JAC Antimicrob Resist
https://doi.org/10.1093/jacamr/dlaf081

JAC-Antimicrobial Resistance

Knowledge, practices, educational needs and hospital engagement in Infection Prevention and Control (IPC) among Italian healthcare workers and students: results from a national multicentre survey

Francesco Di Gennaro[1]†, Francesco Vladimiro Segala[1]†, Roberta Papagni[1]*†, Elda De Vita[1]†, Giacomo Guido [1], Luisa Frallonardo[1], Alessandra Vigna[1], Monica Fiorella[1], Davide Capruzzi[1], Marinella Cibelli[1], Annunziata Ilenia Ritacco[1], Luigi Pisani[2,3], Francesca De Palo[1], Pietro Locantore [4], Alessandra Tolin[5], Federica Penco[6], Marianna Meschiari[7,8], Rita Murri[9,10], Massimo Fantoni[9,10], Cristina Mussini[7] and Annalisa Saracino[1]

[1]Department of Precision and Regenerative Medicine and Ionian Area (DiMePRe-J), Clinic of Infectious Diseases, University of Bari 'Aldo Moro', Bari, Italy; [2]Department of Precision and Regenerative Medicine and Ionian Area (DiMePRe-J), Section of Anesthesiology and Intensive Care Medicine, University of Bari 'Aldo Moro', Bari, Italy; [3]Mahidol Oxford Tropical Research Unit, Mahidol University, Bangkok, Thailand; [4]Unit of Endocrinology, Department of Translational Medicine and Surgery, Università Cattolica del Sacro Cuore, Fondazione Policlinico 'A. Gemelli' IRCCS, Rome 00168, Italy; [5]ASL CN1, Occupational Medicine, University of Turin, Turin, Italy; [6]Intermediate Care Unit, Emergency Department, IRCCS Istituto Giannina Gaslini, Genoa, Italy; [7]Department of Surgical, Medical, Dental, and Morphological Sciences, University of Modena and Reggio Emilia, Modena 41124, Italy; [8]Department of Infectious Diseases, Azienda Ospedaliero-Universitaria, Policlinico of Modena, Modena, Italy; [9]U.O.C. Malatte Infettive, Dipartimento di Scienze Mediche e Chirurgiche, Fondazione Policlinico Gemelli IRCCS, Rome, Italy; [10]Sezione di Malattie Infettive, Università Cattolica Sacro Cuore, Rome, Italy

*Corresponding author. E-mail: robertapapagni0@gmail.com
†Equally contributed.

Received 30 December 2024; accepted 15 April 2025

Objective: This study assesses the knowledge, practices, educational needs and hospital engagement in IPC among healthcare workers (HCWs) and students in Italy.

Methods: A national cross-sectional observational study was conducted from April to July 2024. Participants completed a validated questionnaire based on WHO and CDC guidelines. Four outcomes were evaluated: (i) knowledge of IPC, (ii) self-reported compliance, (iii) satisfaction with education and (iv) hospital engagement in IPC.

Results: Among respondents ($n = 1063$, 67.75% female) significant gaps in IPC knowledge were noted, with only 66.1% correctly identifying key hand hygiene moments. Compliance was low, with only 43.3% always adhering to hand hygiene rules. Satisfaction with IPC education was also low (28%). While alcohol-based hand gel was widely available (84.2%), only 36.6% received formal hand hygiene training before onboarding.
Multivariate analysis revealed that female HCWs had higher IPC knowledge [adjusted odds ratio (aOR) 1.55, 95% CI: 1.04–2.31] and better compliance (aOR 1.72, 95% CI: 1.01–2.92). Younger HCWs demonstrated greater knowledge and satisfaction. Surgical ward staff, despite greater education satisfaction, exhibited lower IPC knowledge (aOR 0.53, 95% CI: 0.32–0.87). Nurses and health assistants received more hospital IPC training (aOR 1.59, 95% CI: 1.04–2.46; aOR 5.83, 95% CI: 1.94–18.89, respectively). Finally, the presence of a hospital IPC team positively correlated with all outcomes, including higher IPC knowledge (aOR 2.68, 95% CI: 1.79–4.05) and adherence (aOR 3.4, 95% CI: 1.92–6.3).

Conclusion: The study reveals substantial gaps in IPC knowledge, practices and education among Italian HCWs, emphasizing the urgent need for effective targeted interventions that require robust institutional support.

Introduction

Infection prevention and control (IPC) has been identified as one of the most pressing challenges of our time.[1] Transmission-based precautions, which aim to reduce preventable healthcare-associated infections (HAIs) and kerb the spread of antimicrobial resistance (AMR), are widely recognized as standard medical practices due to the establishment and progressive implementation of evidence-based protocols.[2–4]

Despite these measures, HAIs remain one of the most common adverse events in healthcare delivery globally, particularly in settings with inadequate safety protocols and suboptimal care standards.[5] In high-income countries (HICs), ∼7% of patients in acute care settings acquire HAIs, whereas in low- and middle-income countries, the risk is more than double, averaging 15% and occasionally reaching levels 20 times higher than in HICs.[6,7] The burden of HAIs is staggering. In the EU and European Economic Area, an estimated 8.9 million episodes of HAIs occur annually, including 4.4 million in long-term care facilities.[8] Beyond their well-known economic burden, HAIs exacerbate mental health conditions, diminish quality of life and reduce life expectancy for affected individuals.[9,10] Existing evidence indicates that IPC interventions, a cornerstone of the AMR Global Action Plan, can reduce HAI rates by 35%–70%, regardless of a country's income level.[5]

However, organizational, structural and behavioural barriers often hinder the success of these measures, leading to suboptimal IPC implementation.[10] Several studies have investigated the knowledge, attitudes and practices of specific groups of healthcare workers (HCWs), including nurses, nursing students and physicians, in relation to AMR and IPC.[2,11] Although HCWs demonstrate a strong commitment to IPC and express a desire for education and training, they often report insufficient knowledge of antimicrobial stewardship (AMS) and IPC protocols.[12]

Notably, Italy has been identified as the worst performer in Europe in terms of AMR, as highlighted in the latest 2023 ECDC report.[13] The country exhibits alarmingly high resistance rates, particularly for key pathogens such as *Klebsiella pneumoniae* and *Escherichia coli*, which pose significant challenges to IPC measures in healthcare settings. These findings underscore the urgent need for targeted interventions to enhance IPC knowledge, adherence and hospital engagement among Italian HCWs.

Effective IPC requires informed HCWs, yet compliance is often hampered by insufficient understanding of IPC requirements, precautions and the risks of microorganism transmission. Education and training are critical to improving IPC practices, but even with these interventions gaps in understanding persist. Awareness campaigns should emphasize key topics such as hand hygiene, immunization, appropriate use of personal protective equipment (PPE) and infection evaluation.[14,15] Importantly, knowledge alone does not guarantee adherence to IPC practices, as compliance is influenced by various factors beyond education or experience.

In Italy, existing research has predominantly focused on the knowledge, attitudes and practices of medical students or specific groups of healthcare professionals.[2,16] To our knowledge, no studies have examined IPC knowledge, practices, educational needs and hospital engagement across broad groups of HCWs and students at a national level. Therefore, this study aims to address these gaps through a national survey among HCWs and students, with the goal of identifying modifiable gaps and providing actionable recommendations to enhance compliance and improve healthcare safety.

Methods

Study design and participants

A multicentre, cross-sectional, observational study was conducted between 12 April and 13 July 2024 among HCWs and students residing in 21/21 Italian regions. The study was conducted and reported according to the STROBE guidelines for cross-sectional studies.[17] All health sciences university students and HCWs were eligible for the study, with no defined exclusion criteria.

Using a convenience sampling method, participants were recruited through a social media-based campaign conducted by study authors. According to Italian legislation, HCWs who responded to the survey were categorized into five distinct groups: (i) nurses and obstetricians, (ii) medical specialists, (iii) medical residents, (iv) healthcare assistants (HAs) and (v) students and trainees. There were no exclusion criteria. The study was approved by the institutional board of University of Bari (protocol number ID 5710 14/01/2024).

Survey structure and data collection

An anonymous survey assessing knowledge, behaviours and practices was developed in Italian. The survey was created by a working group of healthcare professionals from three different university hospitals: Policlinico di Bari, Ospedale 'Giovanni XXIII' in Bari, Policlinico 'Agostino Gemelli' in Rome and Azienda Ospedaliero-Universitaria di Modena. Survey questions were based on the 'Hand Hygiene Knowledge Questionnaire for Health-Care Workers' developed by WHO and on the 'Checklist to assess students' practice of infection control measures' developed by CDC.[18,19]

The survey was then reviewed and validated through a consensus of five IPC experts (M.M., M.F., R.M., F.P., A.S.). The finalized version of the questionnaire included 77 questions, from an original 85-item questionnaire. The questionnaire was structured with the following sections: participant demographics, participant university education on IPC and participant knowledge, attitudes and practices in IPC. We also included a section on hospital characteristics and level of engagement in IPC. This section inquired whether the hospital was public, private or public–private; whether a dedicated IPC team was present at the time of the survey; whether alcohol-based gel solutions were available in all rooms and whether dedicated educational sessions on IPC were offered to HCWs.

After the questionnaire was validated by the working group, a REDCap project was created, incorporating branching logic where possible to reduce the response time.[20] The survey was then made accessible by the study authors via a link and a QR code, which were distributed at hospital events, university lectures and on social media groups of HCWs. Before taking the survey, respondents had to provide informed consent to take part into the study.

Data management and statistical analysis

Different typologies of postgraduate medical speciality were classified into clinical, clinical services, intensive care units (ICUs) and surgical areas as for the Italian Ministry of University and Research classification (DM 68/2015). Italian regions were categorized into Northern, Central and Southern Italy following the classification system used by the Italian National Institute of Statistics.[21]

To assess the associations between HCWs' knowledge, attitudes and practices and the characteristics of both the HCWs and the hospitals,

we used a multilevel logistic regression model with a random intercept. This model accounted for two levels: individual-level (level 1) and hospital-level (level 2) characteristics. We also estimated the proportion of variance attributable to the clustering effect.

To identify the factors associated with the knowledge, practices and education of study participants, we evaluated four outcomes: the level of knowledge of HCWs and students concerning IPC (outcome 1), the self-reported compliance with IPC practices during daily activities (outcome 2), the respondents' level of satisfaction with their university education in terms of IPC (outcome 3) and the level of hospital engagement in terms of IPC (outcome 4). The binary variables were constructed as follows: outcome 1 ('Knowledge') was coded as 1 if the respondent identified 'after touching the patient' as one of the five moments for hand hygiene; outcome 2 ('Practice') was coded as 1 if participants declared that they 'always' or 'often' wear gloves before touching the patient with exposure to bodily fluids, and 0 if they answered 'sometimes', 'rarely' or 'never'; outcome 3 ('Education') was coded as 1 if participants declared that their level of satisfaction with the IPC teaching provided by their university was at least 7/10, and 0 if it was <7; outcome 4 ('Hospital Engagement') was coded as 1 if the respondent's hospital offered a course on hand hygiene before the start of work activity, and 0 otherwise.

We integrated all HCWs and hospital variables into a multilevel logistic regression model. For 3/4 outcomes, we compared two models: the model containing only participant's characteristics variables cross-tabulated with each outcome (models 1, 3 and 5) and the full model (models 2, 4 and 6) including both participant characteristic variables and hospital characteristic variables cross-tabulated with each outcome. In Model 7, investigating outcome 4, only pertaining variables were included. To minimize biases, students were excluded from the multivariable analysis. The full models are presented as forest plots for each outcome. Statistical analysis was conducted using RStudio software (version 2024.04.2 + 764).

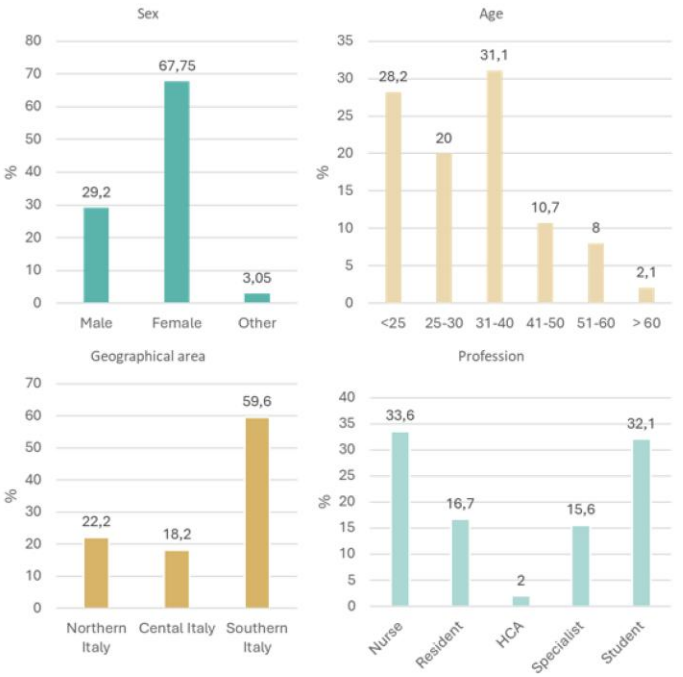

Figure 1. Sociodemographic characteristics of study participants ($n = 1063$). Participant's distribution based on gender identity, age group, geographic area of employment and profession.

Results

Sociodemographic of study participants

Among the 1063 participants (67.75% female), 79.29% were under the age of 40. Notably, over one-third (32.1%) of those who disclosed their occupation (1048 out of 1063) were students, while nursing resulted the most represented profession (33.6%). A significant majority reported working or training in public hospitals (83.7%) and at hospitals in Southern Italy (59.6%) (Figure 1).

Attitude

The study reveals a strongly positive attitude towards IPC among HCWs and students. In fact, almost all of them agreed with the need for monitoring IPC practice in their units (92%), establishing mandatory IPC training sessions (91%) and implementing undergraduate IPC education (89%) (Figure 2).

Despite this, HCWs showed a poor commitment to the education of patients and their family, with the lowest rates observed among physicians (specialists and residents) (Figure 3).

Knowledge

Considering the knowledge related to one of the fundamental practices of IPC, hand hygiene, significant gaps emerged among HCWs and students. Notably, only HAs exceeded the 50% threshold (52.4%) in providing the correct response regarding the minimum duration for hand rubbing with alcohol-based gel. Furthermore, in all professional categories <70% of respondents correctly identified handwashing after patient contact as one of the key moments for hand hygiene, with HAs showing the lowest correct response rate (38.1%) (Table S1, available as Supplementary data at *JAC-AMR* Online).

Regarding the knowledge of contact isolation rules, >70% of HCWs and students correctly reported that it requires the use of a disposable gown. By contrast, when it comes to the PPE required for droplet isolation, very low rates of correct responses were observed across all professional categories (nurses 11.6%, residents 14.9%, HAs 14.3%, specialists 20.1% and students 7.7%) (Table S1).

In the multilevel logistic regression analysis of Model 1 (individual-level variables) female gender was significantly associated with higher knowledge [adjusted odds ratio (aOR) 1.55 (95% CI: 1.04–2.31), $P < 0.05$]. Conversely, a negative correlation was found with all age groups over forty [e.g. >60 years: aOR 0.03 (95% CI: 0–0.17), $P < 0.001$] and with working in clinical services [aOR 0.59 (95% CI: 0.37–0.95), $P < 0.05$] and surgical departments [aOR 0.53 (95% CI: 0.32–0.87), $P < 0.05$] (Table S2).

Model 2 (full model) confirmed the same correlations found in Model 1 and, in addition, a positive correlation between the presence of a hospital IPC teams and staff knowledge [2.68 (95% CI: 1.79–4.05), $P < 0.001$] emerged (Figure 4).

Practice

Despite most respondents from all professional categories reporting the availability of PPE (82.2%) and hand sanitizer (84.2%) in their units, self-reported adherence to hand hygiene protocols resulted low. In fact, <70% of respondents in nearly all professional categories (HAs 57.1%, residents 66.9%, specialists

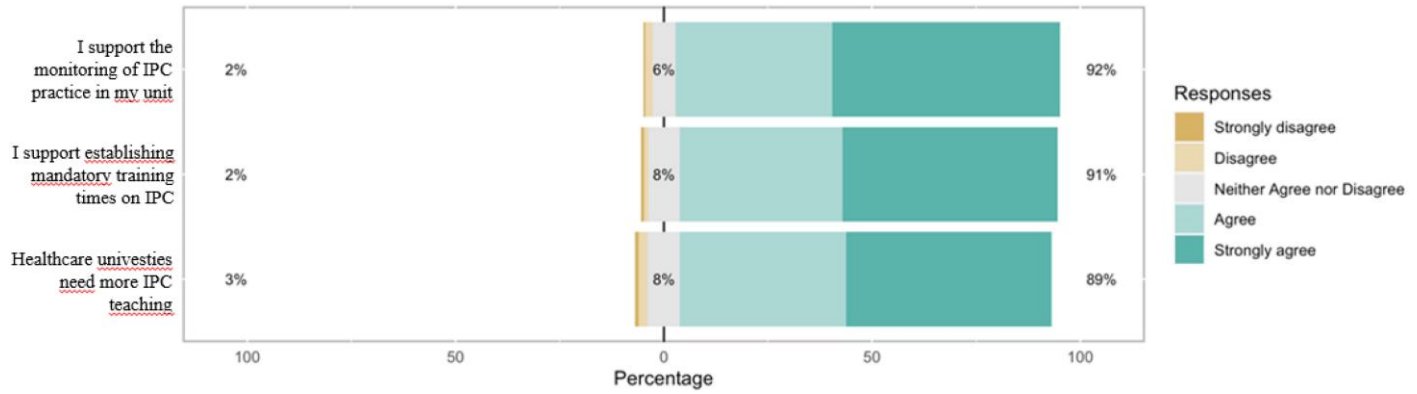

Figure 2. Attitudes towards IPC education and surveillance among study participants. Most participants strongly agree (dark green) or agree (light green) with the need for monitoring IPC practice in their units, establishing mandatory training times for IPC and implementing IPC education during undergraduate studies.

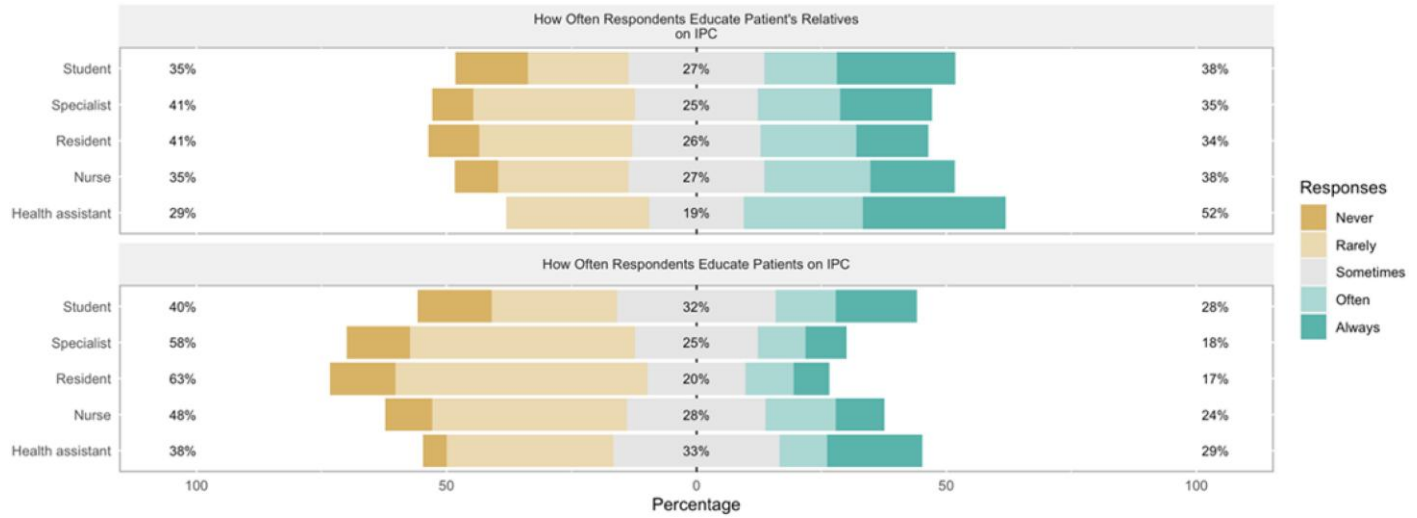

Figure 3. Study participants' engagement in IPC education of patients and their relatives on the workplace, stratified for profession. The percentages on the right represent the sum of the 'often' (light green) and 'always' (dark green) response rates to the questions 'How often do you educate patients' relatives about IPC?' (above) and 'How often do you educate patients about IPC?' (below). The percentages on the left represent the sum of the 'Never' (dark brown) and 'Rarely' (light brown) response rates to the same questions.

69.5%) indicated that they always or almost always follow good handwashing practices during patient care activities, with the only exception of nurses (74.2%).

Regarding use of gloves, most respondents (83.4%) correctly reported always or almost always wearing gloves during care procedures that expose them to patients' bodily fluids, but, on the other hand, 59% reported to use gloves even without exposure to biological fluids (Table S1).

In the multivariate analysis of Model 3 (individual-level variables), female gender [aOR 1.89 (95% CI: 1.14–3.11), $P<0.05$] and working in ICUs [aOR 3.74 (95% CI: 1.28–15.97), $P<0.05$] resulted significantly associated with a higher compliance with IPC practices (Table S2).

With the addition of hospital-related variables in Model 4, the positive correlation between female gender and adherence to IPC guidelines was confirmed [aOR 1.72 (95% CI: 1.01–2.92), $P<0.05$], while a negative correlation with working in hospital in Northern Italy was found [aOR 0.42 (95%CI: 0.19–0.89) $P<0.05$]. Additionally, the positive impact of the presence of a hospital IPC team on compliance with IPC practices [aOR 3.4 (95% CI: 1.92–6.3), $P<0.001$] emerged (Figure 4).

Education

Overall satisfaction with IPC education was very low, with only 28% of respondents providing a score of 7 or higher out of 10 on the corresponding question.

In the descriptive analysis stratified by profession, students demonstrate greater satisfaction with 41.1% of them providing a score of 7 or higher, followed by nurses (29.0%), HAs (23.8%) and last, medical residents and specialists (15.4% and 11.6%, respectively) (Table S1).

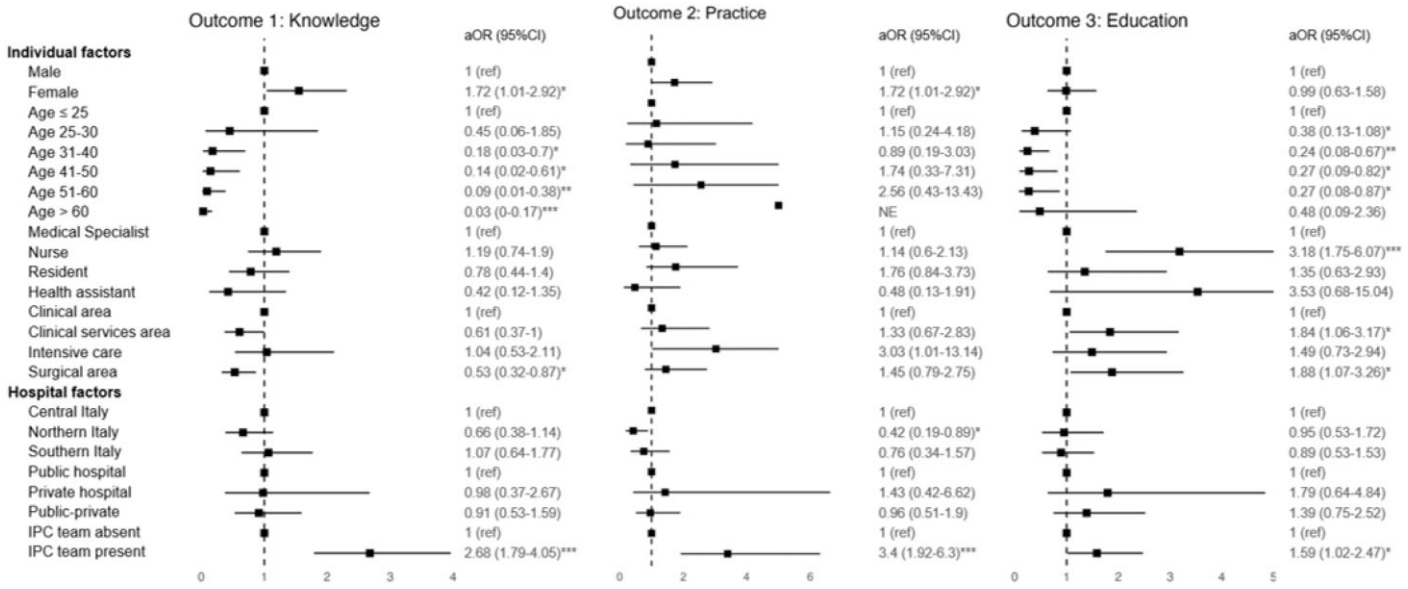

Figure 4. Forest plots of the multilevel multivariate models for the outcomes 'Knowledge', 'Practice' and 'Education' by individual-level and hospital-level variables. Outcome 1 is knowledge of hand hygiene moments (as proxy of IPC knowledge); outcome 2 is the consistent habit of wearing gloves before touching the patient with bodily fluids exposure (as proxy of IPC practice) and outcome 3 is the level of satisfaction about participant's university education in terms of IPC (as proxy of IPC educational offer). ***$P < 0$ 001; **$P < 0.01$, *$P < 0.05$.

In the multivariate analysis of Model 5 (individual-level variables), nurses [aOR 3.09 (95% CI: 1.72–5.85) $P < 0.001$], staff in clinical services [aOR 1.83 (95% CI: 1.07–3.11) $P < 0.05$] and surgical areas [aOR 1.75 (95% CI: 1.03–2.97) $P < 0.05$] showed higher satisfaction regarding IPC education. By contrast, a negative correlation was found with all age groups >30 years (Table S2).

In Model 6 including individual and hospital-related variables, these correlations were confirmed; additionally, the presence of a hospital IPC team emerged as a factor significantly contributing to greater satisfaction with education among HCWs (aOR 1.59 [95% CI: 1.02–2.47] $P < 0.05$) (Figure 4).

Hospital engagement

Despite, as previously mentioned, hospitals resulted equipped with the necessary medical devices required for IPC, only 18.9% of respondents reported the presence of a monitoring system for hand hygiene compliance in their workplace. Of note, only 39.2% indicated to be aware of the presence of an IPC team in their hospital and nearly 40% of respondents disclosed the lack of any kind of guideline regarding IPC in their workplace (Figure 5).

Furthermore, training and education provided by the hospital or department was found to be very low. In fact, only 45.2% of nurses and 57.1% of HAs reported having received formal hand hygiene training before professional onboarding, with even lower rates among physicians (residents 26.3%, specialists 32.9%). Additionally, 60.4% of participants revealed a lack of regular IPC training (Table S1).

At multivariate analysis, nurses [aOR 1.59 (95% CI: 1.04–2.46), $P < 0.05$] and HAs [aOR 5.83 (95% CI: 1.94–18.89), $P < 0.01$] were found to have received more training before professional onboarding. Private hospitals [aOR 3.05 (95% CI: 1.32–7.28), $P < 0.01$] and those with dedicated IPC teams [aOR 3.7 (95% CI: 2.59–5.34), $P < 0.001$] resulted more engaged in implementing IPC practices (Figure 6).

Discussion

This study provides crucial insights into the knowledge, attitudes, practices and education regarding IPC among HCWs and students in Italy, highlighting several gaps and associated key factors.

With a significant percentage of students and HCWs under the age of 40, the participant population is noticeably young. Reaching students and younger HCWs was made easier by the decision to distribute the questionnaire via social media. At the same time, younger respondents' high involvement rates can indicate that they are more aware of IPC issues than their older counterparts. This is further supported by the multilevel logistic regression's finding that a younger age positively correlates with both IPC knowledge and satisfaction with IPC education.

This contrasts with findings from other studies, in which knowledge and adherence to IPC rules resulted to be higher with older age and seniority, probably due to the greater experience and formal and informal periodical training accumulated over the years by older HCWs.[22]

Our findings reveal that significant knowledge gaps in IPC are present across all age groups, highlighting a systemic educational deficiency rather than an issue limited to specific professional categories. Several factors may contribute to this widespread lack of knowledge. First, IPC training has historically been inconsistent, particularly for older HCWs who may not have received structured IPC education during their initial professional training. Over time, the absence of standardized refresher courses has probably contributed to a progressive decline in knowledge.

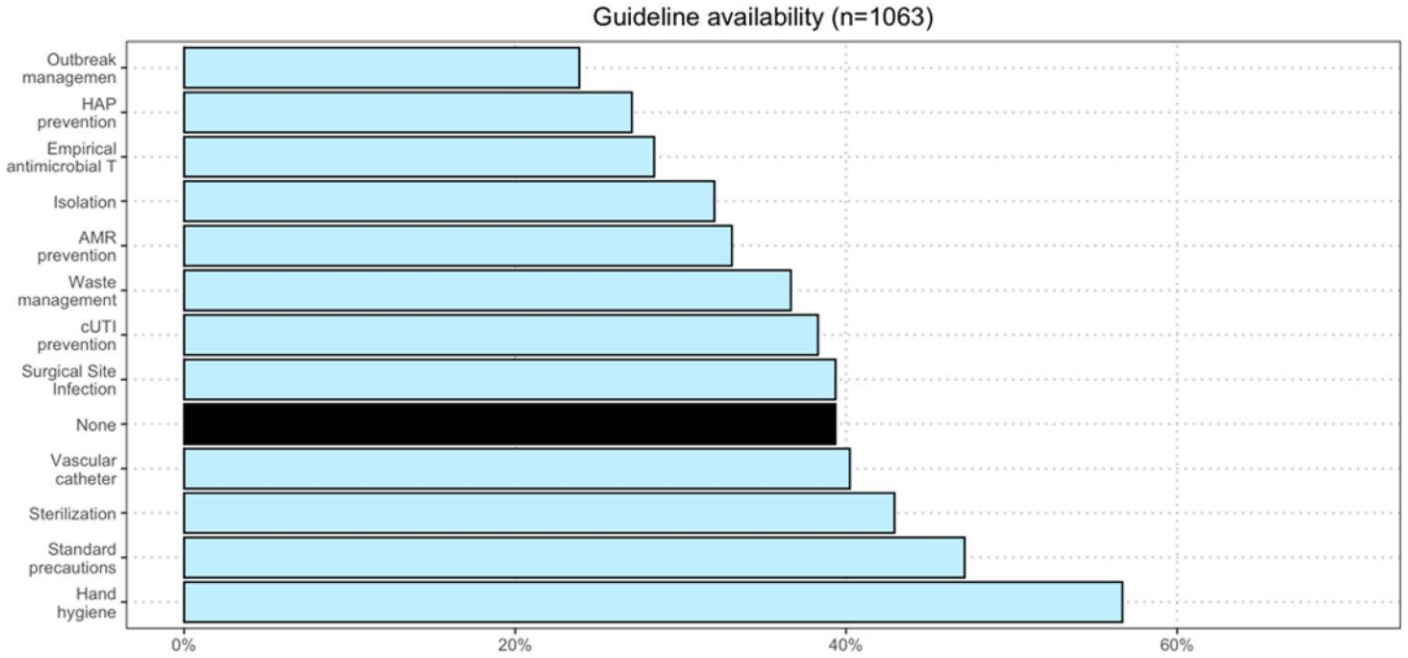

Figure 5. Availability of IPC guidelines at respondent workplace. Nearly 40% of respondents reported the absence of any type of IPC guidelines in their workplace. When present, the most frequently reported were hand hygiene guidelines.

Additionally, while IPC is often included in academic curricula, the emphasis tends to be placed on theoretical principles rather than on practical implementation, reducing the effectiveness of training programmes in fostering adherence to IPC protocols in clinical practice. Another contributing factor could be the limited availability of continuous professional development opportunities, as IPC education is frequently provided at the beginning of a healthcare career but is not necessarily reinforced throughout professional practice. The COVID-19 pandemic may have further exacerbated these gaps, as emergency-driven IPC training, while essential, was not always structured for long-term retention across different professional groups.[23,24] Strengthening IPC education at all career stages is essential to address these shortcomings. A structured and mandatory approach to IPC training, including periodic refresher courses, could help ensure that knowledge remains up to date. Furthermore, adopting more interactive and practical training methods, such as simulation-based learning, may enhance the effectiveness of IPC education. Finally, institutional support plays a key role in reinforcing IPC knowledge and adherence, underscoring the need for continuous educational efforts rather than one-time training sessions.

The study also shows gender disparities in IPC. Women, in addition to being the most represented (67.7%), were found to have greater knowledge, adherence to IPC guidelines and satisfaction with IPC education, suggesting greater awareness and engagement with IPC issues among them. These results are consistent with the findings of a recent Knowledge, Attitude and Practice (KAP) assessment on AMR among Italian nurses, which found a positive correlation between female gender and KAP levels.[2] However, we did not find such a correlation in other studies in our literature review.[22]

Interestingly, in our study regional differences were observed, with a higher participation of HCWs and students from the southern regions of Italy and a significantly lower compliance with IPC practices among HCWs from the northern regions. These data could reflect a different sensitivity to the issue of HAIs and AMR across Italian regions, which cannot be explained by the prevalence of HAIs in different regions as this does not present a north–south gradient but has a patchy distribution.[25] The pronounced regional disparities in IPC practices suggest the need for tailored, region-specific strategies, ensuring equitable access to standardized training programmes, resource allocation, and institutional support across all areas of Italy. The data obtained from the multivariate analysis and the descriptive analysis stratified by profession highlight important insights into the professional categories involved in the study, revealing specific challenges for each of them. Although HAs resulted to have received substantial hospital training before professional onboarding, they exhibited the lowest rate of correct answers to fundamental questions related to hand hygiene and the use of PPE. These results highlight how pre-employment training alone is not sufficient to guarantee good knowledge and adherence to IPC rules, if not associated with effective formal education on IPC during studies and ongoing training after starting work activity. The same applies to nurses, who demonstrated insufficient IPC knowledge even though they resulted the most represented profession in the study and expressed greater satisfaction with their IPC education and hospital training.

On the other hand, despite receiving notably poor undergraduate education and hospital training in IPC, doctors did not show significantly lower knowledge or adherence to IPC standards, which nonetheless remained poor and inadequate.

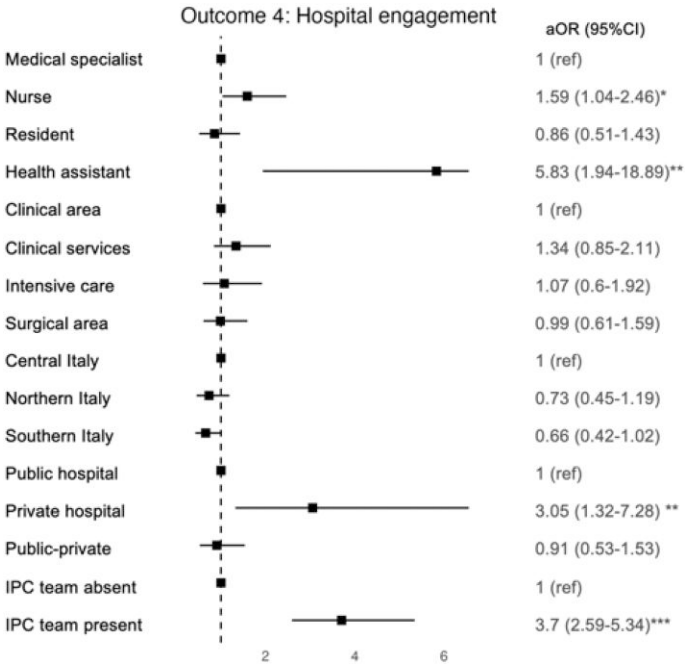

Figure 6. Forest plot of the multilevel multivariate models for the outcome 'Hospital engagement' by individual-level and hospital-level variables. Outcome 4 is the presence of a handwashing course on hand hygiene before the start of work activity in participant's hospital (as proxy of hospital-level IPC engagement). ***$P < 0$ 001; **$P < 0.01$, *$P < 0.05$.

These findings contrast with those reported in other studies in the literature, where both doctors and nurses generally demonstrate good knowledge of IPC measures and CDC hand hygiene guidelines, and doctors typically result in being less observant of accepted IPC practices compared to other professional categories.[22,26]

Interestingly, the great adherence to IPC practices observed among ICU staff suggests a particular sensitivity and commitment in a context where HAIs constitute a constant threat to critically ill patients.

Finally, the low level of knowledge recorded among HCWs of surgical wards, despite greater satisfaction with their education, highlights a decoupling between training, knowledge and practices.

Therefore, our data bring up issues related to the adequacy of IPC training methods, underlining the need to rethink them and measure their effectiveness, especially in settings particularly susceptible to the onset of HAIs, such as surgical departments and ICUs.

The study also reveals a widespread availability of hand sanitizers and PPE in hospitals. However, the adequate provision of these medical supplies is not associated with sufficient knowledge of their proper use to ensure correct application. For example, the widespread use of gloves without exposure to the patient's bodily fluids or the use of FFP2 masks for isolation from droplets, revealed by our study, are practices that contradict international guidelines and contribute to waste of resources and environmental pollution.[27] This underlines how the role of the hospital in IPC is not limited to providing PPE and other medical devices but requires a commitment to ensure continuous training of staff to protect both patients and HCWs and reduce healthcare costs and environmental impact.

In this context, a key role could be played by the hospital IPC team. In fact, several studies have shown that the presence of a dedicated IPC team and protocols significantly increases HCWs' adherence to IPC protocols, thereby reducing the incidence of HAIs.[28,29]

On the other hand, in a meta-analysis, Thandar *et al*. found that while the presence of IPC teams was correlated with increased knowledge and better adherence to IPC practices among nurses, it was not significantly associated with a reduction in HAIs. However, as highlighted by the authors themselves, all the nine studies included in the meta-analysis were of low quality and further evidence is needed.[30]

Our study clearly shows that the presence of an IPC team in hospitals has a positive impact on all the outcomes considered, suggesting it could play a key role in IPC implementation, identifying knowledge gaps and adherence barriers across various professional categories and departments, then developing and evaluating tailored programmes based on these needs. Therefore, institutional support should aim to implement this model, especially in public and under-resourced hospitals. In addition, these findings underscore the critical role of medical education in addressing AMR, emphasizing the need for structured and mandatory IPC training. Integrating IPC and AMS into both undergraduate and postgraduate curricula is essential to ensure that future HCWs develop the necessary competencies for responsible antibiotic use and infection prevention.

While the distribution of the questionnaire through social media allowed for rapid and nationwide dissemination, it may have also introduced selection bias, as voluntary respondents might have been more sensitive and committed to IPC-related topics. This could have led to an overestimation of IPC knowledge, practices and education among HCWs. Additionally, the reliance on self-reported data rather than direct observations introduces the possibility of recall bias and social desirability bias, potentially affecting the accuracy of responses. Self-completion of the questionnaire, while facilitating broad participation, may have also resulted in incompleteness or inaccuracies compared to assisted administration. Future studies should consider incorporating direct observational methods or randomized sampling approaches to obtain more objective measurements of IPC adherence and validate these findings.

Despite these limitations, this study provides valuable insights for health policy and educational strategies, emphasizing the urgent need for multilevel interventions to strengthen IPC and combat AMR. Updating health science curricula to ensure comprehensive IPC and AMS training is crucial for equipping future HCWs with the necessary skills and awareness. Additionally, targeted and ongoing IPC training programmes must be implemented across all career stages to maintain adherence to best practices. Institutional support should be prioritized, particularly in public and under-resourced hospitals, to ensure equitable access to resources, structured IPC programmes and continuous monitoring. Strengthening governmental policies to support IPC and AMR containment at a national level is equally essential. A holistic approach that integrates medical, societal and environmental strategies is critical in addressing IPC challenges and

AMR. Recognizing the interconnectedness of human, animal and environmental health, efforts should extend beyond healthcare settings. Given that 74% of antibiotics are used in intensive farming, as highlighted by the World Organization for Animal Health (WOAH), tackling AMR must also involve reducing antibiotic use in agriculture, promoting sustainable food systems and fostering individual behavioural changes to limit unnecessary antibiotic consumption.[31,32] These comprehensive measures are essential to fostering a culture of safety for both staff and patients while contributing to the global effort to combat HAIs and AMR.

Funding

This research did not receive any specific grant from funding agencies in the public, commercial or not-for-profit sectors. This study was carried out as part of routine work.

Transparency declarations

None to declare.

Author contributions

Conceptualization was developed by F.D.G. The questionnaire draft was prepared by G.G. and L.F. Questionnaire validation was conducted by M.M., M.F., R.M., F.P. and A.S. Dissemination of the questionnaire was the responsibility of A.V., M.F., M.C., D.C., A.I.R., F.D.P. and A.T. Data extraction and data analysis were carried out by F.V.S. Writing and preparation of the original draft was done by R.P. and E.D.V. The draft was reviewed by L.P., P.L. and F.D.G. The study was supervised by A.S. and C.M. All authors have read and agreed to the published version of the paper.

Supplementary data

Tables S1 and S2 are available as Supplementary data at *JAC-AMR* Online.

References

1 Gilbert GL, Kerridge I. What is needed to sustain improvements in hospital practices post-COVID-19? A qualitative study of interprofessional dissonance in hospital infection prevention and control. *BMC Health Serv Res* 2022; **22**: 504. https://doi.org/10.1186/s12913-022-07801-0

2 De Vita E, Segala FV, Frallonardo L *et al.* Knowledge, attitudes, and practices toward antimicrobial resistance among young Italian nurses and students: a multicenter, cross-sectional study. *Ann Glob Health* 2024; **90**: 46. https://doi.org/10.5334/aogh.4488

3 WHO. *Report on the Burden of Endemic Health Care-Associated Infection Worldwide*. World Health Organization, 2011. https://apps.who.int/iris/bitstream/handle/10665/80135/9789241501507_eng.pdf;jsessionid=DAB649CCFF0B8DF3830929DF338348F1?sequence=1.

4 ECDC. Point prevalence survey of healthcare associated infections and antimicrobial use in European acute care hospitals 2022–2023. 2024. https://www.ecdc.europa.eu/en/publications-data/PPS-HAI-AMR-acute-care-europe-2022-2023.

5 WHO. *Global Report on Infection Prevention and Control*. World Health Organization, 2022. https://www.who.int/publications/i/item/9789240051164.

6 OECD, WHO. Addressing the burden of infections and antimicrobial resistance associated with health care—focus on G7 countries. 2022. https://www.oecd.org/health/Addressing-burden-of-infections-and-AMR-associated-with-health-care.pdf.

7 Allegranzi B, Nejad SB, Combescure C *et al.* Burden of endemic health-care associated infection in developing countries: systematic review and meta-analysis. *Lancet* 2011; **377**(9761): 228–41. https://doi.org/10.1016/S0140-6736(10)61458-4

8 Suetens C, Latour K, Kärki T *et al.* Prevalence of healthcare-associated infections, estimated incidence and composite antimicrobial resistance index in acute care hospitals and long-term care facilities: results from two European point prevalence surveys, 2016 to 2017. *Euro Surveill* 2018; **23**: 1800516. https://doi.org/10.2807/1560-7917.ES.2018.23.46.1800516

9 WHO. Global action plan on antimicrobial resistance. 2016. https://www.who.int/publications/i/item/9789241509763.

10 Stone PW, Braccia D, Larson E. Systematic review of economic analyses of health care-associated infections. *Am J Infect Control* 2005; **33**: 501–9. https://doi.org/10.1016/j.ajic.2005.04.246

11 Griffiths P, Renz A, Hughes J *et al.* Impact of organisation and management factors on infection control in hospitals: a scoping review. *J Hosp Infect* 2009; **73**: 1–14. https://doi.org/10.1016/j.jhin.2009.05.003

12 Erasmus V, Daha TJ, Brug H *et al.* Systematic review of studies on compliance with hand hygiene guidelines in hospital care. *Infect Control Hosp Epidemiol* 2010; **31**: 283–94. https://doi.org/10.1086/650451

13 ECDC. Consolidated annual activity report 2023, 2024. https://www.ecdc.europa.eu/sites/default/files/documents/consolidated-annual-activity-report-2023_1.pdf.

14 WHO. Standard precautions: the role of personal protective equipment. In: Infection Prevention and Control [Online Course Series]. World Health Organization, 2021. https://www.classcentral.com/course/openwho-ipc-sp-ppe-en-96825.

15 WHO. World AMR Awareness Week. World Health Organization, 2024. https://www.who.int/campaigns/world-amr-awareness-week.

16 Barchitta M, Sabbatucci M, Furiozzi F *et al.* Knowledge, attitudes and behaviors on antibiotic use and resistance among healthcare workers in Italy, 2019: investigation by a clustering method. *Antimicrob Resist Infect Control* 2021; **10**: 134. https://doi.org/10.1186/s13756-021-01002-w

17 von Elm E, Altman DG, Egger M *et al.* The Strengthening the Reporting of Observational Studies in Epidemiology (STROBE) statement: guidelines for reporting observational studies. *Lancet* 2007; **370**(9596): 1453–7. https://doi.org/10.1016/S0140-6736(07)61602-X

18 WHO. Hand hygiene monitoring tools. 2024. https://www.who.int/teams/integrated-health-services/infection-prevention-control/hand-hygiene/monitoring-tools.

19 CDC. Tools and resources to help healthcare providers to implement infection control measures and prevent healthcare-associated infections. 2024. https://www.cdc.gov/infection-control/php/tools/index.html.

20 Harris PA, Taylor R, Minor BL *et al.* The REDCap consortium: building an international community of software platform partners. *J Biomed Inform* 2019; **95**: 103208. https://doi.org/10.1016/j.jbi.2019.103208

21 Istituto Nazionale di Statistica (ISTAT). Confini delle unità amministrative a fini statistici. 2024. https://www.istat.it/notizia/confini-delle-unita-amministrative-a-fini-statistici-al-1-gennaio-2018-2.

22 Alhumaid S, Al Mutair A, Al Alawi Z *et al.* Knowledge of infection prevention and control among healthcare workers and factors influencing compliance: a systematic review. *Antimicrob Resist Infect Control* 2021; **10**: 86. https://doi.org/10.1186/s13756-021-00957-0

23 Wilson J. Infection prevention and control in the COVID-19 pandemic: what have we learnt? *J Infect Prev* 2021; **22**: 5–6. https://doi.org/10.1177/1757177420984914

24 Żółtowska B, Barańska I, Szczerbińska K *et al.* Preparedness of health care workers and medical students in university hospital in Krakow for COVID-19 pandemic within the CRACoV project. *J Clin Med* 2021; **10**: 3487. https://doi.org/10.3390/jcm10163487

25 PPS3 Working Group. Sorveglianza mediante prevalenza puntuale delle infezioni correlate all'assistenza e sull'uso di antibiotici negli ospedali per acuti (PPS3)—Report riassuntivo. Dipartimento di Scienze della Sanità Pubblica e Pediatriche, Università degli Studi di Torino, 2023. https://www.epicentro.iss.it/sorveglianza-ica/pdf/Summary%20report%20PPS3.pdf.

26 Licata F, Viscomi C, Angelillo S *et al*. Adherence with infection prevention and control measures among Italian healthcare workers: lessons from the COVID-19 pandemic to tackle future ones. *J Infect Public Health* 2024; **17**: 122–9. https://doi.org/10.1016/j.jiph.2023.10.031

27 WHO. Infection prevention and control. 2024. https://www.who.int/teams/integrated-health-services/infection-prevention-control.

28 Ista E, van der Hoven B, Kornelisse RF *et al*. Effectiveness of insertion and maintenance bundles to prevent central-line-associated bloodstream infections in critically ill patients of all ages: a systematic review and meta-analysis. *Lancet Infect Dis* 2016; **16**: 724–34. https://doi.org/10.1016/S1473-3099(15)00409-0

29 Furuya EY, Dick AW, Herzig CTA *et al*. Central line-associated bloodstream infection reduction and bundle compliance in intensive care units: a national study. *Infect Control Hosp Epidemiol* 2016; **37**: 805–10. https://doi.org/10.1017/ice.2016.67

30 Thandar MM, Rahman MO, Haruyama R *et al*. Effectiveness of infection control teams in reducing healthcare-associated infections: a systematic review and meta-analysis. *Int J Environ Res Public Health* 2022; **19**: 17075. https://doi.org/10.3390/ijerph192417075

31 World Organisation for Animal Health (WOAH). Annual Report on Antimicrobial Agents Intended for Use in Animals. WOAH, 2022. https://www.woah.org/en/article-types/annual-report/.

32 Segala FV, Guido G, Stroffolini G *et al*. Insights into the ecological and climate crisis: emerging infections threatening human health. *Acta Trop* 2025; **262**: 107531. https://doi.org/10.1016/j.actatropica.2025.107531