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Healthcare Workers' Knowledge, Awareness, and Practices Regarding Antimicrobial Use, Resistance, and Stewardship in Saudi Arabia

Mahmoud S Abdallah[1], Osaid T Al Meanazel[2], Mohammed Mudhhi Alruwaili[2,3], Hayam Ali AlRasheed[4]

[1]Department of PharmD, Faculty of Pharmacy, Jadara University, Irbid, 21110, Jordan; [2]Department of Pharmacy, Faculty of Pharmacy, Jadara University, Irbid, 21110, Jordan; [3]Judidah Arar Hospital, the Northern Border Health Cluster, Arar, Saudi Arabia; [4]Department of Pharmacy Practice, College of Pharmacy, Princess Nourah bint Abdulrahman University, Riyadh, 11671, Saudi Arabia

Correspondence: Mahmoud S Abdallah, Department of PharmD, Faculty of Pharmacy, Jadara University, Irbid, 21110, Jordan, Email m.mohamed@jadara.edu.jo; Hayam Ali AlRasheed, Department of Pharmacy Practice, College of Pharmacy, Princess Nourah bint Abdulrahman University, P.O.Box 84428, Riyadh, 11671, Saudi Arabia, Email Haalrasheed@pnu.edu.sa

Background and Aim: Antimicrobial resistance (AMR) is a major global health threat, primarily driven by inappropriate antibiotic use. This cross-sectional study assessed the knowledge, attitudes, and practices of healthcare professionals in Saudi Arabia regarding antimicrobial use, resistance, and stewardship to identify gaps contributing to misuse.

Methodology: An observational cross-sectional study was conducted using a validated self-administered questionnaire among physicians, nurses, and pharmacists. Data were analyzed using univariate and multivariate methods.

Results: Among 236 respondents (45.3% physicians, 31.8% nurses, 22.9% pharmacists), most were aged 26–35 (33.9%), with nearly equal gender distribution (53.0% women). While 85.2% were aware of AMR, 64.1% reported limited access to infection control policies. Most (94.9%) acknowledged that unnecessary antibiotic use contributes to resistance, and 96.2% understood its transmissibility. Daily antibiotic prescribed, dispensed, or administered was reported by 57.6%. Key barriers to appropriate prescribing included time constraints (84.7%) and diagnostic uncertainty (75.8%). Only 20.3% used clinical guidelines, whereas 35.2% relied on pharmaceutical industry materials. In the multivariate regression, knowledge scores increased with age (+0.31 per decade, $p = 0.024$), profession was the strongest predictor ($\beta = 6.4$, $p < 0.001$), and antimicrobial stewardship (ASP) training improved scores by 1.6 points.

Conclusion: Significant gaps exist in access to guidelines and adherence to evidence-based practices. Targeted ASP interventions focusing on professional education, improved resource availability, and institutional support are essential to enhance stewardship and combat AMR in Saudi Arabia.

Keywords: healthcare workers, knowledge, practices, antimicrobial resistance, antimicrobial stewardship, Saudi Arabia

Introduction

Antimicrobials, like antibiotics, antivirals, and antifungals, play a vital role in preventing and treating infections in healthcare settings.[1] Antibiotics are often grouped based on how they work. Bacteriostatic antibiotics, like doxycycline, clindamycin, and azithromycin slow down the growth of bacteria, giving the immune system a chance to fight off the infection. On the other hand, bactericidal antibiotics, such as amoxicillin, gentamicin, ciprofloxacin, and vancomycin, kill the bacteria outright.[2]

Antimicrobials are essential for treating serious infections, but when they are overused or used inappropriately, especially broad-spectrum antibiotics, they can upset the body's natural balance of microbes. This disruption can lead to problems like opportunistic infections, overgrowth of normally harmless organisms, and the emergence of drug-resistant bacteria, which creates serious challenges for both patient care and public health.[3]

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Antimicrobial resistance (AMR) is now one of the biggest health problems worldwide. Many types of bacteria, both Gram-positive and Gram-negative, have found ways to resist the antibiotics we usually rely on. In hospitals, common bacteria like *Staphylococcus aureus*, coagulase-negative staph, and *Enterococcus* have become resistant to several antibiotics.[4] For instance, penicillin was once very effective against *S. aureus* when it was first used in the 1940s, but it did not take long for the bacteria to start fighting back. Today, most strains no longer respond to penicillin and similar antibiotics.[5,6] Similarly, vancomycin-resistant enterococci started appearing in the 1980s, and penicillin-resistant *Streptococcus pneumoniae* is still a major concern around the world today.[7]

Gram-negative organisms, including *Pseudomonas aeruginosa, Acinetobacter baumannii*, and members of the *Enterobacteriaceae* family, present an even greater challenge due to their inherent and acquired resistance mechanisms. The outer membrane of Gram-negative bacteria acts as a formidable barrier, and resistance is often mediated by plasmid-encoded enzymes such as extended-spectrum β-lactamases.[8] Carbapenem-resistant Enterobacteriaceae, classified as carbapenemase-producing or non-carbapenemase-producing, represent a major threat, driven by enzymes such as Klebsiella pneumoniae carbapenemase, New Delhi metallo-β-lactamase, Verona integron-encoded metallo-β-lactamase, and oxacillinase-48-like.[9,10]

The misuse and overuse of antibiotics are major contributors to the acceleration of AMR. Prior exposure to antibiotics significantly increases the risk of resistant infections, especially involving third-generation cephalosporins, fluoroquinolones, and carbapenems.[11,12] This issue is particularly pronounced in regions where antibiotics are easily accessible without prescription and public awareness is limited.

In Saudi Arabia, research has shown worrying trends in how antibiotics are used by the general public. A large number of people buy antibiotics without a prescription (63.6%), and many stop taking them as soon as they start feeling better, even if treatment is not finished (71.1%).[13] In the Northern region, self-medication is common, especially among young adults. Many people turn to it because it's convenient and helps save money.[14] Although some studies show that the public has a good understanding and follows proper practices when it comes to antibiotics, attitudes are still a problem. For example, in one national study, 76.8% of participants understood the dangers of stopping antibiotics too soon, but still had negative attitudes toward completing their courses.[15] Alarmingly, even among health-related students in Saudi universities, misconceptions about antibiotic use and resistance persist.[16]

Previous studies conducted in Saudi Arabia and neighboring countries have revealed variable levels of knowledge and awareness among healthcare professionals regarding antimicrobial use and stewardship. For instance, some investigations reported good general awareness of antimicrobial resistance but identified significant gaps in understanding antimicrobial stewardship principles and guideline adherence among physicians, nurses, and pharmacists.[17,18] In addition, studies in Gulf and Middle Eastern settings have shown that professional background, years of experience, and prior training in antimicrobial stewardships (ASPs) are significant predictors of appropriate prescribing behavior and stewardship knowledge.[19,20] However, despite these findings, comprehensive multi-professional comparisons within the Saudi healthcare context remain limited, leaving an important gap in understanding the factors influencing stewardship-related practices across different healthcare roles.

Therefore, the purpose of this study was to assess the knowledge, awareness, and behaviors of healthcare workers about antimicrobial use, resistance, and stewardship in Saudi Arabia, thereby pointing up any gaps and misunderstandings that can lead to incorrect antibiotic prescribing. The findings of this research are expected to support policymakers and healthcare administrators in designing targeted educational interventions and strategies to optimize antibiotic use and curb antimicrobial resistance across healthcare settings in the Kingdom.

Methods

Study Design and Ethical Considerations

This observational cross-sectional study was conducted among healthcare workers in Saudi Arabia. Data collection began in November 2024 and continued until the predetermined target sample size was achieved in February 2025. Ethical approval for this study was obtained from the Institutional Review Board (IRB) of the Faculty of Pharmacy at Jadara University with IRB number (PHARM-JA-9/2024) during thesis registrations requirement in Jadara University, and the

ethical approval was exempted by the Department of Training, Institutional Development, and Academic Affairs in AL-Jouf region, Ministry of Health, Kingdom of Saudi Arabia where the data were collected as the study is theoretical and involves only the analysis of survey data collected from healthcare practitioners, without the involvement of living subjects or the implementation of any medical interventions. Written informed consent was obtained from all participants prior to recruitment. All data were anonymized to ensure confidentiality.

Inclusion Criteria

The study included a broad spectrum of healthcare professionals. Participants encompassed medical physicians (eg, general practitioners, surgeons, and specialists in public health, microbiology, and infectious diseases), nurses (eg, general nurses, surgical nurses, public health specialists, and infection prevention/control nurses), and pharmacists.

Sample Size Calculation

The required sample size was calculated based on a previously reported prevalence of 33% of healthcare workers identifying settings where unnecessary antimicrobial use occurs,[21] assuming a 95% confidence level and a 6% margin of error, the estimated sample size was 236 participants according to the following equation,[22] where n represents the sample size, z is the z-statistic corresponding to the desired confidence level (Z = 1.96), P is the expected prevalence, and d is the allowable margin of error.

$$n = \frac{Z^2 \mathrm{P}(1 - \mathrm{P})}{\mathrm{d}^2}$$

To compensate for potential 20% non-response, a total of 300 healthcare professionals were approached. A convenience sampling technique was used to recruit physicians, nurses, and pharmacists from hospitals primary healthcare centers, and pharmacies across different regions of Northern Saudi Arabia.

Data Collection Tool

Data were collected using a previously published, validated questionnaire administered in paper form through direct visit to enhance the response rate and minimize the missing data.[23] This comprehensive self-administered tool was employed to evaluate healthcare workers' knowledge, awareness, and practices concerning antimicrobial use, resistance, and stewardship in Saudi Arabia. Questionnaire validity was established through face and content validity, while the reliability of the knowledge items used for the analysis was confirmed using Cronbach's alpha on a sample of 60 subjects, yielding a coefficient of 0.723, indicative of good internal consistency.

Outcomes

The outcome variable of this study was the knowledge score related to antimicrobial use, resistance, and stewardship among healthcare professionals. This score was derived from the knowledge domain of the validated questionnaire, which assessed participants' understanding of antibiotic indications, resistance mechanisms, stewardship principles, and infection control measures. Each correct response was assigned one point, and total scores were computed to represent overall knowledge levels. The covariates (independent variables) in this study encompassed sociodemographic and professional variables. Sociodemographic factors included age and gender. Professional characteristics covered profession (physician, nurse, or pharmacist), years of practice, type of healthcare facility (hospital or pharmacy), and prior participation in antimicrobial stewardship (ASP) training. These variables were selected based on prior literature and their theoretical relevance to antimicrobial resistance and stewardship practices. They were initially assessed in univariate analyses to explore potential associations and subsequently included in multivariate linear regression models to identify independent predictors of the knowledge score.

Recruitment

Participants were recruited using convenience sampling method through in-person visits conducted at various healthcare facilities in Northern Saudi Arabia primarily in the Al-Jouf Province, including the cities of Sakakah, Qurayyat, and Arar.

This region includes diverse network of hospitals, primary healthcare centers, and pharmacies that collectively provide a wide range of medical, nursing, and pharmaceutical services. Eligible healthcare professionals who were available and willing to participate at the time of data collection were invited to complete the questionnaire. These visits were aimed at raising awareness about the study and encouraging voluntary participation among eligible healthcare workers.

Statistical Analysis

After data collection using the paper form questionnaire, all responses were checked for completeness, extracted using Excel file, coded, and entered into SPSS version 27. Data cleaning was performed to identify and correct missing or inconsistent values. Normality of knowledge score was checked using the Kolmogorov–Smirnov test, although our sample size aligns with the sample size required for the central limit theorem.[24] Inferential statistical methods were applied to explore associations between variables. Independent *t*-tests or one-way analysis of variance (ANOVA) were used to compare means of continuous variables across different groups, such as knowledge scores among various professional categories. When significant differences were identified using ANOVA, post-hoc analyses (eg, Tukey's HSD) were conducted to determine specific group differences. Pearson correlation tests were conducted to determine the relationship between age and practice years, and knowledge scores. Multivariate linear regression analysis was employed to identify independent predictors of appropriate AMR knowledge. Variables included in the multivariate model were selected based on findings from univariate analysis and theoretical relevance. p-values were derived automatically by SPSS based on test-specific probability distributions, and 95% confidence intervals were generated accordingly for regression coefficients and mean differences.

Results

Subjects

The study population consists of 236 healthcare professionals, with physicians comprising the largest proportion (45.3%), followed by nurses (31.8%) and pharmacists (22.9%). Other characteristics are presented in Table 1.

Table 1 Sociodemographic and Basic Data of the Study subjects

	Number (n = 236)	%
Core profession		
Nurse	75	31.8
Physician	107	45.3
Pharmacist	54	22.9
Predominant role		
General	98	41.525
Specialist	138	58.475
Predominantly practice		
Hospital	182	77.1
Pharmacy	54	22.9
Years of experience		
3-5	74	31.4
6-10	74	31.4
11-15	51	21.6
16-20	21	8.9
21-25	9	3.8
>25	7	3.0

(*Continued*)

Table 1 (Continued).

	Number (n = 236)	%
Age		
18-25	72	30.5
26-35	80	33.9
36-45	44	18.6
46-55	18	7.6
56-65	10	4.2
> 66	12	5.1
Gender		
Male	111	47.0
Female	125	53.0
Social media using		
Twitter	56	23.7
Facebook	75	31.8
LinkedIn	39	16.5
YouTube	45	19.1
I do not use social media	21	8.9
Contributing to Antimicrobial resistance program	24	10.2

Knowledge of Antibiotic Resistance

A strong majority (85.2%) of respondents agree or strongly agree that they understand what antibiotic resistance is, indicating a solid foundational awareness. However, when it comes to recognizing the connection between their clinical practice (prescribing, dispensing, or administering antibiotics) and the spread of resistance, uncertainty increases, with 28% being undecided. While 42.8% of respondents feel confident in providing information about prudent antibiotic use, a significant proportion (38.1%) remain undecided, and 18.6% disagree or strongly disagree. Similarly, only 45.7% believe they have sufficient knowledge on appropriate antibiotic use in their practice, while a large proportion (34.3%) remain uncertain. Encouragingly, most participants (54.7%) recognize their key role in controlling antibiotic resistance, but the relatively high level of uncertainty (36%). Access to essential guidelines and materials appears to be a challenge. A substantial number of respondents (64.1%) either disagree or are undecided about having easy access to infection management guidelines, which could hinder evidence-based practice. Similarly, 63.1% are unsure or disagree that they have access to materials for advising on prudent antibiotic use. However, when it comes to opportunities to provide such advice, responses are more balanced, with 45.8% agreeing or strongly agreeing, while 39% remain uncertain. The majority of participants acknowledge the role of environmental factors in antibiotic resistance, with 84.7% agreeing or strongly agreeing that wastewater contributes to the problem. Similarly, most respondents (68.6%) recognize the impact of antibiotic overuse in livestock and food production, though 31.4% are still undecided (Table 2).

A high percentage of respondents correctly identified that antibiotics are not effective against viruses (93.2%) and do not treat cold and flu (87.7%). Participants demonstrated excellent awareness of the consequences of antibiotic misuse. Nearly all respondents (94.9%) understood that unnecessary antibiotic use leads to resistance, and 96.2% recognized that resistant bacteria can spread from person to person. Additionally, awareness of side effects associated with antibiotics (94.1%) and the fact that all antibiotic use increases the risk of resistance (95.8%) was exceptionally high. Most respondents (95.3%) correctly acknowledged that healthy individuals can carry antibiotic-resistant bacteria, a crucial concept in understanding community transmission. Furthermore, an equally high percentage (95.3%) was aware that using antibiotics for growth promotion in farm animals is illegal in the European Union, reflecting good knowledge of regulatory policies (Table 3).

Table 2 Knowledge Assessment Among the Study Participants (Q11, Q13, Q16)

	Strongly Disagree	Disagree	Undecided	Agree	Strongly Agree
Q11: To what extent do you agree?					
I know what antibiotic resistance is	0	7	28	116	85
I know there is a connection between my prescribing, dispensing, OR administering of antibiotics and the emergence and spread of antibiotic-resistant bacteria	0	10	66	81	79
I know what information to give to individuals about the prudent use of antibiotics and antibiotic resistance	0	44	93	61	38
I have sufficient knowledge about how to use antibiotics appropriately for my current practice	0	47	81	61	47
I have a key role in helping control antibiotic resistance	0	22	85	85	44
Q13: To what extent do you agree?					
I have easy access to guidelines I need for managing infections	0	66	84	74	12
I have easy access to the materials I need to advise on prudent antibiotic use and antibiotic resistance	0	50	99	63	24
I have good opportunities to provide advice on prudent antibiotic use to individuals	0	36	92	91	17
Q16: The following environmental and animal health factors are important in contributing to antibiotic resistance					
Environmental factors such as wastewater in the environment	0	0	36	76	124
Excessive use of antibiotics in livestock and food production	0	0	74	83	79

Table 3 Knowledge Assessment Among the Study Participants (Q12)

Q12: Please Answer Whether TRUE or false (n=236)	Correct Answers	%	Incorrect Answers	%
Antibiotics are effective against viruses	220	93.2	16	6.8
Antibiotics are effective against cold and flu	207	87.7	29	12.3
The unnecessary use of antibiotics makes them ineffective	224	94.9	12	5.1
Taking antibiotics has associated side effects or risks such as diarrhea, colitis, allergies	222	94.1	14	5.9
Every person treated with antibiotics is at an increased risk of antibiotic-resistant infection	226	95.8	10	4.2
Antibiotic-resistant bacteria can spread from person to person	227	96.2	9	3.8
Healthy people can carry antibiotic-resistant bacteria	225	95.3	11	4.7
The use of antibiotics to stimulate growth in farm animals is legal in the European Union (EU)	225	95.3	11	4.7

Practice Related to Antibiotic Resistance

A significant proportion of participants frequently prescribed, dispensed, or administered antibiotics, with 57.6% doing so at least once a day. However, patient education efforts were notably lacking. The vast majority (70.3%) rarely or never provided resources on prudent antibiotic use, and 73.3% rarely or never gave verbal advice on the topic (Table 4).

Table 4 Practice Assessment Among the Study Participants (Q14)

Q14: Considering the Last One Week Only in Your Clinical Practice	Once a Day	More than Once a Day	Once a Week	More than Once a Week	Rarely	IDU
How often did you prescribe, dispense, OR administer antibiotics during the last week?	71	65	58	30	12	0
How often did you give out resources (eg leaflets or pamphlets) on prudent antibiotic use or management of infections to individuals during the last one week?	0	0	17	36	166	17
How often did you give out advice related to prudent antibiotic use or management of infections to an individual during the last week?	0	0	43	10	166	17

Abbreviation: IDU, I do not understand the question.

The most commonly reported barriers to providing antibiotic-related advice were insufficient time (84.7%) and uncertainty about what advice to provide (75.8%), followed closely by patients not requiring (74.2%) or being uninterested in the information (69.5%). Language barriers and lack of resources were also mentioned, but to a lesser extent. Notably, 63.1% of respondents reported being able to give advice when needed. While 35.2% of respondents relied on pharmaceutical industry documentation for infection management decisions, only 20.3% used clinical practice guidelines, raising concerns about evidence-based practice. Additionally, continuing education training courses were used by 31.8%, but reliance on previous clinical experience (4.7%) and medical representatives (8.1%). Hand hygiene knowledge appears relatively strong, with 69.1% correctly identifying the World Health Organization (WHO) five moments of hand hygiene, and 71.6% recognizing the need for hand hygiene even when gloves are used. While these numbers are promising, they still indicate that nearly 30% of participants may have gaps in understanding or adherence to proper hand hygiene practices, which could impact infection control. The workplace (39.8%) was the most commonly reported source of information, followed by published guidelines (33.5%) and training courses (29.7%). Interestingly, government policy (26.7%) and scientific organizations (25.4%) also played a role. However, reliance on colleagues (11.9%) and media (8.9%) suggests that informal sources still influence antibiotic-related knowledge. When asked about which information sources had the most influence, government policy (52.1%) ranked highest, while published guidelines (5.9%) had surprisingly little impact. Nearly half of the respondents (48.3%) reported that the information they received changed their views on avoiding unnecessary antibiotic use, but only 24.2% changed their practice based on this information (Table 5).

Table 5 Practice Assessment Among the Study Participants (Q15, Q17-22)

	Number	%
Q15: Reasons that you were not able to give out advice		
The patient does not require information	175	74.2
Patient uninterested in information	164	69.5
Insufficient time	200	84.7
Difficulty getting patient to understand diagnosis	39	16.5
Language barriers	65	27.5
No resources available	33	14.0

(*Continued*)

Table 5 (Continued).

	Number	%
I was not sure what advice to provide	179	75.8
I was able to give out advice or resources as needed	149	63.1
Not applicable	175	74.2
Q17: Which of these do you use regularly to manage infections?		
Clinical practice guidelines	48	20.3
Documentation from the pharmaceutical industry	83	35.2
Medical representatives from the industry	19	8.1
Previous clinical experience	11	4.7
Continuing education training courses	75	31.8
Q18: Answer yes/no		
I can list the WHO's five moments of hand hygiene	163	69.1
I need to perform hand hygiene (as often as recommended) if I have used gloves in contact with patients or biological material	169	71.6
Q19: Information source		
Colleague or peer	28	11.9
My workplace	94	39.8
Media (TV/Radio) adverts	21	8.9
Social Media	21	8.9
Newspaper	12	5.1
Published guidelines	79	33.5
Training - conference/group	70	29.7
Training - one-to-one detailing	60	25.4
Government policy	63	26.7
Scientific organization	60	25.4
My professional body	24	10.2
Q20: The information contributes to changing the views about avoiding unnecessary antibiotics	114	48.3
Q21: Information with the most influence		
Colleague or peer	25	10.6
My workplace	43	18.2
Published guidelines	14	5.9
Training - conference/group	31	13.1
Government policy	123	52.1
Q22: Changing the practice based on the received information	57	24.2

Challenges in Addressing Antibiotic Resistance

A significant portion of respondents (26.7%) admitted to forgetting key messages related to antimicrobial stewardship, while 25.8% had not had an opportunity to apply them. Additionally, 23.3% felt they had no control over implementing changes, which could reflect institutional or systemic barriers. Encouragingly, 24.2% were already adhering to best practices. Respondents were divided on the most impactful level for addressing antibiotic resistance. While 26.3% supported targeting all healthcare workers, 25% believed action is needed at all levels, emphasizing a multifaceted approach. Interestingly, only 16.9% prioritized prescribers and 11.9% focused on the public. The most endorsed intervention was a national campaign (49.2%), followed by national or regional guidelines (32.2%) and posters/leaflets (23.3%). In contrast, TV and radio advertisements (10.2%), newspaper articles (9.3%), and professional organization awareness efforts (12.7%) were seen as less effective. Only 30.1% were aware of their country's national action plan on AMR, indicating a gap in communication or dissemination of these policies. Furthermore, only 6.8% had heard of European Antibiotic Awareness Day (EAAD) or World Antibiotic Awareness Week (WAAW), and even fewer (4.2%) found them effective. The most requested topic was antibiotic resistance (47.5%), followed by how to use antibiotics (22.9%) and medical conditions requiring antibiotics (23.3%). Only 6.4% expressed interest in antibiotic prescription practices (Table 6).

A 69.5% (Agree + Strongly Agree) felt their country had effectively promoted antibiotic stewardship, while 9.7% (Strongly Disagree + Disagree) disagreed. Only 46.6% believed national campaigns had reduced unnecessary antibiotic use, while 16% disagreed and 37.3% remained undecided (Supplementary data, S1).

Table 6 Addressing Challenges Among the Study Participants (Q23-25, Q27-30)

	Number	%
Q23: The most influence on changing the practice		
I was already following the principles of the message(s)	57	24.2
I have not had the opportunity	61	25.8
I forgot about the message	63	26.7
I have no control over it	55	23.3
Q24: The most effective level to tackle resistance to antibiotics		
Individual level (public)	28	11.9
Individual level (prescribers)	40	16.9
Individual level (all healthcare workers)	62	26.3
Regional/National Level	47	19.9
Action at all levels is needed	59	25.0
Q25: Initiatives which focus on antibiotic awareness and resistance		
TV or Radio advertising for the public	24	10.2
Toolkits and resources for healthcare workers	39	16.5
National or regional guidelines on the management of infections	76	32.2
Awareness raising from professional organizations	30	12.7
Conference/Events focused on tackling antibiotic resistance	26	11.0
National or regional posters or leaflets on antibiotic awareness	55	23.3

(*Continued*)

Table 6 (Continued).

	Number	%
Newspaper (national) articles on antibiotic resistance	22	9.3
National campaign	116	49.2
World Antibiotic Awareness Week/European Antibiotic Awareness Day	24	10.2
Q27: My country has a national action plan on antimicrobial resistance	71	30.1
Q28: Hearing about European Antibiotic Awareness Day (EAAD) or World Antibiotic Awareness Week (WAAW)	16	6.8
Q29: EAAD or WAAW is effective	10	4.2
Q30: Topics are likely to receive more information		
Resistance to antibiotics	112	47.5
How to use antibiotics	54	22.9
Medical conditions for which antibiotics are used	55	23.3
Prescription of antibiotics	15	6.4

Prescribing Practices and Decision-Making

Among the 107 prescribers, 35.41% of the respondents prescribe antibiotics daily, while 49.53% do so weekly, indicating frequent antibiotic use in clinical practice. Despite this, only 28.97% agree they are confident in making antibiotic prescribing decisions, while 57.01% remain undecided. Trust in antibiotic guidelines is moderate, with 39.25% agreeing and 28.97% strongly agreeing that they have confidence in available guidelines. Most respondents recognize their role in controlling antibiotic resistance)37.38% strongly agree, and 36.45% agree). However, 20.56% remain undecided. About 82.24% (agree + strongly agree) acknowledge that easy access to antibiotic guidelines should facilitate evidence-based prescribing. About 72.90% feel supported in avoiding unnecessary prescriptions, though 23.36% remain undecided, possibly reflecting external pressures influencing prescribing behavior (Supplementary data, S2).

Regarding influences on antibiotic prescribing, out of 107 participants, 15.0% reported that they would have preferred not to prescribe antibiotics but were unable to do so once a day, and 6.5% did so more than once a day. Fear of patient deterioration or complications led 13.1% to prescribe antibiotics once a day and 7.5% more than once a day. Prescribing to save time rather than explain non-indication occurred once a day in 9.3% participants and more than once a day in 6.5%. Shortening the prescribed course happened once a day in 9.3% and more than once a day in 5.6%. In situations where follow-up was not possible, 10.3% reported prescribing more than once a day. Diagnostic uncertainty led 17.8% to prescribe once a day and 8.4% more than once a day. Notably, prescribing to maintain the patient relationship was never reported on a daily basis. Additionally, prescribing shorter courses than recommended occurred once a day in 5.6% and more than once a day in 21.5% (Supplementary data, S3).

Antibiotic Resistance Knowledge Determinants

Males had a slightly higher mean score in antibiotic resistance knowledge than females, but the difference was not statistically significant, suggesting gender does not play a major role (36.4 vs 35.5, $p = 0.095$). However, the profession mattered, whereas physicians and pharmacists had significantly higher knowledge levels than nurses (38.4 and 37.5 vs 31.3, $p < 0.001$), indicating that education and professional training play a role. Where someone practices also made a difference; those in pharmacy settings had better knowledge than those in hospitals (37.5 vs 35.5, $p = 0.002$). On the other hand, a generalist healthcare worker had higher level of knowledge regarding AMR than a specialist (37.3 vs 34.96, $p < 0.001$). Awareness of AMR itself was a game-changer. Those who were aware had much higher knowledge scores

(40.4 vs 35.4, $p < 0.001$). Interestingly, age and years of experience had a significant impact on knowledge ($p = 0.005$ and 0.015, respectively) (Table 7).

Multivariate Analysis

The linear regression analysis identifies key predictors of AMR knowledge scores. Profession emerged as the strongest predictor, with physicians and pharmacists scoring significantly higher than nurses ($\beta = 6.374$, $p < 0.001$). ASP training was also significantly associated with increased knowledge ($\beta = 1.603$, $p = 0.012$), indicating the value of structured educational programs in enhancing awareness. Age, measured in year intervals, showed a modest but significant positive effect ($\beta = 0.308$, $p = 0.024$), suggesting that knowledge may increase with experience or continued exposure. In contrast, gender ($\beta = -0.294$, $p = 0.397$) and years of practice ($\beta = 0.041$, $p = 0.781$) were not significant predictors, implying that neither gender nor duration of professional experience alone significantly influences AMR knowledge. Notably, specialists scored lower than generalists ($\beta = -1.377$, $p < 0.001$) (Table 8).

Table 7 Subjects' Characteristics Associated with Antimicrobial Resistance Knowledge Score (Q11-13)

		Number	Mean	SD	Test value	p-value
Gender (¥)	Male	111	36.43	4.320	1.67	0.095
	Female	125	35.50	4.173		
Core profession (€)	Nurse	75	31.28[a]	2.704	152.5	<0.001*
	Physician	107	38.41[b]	2.465		
	Pharmacist	54	37.52[b]	3.533		
Predominant practice(¥)	Hospital	182	35.47	4.352	3.16	0.002*
	Pharmacy	54	37.52	3.533		
Predominant role (¥)	General	98	37.32	3.881	−4.34	<0.001*
	Specialist	138	34.96	4.26		
AMR training (¥)	No	212	35.44	4.116	8.05	<0.001*
	Yes	24	40.38	2.667		
Age (§)		236	r=0.181			0.005*
Experience (§)		236	r=0.158			0.015*

Notes: *, significant p-value at 0.05 level using *t*-test (¥), ANOVA test (€), and Pearson correlation test (§) as appropriate. Different superscript letters indicate significant differences in post hoc comparisons using Tukey's test after the ANOVA test.
Abbreviations: AMR, antimicrobial resistance; SD, standard deviation.

Table 8 Linear Regression for Antimicrobial Resistance Knowledge Score (Q11-13)

	Beta	SE for Beta	Test Statistic	p-value
(Constant)	31.218	0.664	47.027	0.000
Gender (female vs male)	−0.294	0.346	−0.849	0.397
Age (years intervals)	0.308	0.136	2.266	0.024*

(*Continued*)

Table 8 (Continued).

	Beta	SE for Beta	Test Statistic	p-value
Practice years as intervals	0.041	0.146	0.279	0.781
Profession (physician/pharmacist vs nurse)	6.374	0.381	16.749	<0.001*
ASP training	1.603	0.634	2.528	0.012*
Specialist vs generalist	−1.377	0.380	−3.620	<0.001*

Notes: Beta, regression coefficient; SE, standard error; *, significant p-value ≤ 0.05. Age (years as intervals): 1 = 18 years, 2= 18–25 years, 3= 26–35 years, 4–36-45 years, 5 = 46–55 years, 6= 56–65 years, 7 > 66 years. Practice years as intervals: 1= 0–2 years, 2= 3= 3–5 years, 4= 6–10 years, 5= 11–15 years, 6= 16–20 years, 7= 21–25 years, 8 >25 years.
Abbreviation: ASP, antimicrobial stewardship program.

Discussion

AMR remains one of the most pressing global health challenges, requiring urgent intervention at multiple levels of healthcare.[25] The present study provides novel insights into the determinants of antimicrobial stewardship knowledge among healthcare professionals in Saudi Arabia. Unlike earlier surveys focusing on single professions or descriptive analyses, our study used multivariate modeling to identify independent predictors across physicians, pharmacists, and nurses. This approach highlights the roles of prior training and clinical experience as modifiable factors that could enhance stewardship practices. This study is particularly significant as it provides a comprehensive assessment of healthcare professionals' knowledge, awareness, and practices regarding ASP in Saudi Arabia, a country facing rising antibiotic consumption and resistance concerns.[26] By examining prescribing behaviors, resource accessibility, and barriers to ASP implementation, the study identifies critical gaps in knowledge translation and clinical application, underscoring the necessity for targeted educational interventions. Given that physicians, pharmacists, and nurses all play pivotal roles in antimicrobial use, understanding the dynamics of interdisciplinary stewardship efforts allows for more refined strategies in optimizing antibiotic prescribing and promoting responsible usage.

The results of this study highlight several systemic and behavioral factors influencing antimicrobial prescribing, reinforcing trends observed in international ASP literature. While awareness of AMR and stewardship principles was relatively strong, practical application remains inconsistent, with prescribing decisions often influenced by time constraints, diagnostic uncertainty, patient expectations, and fear of complications. The identification of knowledge-to-practice gaps, particularly among nurses and other specialists, emphasizes the need for structured, profession-specific ASP training programs. Additionally, the disparities in resource availability, especially in hospital settings suggest institutional-level improvements are necessary to facilitate guideline adherence and evidence-based decision-making. Crucially, the study reveals suboptimal engagement with national AMR campaigns and global awareness initiatives, reinforcing the necessity for enhanced policy-driven strategies that integrate ASP into routine clinical practice. These insights provide actionable recommendations for strengthening ASP at the provider, institutional, and national levels, paving the way for more effective resistance mitigation strategies within Saudi Arabia's healthcare system.

To place our findings in a broader context, several international studies have examined healthcare professionals' knowledge and practices regarding antimicrobial stewardship. For instance, surveys in Europe and North America report similar high awareness of antimicrobial resistance but variable translation into practice, reflecting systemic and behavioral barriers such as time constraints, diagnostic uncertainty, and patient expectations.[25,27,28] Studies in other Middle Eastern countries have shown somewhat lower knowledge scores among nurses and general practitioners compared to physicians and pharmacists, highlighting gaps in interdisciplinary stewardship training.[18,29] Differences in findings across regions may be attributed to variations in healthcare infrastructure, availability of stewardship resources, institutional support, and prior exposure to formal training programs. Our study contributes novel insights by assessing determinants of antimicrobial stewardship knowledge across multiple professional groups in Saudi Arabia, demonstrating that prior

training, practice setting, and professional role are key predictors of knowledge and emphasizing the importance of tailored, context-specific interventions.

The hospital-based practice settings observed in our sample reinforce the need for stewardship strategies beyond infectious disease specialists. Research from Hadano and Matsumoto,[30] suggests that general practitioners and non-infectious specialists frequently encounter ASP challenges, yet many lack structured training in ASP principles. This aligns with our findings, indicating that ASP education should be expanded beyond infectious disease experts to enhance rational antibiotic use across multiple specialties.

Regarding experience and career progression, the skew toward early-to-mid-career professionals presents a unique opportunity for educational interventions aimed at forming long-term prescribing habits. This observation is supported by Guo et al (2022), who argue that ASP training should target younger professionals, given their increased receptiveness to adopting new guidelines and best practices.[31]

Interestingly, while self-reported awareness of antibiotic resistance was high, participants exhibited modest confidence in applying their knowledge to patient communication and appropriate antibiotic use. This echoes trends identified by a previous study, where healthcare workers expressed strong awareness but uncertainty in real-world ASP applications.[32]

One further important determinant of ASP efficacy turned out to be resource access. A significant number of participants indicated ambiguity or disagreement about the availability of guidelines and instructional resources, therefore indicating institutional support inadequacies. Similar results were reported in a prior study in which healthcare professionals claimed trouble finding clinical tools for responsible antibiotic prescribing.[33] Despite high awareness levels, participation in formal AMR training programs remained alarmingly low, indicating a gap in active engagement with stewardship initiatives.[34] Another study documented similar findings, reporting that while healthcare workers recognized the importance of ASP, their involvement in structured programs was limited.[20]

Finally, the strong foundational knowledge regarding antibiotic resistance, evidenced by the high rate of correct responses in antimicrobial knowledge assessments, suggests a solid baseline understanding among healthcare workers. The role of healthcare workers in reducing misconceptions and promoting prudent antibiotic use remains pivotal, and strengthening educational programs focused on translating knowledge into clinical practice should be a priority moving forward.[35] Overall, our findings are consistent with existing literature,[36] reinforcing the persistent knowledge-to-practice gap that hampers effective ASP implementation. While awareness levels are promising, efforts must focus on bridging the gap between theoretical knowledge and real-world application, improving access to ASP resources, and fostering active participation in stewardship programs.

The top barriers preventing healthcare professionals from offering antimicrobial advice included time constraints, uncertainty about what advice to provide, and lack of patient interest. These challenges mirror findings by a previous study, which reported that clinicians often refrain from ASP discussions due to heavy workloads and patient reluctance to receive counseling. Importantly, time constraints are recognized globally as a leading barrier to effective stewardship, and studies suggest that integrating ASP guidance into routine consultations can improve adherence.[27] Another noteworthy challenge is language barriers, which can limit communication between healthcare providers and patients. Similar findings have been reported in ASP studies within multicultural healthcare settings, where non-native speakers face challenges in accessing clear antimicrobial guidance.[28] Institutional efforts to develop multilingual ASP resources could play a pivotal role in enhancing accessibility and patient comprehension.

The findings suggest minimal gender differences in AMR knowledge scores, with male participants scoring slightly higher than females, though the difference lacks statistical significance. This aligns with previous studies,[37,38] which reported no significant gender-based disparities in AMR awareness among healthcare professionals. However, some global ASP studies have found that male practitioners tend to report higher confidence in antibiotic stewardship, suggesting that further qualitative investigations may be needed to explore confidence versus theoretical knowledge disparities.[39] A significant variation in knowledge scores is observed among different healthcare professions in the univariate and multivariate analyses, with physicians, pharmacists, and outperforming nurses. These trends align with previous studies, which found that physicians and pharmacists exhibited stronger knowledge of AMR guidelines compared to nurses, likely due to greater exposure to antimicrobial prescribing and stewardship training.[18,29]

However, the lower scores among nurses suggest that interdisciplinary ASP training should be reinforced, as nurses play a critical role in antimicrobial administration and patient education.[33] The results show that pharmacy-based practitioners exhibit significantly higher AMR knowledge scores than hospital-based practitioners. This supports findings from a previous study, where pharmacists demonstrated greater familiarity with antibiotic guidelines due to their integral role in dispensing and counseling.[40,41] In addition, the hospital has a variety of specialties, including nurses who showed lower AMR knowledge. The knowledge gap in hospital-based settings suggests a need for targeted ASP interventions, as hospital environments are major drivers of AMR due to high antibiotic utilization rates.[42] Healthcare professionals with prior ASP training or direct involvement in ASP initiatives scored significantly higher than those without ASP exposure in the univariate and multivariate analyses. This underscores findings from a previous study, which reported direct ASP engagement as a key predictor of improved ASP knowledge.[43] These results strongly support mandatory ASP training incorporation into medical and pharmacy education curricula.

Age and experience are positive predictors of AMR knowledge, supporting trends found in past research, whereby more experienced healthcare professionals showed stronger ASP knowledge.[44–46] Such results highlight the need for early-career educational programs to accelerate ASP learning curves in the younger physician population. These results draw attention to trends in antimicrobial stewardship that line up with worldwide studies, including variations in knowledge depending on occupation, the influence of the practice environment, and how direct contact with AMR typically increases awareness. More focused, multidisciplinary training, especially in hospital environments, helps to boost stewardship initiatives in Saudi Arabia. The findings underscore the need for enhanced integration of healthcare professionals within hospital antimicrobial stewardship committees. Strengthening institutional policies that promote continuing education and interprofessional collaboration can improve antimicrobial prescribing behaviors and resistance containment. Tailored educational initiatives and regular training workshops could help bridge knowledge gaps revealed in this study.

Limitations

This study has several limitations. First, its cross-sectional design precludes any inference of causality. Second, the use of self-reported questionnaires and may introduce reporting bias. Third, the relatively small sample size may limit the generalizability of the findings. Furthermore, although the sample included a wide range of healthcare professionals, proportional representation by professional category was not achieved due to the convenience sampling approach. Additionally, the study was conducted in northern Saudi Arabia, which may further restrict the applicability of the results to the broader national population.

Conclusion

This study highlights key determinants of antimicrobial stewardship (ASP) knowledge among Saudi Arabian healthcare professionals. While awareness of antimicrobial resistance is generally high, practical application is hindered by time constraints, diagnostic uncertainty, patient expectations, and limited institutional support. Nurses scored lower than physicians and pharmacists, emphasizing the need for multidisciplinary, targeted educational interventions. Age, experience, and prior training significantly influenced knowledge, suggesting that early-career professionals and specialists should be prioritized in future ASP programs. These findings underscore the importance of strengthening institutional support, improving access to ASP resources, and integrating structured stewardship training into clinical practice. Future research should evaluate the effectiveness of such interventions on improving real-world prescribing behavior and reducing antimicrobial resistance.

Data Sharing Statement

The raw data supporting the conclusion of this article will be made available by the authors upon request.

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Author Contributions

All authors made a significant contribution to the work reported, whether that is in the conception, study design, execution, acquisition of data, analysis and interpretation, or in all these areas; took part in drafting, revising or critically reviewing the article; gave final approval of the version to be published; have agreed on the journal to which the article has been submitted; and agree to be accountable for all aspects of the work.

Disclosure

The authors declare no conflicts of interest in this work.

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