Received: 12 September 2023 | Accepted: 25 November 2023

DOI: 10.1002/hcs2.81

REVIEW

HEALTH CARE SCIENCE

Identifying a competency improvement strategy for infection prevention and control professionals: A rapid systematic review and cluster analysis

Nuo Chen[1] | **Shunning Li**[2] | **Zhengling Kuang**[3] | **Ting Gong**[4] | **Weilong Zhou**[5] | **Ying Wang**[6,7]

[1]School of Public Health and Management, Hubei University of Medicine, Shiyan, China

[2]Tianjin Key Laboratory of Retinal Functions and Diseases, Tianjin Branch of National Clinical Research Center for Ocular Disease, Eye Institute and School of Optometry, Tianjin Medical University Eye Hospital, Tianjin, China

[3]State Key Laboratory of Experimental Hematology, National Clinical Research Center for Blood Diseases, Haihe Laboratory of Cell Ecosystem, Institute of Hematology & Blood Diseases Hospital, Chinese Academy of Medical Sciences & Peking Union Medical College, Tianjin Institutes of Health Science, Tianjin, China

[4]Shanghai Institute of Cardiovascular Diseases, Zhongshan Hospital and Institutes of Biomedical Sciences, Fudan University, Shanghai, China

[5]Department of Infection Control and Prevention, West China Second University Hospital, Sichuan University, Chengdu, China

[6]Department of Infection Prevention and Control Management, Zhongnan Hospital of Wuhan University, Wuhan, China

[7]Hubei Engineering Center for Infectious Disease Prevention, Control and Treatment, Wuhan, China

Correspondence
Ying Wang, Department of Infection Prevention and Control Management, Zhongnan Hospital of Wuhan University, Wuchang District Donghu Rd 169, Wuhan 430071, China.
Email: wangying621@whu.edu.cn

Funding information
The National Natural Science Foundation of China, Grant/Award Number: 52178080; Major Research Project of the Hospital Management Research Institute of the National Health Commission, Grant/Award Number: GY2023011; National Institute of Hospital Administration Management of China, Grant/Award Number: GY2023049

Abstract

Remarkable progress has been made in infection prevention and control (IPC) in many countries, but some gaps emerged in the context of the coronavirus disease 2019 (COVID-19) pandemic. Core capabilities such as standard clinical precautions and tracing the source of infection were the focus of IPC in medical institutions during the pandemic. Therefore, the core competences of IPC professionals during the pandemic, and how these contributed to successful prevention and control of the epidemic, should be studied. To investigate, using a systematic review and cluster analysis, fundamental improvements in the competences of infection control and prevention professionals that may be emphasized in light of the COVID-19 pandemic. We searched the PubMed, Embase, Cochrane Library, Web of Science, CNKI, WanFang Data, and CBM databases for original articles exploring core competencies of IPC professionals during the COVID-19 pandemic (from January 1, 2020 to February 7, 2023). Weiciyun software was used for data extraction and the Donohue formula was followed to distinguish high-frequency technical terms. Cluster analysis was

Abbreviations: COVID-19, coronavirus disease 2019; lPC, infection prevention and control; lPCP, infection prevention and control professional; HAl, healthcare-acquired infection; HAls, healthcare-associated infections; PPE, personal protective equipment; WHO, World Health Organization.

Nuo Chen, Shunning Li, Zhengling Kuang, and Ting Gong contributed equally to this study.

performed using the within-group linkage method and squared Euclidean distance as the metric to determine the priority competencies for development. We identified 46 studies with 29 high-frequency technical terms. The most common term was "infection prevention and control training" (184 times, 17.3%), followed by "hand hygiene" (172 times, 16.2%). "Infection prevention and control in clinical practice" was the most-reported core competency (367 times, 34.5%), followed by "microbiology and surveillance" (292 times, 27.5%). Cluster analysis showed two key areas of competence: Category 1 (program management and leadership, patient safety and occupational health, education and microbiology and surveillance) and Category 2 (IPC in clinical practice). During the COVID-19 pandemic, IPC program management and leadership, microbiology and surveillance, education, patient safety, and occupational health were the most important focus of development and should be given due consideration by IPC professionals.

KEYWORDS
infection prevention and control professionals, competency improvement, cluster analysis, COVID-19, review

1 | INTRODUCTION

Infection prevention and control (IPC) is the taking of effective measures and nonpharmaceutical interventions to reduce the spread of illnesses such as coronavirus disease 2019 (COVID-19) and is an essential prerequisite for general medical treatment [1, 2]. Infection prevention and control professionals (IPCPs) have dual managerial and operational responsibilities [3]. The World Health Organization (WHO) publication, "Minimum requirements for infection prevention and control programmes" describes the minimum requirements for IPC programs at the national level [4]. However, despite this publication, significant gaps remain in practice around the world. A survey of 106 countries about the national minimum standards for IPC showed that only four countries met the WHO requirements [5]. In another survey, only five (45.45%) of the 11 nations studied had IPC physician training programs [6]. In a separate study of 20 low-income countries, only nine countries (45%) had a national IPC program, only four (20%) reported the existence of documents on implementing IPC strategies, and only one (5%) monitored adherence to IPC practices, highlighting deficits in IPC management systems and leadership [7]. A study of 65 hospitals found that 17 (26.15%) showed insufficient microbiological and surveillance capability for IPC [8]. The same situation exists in China. For example, a study there found that only 24.03% of IPCPs had enough knowledge to be prepared to face the COVID-19 pandemic, indicating deficiencies in education and training resources [9]. The Chinese IPC program has advanced significantly, but further training and educational resources are still needed. Other gaps include insufficient functioning IPC programs with annual work plans, lack of expertise in conducting IPC monitoring, inadequate IPC training, need for construction of a COVID-19-safe environment, and need to secure adequate IPC supplies, particularly personal protective equipment (PPE) [4].

COVID-19 no longer constitutes a public health emergency of international concern, but the pandemic provided insights into where current IPC efforts are working or insufficient. We conducted a systematic scoping review of lessons from the pandemic and carried out cluster analysis to provide practice recommendations for IPCP training and core competencies.

2 | METHODS

2.1 | Literature search strategy

A comprehensive systematic literature search was conducted without restrictions on region, publication type, or language. We searched the PubMed, Embase, Cochrane Library, Web of Science, CNKI, WanFang Data, and CBM databases using the terms provided in Table 1. The study period was from January 1, 2020 to February 7, 2023. To provide more evidence, we also searched the reference lists of the included studies and the relevant clinical practice guidelines.

TABLE 1 Search strategies used for PubMed and WanFang Data.

Databases	Search strategies
PubMed	#1 "hospitals" [Mesh] OR hospital OR ward OR hospital setting OR infirmary OR health care OR healthcare OR nosocomial [Title/Abstract]
	#2 Covid-19 [Mesh] OR coronavirus diseases 2019 OR SARS-CoV-2 OR 2019-nCoV [Title/Abstract]
	#3 "infection control practitioners" [Mesh] OR practitioner, infection control OR practitioners, infection control OR infection control practitioner [Title/Abstract]
	#4 competency OR capacity OR ability OR capability OR competence [Title/Abstract]
	#5 #1 AND #2 AND #3 AND #4
WanFang data	#1 medical institutions OR hospital OR nosocomial OR ward OR healthcare [Title/Abstract]
	#2 Covid-19 OR coronavirus disease 2019 OR SARS-CoV-2 OR 2019-nCoV [Title/Abstract]
	#3 infection preventionists OR infection control professionals OR infection prevention and control professionals OR infection prevention and control practitioners [Title/Abstract]
	#4 ability OR skill OR competency OR capacity [Title/Abstract]
	#5 #1 AND #2 AND #3 AND #4

2.2 | Inclusion and exclusion criteria

Studies with the following characteristics were included: (1) an original article on IPCP core competencies during the COVID-19 pandemic; (2) in English or Chinese; and (3) using qualitative, cross-sectional, before–after, retrospective, or prospective observational study designs. Exclusion criteria included inappropriate study design, letters, conference abstracts, commentaries, case reports, and reviews with limited data, or inaccessible literature.

2.3 | Data extraction

Each study was screened by two independent reviewers against the study eligibility criteria. The retrieved data were crosschecked to ensure accuracy and any disagreements were resolved through discussion among the reviewers. The extracted information included the following:

(a) Publication data: name of first author, publication year, geographic location, and literature types (qualitative, cross-sectional, before–after, retrospective, or prospective observational studies).
(b) Technical terms related to IPCPs' core competencies: the WHO guideline was imported to Weiciyun software (https://fenci.weiciyun.com/) to search for technical terms and to combine the domains of IPC core competencies (Table 3 of the WHO guideline) [10]. Following the integration, 80 technical terms were included in the analysis (Supporting Information S1: Tables S1 and S2).
(c) Frequency of technical terms: The included literature was imported into the Weiciyun software and the frequencies of technical terms in each paper were extracted using a general analysis function.

2.4 | Statistical analysis

(a) Data integration: First, technically synonymous terms were normalized and combined, and overly vague terms were removed. Second, the list of technical terms was ordered by the frequency of each word in the literature.
(b) Acquisition and classification of high-frequency terms: First, high-frequency terms were defined using the following formula proposed by Donohue in 1973 [10]:

$$T = (-1 + \sqrt{1 + 8 \times I_1})/2, \quad (1)$$

where T is the dividing frequency of the high-frequency and low-frequency terms, and I_1 is the number of technical terms mentioned only once.

Second, high-frequency terms for the same role were classified as a single core competency following the WHO guidelines [11]. The frequency of each core competency was then calculated.
(c) Cluster analysis: First, the word frequency matrix table is constructed by the occurrence of high-frequency words related to core competence in each paper and their corresponding article numbers. Second, we used SPSS software (version 26, IBM) to perform hierarchical clustering using the within-group linkage method on the matrix results. The approximate matrix was obtained

after hierarchical clustering (Supporting Information S1: Table S3), and the competencies with similar difference values were grouped into a single category. The squared Euclidean distance was used as the metric in the clustering approach, and the clustering was visualized using a dendrogram.

3 | RESULTS

3.1 | Literature search

The initial database search yielded 383 unique citations, of which nine were from PubMed, 10 from Embase, two from the Cochrane Library, 193 from Web of Science, 158 from CNKI, five from WanFang Data, and six from CBM. Fifteen duplicates were removed. After excluding studies whose titles and abstracts suggested that they did not meet the inclusion criteria, 58 publications remained. Of these, 10 had limited data and two were inappropriate types of paper. The final meta-analysis therefore included 46 eligible studies. The list of excluded studies and the reasons for their exclusion are shown in Figure 1.

3.2 | Study characteristics

Of the 46 studies included in the analysis, 14 were carried out in the United States [12–25], 11 in China [26–36], four in each of the United Kingdom [27, 37–39] and Switzerland [6, 7, 40, 41], three in Italy [42–44], two in South Africa [45, 46] and one in each of Germany [8], Saudi Arabia [47], Finland [48], the Netherlands [49], Australia [50], Ghana [51], Pakistan [52], and Singapore [53]. There were 20 cross-sectional studies [8, 15–17, 24, 25, 31, 32, 34–37, 39–41, 49–52, 54], 15 qualitative studies [6, 7, 13, 14, 19, 21, 23, 26, 28, 29, 38, 42, 45, 46, 48], eight before–after studies [12, 20, 22, 27, 30, 33, 47, 53], two retrospective studies [18, 44] and one prospective observational study [43] (Table 2).

3.3 | Technical terms related to IPCPs' core competencies

Overall, 39 technical terms related to IPCPs' core competencies were extracted in this study, including four words with a frequency of two and six words with a frequency of one. Using the Donohue formula, the

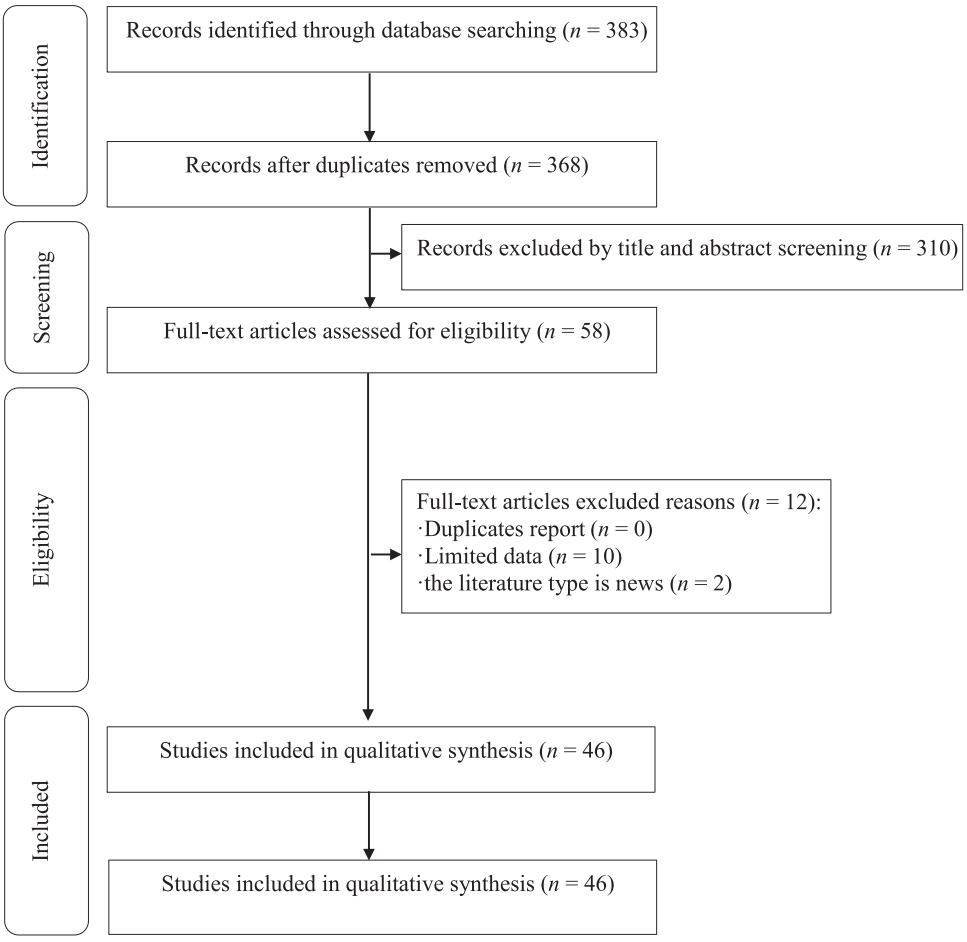

FIGURE 1 Flow chart of study identification.

TABLE 2 Characteristic of studies.

Study	Country	Article type	High-frequency terms
Tsioutis 2020 [6]	Basel, Switzerland	Qualitative research	IPC training, Microbiology, Waste management
Tomczyk 2021 [7]	Geneva, Switzerland	Qualitative research	IPC training, Hand hygiene, Device-associated infection
Aghdassi 2020 [8]	Berlin, Germany	Cross-sectional study	IPC training, Antimicrobial resistance, Hand hygiene
Alsuhaibani 2021 [12]	Iowa, USA	Before–after study	Hand hygiene, Occupational health, Central line-associated bloodstream infections, Catheter-associated urinary tract infections
Herstein 2021 [13]	Nebraska, USA	Qualitative research	Emergency management, Isolation rooms
Holdsworth 2020 [14]	Norcross, USA	Qualitative research	Use of PPE
Rebmann 2021 [15]	Missouri, USA	Cross-sectional study	Use of PPE, Hand hygiene
Rebmann 2020 [16]	Missouri, USA	Cross-sectional study	Use of PPE, Hand hygiene
Schildhouse 2022 [17]	Michigan, USA	Cross-sectional study	Use of PPE, Central line-associated bloodstream infections, Catheter-associated urinary tract infections
Fakih 2021 [18]	Missouri, USA	Retrospective study	Central line-associated bloodstream infections, Catheter-associated urinary tract infections
Tadavarthy 2020 [19]	Philadelphia, USA	Qualitative research	Hand hygiene, Waste management
Penna 2022 [20]	Georgia, USA	Before–after study	Antibiotic resistance, IPC training, Hand hygiene
Rebmann 2021 [21]	Missouri, USA	Qualitative research	Ventilator-associated pneumonia, Catheter-associated urinary tract infections
Pokrajac 2020 [22]	California, USA	Before–after study	Use of PPE, Hand hygiene
Collins 2021 [23]	Washington, USA	Qualitative research	Use of PPE, IPC training
Rebmann 2021 [24]	Missouri, USA	Cross-sectional study	Use of PPE, Occupational health
Cole 2020 [25]	California, USA	Cross-sectional study	Hand hygiene, Use of PPE
Cui 2021 [26]	Hangzhou, China	Qualitative research	Occupational health, IPC training
Li 2022 [27]	Chengdu, China	Before–after study	Emergency management, Isolation rooms, IPC training
Zhang 2020 [28]	Wuhan, China	Qualitative research	Emergency management, IPC training
Du 2021 [29]	Chengdu, China	Qualitative research	Occupational health, IPC training
Tan 2020 [30]	Beijing, China	Before–after study	Use of PPE, Hand hygiene
Yao 2021 [31]	Guizhou, China	Cross-sectional study	Emergency management, IPC training, Antimicrobial resistance
Zhang 2021 [32]	Xian, China	Cross-sectional study	Waste management, Antimicrobial resistance, HAI surveillance
Zang 2021 [33]	Nanjing, China	Before–after study	Hand hygiene, Use of PPE, Emergency management, Occupational health, IPC training
He 2020 [34]	Anhui, China	Cross-sectional study	Hand hygiene, Antimicrobial resistance, Waste management, IPC training
Chen 2021 [35]	Guangdong, China	Cross-sectional study	Catheter-associated urinary tract infections, Ventilator-associated pneumonia, Surgical site infection, Antimicrobial resistance, Hand hygiene, IPC training
Cui 2022 [36]	Shanghai, China	Cross-sectional study	Antimicrobial resistance, Emergency management, Microbiology, Epidemiology, Occupational health, IPC training
Castro-Sánchez 2020 [54]	London, UK	Cross-sectional study	Use of PPE, Patient safety, Hand hygiene, IPC training

(Continues)

TABLE 2 (Continued)

Study	Country	Article type	High-frequency terms
Chater 2022 [37]	London, UK	Cross-sectional study	Antimicrobial resistance
Kamere 2022 [38]	London, UK	Qualitative research	Antimicrobial resistance, Healthcare-associated infections (HAIs) surveillance, Hand hygiene, IPC training
Norton 2020 [39]	Bury St Edmunds, UK	Cross-sectional study	Use of PPE, IPC training, Hand hygiene
Tomczyk 2022 [40]	Geneva, Switzerland	Cross-sectional study	IPC training, Hand hygiene
Tartari 2020 [41]	Geneva, Switzerland	Cross-sectional study	Antimicrobial resistance, IPC training, HAI surveillance, Hand hygiene
Puro 2022 [42]	Rome, Italy	Qualitative research	IPC training, Disinfection and sterilization of tools and equipment, Hand hygiene
Cattelan 2020 [43]	Padova, Italy	Prospective observational study	Use of PPE, HAI surveillance, Hand hygiene
Mauro 2021 [44]	Naples, Italy	Retrospective study	Emergency management, Pre-checking and triage
Mehtar 2020 [45]	Cape Town, South Africa	Qualitative research	Surgical site infection
Patel 2020 [46]	Johannesburg, South Africa	Qualitative research	Use of PPE
Lingawi 2022 [47]	Makkah, Saudi Arabia	Before–after study	Use of PPE, Hand hygiene
Lohiniva 2022 [48]	Helsinki, Finland	Qualitative research	Hand hygiene, Use of PPE
Dekker 2020 [49]	Amsterdam, Netherlands	Cross-sectional study	Hand hygiene
Sotomayor-Castillo 2021 [50]	NSW, Australia	Cross-sectional study	Use of PPE, Emergency management
Oppong 2022 [51]	Accra, Ghana	Cross-sectional study	Standard precautions, Hand hygiene, Waste management, IPC training
Savul 2020 [52]	Islamabad, Pakistan	Cross-sectional study	Standard precautions, Transmission-based precautions, Hand hygiene, IPC training
Wee 2020 [53]	Singapore	Before–after study	Standard Precautions, Hand hygiene, Central line-associated bloodstream infections

Abbreviations: HAI, healthcare-associated infection; IPC, infection prevention and control; PPE, personal protective equipment.

threshold of the high-frequency terms was defined as 3 ($T = 3$), indicating that the high-frequency terms should occur more than twice. This gave a total of 29 high-frequency technical terms. Some of these had similar meanings, and we therefore added them together. Other terms were not included because of their relatively low frequency but were still considered.

Figure 2 shows that "IPC training" occurred with the highest frequency (184 times, 17.3%), followed by "hand hygiene" (172 times, 16.2%). The least common phrase was "pre-checking and triage" (three times, 0.3%). The core competency category "IPC in clinical practice" contained the highest number of high-frequency terms (13), and "education" contained the lowest number (one). A higher frequency suggests that this competency is more valued. The importance of these low-frequency competencies should thus be strengthened in future research and clinical practice.

The innermost blue part of the circular Manhattan plot indicates the five core competencies of IPCPs. The multi-colored middle layer shows all the high-frequency terms categorized into the five core competencies. The numbers show the total frequency and proportion of the total of each high-frequency term. The legends top to bottom and left to right correspond to the frequency data from most to least.

Figure 3 shows that the core competency "IPC in clinical practice" had the highest frequency (367 times, 34.5%), followed by "Microbiology and surveillance" (292

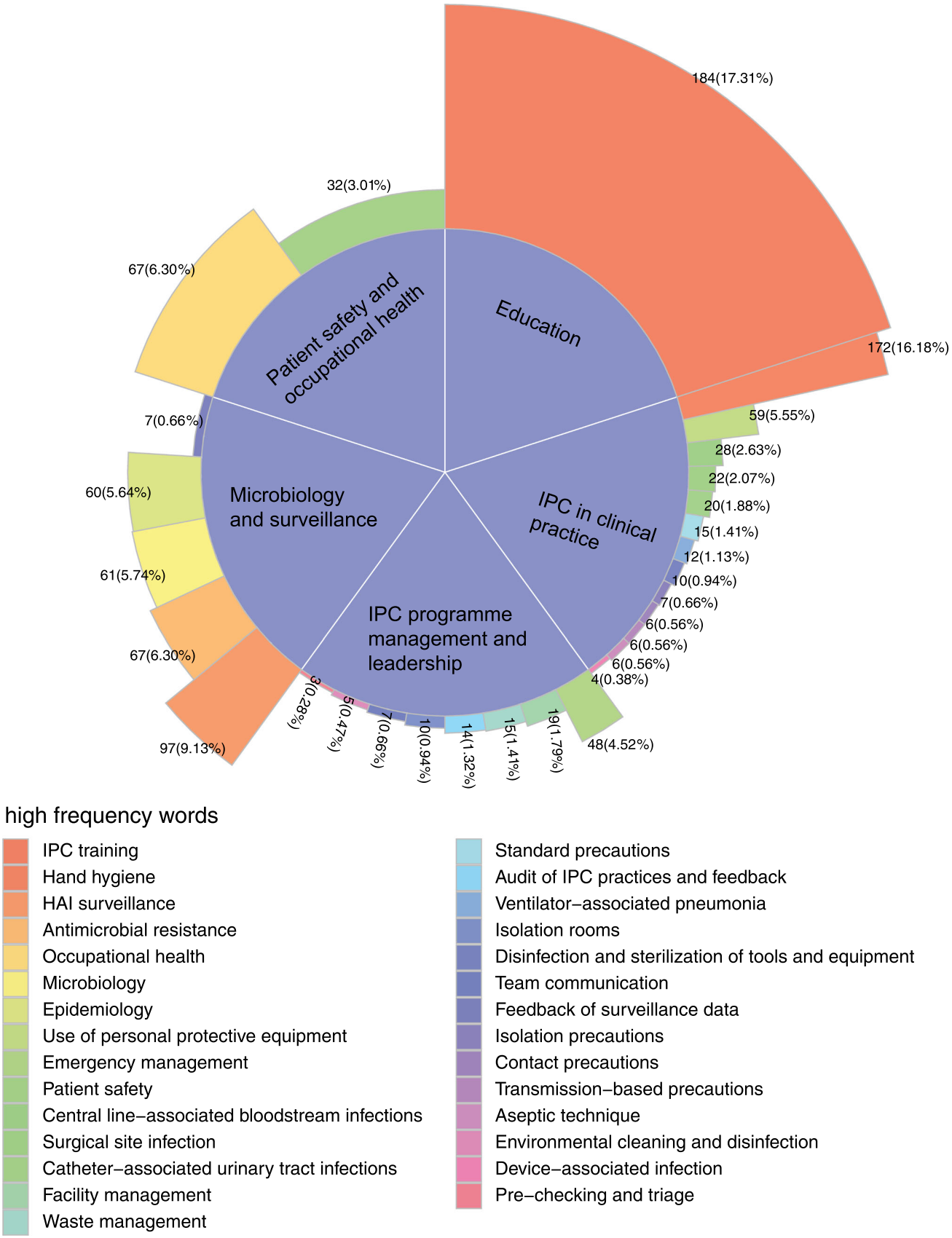

FIGURE 2 Frequency distribution of high-frequency terms related to the five core competencies of infection prevention and control professionals (IPCPs).

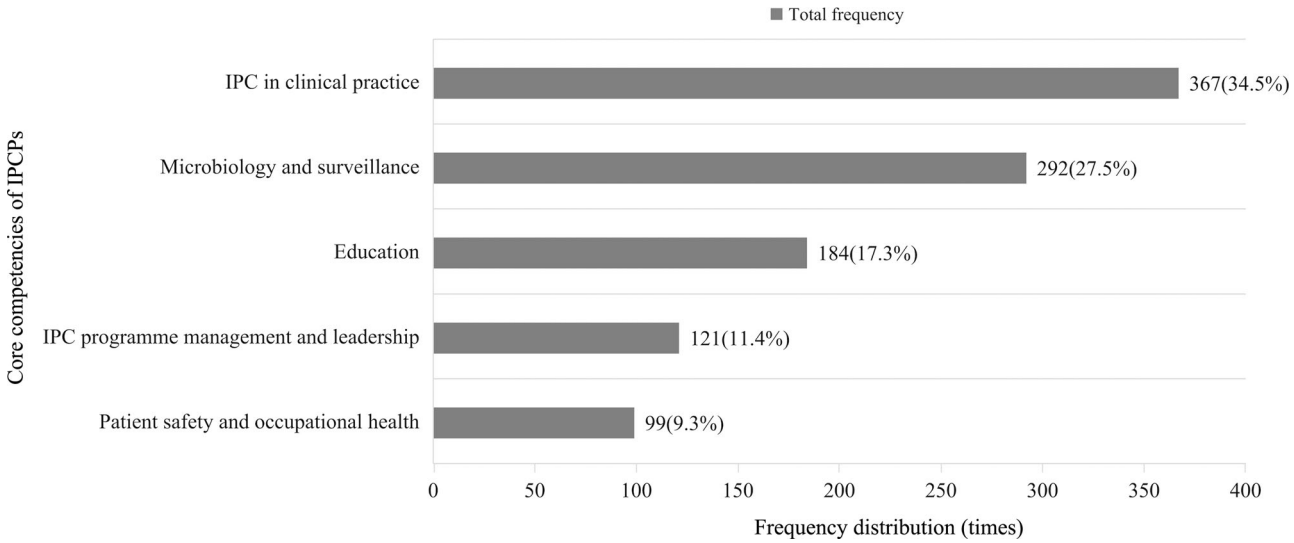

FIGURE 3 Frequency distribution of five core competencies of infection prevention and control professionals (IPCPs). The *X*-axis shows frequency and the *Y*-axis shows the five core competencies of IPCPs.

times, 27.5%). The frequency of "Patient safety and occupational health" was the lowest (99 times, 9.3%). The maximum frequency ("IPC in clinical practice") was 73% higher than the minimum frequency ("Patient safety and occupational health"). This suggests that IPC in clinical practice is widely understood, and a focus. However, patient safety and occupational health are of less concern, and may even be ignored. The lower the frequency, the less that competence is discussed, indicating areas for development. We found significant differences among the five core competencies of IPCPs, highlighting varying levels of attention on these competences.

3.4 | Cluster analysis

The results of the cluster analysis are shown in Figure 4 and Supporting Information S1: Table S3. With a distance threshold of 20, the cluster analysis identified two core competency categories: Category 1: IPC program management and leadership, Patient safety and occupational health, Education, and Microbiology and surveillance; and Category 2: IPC in clinical practice. The clustering coefficient was 5669.

A detailed explanation of the competences is shown in Table 3.

4 | DISCUSSION

Among the core competencies of IPCPs, it is particularly important to focus on IPC program management and leadership, microbiology and surveillance, education, and patient safety and occupational health. To enable IPCPs to cope with emerging infectious diseases with unknown causes or to prevent and control infections in hospitals, they should preferentially conduct microbiological surveillance backed up by multiple means, and ensure that they keep learning and attending training.

IPC in clinical practice is a comprehensive and highly regarded skill with many facets, including recognizing the risk of healthcare-acquired infections (HAIs), combining multiple approaches to IPC in clinical practice, and appraisal of outcomes. A prospective study found that a comprehensive hospital infection control strategy could successfully prevent infection among IPCPs, suggesting the importance of IPC program management and leadership [43]. Risk stratification models used in clinical practice can identify high-risk patients and assist nursing teams to manage resources including interventions, hospital beds, and staffing [63]. The clinical practice element of IPC, including but not limited to PPE usage guidelines and antimicrobial stewardship, patient monitoring, environmental surveillance, environmental cleaning and disinfection, and hand hygiene, plays an important role [43, 64].

We also found that the five core competencies are tightly linked. A cross-sectional study in four community hospitals in California found that the number of multidrug-resistant organisms could be decreased by providing additional education to IPCPs about appropriate PPE usage and the importance of hand hygiene, highlighting the capacity of education to improve microbiological surveillance [25]. A large-scale London hospital group developed the "PPE Helper Program", which provided IPCPs with PPE support and education [54]. Enrolled workers had higher skills than

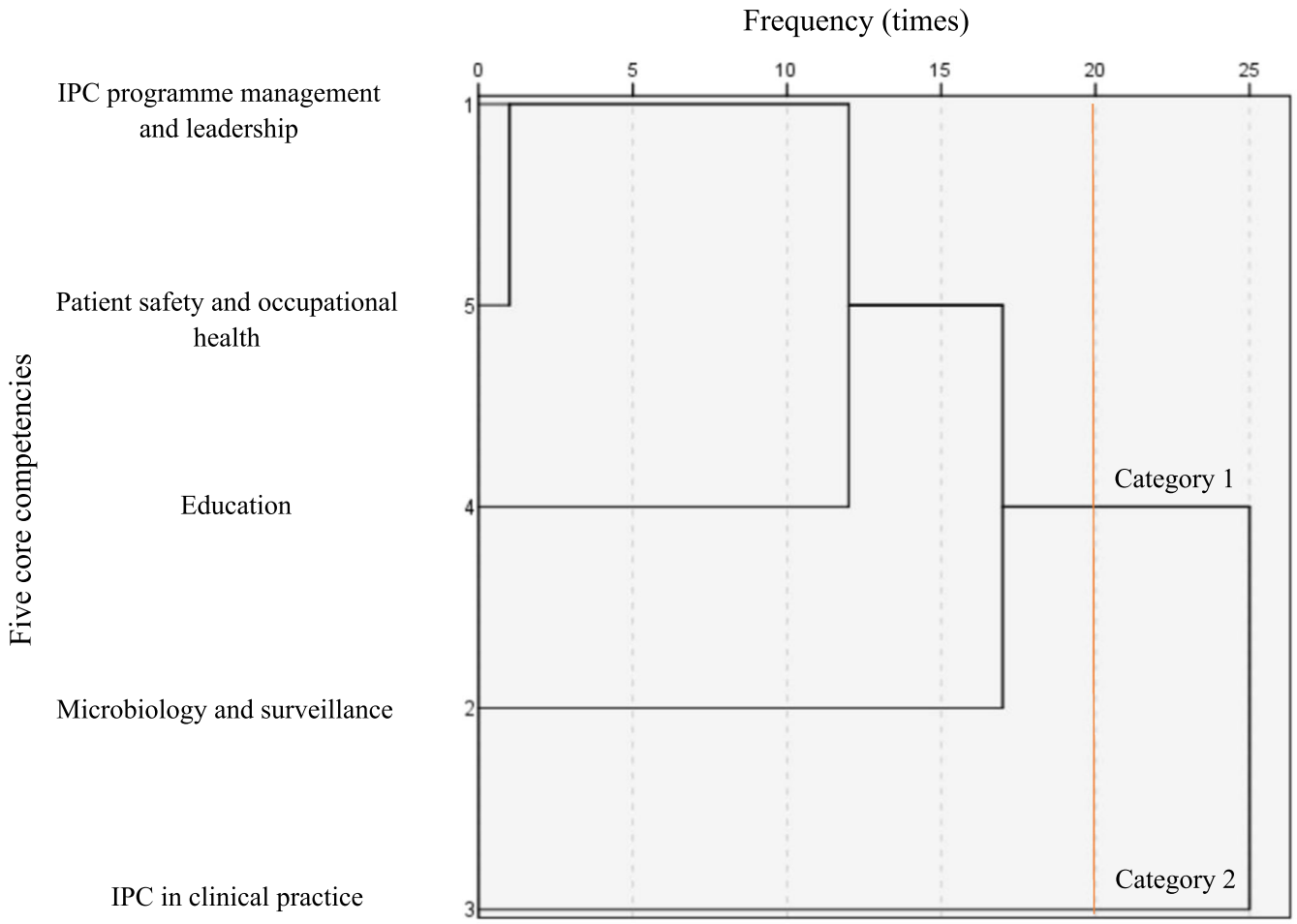

FIGURE 4 Cluster dendrogram of infection prevention and control professionals (IPCPs') core competencies. The horizontal coordinate shows the frequency of the five core competencies in the 46 studies, and the vertical coordinate the five core competencies. The red lines divide the five core competencies into the two categories.

their non-enrolled peers in using PPE appropriately (82.5% vs. 56.5%) [54]. A multicountry survey of 262 IPCPs of 10 nationalities showed that those who had received antimicrobial resistance training had significantly higher scores than those who had not [37].

Among the two categories of competencies, the first category focuses on comprehensive competencies and the second on clinical sensory control practice. We have some suggestions to help IPCPs use the competencies to improve their practice, including the following.

(a) Establish training courses: when training new IPCPs, assist them to acquire work experience to strengthen their training, especially on correct and responsible use of antibiotics [56]; communicating with patients and their families [55]; epidemiology, clinical manifestations, and complications of HAIs [60]; basic precautions such as hand hygiene, use of PPE, and disposal of waste and sharp tools [59] and to help them develop a good mindset and value the patient and health;
(b) Develop assessment indicators: personal competency assessment indicators should be established based on the four competencies that need to be prioritized for development and targeted improvement of personal competencies;
(c) Regular assessment: managers of IPCPs should plan and implement IPC programs, regularly inspect and summarize the training courses, and help IPCPs identify gaps in their knowledge.

This study has some limitations. First, this article focuses on the priorities for developing core competencies during the COVID-19 pandemic. The literature from before the pandemic was not included in the analysis, and thus the conclusion has time limitations. Further research is needed to combine our findings with the literature from before the pandemic. Second, the study did not consider factors such as the varying levels of medical resources in different areas, different educational backgrounds, or the job tenure of IPCPs. For example, different countries and

TABLE 3 A detailed explanation of the five core competencies.

Category	IPCPs' core competencies	Detailed explanation	
Category 1	IPC program management and leadership	Use management strategies and leadership to plan and operationalize an IPC program, develop evidence-based IPC guidelines, standard operating protocols, training resources and monitoring tools, and undertake monitoring and feedback of adherence to guidelines and recommendations. Support the achievement of adequate infrastructure for water, sanitation and hygiene and IPC and procurement of supplies. Assess the infection risks related to building design, construction and renovation, and provide guidance based on IPC principles. Use communication skills to interact with teams, senior management, patients and families, and other audiences [55].	
	Microbiology and surveillance	A coherent set of actions to promote the responsible use of antimicrobials. The primary goal of antimicrobial stewardship is to optimize clinical outcomes while minimizing unintended consequences of antimicrobial use, including toxicity, the selection of pathogenic organisms (such as *Clostridium difficile*), and the emergence of resistance [56]. Facility-based healthcare-acquired infection (HAI) surveillance should be performed to guide IPC interventions and detect outbreaks, including antimicrobial resistance surveillance, with timely feedback of results to healthcare workers and stakeholders and through national networks [4].	
	Education	IPC education should be in place for all healthcare workers by using team- and task-based strategies that are participatory and include bedside and simulation training to reduce the risk of HAI and antimicrobial resistance [4].	
	Patient safety and occupational health	Demonstrate an understanding of the key principles of quality and patient safety and of the epidemiology, burden of risk factors and causes of adverse events, near-misses, accidents, and dangerous incidents in healthcare. Contribute to designing, developing, implementing, and evaluating quality improvement and patient safety programs. Understand the infection risks related to employment and support the implementation of appropriate preventive measures to provide a safe environment and healthy workforce [11].	
Category 2	IPC in clinical practice	Standard precautions	A set of activities designed to prevent the transmission of organisms between patients/staff for the prevention of HAI. They must be applied to all patients who require healthcare, by all healthcare workers in all healthcare settings. They include hand hygiene; use of PPE; handling and disposal of waste and sharps; handling and management of clean and used linen; environmental cleaning; and decontamination of equipment [57].
		Transmission-based precautions	Additional measures focused on the specific mode of transmission of the microorganism and always used in addition to standard precautions. They are grouped into categories according to the route of transmission of the infectious agent. Transmission-based precautions should be applied when caring for patients with known infections, patients who are colonized with an infectious organism and asymptomatic patients who are suspected of/under investigation for colonization or infection with an infectious microorganism [58].

TABLE 3 (Continued)

Category	IPCPs' core competencies	Detailed explanation	
		Decontamination and reprocessing of medical devices and equipment	All steps that are necessary to make a contaminated reusable medical device ready for its intended use. These steps may include cleaning, functional testing, packaging, labeling, disinfection, and sterilization [59].
		Catheter-associated blood-stream infection prevention Catheter-associated urinary tract infection prevention Surgical site infection prevention Prevention of healthcare-associated pneumonia	Understand the epidemiology, risk factors, burden, clinical presentation, and complications of catheter-associated bloodstream infections, catheter-associated urinary tract infections, surgical site infections, and healthcare-associated pneumonia, use evidence-based guidelines for prevention, and monitor the implementation of IPC measures [60].
		Healthcare-associated outbreak prevention and management	Prevent, detect, manage, and control healthcare-associated outbreaks. Conduct IPC training activities and develop effective communications during outbreaks in healthcare facilities [61].
		COVID-19 blood tests	COVID-19 blood tests and related treatments are more effective when the budget, IPCP education level, and national development level are high [62].

Abbreviations: COVID-19, coronavirus disease 2019; HAI, healthcare-associated infection; IPC, infection prevention and control; PPE, personal protective equipment.

regions have different levels of medical resources, and the equipment and health conditions provided during the pandemic were very different. The education level of IPCPs in different medical institutions is also inconsistent, resulting in different response speeds to disease prevention and COVID-19. IPCPs with greater experience may be better able to make quick judgments about the severity of an outbreak [65]. In future studies, these factors should be examined in different cases to expand the results. Nevertheless, the identified core competencies could provide a development path for junior IPCPs to rapidly improve their competencies. They could also enable advanced IPCPs to improve their capabilities.

5 | CONCLUSION

Our study summarized the five core competencies of IPCPs during the pandemic and divided them into two categories. We identified four competences in particular for prioritization. These were IPC program management and leadership, microbiology and surveillance, education, and patient safety and occupational health. We suggest that the future training of IPCP personnel should take these four competences as a clear entry point for improving abilities. It is particularly important to focus on the leadership role of senior managers, strengthening communication with patients and their families, correctly using antibacterial drugs, and focusing on patients and their health, especially to reduce the rate of HAIs.

AUTHOR CONTRIBUTIONS

Nuo Chen: Conceptualization and writing—original draft. **Shunning Li**: Writing—original draft and methodology. **Zhengling Kuang**: Writing—original draft and software. **Ting Gong**: Writing—original draft and data curation. **Weilong Zhou**: Formal analysis and supervision. **Ying Wang**: Writing—review and editing and supervision.

ACKNOWLEDGMENTS

The authors are very grateful for the funding support we have received. This study was supported by the National Natural Science Foundation of China (Grant no. 52178080), the Major Research Project of the Hospital Management Research Institute of the National Health Commission (GY2023011) and the National Institute of Hospital Administration Management of China (GY2023049).

CONFLICT OF INTEREST STATEMENT

The authors declare no conflict of interest.

DATA AVAILABILITY STATEMENT

The data that support the findings of this study are available from the corresponding author upon reasonable request.

ETHICS STATEMENT

Ethics approval was waived for this study because no patient data were reported.

INFORMED CONSENT

The need for informed consent was waived for this study because no new patient data were reported.

ORCID

Nuo Chen https://orcid.org/0009-0006-0886-4825

REFERENCES

1. Luo AW, Lu QJ, Pan ZY, Dan P, Wang Q, Li YC, et al. Difficulties and countermeasures in emergency treatment for control of healthcare-associated infection during epidemic of COVID-19. Preventive Med Chin PLA. 2020;38(7):116–8. https://doi.org/10.1186/s13020-020-00397-9
2. Wang JJ, Li SS, Jiang WD, Lv HL, Fang HM, Gan ZH, et al. Practice and exploration of infection control supervision at Fangcang hospital during the COVID-19 pneumonia outbreak. J Med Postgrad. 2022;35(11):1199–201.
3. Jiao LY, Liu XJ, Wang XY, Qian H, Niu ML, Li ZF, et al. Current situation and influencing factors of post competency of full-time nosocomial infection management staff in Hebei province. Hebei Med J. 2022;44(14):2221–4.
4. World Health Organization. Minimum requirements for infection prevention and control (IPC) programmes. Geneva: WHO Press; 2019.
5. Maintaining infection prevention and control measures for COVID-19 in health care facilities. Geneva: WHO Press; 2022.
6. Tsioutis C, Birgand G, Bathoorn E, Deptula A, Ten Horn L, Castro-Sánchez E, et al. Education and training programmes for infection prevention and control professionals: mapping the current opportunities and local needs in European countries. Antimicrob Resist Infect Control. 2020;9(1):183. https://doi.org/10.1186/s13756-020-00835-1
7. Tomczyk S, Storr J, Kilpatrick C, Allegranzi B. Infection prevention and control (IPC) implementation in low-resource settings: a qualitative analysis. Antimicrob Resist Infect Control. 2021;10(1):113. https://doi.org/10.1186/s13756-021-00962-3
8. Aghdassi SJS, Grisold A, Wechsler-Fördös A, Hansen S, Bischoff P, Behnke M, et al. Evaluating infection prevention and control programs in Austrian acute care hospitals using the WHO infection prevention and control assessment framework. Antimicrob Resist Infect Control. 2020;9(1):92. https://doi.org/10.1186/s13756-020-00761-2
9. Zheng CM, Li C, Xiang Q, Xia FF, Chen LP, Zhang SH, et al. Investigation on the status quo of full-time infection control personnel and infection control departments in hospitals and work during the corona virus disease 2019. Contemp Med. 2022;28(14):98–103.
10. Donohue JC. Understanding scientific literature: a Bibliographic approach. Cambridge: The MIT press; 1973.
11. World Health Organization. Core competencies for infection prevention and control professionals. Geneva: WHO Press; 2020.
12. Alsuhaibani M, Kobayashi T, McPherson C, Holley S, Marra AR, Trannel A, et al. Impact of COVID-19 on an infection prevention and control program, Iowa 2020–2021. Am J Infect Control. 2022;50(3):277–82. https://doi.org/10.1016/j.ajic.2021.11.015
13. Herstein JJ, Schwedhelm MM, Vasa A, Biddinger PD, Hewlett AL. Emergency preparedness: what is the future? Antimicrob Steward Healthc Epidemiol. 2021;1(1):e29. https://doi.org/10.1017/ash.2021.190
14. Holdsworth J, Preston A, Gentile P, Rider P, Yallew W, Juno Z. Process for disinfection of N95 respirators during COVID-19 utilizing sterile processing department: a single center acute care hospital. Am J Infect Control. 2021;49(4):489–91. https://doi.org/10.1016/j.ajic.2020.12.004
15. Rebmann T, Alvino RT, Holdsworth JE. Availability and crisis standards of care for personal protective equipment during fall 2020 of the COVID-19 pandemic: a national study by the APIC COVID-19 task force. Am J Infect Control. 2021;49(6):657–62. https://doi.org/10.1016/j.ajic.2021.03.015
16. Rebmann T, Vassallo A, Holdsworth JE. Availability of personal protective equipment and infection prevention supplies during the first month of the COVID-19 pandemic: a national study by the APIC COVID-19 task force. Am J Infect Control. 2021;49(4):434–7. https://doi.org/10.1016/j.ajic.2020.08.029
17. Schildhouse RJ, Gupta A, Greene MT, Fowler KE, Ratz D, Hausman MS, et al. Comparison of the impact of COVID-19 on veterans affairs and non-federal hospitals: a survey of infection prevention specialists. J Gen Intern Med. 2023;38(2):450–5. https://doi.org/10.1007/s11606-022-07961-z
18. Fakih MG, Bufalino A, Sturm L, Huang RH, Ottenbacher A, Saake K, et al. Coronavirus disease 2019 (COVID-19) pandemic, central-line-associated bloodstream infection (CLABSI), and catheter-associated urinary tract infection (CAUTI): the urgent need to refocus on hardwiring prevention efforts. Infect Control Hosp Epidemiol. 2022;43(1):26–31. https://doi.org/10.1017/ice.2021.70
19. Tadavarthy SN, Finnegan K, Bernatowicz G, Lowe E, Coffin SE, Manning M. Developing and implementing an infection prevention and control program for a COVID-19 alternative care site in Philadelphia, PA. Am J Infect Control. 2021;49(1):77–81. https://doi.org/10.1016/j.ajic.2020.07.006
20. Penna AR, Hunter JC, Sanchez GV, Mohelsky R, Barnes LEA, Benowitz I, et al. Evaluation of a virtual training to enhance public health capacity for COVID-19 infection prevention and control in nursing homes. J Public Health Manag Pract. 2022;28(6):682–92. https://doi.org/10.1097/PHH.0000000000001600
21. Rebmann T, Alvino RT, Mazzara RL, Sandcork J. Infection preventionists' experiences during the first nine months of the COVID-19 pandemic: findings from focus groups conducted with association of professionals in infection control &

epidemiology (APIC) members. Am J Infect Control. 2021;49(9):1093–8. https://doi.org/10.1016/j.ajic.2021.07.003
22. Pokrajac N, Schertzer K, Poffenberger CM, Alvarez A, Marin-Nevarez P, Winstead-Derlega C, et al. Mastery learning ensures correct personal protective equipment use in simulated clinical encounters of COVID-19. West J Emerg Med. 2020;21(5):1089–94. https://doi.org/10.5811/westjem.2020.6.48132
23. Collins N, Crowder J, Ishcomer-Aazami J, Apedjihoun D. Perceptions and experiences of frontline urban Indian organization healthcare workers with infection prevention and control during the COVID-19 pandemic. Front Sociol. 2021;6:611961. https://doi.org/10.3389/fsoc.2021.611961
24. Rebmann T, Alvino RT, Mazzara RL, Sandcork J. Rural infection preventionists' experiences during the COVID-19 pandemic: findings from focus groups conducted with association of professionals in infection control & epidemiology (APIC) members. Am J Infect Control. 2021;49(9):1099–104. https://doi.org/10.1016/j.ajic.2021.06.008
25. Cole J, Barnard E. The impact of the COVID-19 pandemic on healthcare acquired infections with multidrug resistant organisms. Am J Infect Control. 2021;49(5):653–4. https://doi.org/10.1016/j.ajic.2020.09.013
26. Cui L, He A, Wang X, Wang Y, Huang X, Ni Z. Development and validation of a competency evaluation model for hospital infection prevention and control practitioners in the post-pandemic era: a mixed methods study. J Hosp Infect. 2022;119:132–40. https://doi.org/10.1016/j.jhin.2021.08.028
27. Ma L, Zou S, Liu Y, LA J, Yang J. The application of hazard vulnerability analysis in the prevention and control of COVID-19 in medical institutions. Iran J Publ Health. 2021;50(2):271–9. https://doi.org/10.18502/ijph.v50i2.5339
28. Zhang X, Wang Y. Prevention and control mechanism for coronavirus disease 2019 epidemic at the primary level: perspective from China. Epidemiol Infect. 2020;148:e161. https://doi.org/10.1017/S0950268820001636
29. Du Q, Zhang D, Hu W, Li X, Xia Q, Wen T, et al. Nosocomial infection of COVID-19: a new challenge for healthcare professionals (Review). Int J Mol Med. 2021;47(4):31. https://doi.org/10.3892/ijmm.2021.4864
30. Tan W, Ye Y, Yang Y, Chen Z, Yang X, Zhu C, et al. Whole-Process emergency training of personal protective equipment helps healthcare workers against COVID-19: design and effect. J Occup Environ Med. 2020;62(6):420–3. https://doi.org/10.1097/JOM.0000000000001877
31. Yao Y, Zha ZH, Li LZ, You CQ, Luo GY, Zeng N. Investigation on the current status of construction of professional team for nosocomial infection in 298 medical institutions in Guizhou province. Chin J Disinfect. 2021;38(9):685–7.
32. Zhang Q, Li Q, Ping BH, Li BZ. Investigation on current status of nosocomial infection management team in Shaanxi province. Chin Health Qual Manag. 2021;28(8):19–23.
33. Zang F, Ge ZJ, Liu J, An HY, Liu B, Hu X, et al. Effect of training on infection prevention and control skills of primary medical staff in Jiangsu province. Chin J Gen Pract. 2021;19(7):1214–7.
34. He Q, Zhao H, Ke YF, Li XN, Xu YF. Investigation on the status of nosocomial infection management in Chinese medicine medical institutions in a province. J Tradit Chin Med Manag. 2020;28(3):34–7.
35. Chen SX, Zhu C, Ye P, Zhu YP. Investigation and analysis of infection management in secondary medical institutions in a city. Chin Health Qual Manag. 2021;28(10):38–41.
36. Cui YW, Wang KK, Li CY, Jiang NZ, Gao XD, Shi QF. Current status of post competency of nosocomial infection control personnel in different grades of medical institutions of Shanghai in 2021. Chin J Nosocomiology. 2023;33(2):281–5. https://doi.org/10.1016/j.pacs.2023.100546
37. Chater AM, Family H, Abraao LM, Burnett E, Castro-Sanchez E, Du Toit B, et al. Influences on nurses' engagement in antimicrobial stewardship behaviours: a multi-country survey using the theoretical domains framework. J Hosp Infect. 2022;129:171–80. https://doi.org/10.1016/j.jhin.2022.07.010
38. Kamere N, Garwe ST, Akinwotu OO, Tuck C, Krockow EM, Yadav S, et al. Scoping review of national antimicrobial stewardship activities in eight African countries and adaptable recommendations. Antibiotics. 2022;11(9):1149. https://doi.org/10.3390/antibiotics11091149
39. Norton EJ, Georgiou I, Fung A, Nazari A, Bandyopadhyay S, Saunders KEA. Personal protective equipment and infection prevention and control: a national survey of UK medical students and interim foundation doctors during the COVID-19 pandemic. J Public Health. 2021;43(1):67–75. https://doi.org/10.1093/pubmed/fdaa187
40. Tomczyk S, Twyman A, de Kraker MEA, Coutinho Rehse AP, Tartari E, Toledo JP, et al. The first WHO global survey on infection prevention and control in health-care facilities. Lancet Infect Dis. 2022;22(6):845–56. https://doi.org/10.1016/S1473-3099(21)00809-4
41. Tartari E, Tomczyk S, Pires D, Zayed B, Coutinho Rehse AP, Kariyo P, et al. Implementation of the infection prevention and control core components at The National level: a global situational analysis. J Hosp Infect. 2021;108:94–103. https://doi.org/10.1016/j.jhin.2020.11.025
42. Puro V, Coppola N, Frasca A, Gentile I, Luzzaro F, Peghetti A, et al. Pillars for prevention and control of healthcare-associated infections: an Italian expert opinion statement. Antimicrob Resist Infect Control. 2022;11(1):87. https://doi.org/10.1186/s13756-022-01125-8
43. Cattelan AM, Sasset L, Di Meco E, Cocchio S, Barbaro F, Cavinato S, et al. An integrated strategy for the prevention of SARS-CoV-2 infection in healthcare workers: a prospective observational study. Int J Environ Res Public Health. 2020;17(16):5785. https://doi.org/10.3390/ijerph17165785
44. Mauro A, Improda N, Zenzeri L, Valitutti F, Vecchione E, Esposito S, et al. Infection control strategy and primary care assistance in campania region during The National lockdown due to COVID-19 outbreak: the experience of two tertiary emergency centers. Ital J Pediatr. 2021;47(1):19. https://doi.org/10.1186/s13052-021-00963-3
45. Mehtar S, Wanyoro A, Ogunsola F, Ameh EA, Nthumba P, Kilpatrick C, et al. Implementation of surgical site infection surveillance in low- and middle-income countries: a position statement for the international society for infectious diseases. Int J Infect Dis. 2020;100:123–31. https://doi.org/10.1016/j.ijid.2020.07.021
46. Patel M. Infection control in dentistry during COVID-19 pandemic: what has changed? Heliyon. 2020;6(10):e05402. https://doi.org/10.1016/j.heliyon.2020.e05402

47. Lingawi HS, Aldahlawi SA, Afifi IK. A COVID-19 university-based dental clinic experience and infection control protocol modification for safe clinical education. Eur J Dent. 2023;17(3):845–54. https://doi.org/10.1055/s-0042-1757467
48. Lohiniva AL, Toura S, Arifulla D, Ollgren J, Lyytikäinen O. Exploring behavioural factors influencing COVID-19-specific infection prevention and control measures in Finland: a mixed-methods study, December 2020 to March 2021. Euro Surveill. 2022;27(40):2100915. https://doi.org/10.2807/1560-7917.ES.2022.27.40.2100915
49. Dekker M, van Mansfeld R, Vandenbroucke-Grauls C, de Bruijne M, Jongerden I. Infection control link nurse programs in Dutch acute care hospitals; a mixed-methods study. Antimicrob Resist Infect Control. 2020;9(1):42. https://doi.org/10.1186/s13756-020-0704-2
50. Sotomayor-Castillo C, Nahidi S, Li C, Macbeth D, Russo PL, Mitchell BG, et al. Infection control professionals' and infectious diseases physicians' knowledge, preparedness, and experiences of managing COVID-19 in Australian healthcare settings. Infect Dis Health. 2021;26(4):249–57. https://doi.org/10.1016/j.idh.2021.05.002
51. Oppong TB, Amponsem-Boateng C, Kyere EKD, Wang Y, Gheisari Z, Oppong EE, et al. Infection prevention and control preparedness level and associated determinants in 56 acute healthcare facilities in Ghana. Infect Drug Resist. 2020;13:4263–71. https://doi.org/10.2147/IDR.S273851
52. Savul S, Lalani FK, Ikram A, Khan MA, Khan MA, Ansari J. Infection prevention and control situation in public hospitals of Islamabad. J Infect Dev Ctries. 2020;14(9):1040–6. https://doi.org/10.3855/jidc.12779
53. Wee LEI, Conceicao EP, Tan JY, Magesparan KD, Amin IBM, Ismail BBS, et al. Unintended consequences of infection prevention and control measures during COVID-19 pandemic. Am J Infect Control. 2021;49(4):469–77. https://doi.org/10.1016/j.ajic.2020.10.019
54. Castro-Sánchez E, Alexander CM, Atchison C, Patel D, Leung W, Calamita ME, et al. Evaluation of a personal protective equipment support programme for staff during the COVID-19 pandemic in London. J Hosp Infect. 2021;109:68–77. https://doi.org/10.1016/j.jhin.2020.12.004
55. World Health Organization. Interim practical manual supporting facility implementation of the WHO guidelines on core components of infection prevention and control programmes. Geneva: WHO; 2018.
56. Dellit TH, Owens RC, McGowan Jr. JE, Gerding DN, Weinstein RA, Burke JP, et al. Infectious diseases society of America and the society for healthcare epidemiology of America guidelines for developing an institutional program to enhance antimicrobial stewardship. Clin Infect Dis. 2007;44(2):159–77. https://doi.org/10.1086/510393
57. The Northern Ireland Regional Infection and Prevention Control ManualStandard precautions. [cited 2019 Oct 29]. Available from: https://www.niinfectioncontrolmanual.net/standard-precautions
58. The Northern Ireland Regional Infection and Prevention Control Manual. Transmission-based precautions. [cited 2019 Oct 29]. Available from: https://www.niinfectioncontrolmanual.net/transmission-based-precautions
59. World Health Organization. Decontamination and reprocessing of medical devices for health care facilities. Geneva: WHO Press; 2016.
60. United States Centers for Disease Control and Prevention. Guidelines for the prevention of intravascular catheter-related infections. [cited 2020 Sep 3]. https://www.cdc.gov/mmwr/preview/mmwrhtml/rr5110a1.htm
61. World Health Organization. Improving infection prevention and control at the health facility: interim practical manual supporting implementation of the WHO guidelines on core components of infection prevention and control programmes. Geneva: WHO Press; 2018.
62. Kamran F, Tang S, Otles E, McEvoy DS, Saleh SN, Gong J, et al. Early identification of patients admitted to hospital for covid-19 at risk of clinical deterioration: model development and multisite external validation study. BMJ. 2022;376:e068576. https://doi.org/10.1136/bmj-2021-068576
63. Anguraj S, Ketan P, Sivaradjy M, Shanmugam L, Jamir I, Cherian A, et al. The effect of hand hygiene audit in COVID intensive care units in a tertiary care hospital in south India. Am J Infect Control. 2021;49(10):1247–51. https://doi.org/10.1016/j.ajic.2021.07.008
64. Lei R, Mohan C. Immunological biomarkers of COVID-19. Crit Rev Immunol. 2020;40(6):497–512. https://doi.org/10.1615/CritRevImmunol.2020035652
65. Reese SM, Gilmartin HM. Infection prevention workforce: potential benefits to educational diversity. Am J Infect Control. 2017;45(6):603–6. https://doi.org/10.1016/j.ajic.2017.03.029

SUPPORTING INFORMATION

Additional supporting information can be found online in the Supporting Information section at the end of this article.

How to cite this article: Chen N, Li S, Kuang Z, Gong T, Zhou W, Wang Y. Identifying a competency improvement strategy for infection prevention and control professionals: a rapid systematic review and cluster analysis. Health Care Sci. 2024;3:53–66. https://doi.org/10.1002/hcs2.81