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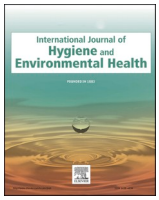

Infection prevention and control knowledge and educational needs among nurses in healthcare settings: results from the Hygeia European survey☆

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ABSTRACT

Knowledge of infectious agents, modes of transmission, and routes of spread play a central role in planning and performing infection prevention and control (IPC) procedures. The European Hygeia survey involved an online questionnaire that was administered from March 2025 to August 2025 to nurses from acute Hospitals and long-term facilities in Italy, Spain, Sweden and Turkey, to monitor their training on hygiene and related topics, in order to provide them up-to-date, reliable and easily accessible professional education and training to strengthen their knowledge on IPC procedures. A total of 438 nurses were included in the study; their median age was 42 years and 368 (84%) were women and 66 (15%) men; 4 (1%) not stated. Most nurses attended at least one hygiene course (321, 75%), 364 (84%) nurses were interested in attending a hygiene course. There were a few statistically significant differences in education level, in particular, nurses with university degree had a greater self-perceived knowledge in hygiene and prevention with adjusted Odds Ratios (aOR) = 3.77, CI: 1.38-10.30, p = 0.010 and infections (aOR = 2.96, CI: 1.09-8.01, p = 0.033) than nurses with diploma. Our study showed most nurses had a good self-perceived knowledge in hygiene prevention and protection measures and were willing to take part in future courses on this subject. Greatest knowledge deficiencies were related to disinfection and sterilization and infection control fields, future education courses should aim to address this issue.

1. Introduction

Healthcare-associated infections (HAIs) are a major threat for patients and healthcare workers (HCWs), for this reason knowledge of infection prevention and control (IPC) procedures must be a top priority for national health care programs, especially in resource constrained countries (WHO, 2018). Knowledge of infectious agents, modes of transmission, and routes of spread play a central role in planning and implementing IPC. Poor or inadequate knowledge and incorrect attitudes among HCWs can directly influence their practices and lead the spread of infective diseases (Khatrawi et al., 2023).

IPC procedures require a multimodal strategy through the application of multiple intervention measures, including training and continuous updating on preventive measures, the dissemination of technical skills and the implementation of evidence-based healthcare practices. Staff involved in health, social-health and residential care often does not have adequate training on the prevention of the risk of HAIs and neglects updating on prevention measures. Lack of knowledge about the adequacy, effectiveness and use of IPC measures leads to poor compliance. Education and training are the cornerstones to overcome these barriers and improve IPC (Alhumaid et al., 2021).

The World Health Organization (WHO) promotes the integration of IPC education into undergraduate nursing curricula, in order to support students with adequate knowledge and skills to implement evidence-based practices on IPC in clinical settings (WHO, 2024). However, a recent review and several European studies reported a significant theoretical gap on epidemiology, transmission mechanisms, and risk factors for HAIs, in particular between theoretical understanding and practical application of IPC among nursing students and underlined the improvement of knowledge with academic progression, clinical

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experience, and the use of active and contextualized teaching strategies (Giordano et al., 2025; Ojo and Ojo, 2017; Parreira et al., 2022; Benedetti et al., 2023; di Gennaro et al., 2025). Changing the behavior of HCWs may require complex approaches and several factors could influence adherence to IPC guidelines (Houghton et al., 2020; Chapman et al., 2020; Silva et al., 2021).

Few data are available on European educational needs in IPC. In this context, the European Hygeia project (HYGEIA project) was conceived, to provide an up-to-date, reliable, and easily accessible professional education and training to help implement and strengthen knowledge regarding the prevention of the transmission of pathogenic microorganisms in healthcare settings, in particular the third part of the project involved an international survey to assess the training needs of nurses in healthcare settings on hygiene and IPC-related topics.

2. Material and method

2.1. Ethics

Ethical Committee of the Polytechnic University of Marche approval was received on 7th March 2025 with protocol n° 0062216.

2.2. Study design

The HYGEIA Survey Study was conducted in 4 countries involved in the HYGEIA project: Italy, Spain, Sweden and Turkey. This was part of a European study entitled: Hygiene in hospital, community and residential care settings: an innovative mobile vocational training for HCWs that was financed by Erasmus+ 2014-2020, Erasmus + program for strategic partnerships for adult education. (AGREEMENT Number: 2020-1-SE01-KA202-077958). The European Hygeia project was launched in December 2020 through a partnership including: the Polytechnic University of Marche in Italy; the Fundacion para la Formacion e investigacion sanitaria de la Region de Murcia in Spain and Linköping University in Sweden; as well as several private Italian, Turkish, and Swedish companies active in the fields of information systems and digital health services. The project was conducted with periodic online meeting and in person meeting in Spain and in Italy once a year from December 2020 to December 2023.

The HYGEIA project included three parts: first, a survey to monitor nurses' knowledge of infection prevention and analyze their training needs in IPC, second, the development of a hygiene manual, third, the creation of a video game, with multiple-choice quizzes and games, to test their hygiene knowledge and simultaneously provide knowledge and insights into IPC. During the study period the questionnaire for the survey, the manual and the video game were built after literature search (Gasperini et al., 2022, 2023). Some of the survey questions were retrieved from the "Hand hygiene self-assessment framework" of WHO, while others were developed ad-hoc by the leading team together with the hygiene experts (B.G, M.M, E.P.) of the Italian group and M.P of the Spanish group, consulting international guidelines on IPC (WHO, 2010; WHO, 2012; WHO, 2018, CDC, 2007; CDC, 2008). The survey was developed in English and then translated and adapted by native speakers into Italian, Spanish, Swedish and Turkish. The questionnaire was firstly administered to 25 nurses and tested for reliability with the Alpha of Cronbach method, obtaining a value of 0.95 that suggested a good reliability of the questionnaire.

2.3. Selection of study sites, participants, and sampling technique

We completed the survey part for research purpose 2 years after the end of the Hygeia project and attainment of the Ethical approval. We reported in this manuscript the results of the survey.

The survey was performed by the Polytechnic University of Marche in Italy; the Fundacion para la Formacion e investigacion sanitaria de la Region de Murcia in Spain; Linköping University in Sweden; and a Turkish company active in the fields of information systems, digital health services (Innatolia). Nurses' contact details were obtained through institutional channels and participation depended on internal dissemination practices within each facility. Therefore, the sampling strategy can be defined as voluntary response sampling, as nurses self-selected to participate after receiving the survey invitation.

An anonymous online questionnaire was administered from March 2025 to August 2025 to nurses from Hospitals and long-term facilities; nurses were recruited among those affiliated with the participating institutions. Participation was voluntary and anonymous, and completion of the online questionnaire was considered as implied informed consent, in accordance with applicable regulations.

Inclusion criteria were: age >18 years, working in healthcare setting, including hospital, long term facility or other private care structures; exclusion criteria<18 years.

The questionnaire was filled electronically and anonymously by the nurses who wanted to participate to the project with Google Forms. The survey link was distributed via nurse coordinators and institutional email lists hence participation depended on internal dissemination practices within each facility and the coordinators' engagement in Italy and Spain, whereas in Sweden and Turkey the mail was sent directly to the interested nurses.

The emails contained a brief description of the project, the link to the electronic questionnaire and a PDF file-confirming acceptance of the data collection request. It was not possible to complete the questionnaire more than once from the same company email address, as a new compilation would have overwritten the previous one. The online method was used to prevent tampering. The link was inaccessible after one month from the time it was sent. Email addresses were collected via the respective company websites through transparent administration. Processing and compliance with privacy regulations was guaranteed in accordance with current legislation (EU Regulation, 2016/679).

The Polytechnic University of Marche in Italy; the Fundacion para la Formacion e investigacion sanitaria de la Region de Murcia in Spain enrolled the majority of nurses because they directly involved Hospitals and long-term facilities, whereas Linköping University in Sweden and the Turkish company did not have any connection with those structures and could enroll only a limited number of nurses, however we inserted them in the survey because of our partnership in the European Hygeia project. The study included 438 nurses in total: 317 (72%) from Italy, 87 (20%) from Spain, 27 (6%) from Turkey, and 7 (2%) from Sweden.

2.4. Data curation

Data were gathered using google forms. An excel file was created with the answers. There were no missing data due to the rules imposed to fill the questionnaire, as every answer was mandatory to go forward with the survey. Questions with multiple choices were recorded in dichotomic variables to obtain a frequency for each option. The congruity of answers was checked by two independent researchers. Disagreements were resolved with discussion. Open answers were coded identifying key words using a string search for each column in the excel file. A restricted access to the database was arranged to safeguard sensitive data.

The questionnaire investigated 6 main dimensions: sociodemographic data (e.g., age, gender, education), previous training on hygiene, willingness to learn more on hygiene and related aspects, knowledge on issues related to hygiene and IPC related topics. Items related to knowledge were rated on a five-point Likert scale: 1 = very good, 2 = good, 3 = neither good nor poor, 4 = poor and 5 = very poor, with lower scores indicating greater knowledge. In Italy data were collected from 4 acute hospitals: Hospital of Pesaro, Hospital of Urbino, Hospital of Macerata and University hospital of Marche in Ancona and long-term facilities of Marche Region, nurses affiliated to Fundacion para la Formacion e investigacion sanitaria de la Region de Murcia in Spain and Linköping University in Sweden and Innatolia education

Table 1
Self-reported demographic, education and working data of study nurses (N = 438).

Gender	N (%)
Male	66 (15)
Female	368 (84)
Not stated	4 (1)
Age range	
≤29	87 (20)
30-49	200 (46)
≥50	145 (34)
Education	
Diploma in practical nursing[a]	93 (21)
Bachelor's degree	291 (67)
Master's degree/Doctorate	54 (12)
Year of work in healthcare setting	
0-2 years	43 (10)
3-6 years	74 (17)
>6 years	321 (73)
Work with patients	409 (94)
Work setting	
Hospital	342 (78)
Long term facilities	44 (10)
Community care	37 (8)
Other	15 (3)

[a] Including: non degree education courses.

company in Turkey.

Given the voluntary response sampling strategy, the sample size calculation can be considered as an approximate indication of the desired level of precision. Based on an estimated 30% response rate, we calculated the minimum sample size required to achieve a 95% confidence interval with a 5% margin of error (Corner and Lemonde, 2019). Given a total population exceeding 10,000 nurses—comprising approximately 8600 in the Region of Murcia (Spain) and 5600 in the Marche Region (Italy)—a sample size of 313 was determined to be sufficient for answering the research questions (sample size calculator, https://www.calculator.net/).

2.5. Data analysis

A descriptive analysis was performed to summarize the socio-demographic characteristics, in particular, age was reported as median and interquartile range (IQR, Q1-Q3) and frequencies were reported as percentages. Nurses' knowledge of hygiene, protective measures, disinfection and sterilization, infections, and personal protective equipment was compared in absolute numbers and percentages. A multivariate logistic regression analysis of the investigated factors (years of experience; gender; education, work with patients and work in hospital) was performed in relation to self-perceived knowledge. Table 3 reported the adjusted Odds Ratio (aOR) along with their confidence intervals (95% CI) and p-values, the reference category was reported for each group: gender, age, education, work experience in healthcare setting, contact with patients and place of work. A probability value (P value) less than 0.05 was considered to be statistically significant.

The Pareto chart was used to identify the hygiene topics that needed improvement. It contained both bars and a line graph, where individual values were represented in descending order by bars, and the cumulative total was represented by the line. According to Pareto method, the 20% of most frequent item would represent the 80% of problem solution (Craft and Leake, 2002).

3. Results

Median age was 42 years (IQR = 19); most nurses were women (84%) and had Bachelor's degree (67%); working time in healthcare setting was mostly >6 years (73%). They worked mainly in Hospital (78%) and with patients (94%) (Table 1).

Table 2 showed very good/good knowledge based on gender, age, education, work experience in the healthcare setting, working with patients, and workplace in most investigated topics (general knowledge in IPC, Infection, Handling of sharp objects, hygiene and prevention measures and PPE), with general >90% of good/very good scores, whereas greatest knowledge deficiencies were related to disinfection and sterilization fields. As concerning nurses' low and very low knowledge, the Pareto chart showed that greatest deficiencies were knowledge of disinfection and sterilization and infection control (Fig. 1). Gender, age, years of work in healthcare setting, work with patients and in hospital did not affect the nurses' self-perceived knowledge in hygiene (Table 3). There were a few statistically significant differences in

Table 2
Self-reported knowledge on hygiene and IPC topics according to gender, age, education, work experience in healthcare setting, contact with patients and place of work. The percentages were referred to very good/good knowledge.

	General professional knowledge in hygiene and prevention and protection measures	Disinfection and sterilization	Infection	Handling of sharp objects	Hygiene and prevention measures	PPE
	N (%)	N (%)	N (%)	N (%)	N (%)	N (%)
Gender						
Female	334 (91)	289 (79)	341 (93)	346 (94)	368 (100)	347 (95)
Male	61 (92)	57 (86)	63 (95)	63 (95)	64 (97)	61 (92)
Age						
≤29	77 (89)	70 (80)	84 (97)	79 (91)	86 (99)	75 (86)
30-49	178 (89)	152 (76)	184 (92)	186 (93)	198 (99)	193 (97)
≥50	137 (94)	122 (84)	134 (92)	141 (97)	145 (100)	137 (94)
Education						
Diploma in practical nursing[a]	80 (86)	74 (80)	80 (86)	86 (92)	93 (100)	85 (91)
Bachelor's degree	267 (92)	226 (78)	276 (95)	277 (95)	288 (99)	275 (95)
Master's degree/ Doctorate	51 (94)	49 (91)	52 (96)	49 (91)	54 (100)	51 (94)
Year of work in healthcare setting						
0-2 years	38 (88)	31 (72)	42 (98)	40 (93)	43 (100)	38 (88)
3-6 years	65 (88)	60 (81)	69 (93)	68 (92)	72 (97)	65 (88)
>6 years	295 (92)	258 (80)	297 (93)	304 (95)	320 (100)	308 (96)
Work with patients	370 (90)	324 (79)	380 (93)	385 (94)	406 (99)	385 (94)
Work in hospital	309 (90)	271 (79)	320 (94)	324 (95)	339 (99)	322 (94)

[a] Including: non degree education courses.

Table 3
Multivariate logistic regression analysis of very good/good self-reported knowledge on hygiene and IPC topics.
Hygiene and prevention measures had aOR of 1 in most comparisons and were therefore excluded.

		aOR	95% CI		p-value
General professional knowledge in hygiene and prevention and protection measures					
Gender	Females (ref Males)	1.02	0.36	2.84	0.974
Age	30-49 (ref ≤29)	0.97	0.26	3.61	0.967
	≥50 (ref ≤29)	3.63	0.64	20.47	0.145
Education	Bachelor's degree (ref. Diploma)	**3.77**	**1.38**	**10.30**	**0.010**
	Master's degree/ Doctorate (ref. Diploma)	3.94	0.88	17.70	0.073
Years of work in healthcare setting	3-6 years (ref. 0-2 years)	1.11	0.32	3.91	0.868
	>6 years (ref. 0-2 years)	1.45	0.31	6.89	0.640
Work with patients	yes (ref. no)	0.73	0.09	3.04	0.773
Work in hospital	yes (ref. no)	0.49	0.17	1.44	0.200
Disinfection and sterilization					
Gender	Females (ref Males)	0.57	0.26	1.24	0.158
Age	30-49 (ref ≤29)	0.48	0.17	1.40	0.180
	≥50 (ref ≤29)	0.72	0.20	2.55	0.608
Education	Bachelor's degree (ref. Diploma)	0.93	0.45	1.89	0.831
	Master's degree/ Doctorate (ref. Diploma)	2.19	0.70	6.89	0.179
Years of work in healthcare setting	3-6 years (ref. 0-2 years)	1.95	0.72	5.28	0.190
	>6 years (ref. 0-2 years)	2.54	0.75	8.62	0.134
Work with patients	yes (ref. no)	1.08	0.34	3.43	0.899
Work in hospital	yes (ref. no)	0.86	0.45	1.65	0.658
Infection					
Gender	Females (ref Males)	0.81	0.23	2.94	0.754
Age	30-49 (ref ≤29)	0.42	0.07	2.42	0.335
	≥50 (ref ≤29)	0.62	0.08	4.87	0.652
Education	Bachelor's degree (ref. Diploma)	**2.96**	**1.09**	**8.01**	**0.033**
	Master's degree/ Doctorate (ref. Diploma)	3.69	0.70	19.36	0.122
Years of work in healthcare setting	3-6 years (ref. 0-2 years)	0.48	0.05	4.83	0.536
	>6 years (ref. 0-2 years)	0.67	0.06	7.99	0.750
Work with patients	yes (ref. no)	0.68	0.08	5.70	0.719
Work in hospital	yes (ref. no)	1.17	0.46	2.97	0.749
Handling of sharp objects					
Gender	Females (ref Males)	0.88	0.34	3.31	0.852
Age	30-49 (ref ≤29)	3.15	0.44	22.67	0.254
	≥50 (ref ≤29)	9.44	0.96	29.51	0.054
Education	Bachelor's degree (ref. Diploma)	2.30	0.71	7.38	0.164
	Master's degree/ Doctorate (ref. Diploma)	1.37	0.32	5.83	0.667
Years of work in healthcare setting	3-6 years (ref. 0-2 years)	0.64	0.12	3.24	0.585
	>6 years (ref. 0-2 years)	0.30	0.03	3.10	0.310
Work with patients	yes (ref. no)	2.13	0.39	11.49	0.379
Work in hospital	yes (ref. no)	1.47	0.48	4.50	0.496
Use of PPE					
Gender	Females (ref Males)	1.41	0.46	4.37	0.548
Age	30-49 (ref ≤29)	3.60	0.58	22.21	0.168
	≥50 (ref ≤29)	2.00	0.23	17.22	0.526
Education	Bachelor's degree (ref. Diploma)	2.08	0.66	6.58	0.211
	Master's degree/ Doctorate (ref. Diploma)	1.98	0.41	9.62	0.397
Years of work in healthcare setting	3-6 years (ref. 0-2 years)	0.72	0.19	2.73	0.627
	>6 years (ref. 0-2 years)	1.44	0.17	12.20	0.736
Work with patients	yes (ref. no)	3.90	0.88	17.24	0.072
Work in hospital	yes (ref. no)	0.92	0.31	2.72	0.873

education level, in particular, nurses with university degree had a greater self-perceived knowledge in general knowledge of hygiene and prevention (aOR = 3.77, CI: 1.38-10.30, p = 0.010) and infections (aOR = 2.96, CI: 1.09-8.01, p = 0.033) than nurses with diploma.

As concerning past attendance to hygiene and IPC courses, 321 (75%) nurses stated to have attended at least one hygiene course and 364 (84%) nurses were interested in future education in this field. The most frequently selected topics for future training were good practices and suggestions (26%), preventive and protective hygiene measures when caring for a patient (22%) and hygiene and prevention measures (19%) (Table 4). The main reasons for not being interested in future education were: interest in courses on other topics (44%), no need in education in this field (32%) or being busy (22%).

4. Discussion

Understanding barriers and facilitators to IPC measures adherence is essential to design promptly interventions and strategies to optimize the allocation of resources, and to be prepared to face future pandemic events. This study was performed after the COVID-19 pandemic. This allowed monitoring nurses' level of knowledge and education needs on IPC procedures.

The assessment of self-perceived professional knowledge in hygiene and IPC was rated as good/very good by most nurses (91-92%). These data were in agreement with recent studies that showed a 71.4%-74.1% of nurses that have good knowledge, attitude, and practices toward high-risk microbial infections (Sodhi et al., 2023; Khatrawi et al., 2023). These results were further confirmed by a systematic review, reporting that HCWs had an adequate, good, and/or high knowledge of standard precautions and hand hygiene (Alhumaid et al., 2021). A UK survey indicated that the nurses had good knowledge and understanding of IPC and reported high adherence to guidelines, particularly those related to hand hygiene and sharps disposal (Dowding et al., 2020).

Self-perceived knowledge in hygiene and IPC was not affected by gender, age, work experience in healthcare setting, contact with patients and place of work. There were a few statistically significant differences in education level, in particular, nurses with university degree had a greater self-perceived knowledge in general knowledge of hygiene and prevention (aOR = 3.77, CI: 1.38-10.30, p = 0.010) and infections (aOR = 2.96, CI: 1.09-8.01, p = 0.033) than nurses with diploma. Other studies showed that the improvement in IPC knowledge was correlated with increasing academic experience, the years of study and post degree specialization, this could be due to greater experience on care settings and practical learning (D'Alessandro et al., 2014; Giordano et al., 2025; Fortunka et al., 2024).

Khatrawi and colleagues showed that good knowledge, attitude, and practices toward high-risk microbial infections was not dependent on age of experience in health care and also underlined the need for improvement through educational seminars and awareness programs, in order to provide better adherence to barrier protection measures (Khatrawi et al., 2023).

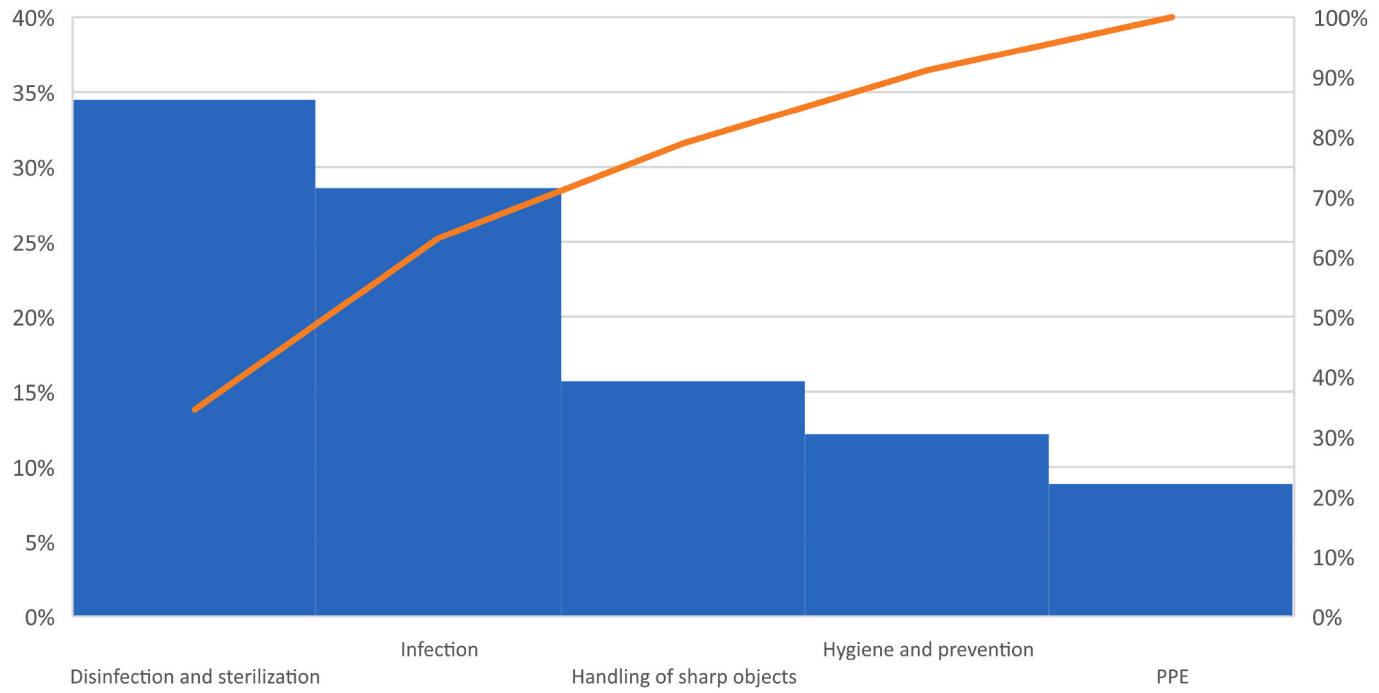

Fig. 1. Poor/very poor knowledge in hygiene and prevention and protection measures topics
The greatest deficiencies of the survey participants were in their knowledge of disinfection and sterilization and infection control. The red line represents the Pareto Line and identifies the main topic that needs future improvement, namely knowledge of disinfection and sterilization and infection control. (For interpretation of the references to colour in this figure legend, the reader is referred to the Web version of this article.)

Table 4
Self-reported participation to previous courses on hygiene and IPC and future interest in further education on hygiene and IPC.

	N (%)
Previous attendance to hygiene courses	321 (75)
Topics of previous hygiene courses	
Theoretical knowledge on hygiene and prevention and protection measures	231 (25)
Practical knowledge of hygiene and prevention and protection measures (e.g. how to use disinfection products or other protective equipment, which ones and how often)	225 (25)
How to maintain hand hygiene and apply hygiene measures and prevention and protection measures in common spaces or group situations	222 (25)
How to maintain hand hygiene and apply hygiene measures, prevention and protection measures when caring for a patient	195 (22)
Good practices and suggestions	33 (4)
Interest in attending to hygiene courses	364 (84)
Topics for future training	
Measures of prevention and protection	153 (14)
Preventive and protective hygiene measures when caring for a patient	249 (22)
Preventive and protective hygiene measures in common areas or in group situations	212 (19)
Hygiene and prevention measures	211 (19)
Good practices and suggestions	291 (26)

A recent review showed that nursing students had good knowledge of IPC, in particular those concerning standard precautions and hand hygiene (Giordano et al., 2025). However, significant gaps were identified among nursing students, especially in epidemiology, transmission mechanisms, and HAIs risk factors. This was also reported by a recent study in Italy showing that only 66.1% of nursing students were able to correctly identify key hand hygiene moments (Di Gennaro et al., 2025). A cross-sectional study supported the need for a dedicated curricular focus on HAIs prevention and control learning, implementing a complementary and coordinated liaison between teachers and tutors in academic and clinical settings in Portugal, Spain, Poland, and Finland (Parreira et al., 2022). Our study also showed some knowledge gaps, in particular the greatest deficiencies were knowledge of disinfection, sterilization and infection control.

Understanding and filling educational gaps in IPC guidelines is essential to prevent future epidemics and improve preparation for the emergence of new infectious diseases (Vicentini et al., 2024). The development of a manual on IPC can support the implementation of these guidelines in health care facilities, outlining protocols and practices to prevent and manage infections (Gastaldi et al., 2024). The survey of our study helped to identify the subjects that should be improved in future educational project. These topics were implemented in Hygeia manual that was dedicated to operators in European healthcare facilities and was based on the recommendations of the main international public health organizations (WHO, 2012, 2018, 2020, 2021; CDC, 2007; CDC, 2008; Gasperini et al., 2022).

Nursing curricula should align with validated international guidelines, and adopt active, practice-oriented teaching approaches (Giordano et al., 2025). In Italy hygiene is a part of nurse curriculum, as in Spain and in other European countries. A recent study was performed on the curriculum of Nursing Bachelor's degrees across 15 European countries, in order to describe nursing course curricula. It revealed variations in the duration of training (3-year or 4-year programs), discrepancies in the balance between theoretical and clinical education and highlighted the need for standardized nursing curricula across Europe to ensure consistency in quality and professional competencies (Antão et al., 2025).

Targeted, simulation-based training is essential to improve HCW compliance with hand hygiene and PPE protocols, thereby reducing HAIs. Integrating ongoing IPC training, coupled with mandatory, standardized education and regular audits, allows addressing new infectious disease challenges and strengthening the clinical skills necessary for a safe care environment (Zhang et al., 2024). At the policy level, integrating IPC as a mandatory, cross-cutting component of all undergraduate and postgraduate healthcare curricula is a critical policy-level

requirement to ensure uniform training standards (Mukona et al., 2025).

The main limitation of this study was that the number of nurses from each of the four countries was uneven and also arrangements for IPC protocols and services differed in these four countries. Other limitations were: the focus only on self-administered survey and self-reported knowledge; whereas attitudes and practical skills related to hygiene were not assessed, despite their importance in IPC. Further studies including the application of a more structured questionnaire and the assessment of nurses' practical skill could better define the knowledge needs. Another potential limit could be the use of voluntary response sampling that may have introduced selection bias.

On the other hand, our study has notable strengths. First of all, it is an international study assessing the self-perceived knowledge of nurses across four countries in Europe. Then, it provides a contemporary glimpse on the current state of awareness of nurses concerning a fundamental topic, such as the HAIs across Europe.

5. Conclusion

Infection prevention and control are critical in all care settings, showing a strong correlation with nurses' knowledge, awareness, and implementation of hygiene and protective measures. Our study showed that most nurses had a good/very good self-perceived knowledge in hygiene and prevention and protection measures and were willing to take part in future courses on this subject. The main topic needing future improvement was knowledge of disinfection and sterilization and infection control. A multimodal approach should be implemented to guarantee continuing education programs and training, to improve the awareness and compliance to IPC practices.

CRediT authorship contribution statement

Chiara Peconi: Writing – review & editing, Data curation, Conceptualization. **Beatrice Gasperini:** Data curation. **Donatella Sarti:** Writing – original draft, Data curation. **Matteo Renzi:** Data curation. **Gilda Pelusi:** Validation. **Enrica Martini:** Visualization, Conceptualization. **Emilia Prospero:** Supervision, Project administration, Conceptualization. **Arianna Poli:** Investigation, Data curation. **Knut Martensson:** Conceptualization, Investigation, Project administration. **Burak Bayram:** Conceptualization, Investigation, Project administration. **Erdogan Ezeroglu Burak:** Conceptualization, Investigation, Project administration. **Maria Del Pilar Lopez Acuna:** Conceptualization, Investigation, Project administration. **Kety Gutierrez:** Conceptualization, Investigation, Project administration. **Thomas Bergstrom:** Conceptualization, Investigation, Project administration.

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