vs 30.0% (P=0.06), OR 1.17 (95% CI 0.99—1.37, P=0.065) 2. All infections: rate ratio 0.63 (95% CI 0.42—0.93, P=0.022)	1. A multi-faceted HH programme significantly increased HH adherence and reduced the incidence of infections in LTCFs.
Chami *et al.* (2012) - France	Cluster randomized controlled trial	50 NHs	Intervention: 82.4 years ± 11.0, female 76.3%. Control: 83.0 years ± 10.3, female 76.3%	Intervention: 23 NHs (2325 residents). Control: 24 NHs (2190 residents)	1. Interactive educational meeting 2. Posters and infection prevention kits, reminders 3. Promotional materials Control: none	5 months	1. Incidence rate of the first episode of infection	1. Adjusted hazard ratio 0.99 (95% CI 0.87—1.12, P=0.15)	1. A multi-component infection control programme had no significant effect on infection rates among residents in NHs.

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Table III (*continued*)

Author	Design	Setting	Residents' characteristics	Sample size	Description of intervention	Duration	Outcome	Effectiveness	Results
Non-randomized trials									
Freeman-Jobson *et al.* (2016) - USA	Before–after study with one group	Three LTCFs	NR	42 care workers	Education programme (three sections)	30 min	Knowledge related to UTIs	1. Before/after 6.5±2.69/ 8.21±1.42 ($P<0.01$), d=2.27	1. Knowledge scores improved significantly after the educational programme.
Sassi *et al.* (2015) - USA	Before–after study with one group	One LTCF	NR	[Fomites] Before: 106 samples. After: 105 samples [Staff hands] Before: 28 samples. After: 29 samples	Hygiene intervention 1. Training: active ingredients, safety precautions, effective times, recommended times to use the product and recommended methods 2. Product placement: hand sanitizer, wipes, antiviral tissue and gloves	14-day (training session: 15–30 min)	1. Percent of MS-2 positive 2. MS-2 concentrations	1. Risk ratio: 0.66 (95% CI 0.47–0.93, $P=0.016$] 2. Reduced by 4 logs for fomites ($P=0.04$) and 3 logs on the staff's hand ($P=0.0002$)	1. There was a 16.7% reduction in the number of MS-2 positive. 2. There was a significant reduction in recovered MS-2 on sampled fomites and staff hands.
Schweon *et al.* (2013) - USA	Before–after study with one group	One NH	NR	1 NH	HH programme 1. Provision of HH product and wipes 2. HH education for HCW and patients 3. Poster as reminder 4. HH champion 5. HH compliance monitoring	Training and implementation period: 1 month	1. Infection rates of LTRIs (per 1000 resident-days) 2. Infection rates of SSTIs 3. MRSA and VRE incidence 4. HH compliance	1. Rate ratio: 0.525 (95% CI 0.46–0.60, $P<0.001$) 2. Before/ after: 0.30/ 0.25 ($P=0.65$), rate ratio: 0.833 (95% CI 0.71–0.99) 3. Rate ratio for MRSA incidence: 1.038 (95% CI 0.92–1.17, $P=0.543$) 4. 54%	1. There was a significant reduction in LRTIs as well as a non-significant reduction in SSTIs. 2. The incidence rates of MRSA, VRE, *Clostridium difficile* and gastrointestinal illness were not significantly reduced post-intervention.

Maeda and Akagi (2014) - Japan	Before—after study with control group	Long-term care unit	Intervention: 83.4 years ± 1.5, 16 male. Control: 85.8 years ± 2.0, nine male	Intervention: 31 residents. Control: 32 residents	Oral care protocol (at least twice per day) 1. Tooth and tongue brushing using a toothbrush, and oral mucosa brushing using a sponge brush and a 0.2% chlorhexidine solution 2. Moisturizing the inner mouth with glyceryl poly methacrylate gel 3. A salivary gland massage Control: oral care not performed regularly	1 year	1. Incidence of pneumonia (per number of hospitalized days, mean rate for each subject) 2. Number of days with fever	1. Intervention: 0.45±0.23. Control: 1.20±0.28 (P=0.006). OR 0.01 (95% CI 0.001—0.02, P<0.001) 2. Intervention: 17.48±2.85. Control: 24.57±2.92 (P=0.04). OR 0.01 (95% CI 0.004—0.04, P<0.001)	1. Oral hygiene implementation reduced the incidence of pneumonia and the number of days with fever.
Kokubu *et al*. (2008) - Japan	Before—after study without control group	One NH	86.0 years ± 10.4, six male	25 residents	Oral care protocol 1. Daily oral care: three times per day 2. Professional care: 20 min twice per month by dental hygienists	6 months	1. Proportion of subjects with decreasing opportunistic pathogens 2. Proportion of subjects with at least four species and strains of opportunistic pathogens	(1 month vs 6 months) 1. Teeth: 28.6% vs 68.4% (P=0.011). Mucosa: NS. Tongue: 44.0% vs 56.5% (NS) 2. Teeth: 47.6% vs 5.3% (P=0.003). Mucosa: 44.0% vs 17.4% (NS). Tongue: NS	1. Daily oral care with professional oral care was found to be effective in reducing a few pathogens on the teeth.

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Table III (*continued*)

Author	Design	Setting	Residents' characteristics	Sample size	Description of intervention	Duration	Outcome	Effectiveness	Results
Ho, Tse and Boost (2012) - Hong Kong	Before–after study with control group	Three NHs	NR	Intervention: two NHs (15 residents, 10 staff). Control: one NH (15 residents, 10 staff)	Infection control programme concerning EF (education programme). Control: none	2 weeks	1. Knowledge and practical skill regarding EF 2. Presence of MRSA	1-1. Knowledge Intervention vs control: 17.7±1.6 vs 15.2±1.2 ($P<0.01$), d=1.77. 1-2. Practical skill: intervention vs control: 91.2±7.9 vs 62.1±7.9 ($P<0.01$), d=3.68 2. Intervention vs control: 0.4±0.7 vs 2.3±2.01 ($P<0.01$), d=1.26	1. An infection control programme concerning EF can significantly improve knowledge and practical skill in the intervention group.
Eveillard *et al.* (2011) - France	Before–after study with one group	Four healthcare settings	NR	Four healthcare settings	A multi-faceted HH intervention: feedback, three 6-h training, assessment of HH performance, verbal reminder and organization of one full-day communication session	Nov 2008–May 2009	1. HH compliance 2. Proportion of glove wearing among participants 3. Quality of hand rubbing	1. Before/after: 61.2%/60.7% (NS) 2. Before/after: 52.0%/71.4% ($P<0.001$), d=0.46 3. Before/after: 71.9%/85.0% ($P<0.00001$), d=0.44	1. The multi-faceted HH intervention had a non-significant effect on overall HH compliance. 2. A significant improvement was observed in the proportion of participants wearing gloves and in the quality of hand rubbing.

NR, not reported; MRSA, meticillin-resistant S*taphylococcus aureus;* NH, nursing home; MDRO, multi-drug-resistant organism; HCW, healthcare worker; CAUTI, catheter-associated urinary tract infection; LRTI, lower respiratory tract infection; WHO, World Health Organization; ABHR, alcohol-based hand rub; HH, hand hygiene; UTI, urinary tract infection; SSTI, skin and soft tissue infection; VRE, vancomycin-resistant enterococci; NS, not significant; EF, enteral feeding; CI, confidence interval; OR, odds ratio; d, Cohen's d effect size.

Table IV
Components and effectiveness of infection prevention and control (IPC) programmes in included studies

Study	WHO's IPC components							Multi-modal strategies					Effectiveness
	Implementation of IPC strategies	Education and training	Surveillance	Multi-modal strategies	Monitoring and feedback	Work load, staffing, and bed occupancy	Built environment, materials and equipment	System change	Training and education	Monitoring and feedback	Reminder and communication	Culture of safety	
Peterson *et al.* (2016)	○	○	○	1			○		○				•OI(-)^{NS}: MRSA infection in first year •OI(+)^{S}: MRSA infection in second year
Koo *et al.* (2016)	○	○	○	2	Feedback				○	○			•PI(+)^{S}: knowledge
Mody *et al.* (2015)	○	○	○	4	Monitoring and feedback		○	○	○	○	○		•OI(+)^{S}: prevalence of all MDROs, MRSA acquisition risk, new CAUTI incidence
Juthani-Mehta *et al.* (2015)	○	○		2	Monitoring				○	○			•OI(-)^{NS}: rates of first pneumonia and LRTI
Bellini *et al.* (2015)	○	○	○	1			○		○				•OI(+)^{NS}: MRSA prevalence
Ho *et al.* (2012)	○	○		4	Monitoring and feedback		○	○	○	○	○		•OI(+)^{S}: respiratory outbreaks, MRSA infection •PI(+)^{S}: HH compliance
Chami *et al.* (2012)	○	○		3			○	○	○		○		•OI(+)^{NS}: incidence of first infections
Yeung *et al.* (2011)	○	○		4	Feedback		○	○	○	○	○		•OI(+)^{S}: incidence of all infections •PI(+)^{NS}: compliance
Nishiyama *et al.* (2010)	○			0									•OI(- or +)$^{S\ or\ NS}$
Baldwin *et al.* (2010)	○	○		3	Monitoring and feedback				○	○		○	•OI(+)^{NS}: MRSA prevalence •PI(+)^{S}: audit score
Freeman-Jobson *et al.* (2016)	○	○		1					○				•PI(+)^{S}: knowledge
Sassi *et al.* (2015)	○	○		2			○	○	○				•OI(+)^{S}: percentage of MS-2 positive
Maeda and Akagi (2014)	○			0									•OI(+)^{S}: incidence of pneumonia
Schweon *et al.* (2013)	○	○		5	Monitoring		○	○	○	○	○	○	•OI(+)^{S}: LRTI •OI(-)^{NS}: MRSA
Ho, Tse and Boost (2012)	○	○		1					○				•OI(+)^{S}: MRSA prevalence •PI(+)^{S}: knowledge, practical skill
Eveillard *et al.* (2011)	○	○		4	Monitoring and feedback				○	○	○	○	•PI(+)^{S}: quality of HH •PI(-)^{NS}: compliance
Kokubu *et al.* (2008)	○			0									•OI(- or +)$^{S\ or\ NS}$

WHO, World Health Organization; OI, outcome indicator; PI, performance indicator; MRSA, meticillin-resistant S*taphylococcus aureus*; MDRO, multi-drug-resistant organism; CAUTI, catheter-associated urinary tract infection; LRTI, lower respiratory tract infection; HH, hand hygiene; S, significant; NS, not significant.

assessment of key domains. With the exception of one study [26] (from these five studies), four studies had significant results pertaining to outcome indicators of residents [MDRO prevalence, incidence of pneumonia and catheter-associated urinary tract infections (CAUTIs)] and performance indicators of HCWs (hand hygiene compliance and knowledge) [15,18,19,25]. Of these, one study examined the specific oral care protocol [25], and one study implemented an education programme focused on enteral feeding [18]. The IPC interventions of the remaining two studies included an MDRO infection prevention programme and a hand hygiene improvement programme [15,19].

Based on the results from seven studies, the IPC programmes were shown to significantly improve performance indicators such as compliance, knowledge and quality related to practices [14–16,18,20,27,28]. However, the quality of this evidence is low. None of the studies examined compliance with transmission-based precautions or other critical measures for preventing MDRO infections or pneumonia.

Education and training, and monitoring and feedback

Fourteen studies included education and training components for bringing about behavioural changes in HCWs. Of these, three studies at low risk of bias (two cluster randomized trials and one before–after study) found significant results in the prevalence and infection rates of MDROs. Methods such as video presentations, demonstrations and structured observations were used to train personnel in the appropriate infection control practice. Four of the studies including education and training applied two or more techniques for HCWs [18–20,27]. The length of education and training was usually from 15 min to 2 h. Studies with repetitive education sessions at intervals reported a significant improvement in the knowledge of HCWs, and reductions in the prevalence and infections associated with MDROs [19,20]. Topics of education were hand hygiene, standard precautions, transmission-based precautions, infection control principles, disinfection and implementation of specific protocols. For example, Baldwin *et al.* [14] included the principles of infection control practices, practical demonstrations, and disinfection of equipment and the environment in a 2-h training session as part of the IPC programme.

Eight studies included both education and training, and monitoring and feedback in IPC interventions. Two of these studies which were at low risk of bias (two cluster randomized trials) reported a significant effect on MDRO rates, CAUTIs and respiratory infections. Only three of eight studies included feedback on infection data [16,19,20]. Monitoring and feedback of three studies focused on the practical compliance of HCWs in aspects such as hand hygiene, use of products and protocol adherence [14,15,27].

Surveillance

Only four studies implemented surveillance components in interventions for the active detection of infectious diseases [19–21,23]. These studies including surveillance were published relatively recently (2015–2016) and found generally successful results in performance- and infection-related outcomes (four cluster randomized trials – one with low risk of bias, two with unclear risk of bias and one with high risk of bias). One randomized trial including surveillance at low risk of bias reported significant decreases in MDRO prevalence, meticillin-resistant *Staphylococcus aureus* acquisition and CAUTI incidence [19]. This study implemented an IPC programme which included monitoring, feedback and multi-modal strategies with four elements, and differed from the other three studies in these aspects.

Active, prospective surveillance was used to screen for MDROs and to detect HAIs at an early stage. Surveillance definitions used in the studies were clinical definitions or based on the revised McGeer criteria; these criteria are appropriate for LTCF settings.

Multi-modal strategies

Fourteen of the reviewed studies included WHO multi-modal strategies with one or more elements. Four studies evaluating the IPC programme specific to hand hygiene implemented four or more elements of the WHO multi-modal strategy [15–17,27]. Only one study with a before–after design applied all five elements of the WHO multi-modal strategy [17]. Only three studies used the culture of safety element as part of a multi-modal strategy.

Assessment of the evidence from five studies (two cluster randomized trials with low risk of bias, one cluster randomized trial with unclear risk of bias, one before–after study with unclear risk of bias and one before–after study with high risk of bias) showed that the IPC programmes including four or more elements of the WHO multi-modal strategy were generally associated with decreased respiratory infections or MDRO infections, and resulted in improved adherence to hand hygiene in LTCFs [15–17,19,27]. Only one study with unclear risk of bias [17] which applied all five elements of the WHO multi-modal strategy reported a large reduction in lower respiratory tract infections, but not in MDRO incidence.

Work load, staffing and bed occupancy

None of the eligible studies included work load, staffing and bed occupancy components.

Built environment, materials and equipment

Eight studies included built environment, materials and equipment components in the IPC interventions. In all eligible studies, environmental disinfection, infection prevention kits, hand hygiene products (such as alcohol-based hand rubs) or personal protective equipment were provided for appropriate practices and for environment-related aspects to reveal effective implementation of IPC programmes. Inconsistent results on infection rates and performance indicators were reported in the eight studies including these components. However, evaluation of the evidence from four studies (two cluster randomized trials with low risk of bias, one cluster randomized trial with unclear risk of bias and one before–after study with unclear risk of bias) indicated that if this component is combined with four or more elements of the WHO multi-modal strategy, there may be a significant reduction in the incidence of MDRO infections, respiratory infections and the overall infection rate [15–17,19].

Discussion

IPC involves activities aimed at diagnosing problems through surveillance and improving infection control practices by applying various techniques for bringing about behavioural changes in HCWs. It also includes outcome evaluation and additional means such as feedback and reminders to maintain

proper practices [9]. In general, implementation of IPC programmes results in a reduction of HAI rates by more than 30% [30]. Poor compliance with infection control practices and the unique nature of long-term care suggests the need for the implementation of IPC programmes [29]. This review analysed the effectiveness and components of IPC programmes in LTCFs based on the WHO IPC manual. It is not possible to specifically describe the effect size of individual components, and to strongly recommend one type of intervention over the other types of interventions due to the heterogeneity of interventions in the eligible studies. However, single interventions are not sufficient to ensure consistent and successful results in IPC [31]. Application of a comprehensive multi-component approach is recommended to achieve the goals of IPC activities [9,31,32]. Thus, several suggestions are proposed for effective IPC implementation after reviewing the results of interventions in which individual components were used alone or in combination with other components.

It is suggested that an education, monitoring and feedback component should be included in any IPC intervention to bring about behavioural change in HCWs at LTCFs. Considering the low level of knowledge and capacity of workers for infection control in LTCFs compared with acute settings [8], this is needed to apply behaviour modification methods to promote active participation and ongoing education to achieve consistent results, as opposed to lectures. It is also suggested that tools and visual materials which can be used easily by caregivers who lack expertise in infection control should be adopted. Such measures would help in successful implementation of IPC activities in LTCFs with poor resources. In most of the studies which were reviewed, monitoring or feedback was conducted on performance and compliance of HCWs rather than on infection rates. In order for IPC programmes to be effective, appropriate infection control practices should be implemented consistently by HCWs. Therefore, monitoring and timely feedback should be followed to guarantee that the recommended practices are actually performed and to facilitate behavioural changes [4]. Monitoring and feedback on infection rates is strongly recommended because infection prevention is the fundamental purpose of the IPC programmes [33]. HCWs may not believe that inappropriate practice on their part may have resulted in increased risk of HAIs in residents [34]. Therefore, ongoing feedback on the results of surveillance of HAIs may help raise awareness of the relationship between infection and infection control practices in HCWs.

There was some evidence that IPC programmes including a WHO multi-modal strategy with four or more elements were associated with decreased respiratory infections or MDRO infections, and improved adherence to handwashing practices in LTCFs. In this review, the evidence was based on the relatively large effects on infection prevention (reported consistently by four studies [15–17,19]) and on hand hygiene compliance (reported by one study [15]) associated with the inclusion of four or more elements of the WHO multi-modal strategy. The WHO multi-modal strategy has been applied and proven to be effective in several studies of hand hygiene practices [35–38].

Some combinations of components may have a synergistic effect when applied with other components. Among the four studies including surveillance, one study (three-year randomized trial) with methodological rigor showed that surveillance was effective in reducing HAIs when used in combination with education, monitoring, feedback, and four or more elements of the WHO multi-modal strategy [19]. Surveillance is critical to developing and evaluating infection control processes as the first step [34]. This allows for the early detection of HAIs and the identification of outbreaks in healthcare settings. Another important role of surveillance is as a tool for the evaluation of IPC programmes and for replanning through data analysis. There is evidence that surveillance leads to a 25–57% reduction in HAIs [30]. For these reasons, surveillance should be included in all IPC programmes [34]. This combination of components may increase the comprehensiveness of IPC programmes and help to achieve success by facilitating the processes of data collection and analysis, diagnosis, implementation, dissemination and evaluation. However, the evidence supporting this contention was not conclusive, and further studies are needed to provide good-quality evidence for the effectiveness of the surveillance component.

In addition to the above, the built environment, materials and equipment component was reported to affect a reduction in MDRO infections and respiratory infections when applied in conjunction with WHO multi-modal strategies including four or more elements [15–17,19]. An appropriate environment and placement of resources are the foundations for infection control practices of HCWs in healthcare settings [9]. Thus, resource availability should be enhanced and an optimized environment should be provided in which the required practices can be performed easily by HCWs. According to the Effective Practice and Organisation of Care taxonomy [39], this component is related to structural interventions. It is thought that if a structural intervention is accompanied by a professional intervention for changing infection control practices of HCWs (such as the WHO multi-modal strategy), a synergistic effect may be observed.

Surveillance and built environment, materials and equipment for IPC are resource-intensive components [4]. Most importantly, these two components are the cornerstones for the consistent application of IPC programmes, and thus cannot be ignored. However, it may be difficult to apply these components in LTCFs where the available human resources, laboratory systems and funding are limited. Taking into consideration the available resources, a priority-based approach can be applied by risk assessment in low-resource settings [9]. Priority could be placed on the problems identified as high risk based on appropriate risk assessment, and resources may be used to mitigate the risk.

Several suggestions for future research are given below. Improvement of knowledge, compliance and quality of practice by IPC programmes was consistently reported in included studies, compared with results in infection rates. This observation may indicate that behavioural changes in HCWs as process indicators are not sufficient to ensure significant reductions in HAIs as outcomes. Long-term maintenance of successful behavioural changes may be required to influence infection rates. However, in this review, there were no studies which conducted follow-up tests to examine the sustainability of effects. Thus, evidence for the longstanding effectiveness of IPC interventions remains necessary. Another problem is that the validity and reliability of tools for measuring knowledge, audit and quality of performance among HCWs were not fully described in the studies included in this review. Thus, there is a need for generalized,

validated tools or methods to measure knowledge, compliance and audit of infection control practice.

On the other hand, additional strategies such as transmission-based precautions are required to prevent the spread of pathogens such as MDROs, scabies and respiratory viruses. However, none of the studies included in this review evaluated the compliance of these strategies among HCWs. Further studies of MDRO-related interventions may need to assess adherence to precautionary practices in HCWs.

Strengths and limitations

Variability of the IPC programme topics and components in LTCFs increased the difficulty of synthesis and arriving at conclusions for evidence regarding the efficacy or sustained impact of the intervention. A strength of this study is that the effect and the components of the IPC interventions focusing on LTCF settings were analysed based on the recommended core components in the WHO manual [9]. This facilitated the development of a systematic, analytical and comprehensive analysis of IPC programmes in LTCFs.

This systematic review did not include interventions specific to antibiotic stewardship because the scope of the antibiotic stewardship programme is focused on the use and prescription of antimicrobial medications or medical costs. Future reviews for measures to prevent MDROs in LTCFs may consider such interventions. In addition, a meta-analysis was not performed because the methods for measuring outcomes were inconsistent among the included studies. In the future, consistent indicators and methods are needed to consolidate the quantified effect of IPC programmes in LTCFs.

In conclusion, this review suggests that education, monitoring and feedback are essential components in strategies to affect behavioural changes in HCWs at LTCFs. Most importantly, according to the results of the studies included in this review, use of four or more elements of the WHO multi-modal strategy is a critical factor in the implementation and success of IPC programmes. Combinations of several of the above-mentioned components may be highly effective in improving outcomes; compared with the use of individual components, combinations of these components showed synergistic effects. Evidence for the impact of surveillance on outcomes in LTCFs was inadequate to draw definitive conclusions. More studies with sound methodology including all five elements of the WHO multi-modal strategy and surveillance are needed to generate evidence for the effectiveness of these components on infection prevention in LTCF populations.

In practice, efforts to improve organizational and infrastructural environments are required, along with behavioural change strategies for HCWs, to maintain the effect of IPC activities. Considering the limited human resources in LTCFs, public health policy needs to be modified to increase staffing for efficient workload management in this setting.

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None declared.

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