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Research in context

Evidence before this study

Numerous studies have evaluated the knowledge and perceptions of physicians regarding antimicrobial resistance (AMR), which is considered a low priority and a distant consequence of individual antibiotic prescribing. Recent studies showed that physicians are aware of the threat of AMR, but few see their own infection control practices and antibiotic practices as a risk for their patients, and instead blame other healthcare settings and professionals for antibiotic resistance.

The medical profession's knowledge and perceptions of measures to control AMR, especially hand hygiene, have been rarely studied. Yet, medical professionals have less direct contact with patients than non-medical healthcare workers (HCWs), whose knowledge and perceptions of AMR and control measures (hand hygiene and contact precaution) have been explored more frequently. But the combined knowledge and perceptions of medical and non-medical HCWs have never been evaluated in a large-scale population.

Implications of all the available evidence

The literature shows that HCWs have modest knowledge and awareness of AMR and infection control measures. Medical HCWs consider that greater compliance with hand hygiene is less critical than antibiotic stewardship in controlling AMR. Despite guidelines to control the AMR spread, compliance with recommended infection control practices, such as hand hygiene, is not optimal among non-medical HCWs. It is therefore unclear which type of education should be used and tailored to different healthcare settings and jobs.

Added value of this study

This survey explored knowledge and perceptions of the risk of AMR transmission in a large national sample of healthcare facilities and HCWs. Our findings show that knowledge and perceptions of AMR are uneven among HCWs, as is their willingness to perform better. Interventions designed to control AMR should therefore be tailored to the diversity of healthcare facilities and HCWs.

Summary
Background. Our aim was to evaluate the knowledge and perceptions of healthcare workers (HCWs) on antimicrobial resistance (AMR) and associated control measures.
Methods. A multicentre cross-sectional study was conducted in 58 randomly selected French healthcare facilities with questionnaires including professional and demographic characteristics, knowledge of multidrug-resistant organism transmission and control, and perception of AMR. A logistic regression analysis was used to identify factors associated with better AMR knowledge. This study was registered under the number NCT02265471.
Findings. Between June 2014 and March 2016, 8,716/11,753 (participation rate, 74%) questionnaires were completed. The mean knowledge score was 4·7/8 (SD: 1·3) and 3·6/8 (SD: 1·4) in medical and non-medical HCWs, respectively. Five variables were positively associated with greater knowledge: working in a university hospital (adjusted odds ratio, 1·41, 95% CI 1·16–1·70); age classes 26–35 years (1·43, 1·23–1·6) and 36–45 years (1·19, 1·01–1·40); medical professional status (3·7 , 3·09–4·44), working in an intensive care unit (1·28, 1·06–1·55), and having been trained on control of AMR (1·31, 1·16–1·48). After adjustment for these variables, greater knowledge was significantly associated with four cognitive factors: perceived susceptibility, attitude toward hand hygiene, self-efficacy, and motivation.
Interpretation. We found unexpectedly poor knowledge of AMR and control measures among French HCWs. Training about hand hygiene and control of AMR is critical in shaping beliefs and perceptions about control of AMR and should be simplified.

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Introduction

Antimicrobial resistance (AMR) is a growing problem worldwide. Multidrug-resistant organisms (MDROs) are challenging healthcare workers (HCWs) in their daily practice and there is a need for improved infection prevention and control (IPC) practices and antibiotic stewardship. Many guidelines and training materials designed for the control of MDROs have been issued and successful interventions served as a framework for the implementation of further control programmes. However, recommendations alone are not enough to improve compliance with best practices. As demonstrated in the context of hand hygiene, guidelines must be associated with an implementation process taking contextual and behavioural aspects into consideration.[1] A strong association between knowledge, perceptions, and ultimately actions has been suggested in previous research regarding AMR.[2] Some studies found an impact of knowledge, attitudes, and personal perceptions, including perceived benefits and barriers, on the behaviours and practices of HCWs in IPC. [3,4,5]

Several surveys of the knowledge and perception of AMR have primarily focused on antibiotic prescribing, missing infection control measures and have excluded non-medical staff.[6] Several recent studies jointly assessed knowledge, attitudes, and practices in both AMR and transmission precautions. They showed that few physicians were aware of their own infection control practices, though they were aware of the threat of AMR.[7,8] However, most studies usually included junior doctors or medical students, and not senior physicians.[9]

Our aim was to evaluate the knowledge and perceptions of medical and non-medical HCWs about control measures associated with AMR. We hypothesised that knowledge could shape perceptions on the threat of MDROs, as well as their epidemiology and route of transmission. Hence, a questionnaire-based survey was developed to identify the association between knowledge, perceptions, and reported practice, with a view to defining the barriers to adherence to best practices.

Methods

Hospitals and participants

The study was conducted in 58 randomly selected French healthcare facilities (HCFs), including university hospitals or referral centres for cancer (UHs, n=9), non-university public hospitals (NUPHs, n=10), private HCFs (n=10), and a group mixing local hospitals, long-term care and rehabilitation facilities, and nursing homes (LTCFs, n=29). Random sampling was used to select participating HCFs, stratified on the five geographical areas corresponding to the interregional coordinating centres for infection prevention and control (CCLIN).

Each selected HCF was asked to participate. When an HCF declined to participate, another HCF was randomly selected following the same scheme of stratification sampling and asked to participate. Each HCF was approached through the local infection prevention and control (IPC) team. The number of clinical units included in the study in each HCF was dependant on the number of beds; from 15–50% of clinical units randomly selected in large HCFs according to the number of beds in the HCF, to 100% in small HCFs. Adult and paediatric clinical units were eligible, including intensive care (ICU), medical and surgical units, rehabilitation and long-term care, emergency, outpatient, and radiology units. Eligible HCWs included physicians (senior, junior, and medical students) and non-medical professionals (nurses, nurse aides, dieticians, therapists, radiology technicians, students, and head nurses) present during the day and night shifts. HCWs not included were those working in laboratories, housekeeping personnel, and administrative personnel.

Study design

We performed a cross-sectional study of the knowledge, beliefs and perceptions of HCWs about MDROs from June 2014 to March 2016. Participants were asked to complete anonymously a self-administered questionnaire that required 10–15 minutes to complete. The total number of HCWs present the day of the survey, representing the denominator of the participation rate, was provided by the human resources services.

Questionnaire

The questionnaire was structured in three different parts: one part about professional characteristics including gender, age, professional status, duration in the position, working unit, main activity of the unit, working shift, and previous training sessions during the last three years about hand hygiene and contact precautions; a second part assessing knowledge of the transmission and control of MDROs (Supplementary Table 1) regarding hand hygiene (three questions), glove use (two questions), and epidemiology of MDROs (three questions); and a third part evaluating the perception of AMR including three dimensions (Supplementary Table 2): the perceived threat of MDROs (three questions), individual cognitive factors for hand hygiene compliance (eight questions), based on the theory of health belief model.[10–13] This model enabled assessment of perceived susceptibility, perceived knowledge, intention to adhere (perceived practice), attitudes toward hand hygiene, perceived behavioural norm, perceived subjective norm, self-efficacy, and motivation (Supplementary Table 3) regarding one specific topic. Items related to beliefs and perception were coded on a 7-point Likert scale, ranging from 1, “strongly disagree” to 7, “strongly agree” with the statement of the item.

Ethical statement

This project (Clinical trial NCT02265471) was approved by the Ethics Committee of the HUPNVS (CEERB Paris Nord, 16-018). The anonymity of all respondents was guaranteed and only non-identifying characteristics were requested.

Statistical analysis

Continuous variables were expressed as mean and standard deviation (SD) or median and interquartile range (IQR), and categorical variables as frequency (percentage). Comparisons between two groups were made using the Chi2 test or Student's t test or their corresponding non-parametric versions, Fisher's test or the Wilcoxon rank sum test, as appropriate. Comparisons between more than two groups were made using the Hochberg method for multiple comparisons in order to adjust for the alpha level.

The principal endpoint was the knowledge score (KS) defined by the sum of correct answers out of eight questions (Supplementary Table 1). The KS was compared among HCF categories, age classes, professional statuses, working units, and other professional characteristics, using the Kruskal–Wallis test.

The KS was then categorised in two classes by its median value, KS lower than four or KS equal to or greater than four. Multivariate logistic regression models were used to assess the association between professional characteristics and KS. Selection of explanatory variables in the multivariate analysis was done using stepwise methods based on the AIC (Akaike Information Criterion).

All questions about perception on the 7-point Likert scale were dichotomised as 1 to 5 ("Strongly disagree", "Disagree", "Somewhat disagree", "Neither agree nor disagree", "Somewhat agree") versus 6 or 7 ("Agree" and "Strongly agree"), the latter denoting positive agreement with the proposition. All other quotations (from 1 to 5) were considered negative. Significant associations between perception and KS in the univariable analysis were then adjusted for significant variables in the first multivariable model. A significance level was set to two-sided 0.05. All analyses were of superiority. R software (v3.14) was used.

Findings

Healthcare facilities and participants

Among the 60 HCFs initially solicited, 46 agreed to participate. Twelve other HCFs were secondarily solicited and were included, giving a total of 58 participating HCFs. A total of 8,716 HCWs completed the questionnaire, including 1,291/2335 (participation rate, 55%) medical HCWs (MWs) and 7,425/9418 (participation rate, 79%) non-medical HCWs (NMWs). The overall participation rate was 74% (8,716/11,753), ranging from 35% to 100% across individual HCFs, and was higher in non–acute care facilities than in acute care hospitals. The characteristics of the population are presented in Table 1. Most participants were female (7,103/8,716; 83%), representing 50% (63/291) and 88% (6469/7425) of MWs and NMWs, respectively. The median age was 33 (IQR [27: 47]) years and 37 (IQR [28: 48]) years in MWs and NMWs, respectively. Overall, 5,753 (68%) and 2,787 (34%) HCWs declared having been trained on hand hygiene and control of AMR over the last three years, respectively.

Knowledge and associated factors

The mean KS on AMR and control measures was 4·7/8 in MWs and 3·6/8 in NMWs (P<0·0001) (Table 2). They both differed between the type of HCFs (p<0·001), with a medical KS significantly higher in UHs, and a non-medical KS significantly lower in the LTCF group.

Handwashing was wrongly thought to be more important after than before contact with a patient (58% MWs, 52% NMWs); alcoholic handrub was correctly considered more effective than antiseptic or plain soap (76% MWs, 50% NMWs) (supplementary Table 1). A large proportion, higher than 90%, believed that gloves were indicated for contact precautions, even though gloves have not been recommended in France since 2010. Standard precautions (hand hygiene after contact with the patient's environment and no glove wearing for contact with the patient's intact skin) were correctly known (higher than 80% in both MWs and NMWs).

Knowledge of the epidemiology of MDROs was greater in MWs; 85% of MWs and 67% of NMWs considered that methicillin-resistant *Staphylococcus aureus* (MRSA) was mainly hand-transmitted. A large proportion of respondents thought that rates of both MRSA (89% MWs, 95% NMWs) and extended-spectrum beta-lactamase-producing *Enterobacteriaceae* (ESBLPE) (83% MWs, 42% NMWs) were increasing, whereas MRSA incidence has been sharply decreasing and ESBLPE incidence is rapidly increasing, in France.

In the univariate analysis (Table 3), variables associated with a KS equal to or greater than four were the type of HCF, male gender, a younger age, a medical professional status, a shorter duration in the position, working in an ICU and having been trained on control of AMR. In the multivariate logistic regression analysis, five variables remained positively associated with greater knowledge: working in a UHs (adjusted odds ratio, 1·41; 95% CI, 1·16–1·70; p<0·005); age classes 26–35 years (1·43, 1·23–1·67, p<0·0001) and 36–45 years (1.19, 1.01–1.40, p=0.037); medical professional status (3·70, 3·09–4·44, P< 0·0001), working in an ICU (1·28, 1·06–1·55, p=0·011) and training on control of AMR within the 3 previous years (1·31, 1·16–1·48, p<0·0001). Working in rehabilitation and long-term care units (0·81, 0·68–0·96, p=0·014) was negatively associated with higher KS.

Knowledge score and perceptions

After adjustment for baseline variables significantly associated with a higher KS (type of HCF, male gender, younger age, medical professional status, working unit, and having received training sessions), a higher KS was significantly associated with four cognitive factors: perceived susceptibility (2·33, 95% CI, 1·95–2·78, p<0·0001), positive attitude toward hand hygiene (1·98, 1·65–2·37, p<0·0001), self–efficacy (1·22, 1·09–1·38, p<0·001), and motivation (1·42, 1·24–1·62, p<0·0001) (Table 4).

Perceptions of the threat of bacterial resistance

Most participants perceived AMR as a national problem (Supplementary Table 2) (98% MWs, 88% NMWs) while fewer (66% MWs, 40% NMWs) viewed AMR as a local problem, with a low impact on their daily practices (65% MWs, 38% NMWs).

Discussion

To our knowledge, this is the first study evaluating the association between knowledge of the epidemiology of AMR and infection control measures, and the individual cognitive factors, including both MWs and NMWs from of a national representative population of HCFs. The 74% participation rate was unexpectedly high and may be ascribable to the active participation of IPC teams, the expectations of this survey, and direct physical contact of investigators with ward staff rather than an impersonal online survey. This large panel therefore accurately reflects the situation in France and enabled the comparison of the KS in different categories of HCFs, professional status, and type of care units.

We found poor knowledge of the current epidemiology of AMR and an unexpectedly modest knowledge of best practices to prevent cross-transmission. Mean KS on AMR and infection control measures were higher in MWs than in NMWs (4·7 vs 3·6) and variations were observed in the professional categories, highlighting two profiles. The professional category with the higher knowledge profile was a young medical doctor, working in an ICU, recently trained and with awareness and readiness to act against AMR. This profile perceived that poor compliance with hand hygiene has consequences for the patient, that hand hygiene is useful, and was willing to comply with hand hygiene according to recommended guidelines. On the other hand, a lower knowledge was associated with nurse aides from small LTCFs.

Noticeable variations were observed in NMWs, particularly between nurse aides and nurses, with respective KS of 3·3 and 4·1. Nurse aides are key people for infection control, because they routinely attend to patient hygiene and diaper changes, which are associated with a high risk of hand contamination and subsequent transmission.[13] This strongly suggests that knowledge should primarily be improved in that population, despite their lower perception of infectious risk and their lower initial education in infection control, as compared to nurses. Small HCFs should also be a target for education. The UHs were associated with greater knowledge and may offer more training and information. As observed in other surveys,[14] professional awareness seemed to increase in the ICU and was associated with greater knowledge. Likewise, a younger age was also associated with greater knowledge, possibly reflecting more education about infection control measures during medical or nursing studies over recent years.

Fifteen years after the introduction of AHR in HCFs in developed countries,[12,15] knowledge on hand hygiene best practices still appeared poor, since AHR was considered less effective than antiseptic or plain soap (24% MWs, 50% NMWs). Similarly, two studies reported that medical students considered poor compliance with hand hygiene as one of the least important contributors to AMR.[8,16] This underestimation of poor hand hygiene as a critical cause of AMR spread and poor knowledge show that there is an urgent need to increase awareness of this simple practice. This clearly suggests that educational messages provided by IPC teams should be simplified, focused on the reasons for and consequences of poor hand hygiene practices and tailored to the healthcare professionals concerned.

Furthermore, less than 50% of HCWs thought that hand hygiene was more important after a contact than before. These results illustrate a general misconception of hand hygiene best practices, even though reported consumption of AHR in France is fairly high compared to other European countries.[17] For better implementation of best practices, HCWs need to understand why they are applying measures. Healthcare-associated infections are the result of a complex chain, including many individuals involved in patient care. The consequences of poor compliance with hand hygiene is intangible for front-line staff, not considering that the actual burden of AMR for patients can derive from individual practices. The perception of AMR as a national problem but not a local or individual one supports this hypothesis.

Despite the withdrawal of gloves for contact precautions in 2010 in France, HCWs still believe they need to wear them. This particular point reflects issues linked to the evolution of evidence-based infection control practices. Several guidelines have recently been issued for controlling transmission of AMR, with evolving recommendations, e.g. the debated need for contact precaution for ESBLP-*E. coli*, and the policy required for controlling highly resistant bacteria.[18,19] These changing recommendations may be confusing for HCWs and complicate the implementation of good practices. At the national level, infection control policies and strategies can also influence the quality of care and local organisation. Designing strategies for the effective implementation of evidence-based infection control practices is essential and should be a priority at all levels.

Our disappointing results about knowledge are potentially the consequence of a non-comprehensive training programme, with 68% of HCWs reporting that they received training on hand hygiene and only 34% on AMR in the 3 previous years. Although these proportions may seem high at a national level, these data demonstrate an unregulated and unstructured education programme. Training and education of HCWs are one of the pillars of infection control programmes.[20] Hitherto, educational programmes have usually been based on classic presentations with lectures to a passive audience. New technologies such as simulation, virtual reality, serious games and e-learning applications bring new possibilities to the field of medical training and could lead to valuable improvement in learning outcomes.[21]

After adjustment for confounding variables, a higher KS was significantly associated with four cognitive factors: perceived susceptibility, attitude toward hand hygiene, self-efficacy, and motivation. Our survey, like another study,[22] indicated that HCWs think that inadequate handwashing is a risk for the patient. Nevertheless, it is unknown whether these cognitive factors impact on higher knowledge, or whether greater knowledge obtained from other sources, such as training sessions and medical education, translate into more belief in and perception of the importance of hand hygiene. They probably are intricate, suggesting that training about hand hygiene and AMR is critical in shaping beliefs and perceptions about control of AMR.

Our survey had some limitations. Firstly, the study was performed in France and was probably not representative of the healthcare systems of other countries. Indeed, to our knowledge, only one study has been conducted in several European countries, but focused on antibiotic prescribing and AMR in medical students.[8] Secondly, the questionnaire was unique and questions could have been understood differently by individuals according to their professional status. Hence, use of a 7-point scale permitted a large range of responses and more precision.[23] Thirdly, it is possible that the respondents were more motivated and better informed than non-respondents, thus increasing the rate of positive responses. However, the high participation rate could offset this bias. Finally, some answers may have been collective rather than individual, thereby falsely increasing KS. However, the distribution of KS across professional status was in the expected range.

In conclusion, this large survey shows that the knowledge HCWs have regarding hand hygiene and infection control measures is likely overestimated by IPC teams and national bodies. Knowledge, beliefs and perception were entangled, suggesting that training is critical in improving performance with hand hygiene. HCWs with a lower educational level and small HCFs should be prioritised. Sharing and adapting IPC tools and education methods used in large university hospitals represent an opportunity for small HCFs. Training should remain focused on clear and unambiguous messages, in particular regarding hand hygiene and alcohol hand rub. Multiple factors are involved and overlap, suggesting the need for system change and the development of hand hygiene improvement strategies to enhance daily practice.

Contributors. GB and JCL conceived the study and are the principal investigators. MEF, FT, PA, CP, ESW, JR, JRZ contributed to the design of the study. LV coordinated recruitment and acquisition of study data. MEF managed the study data and did the statistical analyses. JCL, LV, GB, MEF contributed to the analysis of study data.

All authors contributed to the interpretation of the data and approved the final version of the manuscript after critical review.

Declaration of interests. All authors declare no competing interests.

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Table 1. Population characteristics

	Total (58 HCFs)	University hospitals / Cancer centres (n= 9)	Non-university hospitals (n= 10)	Small, rehabilitation, nursing hospitals (n= 29)	Private clinics (n= 10)
Participants n (%)	8716 (100)	4015 (46)	2187 (25)	1885 (22)	629 (7)
- Total	1291 (15)	818 (20)	285 (13)	99 (5)	89 (14)
- Medical	7425 (85)	3197 (80)	1902 (87)	1786 (95)	540 (86)
- Non-medical					
Male gender n (%)					
- Total	1499 (17)	771 (19)	371 (17)	219 (12)	138 (22)
- Medical	637 (50)	375 (47)	143 (51)	54 (56)	65 (75)
- Non-medical	862 (12)	396 (12)	228 (12)	165 (9)	73 (14)
Age median (IQR)					
- Total	37 (28:48)	34 (27:46)	39 (30:47)	40 (29:50)	39 (30:51)
- Medical	33 (27:47)	29 (25:38)	41 (30:50)	52 (42:60)	54 (41:61)
- Non-medical	37 (28:48)	35 (28:47)	39 (30:47)	39 (29:49)	37 (29:50)
Professional status n (%)					
- Senior physician	787 (9)	395 (10)	213 (10)	93 (5)	86 (14)
- Junior doctor	332 (4)	271 (7)	57 (3)	2 (0)	2 (0)
- Medical student	165 (2)	149 (4)	12 (1)	3 (0)	1 (0)
- Nurse	2842 (34)	1468 (37)	751 (35)	352 (20)	271 (44)
- Nurse aide	2231 (26)	800 (20)	674 (31)	641 (36)	116 (19)
- Hospital service agent	707 (8)	208 (5)	123 (6)	322 (19)	54 (9)
- Medical-technical agent	506 (6)	245 (6)	93 (4)	157 (9)	11 (2)
- Non-medical student	407 (5)	178 (5)	105 (5)	93 (5)	31 (5)
- Other	487 (6)	233 (6)	111 (5)	103 (6)	40 (7)
Duration in the position (median (IQR))					
- Total	10 (4:20)	8 (3:20)	11 (5:20)	10 (4:20)	12 (5:26)
- Medical	6 (2:19)	4 (2:11)	12 (3:20)	24 (10:30)	26 (13:32)
- Non-medical	10 (4:20)	10 (4:20)	11 (5:20)	10 (4:18)	10 (4:22)
Working unit n (%)					
- Medicine	2742 (33)	1720 (45)	790 (38)	104 (6)	128 (21)
- Intensive care unit	776 (9)	535 (14)	175 (8)	0 (0)	66 (11)
- Emergency	395 (5)	245 (6)	139 (7)	2 (0)	9 (2)
- Rehabilitation, long-term care	2491 (30)	227 (6)	522 (25)	1687 (92)	55 (9)
- Surgery	1610 (19)	923 (24)	366 (17)	0 (0)	321 (53)
- Gynaecology-Obstetrics	123 (1)	66 (2)	47 (2)	1 (0)	9 (1)
- Psychiatry	96 (1)	58 (1)	23 (1)	15 (1)	0 (0)
- Other	158 (2)	84 (2)	45 (2)	14 (1)	15 (2)

IQR, interquartile range

Table 2. Knowledge regarding antimicrobial resistance and infection control measures

	N (%)	**Global score (mean (SD))**
Type of healthcare facilities		
- University hospitals / cancer centres	4015 (46)	4·0 (1·4)
- Non-university hospitals	2187 (25)	3·7 (1·4)
- Small, rehabilitation, nursing hospitals	1885 (22)	3·4 (1·5)
- Private clinics	629 (7)	3·8 (1·4)
Professional status		
- **Medical (total)**	**1284 (15)**	**4·7 (1·3)**
- Senior physician	787 (61)	4·6 (1·4)
- Junior doctor	332 (26)	4·9 (1·2)
- Medical student	165 (13)	4·6 (1·3)
- **Non-medical (total)**	**7180 (85)**	**3·6 (1·4)**
- Nurse	2842 (40)	4·1 (1·3)
- Nurse aide	2231 (31)	3·3 (1·3)
- Hospital service agent	707 (10)	2·6 (1·3)
- Medical-technical agent	506 (7)	3·6 (1·4)
- Non-medical student	407 (6)	3·9 (1·3)
- Other	487 (7)	4·0 (1·5)
Working unit		
- Medicine	2742 (32)	3·9 (1·4)
- Surgery	1610 (18)	3·8 (1·4)
- Intensive care unit	776 (9)	4·2 (1·5)
- Rehabilitation, long-term care	2491 (29)	3·5 (1·5)
- Emergency	395 (5)	4;1 (1·4)
- Gynaecology-Obstetrics	123 (1)	3·6 (1·4)
- Psychiatry	96 (1)	3·5 (1·5)
- Other	158 (2)	3·5 (1·6)
Previous training for hand hygiene (last 3 years)		
- Yes	5753 (68)	3·8 (1·5)
- No	2769 (32)	3·7 (1·4)
Previous training in control of antimicrobial resistance (last 3 years)	2787 (34)	4·0 (1·5)
- Yes	5413 (66)	3·7 (1·4)
- No		

Table 3. Factors associated with greater knowledge of antimicrobial resistance and infection control measures

Population-based variables	Population (n, %) KS < 4	KS ≥ 4	Univariate analysis (OR (95% CI) p)	Multivariate analysis (adjusted OR (95% CI) p)
Type of HCF				
- University hospitals / Cancer centres	1385 (34)	2630 (66)	2·04 (1·83–2·28) <0·001	1·41 (1·16–1·70) <0·001
- Non-university hospitals	978 (45)	1209 (55)	1·33 (1·18–1·51) <0·001	0·99 (0·83–1·19) 0·914
- Small, rehabilitation, nursing hospitals	977 (52)	908 (48)	1·00	1·00
- Private clinics	259 (41)	370 (59)	1·54 (1·28–1·84) <0·001	1·08 (0·84–1·39) 0·550
Gender				
- Male	477 (32)	1022 (68)	1·63 (1·44–1·83) <0·001	1·13 (0·97–1·29) 0·096
- Female	3064 (43)	4039 (57)	1·00	1·00
Age (years)				
- <25	511 (41)	726 (59)	1·00	1·00
- 26–35	853 (34)	1634 (66)	1·35 (1·17–1·55) <0·0001	1·43 (1·23–1·67) < 0·0001
- 36–45	747 (41)	1066 (59)	1·00 (0·87–1·16) 0·953	1·20 (1·02–1·41) 0·030
- 46–55	764 (45)	937 (55)	0·86 (0·74–1·00) 0·052	1·11 (0·94–1·31) 0·209
- >55	291 (48)	321 (52)	0·78 (0·64–0·94) 0·011	0·80 (0·64–1·00) 0·055
Professional status				
- Medical	218 (17)	1073 (83)	4·12 (3·53–4·79) <0·001	3·70 (3·09–4·44) <0·0001
- Non-medical	3381 (46)	4044 (54)	1·0	1·0
Duration in the position (years)				
- <3	469 (36)	831 (64)	1·00	–
- 3–10	1070 (40)	1628 (60)	0·86 (0·7–1·0) 0·029	
- >10	1428 (41)	2026 (59)	0·80 (0·7–0·9) 0·001	
Working unit				
- Medicine	1015 (37)	1727 (63)	1·00	1·00
- Surgery	617 (38)	993 (62)	0·95 (0·83–1·07) 0·390	0·99 (0·86–1·15) 0·972
- Intensive care unit	227 (30)	549 (71)	1·42 (1·19–1·68) <0·001	1·28 (1·06–1·55) 0·011
- Rehabilitation, long-term care	1273 (51)	1218 (49)	0·56 (0·50–0·62) <0·001	0·81 (0·68–0·96) 0·014
- Emergency	138 (35)	257 (65)	1·09 (0·88–1·36) 0·423	0·90 (0·70–1·16) 0·414
- Gynaecology-Obstetrics	54 (45)	69 (56)	0·75 (0·52–1·08) 0·124	0·98 (0·66–1·45) 0·906
- Psychiatry	42 (44)	54 (56)	0·76 (0·50–1·13) 0·181	0·91 (0·58–1·43) 0·697
- Other	77 (49)	81 (51)	0·62 (0·45–0·85) 0·003	0·78 (0·55–1·11) 0·166
Previous training in hand hygiene (last 3 years)	1172 (34)	1597 (32)	1·00	1·00
- No	2311 (66)	3442 (68)	1·09 (1·00–1·20) 0·058	1·11 (0·98–1·24) 0·098
- Yes				
Previous training in control of antimicrobial resistance (last 3 years)	2283 (69)	3130 (64)	1·00	1·00
- No	1001 (31)	1786 (36)	1·30 (1·18–1·43) <0·001	1·31 (1·16–1·48) <0·0001
- Yes				

KS, knowledge score; OR, odds ratio; CI, confidence interval;

Table 4. Behavioural factors associated with greater knowledge of antimicrobial resistance and infection control measures

Population-based variables	Population (n (%))		Univariate analysis (OR (95% CI) p)	Multivariate analysis (adjusted OR (95% CI) p)
	KS < 4	KS ≥ 4		
Perceived susceptibility				
- No agreement	503 (14)	528 (6)	1·00	1·0
- Agreement	3096 (86)	4789 (94)	2·37 (2·05–2·75) <0·001	2·33 (1·95–2·78)<0·0001
Perceived knowledge				
- No agreement	1257 (35)	1910 (37)	1·00	1·0
- Agreement	2342 (65)	3207 (63)	0·90 (0·82–0·98) 0·022	1·06 (0·95–1·18) 0·314
Intention to adhere				
- No agreement	1232 (34)	1809 (35)	1·00	–
- Agreement	2367 (66)	3308 (65)	0·95 (0·87–1·04) 0·280	
Attitude toward hand hygiene				
- No agreement	442 (12)	348 (7)	1·00	1·0
- Agreement	3157 (88)	4769 (93)	1·92 (1·66–2·22) <0·001	1·98 (1·65–2·37)<0·0001
Perceived behavioural norm				
- No agreement	1755 (49)	2701 (53)	1·00	1·0
- Agreement	1844 (51)	2415 (47)	0·85 (0·78–0·93) <0·001	0·95 (0·86–1·05) 0·276
Perceived subjective norm				
- No agreement	2025 (56)	3066 (60)	1·00	1·0
- Agreement	1574 (44)	2051 (40)	0·86 (0·79–0·94) 0·001	0·98 (0·89–1·09) 0·742
Self-efficacy				
- No agreement	944 (26)	1226 (24)	1·00	1·0
- Agreement	2655 (74)	3891 (76)	1·13 (1·02–1·24) 0·016	1·22 (1·09–1·38)<0·0001
Motivation				
- No agreement	647 (18)	758 (15)	1·0	1·0
- Agreement	2952 (82)	4359 (85)	1·26 (1·12–1·41) <0·001	1·42 (1·24–1·62)<0·0001

KS, knowledge score; OR, odds ratio; CI, confidence interval;
Adjusted odds ratio: adjusted for type of HCF, gender, age, professional status, working unit and training
See supplementary Table 3 for the formulation of the eight questions about perceptions

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Supplementary Table 1 - Knowledge of antimicrobial resistance and infection control measures

	Total (58 HCFs)		**University hospitals centres / Cancer centres (n= 9)**		**Non-university hospitals (n= 10)**		**Small hospitals, rehabilitation centres, nursing homes (n= 29)**		**Private clinics (n= 10)**	
	MW (n (%))	**NMW (n (%))**	**MW (n (%))**	**NMW (n (%))**	**MW (n (%))**	**NMW (n (%))**	**MW (n (%))**	**NMW (n (%))**	**MW (n (%))**	**NMW (n (%))**
Indication for hand hygiene (correct answer)										
After contact with the patient's environment? (yes)	1102 (88)	5694 (80)	1097 (85)	5699 (77)	245 (86)	1443 (76)	73 (76)	1308 (73)	73 (82)	422 (78)
When performing hand hygiene? (before contact)	536 (42)	3491 (48)	533 (41)	3495 (47)	113 (40)	869 (46)	28 (29)	822 (46)	44 (49)	267 (49)
Best product for hand hygiene? (alcoholic handrub)	955 (76)	3527 (48)	952 (74)	3531 (47)	215 (76)	800 (42)	66 (69)	771 (43)	60 (67)	268 (50)
Indication for glove use (correct answer)										
Wearing gloves for contact with intact skin, standard precautions? (no)	992 (84)	5389 (81)	988 (77)	5394 (73)	211 (74)	1395 (73)	70 (73)	1232 (69)	58 (65)	383 (71)
Wearing gloves for contact with intact skin, contact precautions? (no)	119 (9)	409 (6)	118 (9)	410 (5)	25 (9)	74 (4)	21 (22)	107 (6)	8 (9)	23 (4)
Knowledge of epidemiology of MDROs (correct answer)										
Decreasing methicillin-resistant *Staphylococcus aureus* rates? (yes)	147 (12)	363 (5)	147 (11)	363 (5)	25 (9)	81 (4)	13 (13)	116 (6)	5 (5.6)	43 (8)
Increasing extended-spectrum beta-lactamase-producing *Enterobacteriaceae* rates? (yes)	1068 (84)	3139 (43)	1065 (83)	3143 (42)	219 (77)	757 (34)	81 (84)	647 (36)	66 (74.2)	222 (41)
Transmission of methicillin-resistant *Staphylococcus aureus*? (hands)	1098 (87)	4944 (70)	1094 (85)	4949 (67)	231 (81)	1295 (68)	83 (86)	1055 (59)	71 (79.8)	356 (66)

Abbreviations: HCFs, healthcare facilities; MWs, medical healthcare workers; NMWs, non-medical healthcare workers; MDROs, multidrug-resistant organisms
Since not all questions were answered, the denominator may vary across questions.

Supplementary Table 2 - Perceptions regarding antimicrobial resistance and control measures

Perception-based variables	Total (58 HCFs)		University hospitals / cancer centres (n= 9)		Non-university hospitals (n= 10)		Small hospitals, rehabilitation centres, nursing homes (n= 29)		Private clinic (n= 10)	
	MW (n (%))	NMW (n (%))	MW (n (%))	NMW (n (%))	MW (n (%))	NMW (n (%))	MW (n (%))	NMW (n (%))	MW (n (%))	NMW (n (%))
Health belief perception										
Perceived susceptibility	1170 (91)	6715 (90)	737 (90)	2947 (92)	260 (91)	1697 (89)	92 (93)	1576 (88)	81 (91)	495 (92)
Perceived knowledge	553 (43)	4996 (67)	305 (37)	1993 (62)	135 (47)	1285 (68)	68 (69)	1309 (73)	45 (51)	409 (76)
Intention to adhere/perceived practice	582 (45)	5093 (69)	348 (42)	2166 (68)	137 (48)	1302 (68)	57 (58)	1235 (69)	40 (45)	390 (72)
Attitude toward hand hygiene	1134 (88)	6792 (91)	718 (88)	2945 (92)	244 (86)	1728 (91)	93 (94)	1621 (91)	79 (89)	498 (92)
Perceived behavioural norm	446 (34)	3814 (51)	263 (32)	1596 (50)	109 (38)	950 (50)	37 (37)	954 (53)	37 (42)	314 (58)
Perceived subjective norm	329 (25)	3296 (44)	162 (20)	1350 (42)	94 (33)	806 (42)	39 (39)	871 (49)	34 (38)	269 (50)
Self-efficacy	847 (66)	5699 (77)	511 (62)	2415 (75)	189 (66)	1445 (76)	84 (84)	1395 (78)	63 (71)	444 (82)
Motivation	994 (77)	6317 (85)	614 (75)	2732 (85)	222 (78)	1600 (84)	91 (92)	1518 (85)	67 (75)	467 (86)
Perceived threat of antimicrobial resistance										
National level	1247 (98)	6491 (88)	791 (98)	1669 (89)	276 (98)	1520 (86)	96 (97)	2846 (90)	84 (94)	456 (86)
Local level	837 (66)	2909 (40)	590 (73)	734 (39)	170 (61)	497 (28)	57 (58)	1537 (49)	20 (22)	141 (27)
Daily practice	835 (65)	2755 (38)	552 (68)	713 (38)	181 (65)	554 (31)	69 (70)	1318 (42)	33 (37)	170 (32)

Footnote

HCFs. Health care facilities; MWs. Medical healthcare workers; NMWs. Non-medical healthcare workers

Supplementary Table 3 - Questions on perception of antimicrobial resistance and control measures

Perception category	**Question**
Perceived susceptibility	"Non-compliance with hand hygiene entails risk to the patient"
Perceived knowledge	"I know the recommended indications for hand hygiene"
Intention to adhere/perceived practice	"I do perform hand hygiene as recommended"
Attitude toward hand hygiene	"I think that hand hygiene is a useful measure"
Perceived behavioural norm	"My colleagues perform hand hygiene according to the recommended guidelines"
Perceived subjective norm	"My hand hygiene is taken as an example by my colleagues"
Self-efficacy	"I can comply with hand hygiene according to recommended guidelines"
Motivation	"I can improve my compliance with hand hygiene"