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ORIGINAL RESEARCH

Knowledge of Antibiotic Use and Resistance Among Medical Students in Saudi Arabia

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Introduction: The World Health Organization (WHO) has placed great importance on providing thorough, hands-on training to medical students regarding responsible and appropriate antibiotic prescription. Accordingly, this study aims to gain a better perspective on the knowledge of antibiotic use and resistance among medical students in Jeddah, Saudi Arabia.

Methods: A questionnaire-based cross-sectional study was conducted among medical students in Jeddah, Saudi Arabia, from 1 September to 30 November 2023. The categorical variables are presented as frequencies and percentages. Mann–Whitney and Kruskal–Wallis tests were used to compare the outcomes, and generalised linear regression models were constructed to predict the students' knowledge of antibiotics and antibiotic resistance. A p-value of < 0.05 was taken to indicate statistical significance.

Results: The study included a total of 353 medical students. First-year medical students represented 28.60% of the participants, while females represented 76.80%. Most participants (92.40%) agreed that antibiotics are effective against bacteria, whereas only 25.20% agreed about antibiotics' effectiveness against viruses. More than half of the participants (53.80%) believed that bacterial infections can be resolved without antibiotics. A significant majority (78.20%) agreed that the unnecessary use of antibiotics makes them less effective. More than half of the participants (56.90%) acknowledged that infections caused by resistant bacteria are increasing in Saudi Arabia, and two-thirds (75.10%) believed that healthcare workers could effectively reduce antibiotic resistance in Saudi Arabia. Male students had low knowledge about antibiotics [Beta = −1.429, 95% CI (−2.618, −0.241), P value = 0.019].

Conclusion: Improving the curriculum by incorporating topics like resistance mechanisms and responsible antibiotic usage can address the knowledge gap among male students. This comprehensive training, utilizing various educational methods, is essential for fostering responsible antibiotic practices among future healthcare professionals.

Keywords: antibiotic use, antibiotic resistance, medical students, Saudi Arabia

Introduction

Antimicrobial resistance (AMR) is a worldwide concern that affects both developed and developing countries and thus requires a global response. According to global estimates, AMR could cause 10 million deaths annually by 2050 and result in a $100.2 trillion loss in gross domestic product if not addressed adequately.[1,2] Hence, international efforts are underway to promote responsible antibiotic use and combat resistance.[3]

As a high-income country, Saudi Arabia faces specific challenges in addressing AMR due to high antibiotic usage rates. These challenges include limited access to proper healthcare, which can lead to antibiotic overuse; self-medication practices; and a healthcare infrastructure that facilitates the spread of resistant organisms.[4] Therefore, in 2017, the country developed a National Action Plan on AMR, which is accordant with the World Health Organization's (WHO's) global action plan for controlling and preventing AMR.[5] Moreover, the healthcare component of Saudi Arabia's Vision 2030 focuses on disease prevention, improved care quality (including appropriate antibiotic use), and adherence to international standards (including strategies and action plans for addressing AMR).[6,7]

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The WHO has strongly emphasised the significance of providing comprehensive and practical training to medical students to ensure the responsible and appropriate prescription of antibiotics.[8] Understanding the difficulties linked to antibiotic utilization and AMR is of utmost significance for aspiring healthcare professionals. Similarly, prioritizing their education and providing them with the essential expertise and abilities is vital to empower them in promoting responsible antibiotic practices within their specific domains.[9,10] For instance, a study on medical students' perceptions of antibiotic use identified factors contributing to inappropriate usage, including limited knowledge applicability, insecurity, clinical inertia, doctor-patient relationship challenges, unawareness of updates, and inability to assess validity. Surprisingly, students lacked awareness of AMR, but the study identified modifiable factors that could improve antibiotic utilization.[11]

However, there is a global deficiency in the clinical understanding of essential infectious disease concepts among medical students, as indicated by low scores on knowledge questionnaires and clinical scenario assessments.[12] These findings highlight the need for improvement in medical education worldwide – including both developed and developing countries – to enhance the understanding and skills of medical students in this critical area.[13–15]

Assuring that medical students have a thorough understanding of the proper use of antibiotics is essential in spreading the right message within communities, as these students play a vital role in shaping the future of medicine and are considered essential pillars of the healthcare system.[3,16] Their knowledge and perspectives regarding the use of antibiotics have a major impact on the consequences associated with such use in Saudi Arabia.[17] Although this is a widely recognised problem, few studies have investigated medical students' knowledge in Saudi Arabia.[18,19] Therefore, this study aims to gain a better perspective on the knowledge of antibiotic use and resistance among medical students in Jeddah, Saudi Arabia.

Materials and Methods

Study Design

A cross-sectional study was conducted with medical students at medical College in Jeddah, Saudi Arabia. Over a span of three months, from 1 September to 30 November 2023, electronic questionnaires were sent to the students to gather data. The participants were given details in the questionnaire about the aim of the research and informed that their involvement was voluntary.

Questionnaire Tool

The survey used in this research was adapted from a previous study by Leal et al.[20] Initially, the questionnaire was formulated in English, and proficient bilingual individuals translated it into Arabic, the local language. It underwent revisions to ensure its suitability for the population.

To validate the questionnaire, academic and clinical pharmacology experts provided feedback, and their suggestions were incorporated into the final form to improve it.

To validate our questionnaire, we distributed it to a random sample of 25 medical students to identify issues and make revisions. Involving experts and conducting a pilot study enhance a questionnaire's validity and reliability. The final questionnaire comprised 37 questions and was designed using online cloud-based questionnaire development software (Google Forms). The questionnaire was divided into three sections; the first section gathered information, the second evaluated students' knowledge of antibiotic usage, and the third section focused on students' understanding of antibiotic resistance.

Sample Size and Data Collection

The sample size was calculated using Slovin's formula, with a population of 284 medical students in Saudi Arabia, following Akbar et al; the confidence interval (CI) was 95%, and the margin of error was 5%.[18]

The participants were approached via social media platforms (Twitter, Instagram, WhatsApp, Telegram, and email). All responses were obtained through the Google Forms website and securely stored on a server. Only respondents who completed all 37 questions of the three-part survey were included in the analysis, while those with incomplete responses were excluded. The data collected from the Google Forms spreadsheets were transferred to Microsoft Excel.

Statistical Analysis

A statistical analysis was performed using SPSS (version 26, IBM). The categorical variables are presented as frequencies and percentages. Mann–Whitney and Kruskal–Wallis tests were used to compare the two outcomes (antibiotic use and resistance), numerical variables, and sociodemographic data, with the results expressed as medians, interquartile ranges, and p values.

Generalised linear regression models were constructed to predict the high scores in the students' knowledge of antibiotics and antibiotic resistance based on the statistically significant sociodemographic data for each primary outcome. The regression results are presented as beta coefficients and their respective 95% CIs. A p-value of < 0.05 was taken to indicate statistical significance.

Ethical Approval

This study was conducted in accordance with the Declaration of Helsinki and was approved by the Institutional Review Board and Research Ethics Committee of Batterjee Medical College in Jeddah, Saudi Arabia, with the following reference number: RES-2022-0059. Before answering the questionnaire, we included the following informed consent statement: You are invited to participate in a research study on antibiotic use and resistance. This research aims to gain a better perspective on the knowledge of antibiotic use and resistance among medical students in Jeddah, Saudi Arabia. It is conducted by Batterjee Medical College in Jeddah, Saudi Arabia. Participation is voluntary and anonymous. If you agree to participate in this study, you can start answering the questionnaire. Participation may not benefit you directly, but it will help us learn about Antibiotic Use and Resistance in Saudi Arabia. Thank you for your time and collaboration.

Results

Sociodemographic Data

We received 360 responses. However, seven medical students were excluded because of incomplete responses, yielding a response rate of 98%. Therefore, the study encompassed a total of 353 medical students, with the majority falling within the age range of 18–25 years, constituting 95.70% of the participants. Females represented 76.80% of the participants.

First-year medical students represented 28.60% of the participants, followed by second-year students (27.2%). Most students reported not having any chronic diseases, comprising a significant (90.70%) portion of the sample. The chronic diseases reported include anaemia, asthma, type 1 diabetes mellitus, and depression. Of the students, 89.80% stated that they did not take any regular medications besides antibiotics. The medications reported included insulin; nonsteroidal anti-inflammatory drugs (NSAIDs), such as aspirin and ibuprofen; paracetamol; and selective serotonin reuptake inhibitors (SSRIs), such as sertraline and venlafaxine (Table 1).

Students' Knowledge of Antibiotics

As shown in Table 2, most participants (92.40%) agreed that antibiotics are effective against bacteria, whereas only 25.20% agreed that antibiotics are effective against viruses. More than half (53.80%) believed that bacterial infections can be resolved without antibiotics. While 67.40% of the participants agreed that antibiotics should be continued as prescribed even after symptoms disappear and the infection subsides, 26.10% agreed that it is acceptable to increase the prescribed dose or repeat doses frequently to treat infections rapidly. Surprisingly, 45.90% agreed that "penicillin" is another word for antibiotics. Of the students, 67.40% agreed that antibiotics should be continued as prescribed even after symptoms disappear and the infection subsides.

Students' Knowledge of Antibiotic Resistance

A significant majority of the respondents, 78.20%, agreed that the unnecessary use of antibiotics makes them less effective, as shown in Table 3. Meanwhile, 28.60% of participants agreed that if, during antibiotic treatment (course), a patient feels well or cured, they can stop taking the medicine. Of the respondents, 64% acknowledged the possibility of someone carrying antibiotic-resistant bacteria without being symptomatic. More than half (56.90%) agreed that infections caused by resistant bacteria are increasing in Saudi Arabia. Moreover, a significant majority, 75.10%, believed that healthcare workers can play an effective role in reducing antibiotic resistance in Saudi Arabia. Notably, 38.20% of

Table 1 Sociodemographic Data (n = 353)

Parameter	Category	Description
Age	25 or less	336 (95.7%)
	More than 25	17 (4.3%)
Gender	Male	82 (23.2%)
	Female	271 (76.8%)
Academic Year	1st year	101 (28.6%)
	2nd year	96 (27.2%)
	3rd year	68 (19.3%)
	4th year	40 (11.3%)
	5th year	29 (8.2%)
	6th year	19 (5.84)
Having any chronic diseases	No	320 (90.7%)
	Yes	33 (9.3%)
Taking certain medications on a regular basis (other than antibiotics)	No	317 (89.8%)
	Yes	36 (10.2%)

Table 2 Students' Knowledge of Antibiotic Use

Parameter	Category	N	%
Antibiotics are effective against bacteria	Disagree	3	0.80%
	Neutral	24	6.80%
	Agree	326	92.40%
Antibiotics are effective against viruses	Disagree	214	60.60%
	Neutral	50	14.20%
	Agree	89	25.20%
Antibiotics are effective against common cold	Disagree	139	39.40%
	Neutral	98	27.80%
	Agree	116	32.90%
Antibiotics can kill beneficial bacteria on skin, stomach, intestines etc.	Disagree	28	7.90%
	Neutral	68	19.30%
	Agree	257	72.80%
Antibiotics can hide signs and symptoms of an underlying infection	Disagree	35	9.90%
	Neutral	121	34.30%
	Agree	197	55.80%

(*Continued*)

Table 2 (Continued).

Parameter	Category	N	%
You can get well from bacterial infections without using antibiotics	Disagree	39	11.00%
	Neutral	124	35.10%
	Agree	190	53.80%
Antibiotics often have side effects like diarrhea, nausea, and vomiting	Disagree	25	7.10%
	Neutral	84	23.80%
	Agree	244	69.10%
Antibiotics have serious side effects like liver toxicity, renal damage, and hypersensitivity reactions.	Disagree	33	9.30%
	Neutral	91	25.80%
	Agree	229	64.90%
Antibiotics can be taken with all kinds of food	Disagree	141	39.90%
	Neutral	117	33.10%
	Agree	95	26.90%
Some antibiotics should never be taken with milk such as Tetracyclines	Disagree	27	7.60%
	Neutral	133	37.70%
	Agree	193	54.70%
Other medications can influence the effects of antibiotics	Disagree	13	3.70%
	Neutral	74	21.00%
	Agree	266	75.40%
Antibiotics can influence the effects of other medications	Disagree	13	3.70%
	Neutral	81	22.90%
	Agree	259	73.40%
Antibiotics can cause Clostridioides difficile associated diarrhea	Disagree	33	9.30%
	Neutral	150	42.50%
	Agree	170	48.20%
Penicillin is another word for antibiotics	Disagree	100	28.30%
	Neutral	91	25.80%
	Agree	162	45.90%
Antibiotics should be continued as per prescription even after symptoms disappear and infection subsides.	Disagree	39	11.00%
	Neutral	76	21.50%
	Agree	238	67.40%
It is alright to increase the prescribed dose or repeat doses frequently to treat infections fast	Disagree	181	51.30%
	Neutral	80	22.70%
	Agree	92	26.10%

Table 3 Students' Knowledge of Antibiotic Resistance

Parameter	Category	N	%
Bacteria can become resistant against antibiotics	Disagree	18	5.10%
	Neutral	39	11.00%
	Agree	296	83.90%
Unnecessary use of antibiotics makes them less effective	Disagree	17	4.80%
	Neutral	60	17.00%
	Agree	276	78.20%
If during antibiotic treatment (course), you feel well/cured, you can stop taking them anymore	Disagree	188	53.30%
	Neutral	64	18.10%
	Agree	101	28.60%
A person can be a carrier of antibiotic resistant bacteria without being sick	Disagree	34	9.60%
	Neutral	93	26.30%
	Agree	226	64.00%
Infections by resistant bacteria are increasing in Saudi Arabia	Disagree	19	5.40%
	Neutral	133	37.70%
	Agree	201	56.90%
Antibiotic resistance is an issue in other countries but not in Saudi Arabia	Disagree	109	30.90%
	Neutral	146	41.40%
	Agree	98	27.80%
Healthcare workers can play an effective role in reducing antibiotic resistance in Saudi Arabia	Disagree	17	4.80%
	Neutral	71	20.10%
	Agree	265	75.10%
High antibiotic treatment in animals can cause antibiotic resistance in human beings	Disagree	46	13.00%
	Neutral	143	40.50%
	Agree	164	46.50%
Viruses can become resistant against antibiotics	Disagree	126	35.70%
	Neutral	92	26.10%
	Agree	135	38.20%
Antibiotic resistance is out of control and there is nothing I can do about it	Disagree	179	50.70%
	Neutral	87	24.60%
	Agree	87	24.60%
There are laboratory blood tests that can tell you if you have antibiotic resistance	Disagree	19	5.40%
	Neutral	112	31.70%
	Agree	222	62.90%

(*Continued*)

Table 3 (Continued).

Parameter	Category	N	%
Antibiotic resistance is only a problem for people who take antibiotics regularly	Disagree	117	33.10%
	Neutral	97	27.50%
	Agree	139	39.40%
Bacteria which are resistant to antibiotics can be spread from person to person	Disagree	52	14.70%
	Neutral	92	26.10%
	Agree	209	59.20%
Antibiotic-resistant infections could make medical procedures like surgery, organ transplants and cancer treatment much more dangerous	Disagree	22	6.20%
	Neutral	87	24.60%
	Agree	244	69.10%
To reduce antibiotic resistance, parents should make sure all of their children's vaccinations are up-to-date	Disagree	17	4.80%
	Neutral	103	29.20%
	Agree	233	66.00%
To reduce antibiotic resistance, People should use antibiotics only when they are prescribed by a doctor or nurse	Disagree	10	2.80%
	Neutral	64	18.10%
	Agree	279	79.00%

participants agreed that viruses can become resistant to antibiotics, and 24.60% agreed that antibiotic resistance is out of control and there is nothing they could do about it.

There was no significant association between the sociodemographic data and knowledge of either antibiotic use or antibiotic resistance based on the medians, interquartile ranges, and p values, as shown in Table 4. The value of

Table 4 Association Between Sociodemographic Data and Students' Knowledge of Antibiotic Use and Antibiotic Resistance

Parameter	Category	Antibiotic use		Antibiotic resistance	
		Median (IQR)	P value	Median (IQR)	P value
Age	18–25	38.0 (35.0–40.0)	0.925	38.0 (35.0–40.0)	0.487
	26–35	38.0 (36.0–40.0)		38.0 (36.0–42.0)	
Gender	Male	38.0 (35.0–40.0)	0.514	37.0 (35.0–39.0)	0.069
	Female	38.0 (35.0–41.0)		38.0 (35.0–40.0)	
Academic Year	1st year	38.0 (34.5–40.0)	0.334	37.0 (35.0–40.0)	0.648
	2nd year	38.0 (36.0–41.0)		37.5 (35.0–40.0)	
	3rd year	38.0 (36.0–41.0)		38.0 (36.0–40.0)	
	4th year	37.5 (36.0–41.0)		38.0 (37.0–40.0)	
	5th year	37.0 (35.5–40.0)		38.0 (37.0–39.5)	
	6th year	35.0 (33.0–39.5)		37.0 (35.5–39.0)	

Cronbach's alpha is 0.767, which means that the internal consistency of the data is acceptableIn terms of predictors of knowledge about both antibiotic and antibiotic resistance, no statistical significance was found except for males who had low knowledge about antibiotics [Beta = −1.429, 95% CI (−2.618, −0.241), P value = 0.019] as shown in Tables 5 and 6.

Table 5 Predictors of Student's Knowledge About Antibiotic Based on the Statistically Significant Sociodemographic Data

Parameter	Category	Beta	95% CI		P value
			LB	UB	
Age	18–25	−1.506	−4.033	1.021	0.242
	26–35	Ref.	Ref.	Ref.	Ref.
Gender	Male	−1.429	−2.618	−0.241	0.019
	Female	Ref.	Ref.	Ref.	Ref.
Professional Year	1st year	−0.281	−6.246	5.685	0.926
	2nd year	0.272	−5.686	6.231	0.928
	3rd year	0.606	−5.390	6.602	0.843
	4th year	1.495	−4.570	7.560	0.628
	5th year	−0.265	−6.424	5.894	0.932
	6th year	Ref.	Ref.	Ref.	Ref.

Table 6 Predictors of Student's Knowledge About Antibiotic Resistance Based on the Statistically Significant Sociodemographic Data

Parameter	Category	Beta	95% CI		P value
			LB	UB	
Age	18–25	−0.897	−3.589	1.796	0.513
	26–35	Ref.	Ref.	Ref.	Ref.
Gender	Male	−0.969	−2.239	0.302	0.134
	Female	Ref.	Ref.	Ref.	Ref.
Professional Year	1st year	−0.678	−7.037	5.680	0.834
	2nd year	0.622	−5.729	6.972	0.847
	3rd year	0.722	−5.666	7.109	0.824
	4th year	0.219	−6.242	6.680	0.947
	5th year	−1.050	−7.613	5.512	0.753
	6th year	Ref.	Ref.	Ref.	Ref.

Discussion

The major goal of this study was to evaluate medical students' knowledge of antibiotic use and resistance. Most respondents were under the age of 25, and most were female, a gender predominance that has been observed in several studies (with proportions of 71.8%, 63.7%, and 64% reported, respectively).[21–23]

Interestingly, in our study, males had low knowledge about antibiotics [P value = 0.019], suggesting that differences in learning styles may contribute to varying levels of comprehension of antibiotics among students. In contrast, another study revealed that more male respondents had a better knowledge of antimicrobial use and AMR than females (70.4% vs 55.1%; P=0.035).[24] Males and females commonly exhibit differences in studying styles, including learning preferences, study strategies, time management, and subject preferences.[25] For instance, males often favour hands-on and visual approaches, while females lean toward collaboration and organisation.[25,26] However, these general observations can vary among individuals due to personal factors. Effective studying styles should align with individual strengths, preferences, and learning goals.[27]

Regarding the students' knowledge of antibiotic use, 25.20% thought that antibiotics are useful against viral infections, including the common cold (32.90%). Similarly, another study in Saudi Arabia showed that 18.1% of medical students thought that antibiotics can be used for viral infections, as did 20% in an Italian study.[28,29] While 28.30% of our students reported that they knew what penicillin was and that this term is not synonymous with "antibiotics", a previous study conducted in Saudi Arabia found that 85% of the students knew that penicillin is a form of antibiotics but not another word for antibiotics.[30] In our study, more than half of the students (51.30%) disagreed that an antibiotic's dose or frequency can be increased to treat infections faster. Similarly, studies have shown that medical students know that increasing the dose or frequency of a medication without proper medical guidance can have serious consequences.[15,31] For example, it may lead to an increased risk of side effects, toxicity, or drug interactions. Additionally, it is important to complete the full course of treatment as prescribed, even if symptoms improve, to ensure that the infection is completely eradicated.[28–30,32,33]

Regarding the students' knowledge of antibiotic resistance, most participants (83.90%) acknowledged that bacteria can develop resistance to antibiotics, indicating a good understanding of antibiotic resistance. This echoes the results of a previous study, which showed that 92.91% of students in the healthcare sector possess a good level of knowledge regarding AMR.[9,34] However, another study showed that medicine (66%) and pharmacy (95%) students had a better understanding of antibiotic resistance than nursing and other health science students.[35] A study of 425 medical students at the University of California showed that a programme focused on stewardship, which involved self-paced learning and a collaborative workshop, had an impact on the knowledge and attitudes of preclinical medical students, prompting them to work together for effective antimicrobial stewardship.[36]

More than half of our participants (56.90%) agreed that infections caused by resistant bacteria are increasing in Saudi Arabia. In the same way, several studies from individual institutions in Saudi Arabia have reported that rates of AMR for both Gram-positive and Gram-negative bacteria are on the rise.[37–39] For instance, a national study conducted in Saudi Arabia showed that 32% of *Staphylococcus aureus* is methicillin-resistant, while 33% of *Streptococcus pneumoniae* is resistant to penicillin G, and 26% is resistant to erythromycin.[40] There is currently a need to develop well-structured curricula that cater to undergraduate students in multiple fields, including medicine, pharmacy, and dentistry. These curricula should primarily focus on medicine, microbial virulence, mechanisms of resistance, and responsible antibiotic usage.[34,41]

Several recommendations can be implemented to improve medical education on antibiotic use and antimicrobial resistance, including Enhancing the curriculum by integrating comprehensive education on antibiotic use, resistance mechanisms, and AMR prevention through dedicated courses, lectures, workshops, and case-based learning activities.[10,42] Foster interdisciplinary collaboration among medical, pharmacy, and nursing schools to provide a holistic understanding of antibiotic use and resistance, promoting teamwork in addressing AMR.[43] By offering practical training opportunities like clinical rotations, students can directly observe and participate in appropriate antibiotic prescribing practices, antimicrobial stewardship programs, and real-world scenarios related to AMR.[44] Utilize simulation exercises and virtual patient cases to simulate clinical situations involving antibiotic prescribing and resistance, allowing students to practice decision-making skills in a safe environment.[45,46]

Other recommendations include encouraging lifelong learning through continuing education, promoting interprofessional education, supporting research initiatives, incorporating a global perspective, fostering partnerships and collaboration, and

implementing regular assessments with constructive feedback.[41,47] By implementing these recommendations, medical education can effectively prepare future healthcare professionals to tackle the challenges of antibiotic use and antimicrobial resistance.[48]

This study has a few limitations. First, our study may not be universally representative because of its design (based on an online survey), as it might not capture the responses from medical students who do not use social media. Second, the study was performed at one educational institute in Jeddah, Saudi Arabia. Similar studies should be implemented across multiple institutes to have a better understanding of these processes and take the necessary steps to overcome this global issue. Despite these limitations, the present study of medical students in Saudi Arabia will add to our knowledge in this area, as Saudi Arabia still has a limited number of studies addressing knowledge of antibiotic use and resistance among medical students.

Conclusion

Enhancing the curriculum to address the knowledge gap observed among males regarding antibiotics is crucial. This can be accomplished by integrating subjects such as resistance mechanisms and responsible antibiotic usage into the educational framework, utilizing diverse pedagogical methods such as lectures, workshops, and clinical rotations. It is imperative to provide comprehensive training to medical students that emphasizes responsible antibiotic practices, necessitating improvements in medical education on a global scale. Through an improved curriculum and practical experiences, efforts can be made to cultivate responsible antibiotic use among upcoming healthcare professionals.

Disclosure

The authors report no conflicts of interest in this work.

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