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ORIGINAL RESEARCH

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Prescriber knowledge, behaviour and attitudes regarding antibiotic use and antibiotic resistance in Oman

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ABSTRACT

Background: Antimicrobial resistance threatens patients, healthcare systems, and the world's economy. Antimicrobial stewardship programs use evidence-based strategies to monitor and assess antibiotic use. This study aimed to identify prescribers' knowledge, attitudes, and behavior regarding antibiotic use and antibiotic resistance in Oman.

Research design and methods: A cross-sectional study was conducted using a questionnaire that was adapted from the European Centre for Disease Prevention and Control instruments. The survey was distributed among prescribers in Oman's Ministry of Health.

Results: The survey included a total of 371 prescribers. Most respondents were specialists, and 73% worked in hospitals. Antibiotics' effectiveness against viruses, needless use, and adverse effects were accurately answered by over 95% of prescribers. Eighty-four percent of prescribers realized the connection between their prescribing of antibiotics and the spread of antibiotic-resistant bacteria. Approximately 80% agreed that they address antibiotic resistance and consider it when treating patients. Around 70% of prescribers knew of the Oman national action plan to combat antibiotic resistance. Sixty-six percent of prescribers wanted information regarding antibiotic resistance, 49% about antibiotic use, and 40% about antibiotic prescriptions and medical problems.

Conclusion: The findings highlight the need for interventions to inform prescriber knowledge and behavior, improve antibiotic prescribing practices, and combat the spread of antimicrobial resistance.

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KEYWORDS
Antibiotic resistance; antibiotic use; antimicrobial stewardship; behavior; physicians; prescribers' knowledge

1. Introduction

Antimicrobial resistance (AMR) creates significant risks to patients, healthcare systems, and the world's economy [1]. There are around 1.14 million deaths per year directly resulting from AMR, and an estimated 4.71 million deaths per year were linked to AMR in 2021; by 2050, AMR could cause up to 10 million deaths annually [1–3]. In 2019, Oman reported 177 deaths directly attributed to AMR and 704 deaths linked with AMR [4].

The inappropriate and excessive use of antibiotics plays a crucial role in the development of antimicrobial resistance [5]. The antimicrobial stewardship (AMS) team plays an essential role in fighting antimicrobial resistance and reducing the burden on global health. AMS programs monitor and evaluate the rational use of antibiotics and depend on evidence-based interventions [6,7]. These programs work alongside infection prevention and control interventions. Antimicrobial stewardship (AMS) initiatives have been put into place in hospitals and communities throughout a number of nations. Regional governance methods have been successful in improving AMS and infection prevention in Italy [8]. Community-based stewardship issues in the UK underscore the need for targeted training and defined clinical pathways [9]. In the meantime, a regional strategy covering five African nations highlights the value of cooperation and sustainability, especially in settings with limited resources [10].

Studies have shown that physicians can inappropriately prescribe antibiotics due to a lack of access to guidance and diagnostic tests, and they can also be influenced by patient demand [11,12]. Antimicrobial stewardship is driven by the prescriber's knowledge of appropriate antibiotic use. Overprescribing antibiotics leads to severe infections, complications, longer hospital stays, increased mortality, adverse effects, frequent re-attendance, and issues with medication for self-limiting conditions [13]. The extent and appropriateness of antibiotic usage differs significantly between countries, hospitals, and individual clinicians [14–16]. Some factors that influence antibiotic prescribing are culture norms, hospital policies, peer influence, individual behaviors, and educational background [14,17]. In 2016, a study in Oman found that 63% of the antimicrobial selection was appropriate and highlighted the need to standardize the guidelines across all hospitals in Oman [18]. However, some hospitals create their local guidelines, which found that the prescriber must comply with these

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guidelines and restrict broad-spectrum antibiotics [19]. A significant issue in antibiotic utilization is the prescriber's insufficient knowledge and the pressure to dispense antibiotics without reason [20]. In addition, prescribers' knowledge and skills are important to understanding antimicrobial resistance, and prescribers' clinical skills significantly impact prescribing behaviors [21]. The prescriber's behavioral influence has a significant impact on antimicrobial prescribing failure [22]. Therefore, studying the behavioral factors that optimize antibiotic prescribing is essential [23].

This study aimed to assess prescribers' knowledge, attitudes, and behavior regarding antibiotic use and resistance in Oman healthcare institutions to identify the gaps and areas to improve antimicrobial stewardship.

2. Patients and methods

2.1. Study design

The survey was distributed among doctors in Oman's Ministry of Health (MOH) from February 2023 to August 2023 through the MOH mail system. There were 5,807 doctors registered with the Ministry of Health. Oman has three healthcare systems: the first, operated by the Ministry of Health (MOH), is government-funded and serves public patients; the second system serves the private sector. Other public sectors exist, sponsored by other governmental institutions, such as the Police and Armed Forces The MOH has various hospitals, polyclinics, and Health Centres across Oman. All doctors have to complete the internship year in the MOH institutions. The questionnaires, adapted from the European Center for Disease Prevention and Control (ECDC) instruments [24,25], were slightly modified to suit Oman's situation; this included adding governate and the place of practice in Oman. The survey was prepared in two languages (English and Arabic). Questionnaires were distributed using the online web-based survey software Qualtrics, ensuring broad reach and ease of response. Validation options were enabled to limit the response to one person. We created response validation methods to maintain the integrity of the collected data. These measures ensured that each survey was carried out by an independent person and prevented duplicate submissions from the same respondent. Participants received an invitation to complete a Qualtrics Forms-based online survey with more information about the study through the MOH's mail system. They were also sent through the WhatsApp group of doctors in each MOH institution. Participants received an invitation leading them to an online web-based survey, with an overview of the study and advised that their participation was voluntary and that their responses would be anonymized and kept strictly confidential. Completion of the survey implied informed consent.

The study was approved by the Health Studies and Research Approval Committee in Muscat, Oman (Moh/DGPS/CSR/PRO/approved/137/2022) and the University of Huddersfield Research Integrity and Ethics Committee (SAS-SRIEC-21.12.22–1).

2.2. Survey tool

The survey had seven sections. The first set of questions was developed to gather information about demographic characteristics (e.g. age, gender, governorate, profession, place of work, and years of experience). The survey was designed based on the COM-B behavioral change model, which proposes that behavior is influenced by an individual's capability, opportunity, and motivation.

The second section examines the doctors' actual knowledge with eight true or false questions. Four questions on capability measured awareness of antibiotic use, unnecessary use, or adverse effects; three questions were addressed to antibiotic resistance, and one assessed animal sector antibiotic resistance. The third section has a 5-point Likert scale (strongly agree to disagree strongly, not applicable, undecided, and I don't understand questions) on uses to assess the perceived knowledge, opportunity, motivation, and one health. The fourth section was the frequency with which doctors provided antibiotics or resources related to the prudent use of antibiotics, and the drivers' behavior for initiating prescriptions. The fifth section was about the resources used in professional activity. The sixth section is about sources of information used to improve antibiotic prescribing. The last section concerns awareness of initiatives and action plans in the country. In addition, there were questions regarding the topic needed by doctors, antibiotic prescribing frequency, strategies used to prescribe antibiotics wisely, how doctors tackle antibiotic resistance, and an awareness of initiatives and action plans in the country.

2.3. Statistical analysis

The sample size was calculated using the Raosoft sample size calculator (http://www.raosoft.com/samplesize.html) based on a margin of error of 5% and a confidence level of 95% and a 50% response distribution. The total number of medical doctors registered in MOH was 5807; however, the sample size was 361. The data were analyzed using IBM SPSS Statistics software (version 28.0, Armonk, NY, U.S.A.). The respondents' sociodemographic characteristics were presented as frequencies and percentages. The effect of demographic characteristics on respondents' knowledge scores was described as median and interquartile range and compared with the Wilcoxon-rank sum test or Kruskal–Wallis rank sum test after the normality. The chi-square or Fisher's exact test examined the differences among respondents with full knowledge scores. A univariable and multivariable linear regression model was conducted to assess the predictor of knowledge and adjust for other predictors If the p-value was <0.2 in the univariable linear regression model, we considered them as adjusted variables in the multivariable linear regression. *P*-values <0.05 are considered significant with a 95% confidence level.

3. Results

3.1. Key findings in Oman data

3.1.1. Demographics data

In total, 371 prescribers from different places of practice and governorates in Oman responded to the survey. The majority were from Muscat Governorate (65%). Around 38% of respondents were between 36 and 45 years old. Doctors specializing in medicine were considered the highest responders (36%);

Table 1. Prescribers' sociodemographic characteristics ($n = 371$).

Variable	$N = 371$[1]
Gender	
Female	182 (49%)
Male	189 (51%)
Age	
> 66 years	3 (0.8%)
24–35 years	115 (31%)
36–45 years	141 (38%)
46–55 years	77 (21%)
56–65 years	35 (9.4%)
Governorate	
Ad Dakhiliyah	30 (8.1%)
Ad Dhahirah	12 (3.2%)
Al Batinah North	10 (2.7%)
Al Batinah South	9 (2.4%)
Al Buraymi	4 (1.1%)
Al Wusta	2 (0.5%)
Ash Sharqiyah North	23 (6.2%)
Ash Sharqiyah South	11 (3.0%)
Dhofar	21 (5.7%)
Musandam	6 (1.6%)
Muscat	243 (65%)
Profession	
General practice	127 (34%)
Infectious disease physician	3 (0.8%)
Specialists	133 (36%)
Surgeon	108 (29%)
Role of specialist	
Generalist	151 (41%)
Senior Consultant	51 (14%)
Specialist	169 (46%)
Place of practice	
Hospital (any hospital type)	271 (73%)
Primary health center	78 (21%)
Secondary care center (polyclinic or dialysis center)	22 (5.9%)
Years Of Practice	
> 25 years	44 (12%)
0–2 years	48 (13%)
11–15 years	77 (21%)
16–20 years	48 (13%)
21–25 years	33 (8.9%)
3–5 years	55 (15%)
6–10 years	66 (18%)

[1]Frequency (%)

*Profession refers to doctors' clinical field or practice area.
*The role of a specialist reflects the level of training and experience.

more than 70% of responders worked at the hospital level (Table 1).

3.1.2. Actual capability

Table 2 displays the eight questions that assessed the prescribers' actual knowledge. The prescribers demonstrated a high level of knowledge, achieving correct responses of 95% on 'the effectiveness of antibiotics against viruses,' 97% concerning 'the unnecessary use,' and 97% related to 'the side effects associated with their intake.' They revealed their ability to respond to questions on 'the efficacy of antibiotics against colds' with an accuracy of 85% and 'whether healthy individuals might carry antibiotic resistance' with an accuracy of 87%. Prescribers agreed on 'the spread of antibiotic resistance' and 'the risk of antibiotic resistance during treatments' by 80%. Unfortunately, just 34% of respondents were aware that using antibiotics to stimulate growth in animal farms is illegal in Oman.

The study revealed noteworthy differences in average knowledge scores among different demographic groups. Specifically, the seniors aged of 56–65 years exhibited significantly higher knowledge scores ($p = 0.004$). As detailed in Table S1, specialists also demonstrated significantly higher average knowledge scores ($p = 0.02$). Moreover, a significant prevalence of perfect scores was observed among senior consultants ($p \leq 0.001$) and those with greater than 25 years of experience ($p = 0.018$), as presented in Table S1. Senior consultants, age group (56–65 years) and those with 25 years of experience had a significantly higher percentage of full scores ($p \leq 0.001$).

Table S2 presents the univariable regression model, showing that senior consultants ($p < 0.001$) and prescribers with more than 25 years of experience ($p = 0.015$) have significantly high knowledge scores. The multivariable regression model shows that the prescribers with 3–5 years of experience ($p = 0.046$) had higher knowledge.

3.1.3. Perceived capability Perceived capability

The survey data on perceived knowledge (Table 3) show that around 87% of prescribers either agreed or strongly agreed that they knew what antibiotic resistance is. Above 84% of the prescribers communicated that they have enough information regarding antibiotic use and explain antibiotic resistance to others. Eighty-seven percent of the prescribers agreed and strongly agreed that they have sufficient knowledge about how to use the antibiotic appropriately in their practice.

3.4. Opportunity

Among the prescribers who report having easy access to guidelines for managing the infection (73%). More than 66% of the prescribers agreed and strongly agreed that they have easy access to guidelines and materials that can advise others regarding antibiotic resistance. Meanwhile, 77% of the

Table 2. Prescribers' actual knowledge ($N = 371$).

Key Knowledge Question	Correct Answer	True* N (%)	False* N (%)	Unsure* N (%)
Antibiotics are effective against viruses.	False	12 (3%)	353 (95%)	6 (2%)
Antibiotics are effective against cold infections.	False	29 (8%)	315 (85%)	27 (7%)
The unnecessary use of antibiotics makes them become ineffective.	True	361 (97%)	8 (2%)	2 (1%)
Taking antibiotics has associated side effects or risks such as diarrhea, colitis, allergies.	True	359 (97%)	10 (3%)	2 (1%)
Every person treated with antibiotics is at an increased risk of antibiotic-resistant infection.	True	298 (80%)	37 (10%)	36 (10%)
Antibiotic-resistant bacteria can spread from person to person.	True	295 (80%)	41 (11%)	35 (9%)
Healthy people can carry antibiotic-resistant bacteria.	True	323 (87%)	16 (4%)	32 (9%)
The use of antibiotics to stimulate growth in farm animals is legal in Oman.	False	36 (10%)	126 (34%)	209 (56%)

*Represent the number of respondents (percentage) who answered as true or false or unsure.

prescribers had the opportunity to inform individuals regarding prudent antibiotic use (Table 3).

3.5. Motivation

From the same Table 3, the prescribers showed confidence in prescribing antibiotics and in the information in the guidelines with around 91%. However, only 84% of prescribers strongly agreed and agreed that they knew about the connection between their prescribing antibiotics and emergence and spread of antibiotic-resistant bacteria. Furthermore, around 80% of prescribers agree on their role in controlling antibiotic resistance and consider resistance when treating patients. In addition, the prescribers feel supported when unnecessary antibiotics are not prescribed (96.1%).

Prescribers were asked, 'At what level do you believe it is most effective to tackle antibiotic resistance?' This inquiry uncovers significant insights into the viewpoints of survey respondents concerning the most effective strategy for addressing antibiotic resistance. Around 46% of prescribers agreed with the need for intervention at all levels to tackle this critical concern efficiently, where prescribers tackle antibiotic resistance at individual, national and global levels. This perspective highlights prescribers' awareness and perspectives of antibiotic resistance while also emphasizing the necessity for collaborative efforts among all stakeholders to address the complexities of the issue (Figure S1).

3.6. One Health

In Table 3, one health question found that around 65% of the prescribers agree that the excessive use of antibiotics in livestock and food production is contributing to antibiotic resistance in bacteria from humans. In contrast, 56% were unsure if it is legal to use antibiotics in animal farms (Table 2). Moreover, 52% only agree that environmental factors (e.g. wastewater) can contribute to antibiotic resistance.

3.7. Behaviour

Most participants (44%) reported prescribing antibiotics weekly, indicating a frequent need for antibiotic interventions. Furthermore, 35% indicated they prescribe antibiotics daily, suggesting a substantial daily antibiotic prescription rate. A smaller proportion prescribes antibiotics monthly (13%), quarterly (7%), or yearly (2%), reflecting varying prescription frequencies among prescribers (Figure S2).

The study revealed that although 23% of prescribers did prescribe antibiotics more than once a day, more than 70% would never and rarely give out resources on the prudent use of antibiotics for infections (Table 4). Furthermore, 15% of respondents never advise on prudent antibiotic use.

Table 4 presents prescriber driven' behaviors regarding initiating prescriptions; 50% of the prescribers have never and rarely prescribed antibiotics when they prefer not to do so. In addition, 43% of them would rarely or never prescribe antibiotics because of fear of patient deterioration or complications. Forty-six percent of the prescribers never prescribed antibiotics when they were not indicated. Furthermore, around 66% of the prescribers would never or rarely prescribe antibiotics in situations where prescribers could not conduct a patient follow-up. Around 79% and 64% of prescribers never or rarely prescribe an antibiotic to maintain the relationship with the patient and prescribe an antibiotic because they were uncertain about the diagnosis of infection, respectively. Furthermore, 44% of prescribers would never stop an antibiotic prescription earlier than the prescribed course length; also, around 39% would never discontinue initial treatment because a bacterial infection was not likely.

Table S3 shows that 70.6% of prescribers answered they had received information about avoiding unnecessary antibiotic prescribing. More than 91% of prescribers said that information contributed to changing their views about this, and around 93% changed their practice.

The study shows that more than 60% of prescribers received information on avoiding unnecessary antibiotic prescriptions from the workplace, and based on this, 39.1% of them changed their views. In addition, around 35% of prescribers received information from published guidelines, and only 45.6% changed their views regarding avoiding prescribing unnecessary antibiotics (Figure 1).

The results on strategies employed to prescribe antibiotics prudently reveal variable insights. Patient education emerges as a prominent strategy, with 46% of participants recognizing its importance. Delayed prescribing is another notable approach, with 26% of respondents favoring its implementation. New patient consultation receives attention from 13% of participants, while 8% cite other strategies (e.g. waiting for the culture report and sensitivity, evidence of infections and severity of disease). A minority (7%) reported not employing any specific strategy in their antibiotic-prescribing practices (Figure S3).

3.8. Awareness of national action plans, national initiatives

Out of the prescribers surveyed, 70% were aware of Oman's national action plan on combating antibiotic resistance, 24% were unaware, and 6% were uncertain about its existence.

The results of the awareness initiatives in antibiotic awareness and resistance showed that 65.8% of prescribers were aware of the national or regional guidelines on the management of infections, 39.1% knew from conferences and events focused on tackling antibiotic resistance, and 38.5% that awareness raised from professional organizations. However, only 7.3% said they don't know about awareness initiatives (Table S4).

3.9. Resources for managing infections.

Around 77% of prescribers used clinical practice guidelines to manage infections, while almost 50% contact infection specialists (Table S5). In addition, the prescribers' use of their previous clinical experiences was impressive (41%).

Table 3. Prescriber perceived knowledge ($n = 371$).

	SA[1]	A[1]	D[1]	SD[1]	N/A[1]	U[1]	IDU[1]
Perceived Knowledge							
I know what antibiotic resistance is	135 (36%)	188 (51%)	4 (1.1%)	24 (6.5%)	4 (1.1%)	9 (2.4%)	7 (1.9%)
I know what information to give to individuals about the prudent use of antibiotics and antibiotic resistance	97 (26%)	215 (58%)	8 (2.2%)	17 (4.6%)	5 (1.3%)	28 (7.5%)	1 (0.3%)
I have sufficient knowledge about how to use antibiotics appropriately for my current practice	93 (25%)	231 (62%)	12 (3.2%)	14 (3.8%)	4 (1.1%)	16 (4.3%)	1 (0.3%)
Opportunity							
I have easy access to guidelines I need on managing infections	72 (19%)	199 (54%)	35 (9.4%)	16 (4.3%)	5 (1.3%)	40 (11%)	4 (1.1%)
I have easy access to the materials I need to give advice on prudent antibiotic use and antibiotic resistance	46 (12%)	200 (54%)	50 (13%)	15 (4.0%)	1 (0.3%)	56 (15%)	3 (0.8%)
I have good opportunities to provide advice on prudent antibiotic use to individuals	53 (14%)	235 (63%)	27 (7.3%)	17 (4.6%)	4 (1.1%)	35 (9.4%)	-
Motivation to initiate antibiotic prescriptions							
I know there is a connection between my Prescribing of antibiotics and emergence and spread of antibiotic-resistant bacteria	119 (32%)	192 (52%)	15 (4.0%)	20 (5.4%)	-	20 (5.4%)	5 (1.3%)
I am confident making antibiotic prescribing decisions	42 (11%)	297 (80%)	17 (4.6%)	3 (0.8%)	-	12 (3.2%)	-
I have confidence in the antibiotic guidelines available to me	75 (20%)	266 (72%)	14 (3.8%)	3 (0.8%)	-	13 (3.5%)	-
I have a key role in helping control antibiotic resistance	102 (27%)	201 (54%)	10 (2.7%)	21 (5.7%)	5 (1.3%)	32 (8.6%)	-
I consider antibiotic resistance when treating a patient	19 (5.1%)	280 (75%)	23 (6.2%)	5 (1.3%)	-	44 (12%)	-
I feel supported to not prescribe antibiotics when they are not necessary	30 (8.1%)	328 (88%)	8 (2.2%)	2 (0.5%)	-	3 (0.8%)	-
One Health: environmental and animal health factors that are important in contributing to antibiotic resistance in bacteria from humans							
Environmental factors such as wastewater in the environment are important in contributing to antibiotic resistance in bacteria from humans	25 (6.7%)	169 (46%)	24 (6.5%)	12 (3.2%)	20 (5.4%)	87 (23%)	34 (9.2%)
Excessive use of antibiotics in livestock and food production is important in contributing to antibiotic resistance in bacteria from humans	69 (19%)	171 (46%)	19 (5.1%)	21 (5.7%)	4 (1.1%)	73 (20%)	14 (3.8%)

[1]n (%).

Abbreviations: SA: strongly agree; A: agree; D: disagree; SD: strongly disagree; N/A: not applicable; U: undecided; IDU: I do not understand.

3.10. *Information gaps highlighted by prescribers*

In Figure 2, the prescribers express their need to receive information: 66% need information about resistance to antibiotics, 49% need to know how to use antibiotics, and 40% want to know about the prescription of antibiotics and which antibiotics are used for medical conditions. In addition, 38% of prescribers would like to know about the link between the health of humans, animals, and the environment.

The Findings of this study need to be taken into consideration to encourage the implementation to address the threat of AMR. Additionally, it provides policymakers with baseline data on AMR awareness among prescribers. Furthermore, Training, education programs, and information materials could be a key factor in improving the prescriber behavior, barriers, and therefore improving the prescribing of antibiotics

4. Discussion

This study was conducted among prescribers working in MOH institutions in Oman. This study provides valuable findings that can be used to address the gap and develop training and education interventions. Our study found that only 83 out of 371 prescribers answered all questions about actual knowledge correctly. Furthermore, our survey indicated that 30% of doctors either reported not receiving or not recalling any information on avoiding unnecessary antibiotics in the last 12 months. In addition, around 41% of doctors depend on their experiences rather than following the guidelines, and while 73% stated they have easy access, the rest disagree and were uncertain. Therefore, these findings suggest potential gaps in awareness, training, and practical application of the antibiotic prescribing principle. Contributing factors may include insufficient antibiotic stewardship training, lack of awareness regarding antibiotic use and antibiotic resistance, reliance on experience over guidelines, time pressure, and lack of access to updated guidelines [7,14,26].

It revealed that the prescribers have almost the same high level of knowledge, comparable to other studies done with the same ECDC instrumental tools, regarding the effectiveness of antibiotics against viruses, unnecessary use of antibiotics, and associated side effects [25,27]. While the prescribers demonstrate a moderate level of knowledge of the effectiveness of antibiotics against cold infections, improving their knowledge is essential. The risk of antibiotic resistance infection increases with every person treated with antibiotics, and this may increase the transmission of resistant pathogens between people. Furthermore, our findings regarding the knowledge of responders to antibiotic resistance highlighted the need to increase the awareness about antibiotic use among prescribers. The study showed the need to provide and make it easy to access, local or national guidelines to manage infections and an education program to help them understand antibiotic resistance. Bases on our findings showed that a significant proportion of prescribers write antibiotic prescriptions weekly (44%) and daily (35%), indicating the importance of their participation in the use of antibiotics and the value of comprehensive guidance on managing the infection and antibiotic resistance [28]. However, only 46% of doctors agreed that coordinated action

Table 4. The frequency with which prescribers provided antibiotics or resources related to the prudent use of antibiotics, the behavior of drivers for initiating prescriptions and antibiotic prescribing behaviors ($n = 371$).

Item	> QD [1]	> QW [1]	NVR [1]	R[1]	QD [1]	QW [1]	N/A[1]	IDR[1]
Opportunity to provide antibiotics or resources related to prudent use of antibiotics								
How often did you prescribe antibiotics during the last one week?	86 (23%)	73 (20%)	35 (9.4%)	43 (12%)	56 (15%)	58 (16%)	11 (3.0%)	9 (2.4%)
How often did you give out resources (e.g. leaflets or pamphlets) on prudent antibiotic use or management of infections to individuals during the last one week?	11 (3.0%)	10 (2.7%)	168 (45%)	91 (25%)	15 (4.0%)	28 (7.5%)	27 (7.3%)	21 (5.7%)
How often did you give out advice related to prudent antibiotic use or management of infections to an individual during the last one week?	48 (13%)	47 (13%)	57 (15%)	86 (23%)	36 (9.7%)	61 (16%)	18 (4.9%)	18 (4.9%)
The behavior of drivers for initiating prescriptions								
How often would you have preferred not to prescribe an antibiotic but were not able to during the last one week?	31 (8.4%)	43 (12%)	90 (24%)	97 (26%)	21 (5.7%)	48 (13%)	19 (5.1%)	22 (5.9%)
How often did the fear of patient deterioration or fear of complications lead you to prescribe antibiotics during the last one week?	28 (7.5%)	45 (12%)	70 (19%)	89 (24%)	22 (5.9%)	81 (22%)	23 (6.2%)	13 (3.5%)
How often did you prescribe antibiotics because it took less time than to explain the reason why they are not indicated during the last one week?	11 (3.0%)	11 (3.0%)	171 (46%)	101 (27%)	6 (1.6%)	30 (8.1%)	20 (5.4%)	21 (5.7%)
How often did you prescribe antibiotics in situations in which it was impossible for you to conduct a follow-up of the patient during the last one week?	17 (4.6%)	22 (5.9%)	135 (36%)	111 (30%)	6 (1.6%)	36 (9.7%)	23 (6.2%)	21 (5.7%)
How often did you stop an antibiotic prescription earlier than the prescribed course length during the last one week?	6 (1.6%)	14 (3.8%)	151 (41%)	102 (27%)	11 (3.0%)	34 (9.2%)	23 (6.2%)	30 (8.1%)
Antibiotic prescribing behavior								
How often did you prescribe an antibiotic to maintain the relationship with the patient during the last one week?	11 (3.0%)	7 (1.9%)	231 (62%)	62 (17%)	7 (1.9%)	17 (4.6%)	24 (6.5%)	12 (3.2%)
How often did you prescribe an antibiotic because you were uncertain about the diagnosis of infection during the last one week?	15 (4.0%)	25 (6.7%)	110 (30%)	126 (34%)	5 (1.3%)	49 (13%)	22 (5.9%)	19 (5.1%)
How often did you prescribe a shorter course of treatment as compared to available guidelines during the last one week?	9 (2.4%)	15 (4.0%)	162 (44%)	107 (29%)	4 (1.1%)	27 (7.3%)	19 (5.1%)	28 (7.5%)
How often did you discontinue early (within three days after initiation) a treatment because bacterial infection was not likely after all during the last one week?	9 (2.4%)	22 (5.9%)	145 (39%)	104 (28%)	7 (1.9%)	28 (7.5%)	25 (6.7%)	31 (8.4%)

[1]n (%).

Abbreviations: QD: once a day; QW: once a week; NVR: never; R: rarely; N/A: not applicable; IDR: I do not remember.

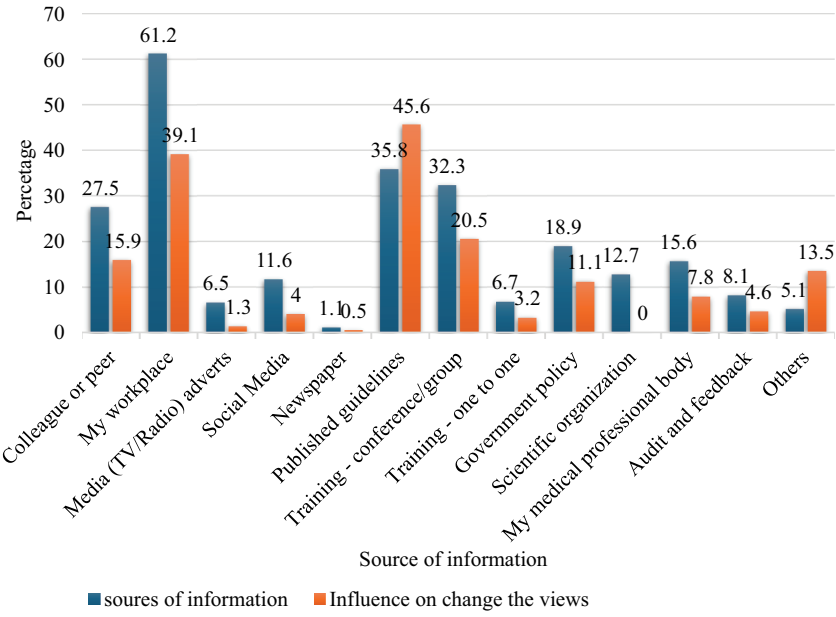

Figure 1. Sources of information about avoiding unnecessary prescribing antibiotics and their influence on changing prescribers' views ($n = 371$).

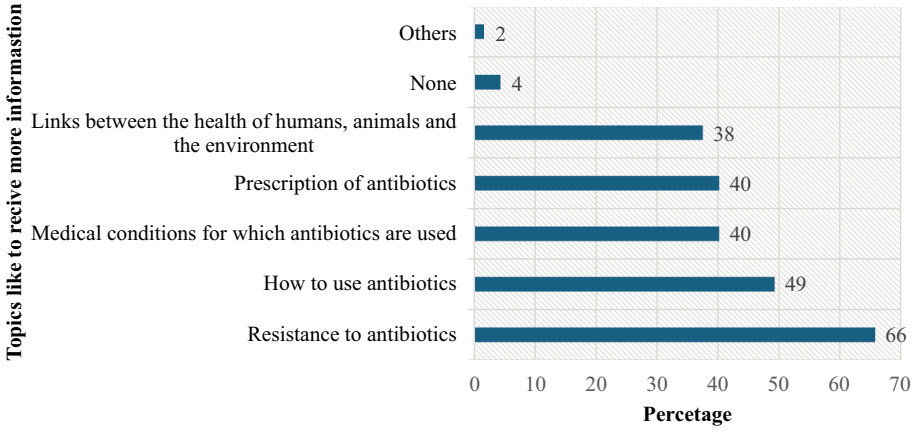

Figure 2. Topics that the prescriber would like to receive more information about.

at all levels (individual, national, regional, and international) is required to combat AMR. A lack of knowledge about the WHO's global action plan and Oman national action plan on AMR and the one health approach, which highlights the linked roles of human, animal, and environmental health, may be the reason for this limited perception of the broader scope of AMR control. In this study, the prescribers showed around 73% easy access to the guidelines and confidence in writing antibiotic prescriptions and following them (91% and 92%, respectively). These findings suggest a positive relationship between access, confidence, and compliance with guidelines; antibiotic prescribing is multifactorial behavior. Prescriber knowledge, patient expectations, diagnostic uncertainty, time pressure, and organizational culture influence it [14,29,30]. Antibiotic prescription is a complex behavior impacted by emotional and cognitive factors, including fear, uncertainty, beliefs, risk perception, and cognitive bias. These factors have a major influence on prescribing practices, and communication between doctors and patients is key to successful prescription decisions [15,31,32].

Human antibiotic use has proven to be mainly responsible for contributing to antibiotic resistance compared to animal and environmental antibiotic use [33].

Our survey reveals that only 52.7% and 65% of prescribers strongly agreed and agreed, respectively, that environmental factors contribute to antibiotic resistance and that the excessive use of antibiotics in food production is an indicator of concern.

Many studies revealed a global knowledge gap, indicating that several domains require development in research on antimicrobial resistance and enhanced education and awareness regarding AMR and its environmental implications [34,35]. Similarly, in the motivation section, the prescriber agreed they have a key role in helping to control antibiotic

resistance, and they are aware of the connection between the prescribing and emergency and the spread of antibiotic resistance bacteria [36,37].

Some studies showed that prescribers recognized antimicrobial resistance, acknowledged the problem from health facilities, and agreed that the excessive use of antibiotics without any microbiological confirmation could cause AMR [38]. The lack of communication and consultation with the prescriber and the clinical microbiologist can lead to inappropriate in antibiotic use [39].

The inappropriate antibiotic prescribing was well identified due to lack of diagnosis [40]. The survey found that 47.4% of prescribers felt forced to prescribe antibiotics against their preference, often citing fears of patient deterioration. Additionally, time limitations and patient demands were significant drivers. The study shows that the prescriber mainly applies the strategy of educating the patient to avoid antibiotic prescriptions. Another study showed the same finding: prescribers may use methods to manage the patient's pressures through effective communication to assure the patient of a likely viral diagnosis, offer non-antibiotic treatment, and justify that to avoid resistance [41].

The study revealed that 70% of prescribers knew about Oman's national action plan for combating antibiotic resistance. All healthcare professionals should be aware of this plan and the use of antibiotics in humans and animals [42]. It provides a roadmap for stakeholders to combat AMR, supporting WHO's Global Action Plan. It contains key elements of a strategy for combating AMR, starting with awareness by increasing the training and education for healthcare, veterinary, and agriculture professionals, public campaigns on antimicrobial use, surveillance, rational use and legal regulations on antimicrobial prescriptions, high standards of infection prevention and control, and collaborating research on AMR between the healthcare, veterinary, and agriculture sectors [42]. Although Oman implements a national action plan on AMR, our research shows that prescribers are not adequately informed about these efforts. This indicates a lack of communication or outreach in the existing awareness campaigns. The WHO states that raising public knowledge is essential to successful AMR interventions. Although Oman has participated in global campaigns like World Antimicrobial Awareness Week, little is known about the country's ongoing, extensive public awareness initiatives. Improving the frequency and visibility of these programs, especially in healthcare facilities, may increase participation in national initiatives and promote improved prescribing practices.

More than 77% of our prescribers used clinical guidelines to manage patient infections. The impact of using clinical practice guidelines in managing patient infection is improving the knowledge of the appropriate use of antibiotics, and it has a long-term effect on changing prescribing habits [43]. Furthermore, other factors can influence prescribers' prescribing of antibiotics [44]. The prescriber used their clinical experience in this study and consulted infection specialists.

Education interventions can elevate the impact of changing prescribers' practices, and these strategies showed significant reductions in antibiotic prescribing rates [45]. Our study's findings showed that prescribers agreed that the information they received helped them avoid unnecessary antibiotic prescriptions in the last 12 months and confirmed that the information contributed to changing their views and practices. The EU/EEA study shows a lower percentage than our result regarding receiving information that did change their views and practices to avoid unnecessary prescribing [24]. Some studies showed that information overload could lead to ignoring relevant information, poor decision-making, and increased pressure on them to rationally use antibiotics [26]. Our study showed that the prescribers are aware of antibiotic awareness and resistance initiatives through conferences and events focused on tackling antibiotic resistance and from professional organizations. Several strategies to improve prescriber knowledge and engagement with AMS and AMR include continuous medical education, which focuses on antimicrobial prescribing and resistance, and integration of stewardship topics into medical curricula to ensure early awareness and long-term practice change [46–48]. In addition, clinical decision support systems and regular audit feedback loops can reinforce evidence-based prescribing [49]. Finally, the aim of this paper was to assess the overall prescribers' knowledge, attitudes, and behavior regarding antibiotic use and resistance in Oman healthcare institutions; conducting sub-group analysis was beyond the scope of this study. However, for future work that aims to provide recommendations to each group (primary and hospital), tailored analysis would be necessary

5. Conclusion

The findings of this study should be used to raise awareness about antibiotic use and antibiotic resistance. Healthcare professionals need to apply their knowledge about antibiotic resistance and change their prescribing behavior to avoid unnecessary prescribing of antibiotics and use the national guidelines [46,50].

Our findings emphasize the need for the antimicrobial stewardship (AMS) team to implement a structured education program for all new prescribers, focusing on appropriate antibiotic use, resistance mechanisms, and local prescribing guidelines. Ensuring easy access to hospital-specific antimicrobial guidelines through digital platforms or printed quick-reference tools will support informed decision-making. Additionally, actively involving prescribers in AMS activities, such as audit and feedback sessions, case discussions, and real-time prescribing reviews, will enhance adherence to best practices and help combat antimicrobial resistance (AMR) effectively.

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Declaration of interest

The authors have no relevant affiliations or financial involvement with any organization or entity with a financial interest in or financial conflict with the subject matter or materials discussed in the manuscript. This includes employment, consultancies, honoraria, stock ownership or options, expert testimony, grants or patents received or pending, or royalties.

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