

Original Article

Knowledge about antibiotics and antibiotic resistance among health-related students in a Saudi University

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Abstract

Introduction: Antibiotic resistance is a threat to public health and safety globally. The inadequate undergraduate education on antibiotic stewardship may contribute to the clinical malpractice of antibiotics, causing serious consequences toward patient health. Thus, this study aimed to evaluate the knowledge of future healthcare workers in Saudi Arabia on antibiotics, antibiotic use, and antibiotic resistance. The factors influencing the students' knowledge were also determined.

Methodology: A cross-sectional study using a survey questionnaire was carried out among 284 Clinical Laboratory Science, Nursing, and Pharmacy students in Saudi Arabia from January to April 2019. Multiple regression analyses were performed to identify the factors influencing the students' knowledge regarding antibiotics, antibiotic use and antibiotic resistance.

Results: The study found that students have above-average knowledge of antibiotics and antibiotic resistance, whereas their knowledge of antibiotic use was inadequate. Several factors, including gender, program, academic level, awareness about antibiotic resistance, attendance to seminars/training, and belief on the seriousness of antibiotic resistance problem, affect students' knowledge. The findings suggest that the knowledge of students in these areas should be improved.

Conclusions: Misconceptions are prominent in certain areas, such as in the concept of antibiotics and their uses. The findings prompt immediate interventions to improve students' knowledge of antibiotics and resistance. Curricular contents must be reviewed and enhanced to suit the specific learning needs of students in terms of these concepts.

Key words: Antibiotics; antibiotic resistance; clinical laboratory science; knowledge; nursing students; pharmacy students.

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Introduction

At present, human consumption of medications has significantly increased [1]. Pharmaceutical medication products are an essential part of the food platter of human life all around the world [2]. Among these products, antibiotics have been used in all drug treatment strategies, as they are essential in the treating and speedy recovery from any disease. However, some misconceptions related to antibiotic use exist among the public and healthcare professionals [3,4]. Given these misconceptions, the inappropriate and excessive use of antibiotics by ordinary people and sometimes medical professionals could lead to adverse events that could harm the patient and accelerate the growth of microbial

resistance against the majority of effective antibiotics [2,5-8].

Antibiotic resistance is a major threat to public health and safety globally. To halt antibiotic resistance, the WHO has set the theme: “No Action Today, No Cure Tomorrow” [9]. The irrational use of antibiotics is alarming, and steps must be taken to prevent antibiotic resistance. The global issue of antibiotic resistance has developed due to multiple factors related to inappropriate, unsupervised, and uncontrolled dispensing and use of antibiotics [10-12]. Hence, guiding the general public and providing proper training to healthcare professionals on antibiotics are necessary to control its irrational usage [13].

Each member of the healthcare team plays a specific role in antibiotic stewardship. Pharmacists play an essential role as drug dispensers to outpatients and inpatients in hospital facilities [14]. The judicious use of drugs to prevent and treat diseases mostly depends on clinical laboratory diagnostic reports of the patient made by a clinical laboratory technician [15]. Nurses administer various therapeutic medications in their daily practice and play a vital role in patient teaching [13]. Thus, educational initiatives on effective and responsible antibiotic stewardship should be promoted among these healthcare professionals [16].

Future healthcare professionals should receive proper undergraduate antibiotic stewardship education to develop adequate knowledge regarding antibiotics, their uses, and antibiotic resistance. These students are essential because they are the future healthcare providers in clinical practice and will be accountable for fostering sensible drug use among their patients [17]. Undergraduate education is an excellent time to emphasize the importance of sensible use of antibiotics among students because after completion of their education, changing their knowledge, attitudes, and practices will be difficult [17]. However, the inadequate undergraduate education on antibiotic stewardship may contribute to the clinical malpractice of antibiotics, causing serious consequences toward patient health [18]. Therefore, this study was conducted to evaluate the knowledge of future healthcare workers in Saudi Arabia on antibiotics, antibiotic use, and antibiotic resistance.

Methodology

A cross-sectional study using survey questionnaires was initiated among Saudi health-related students. The study was limited to three programs: clinical laboratory science (CLS), nursing, and pharmacy. A sample of 284 students, selected through convenience sampling, was surveyed in the research. The students were (1) Saudi nationals; (2) registered in the CLS, nursing or pharmacy programs of the university; (3) sophomore, junior, or senior students; and (4) consented to participate. First-year students were excluded because they are still in the preparatory program of the university and do not have professional courses.

Measure

A survey questionnaire was used to collect data for the study variables. The demographic variables gender, program, year level, and type of living community were inquired. For the variable background on antibiotic and antibiotic resistance concepts, the questionnaire

contained yes/no questions asking about the respondents' awareness on antibiotic resistance, if the students learned about antibiotic resistance problems during their course study, if the students attended a pharmacology course in college, if the students attended seminars/training about antibiotic resistance in the past year, if the students believe that antibiotic resistance is a serious problem, and if the students are aware about the WHO agenda on antibiotic resistance.

The researchers developed the tool to measure the students' knowledge of antibiotics, antibiotic use, and antibiotic resistance based on different published articles measuring the same variables. The researchers extracted the questions focusing on the variables under study. All the questions were presented to a panel of six experts. Each expert evaluated the suitability of the questions in each variable understudied. They also examined the content validity of the questionnaire following the recommendations of Polit and Beck utilizing a 4-point Likert scale measuring the relevance of the items [19]. Based on the responses of the panel of experts, 10, 5, and 8 questions assessing the students' knowledge of antibiotics, antibiotic use, and antibiotic resistance were retained for the final questionnaire, respectively. The item-level content validity index (CVI) ranged from 0.86 to 1.00, with a computed scale-level CVI (average) of 0.93. The questions on knowledge of antibiotics focused on examples of true (i.e., amoxicillin and penicillin) and false (i.e., paracetamol) antibiotics, their effectiveness, the principle and justification of use, duration of treatment, effect on normal microflora of the body, antibiotic sensitivity (allergic reaction), and antibiotics' relationship with disease. The questions used to determine knowledge of antibiotic use were about the indication and self-prescription of antibiotic use. Questions regarding the term, world issue, education, and causes of antibiotic resistance were included in the knowledge of antibiotic resistance section. The response to the questions was true or false. Right answers were coded as one, whereas wrong answers were coded as zero. The total score for each section was calculated with a possible score range of 0–10, 0–5, and 0–8 for knowledge of antibiotics, knowledge of antibiotic use, and knowledge of antibiotic resistance, respectively. A high score denotes a high level of knowledge. Pilot testing was carried out among 30 health-related students. The Kuder–Richardson 20 test was used to compute the tool's reliability considering the nature of the questions. The analyses revealed the alphas of 0.71, 0.82, and 0.76 for knowledge of

antibiotics, antibiotic use, and antibiotic resistance, respectively, indicating acceptable reliability.

Procedure

The researchers sought the approval of the protocol from the research unit of the College of Applied Medical Sciences (log no. RU-0012). An informed consent form was solicited before respondents answered the questionnaire. Information regarding the study was provided during the recruitment phase. The researchers explained the study’s objectives, the involvement needed, the right to refuse participation, and the right to cancel participation to the respondents. Data were collected from January to April 2019. The researchers approached the students during their breaks for recruitment and data collection. Those who signed the informed consent were given the questionnaire. The researchers made sure that each respondent answered the questionnaire independently.

Statistical Analysis

Analyses were performed using SPSS version 22.0. Mean, standard deviations, frequency count, and percentages were used to analyze the data of demographic and knowledge variables. Multiple linear regression analyses were conducted to analyze the demographic factors influencing the students’ knowledge of antibiotics, antibiotic uses, and antibiotic resistance. Dummy variables were created for the variables “program” and “academic year level” before entering them into the regression. *P* values below 0.05 indicated significance.

Results

The mean age was 21.64 (SD = 2.20) years. The majority of the students were males (53.9%) and urban dwellers (52.5%). More than half of the samples comprised nursing students (51.4%), and 28.2% and 20.4% of the respondents were pharmacy and CLS students, respectively. The highest proportion of the sample was sophomores (36.6%), whereas the lowest was seniors (27.8%). Most of the students know the term antibiotic resistance (71.8%), had learned about antibiotic resistance problems during their course study (62.3%), had attended a pharmacology course (57.4%), had attended seminars/training about antibiotic resistance in the past year (52.8%), and were aware of the WHO agenda about antibiotic resistance (63.7%) (Table 1).

Knowledge about Antibiotics

The mean score on the knowledge of antibiotics was 5.73 (SD = 1.68, range = 2–10). The majority of the respondents incorrectly thought that paracetamol is an antibiotic (57.7%), that antibiotics are effective for infections caused by viruses (69.7%), that antibiotics can be used as a substitute for anti-inflammatory drugs for any kind of pain and inflammation (58.8%), that antibiotic use increases the recovery from cough and colds (66.5%), and that it is appropriate to discontinue the antibiotic therapy once the symptoms are relieved (57.7%) (Table 2).

Table 1. Demographic variables of the respondents (n = 284).

Variable	n (%)
Age^a (Mean/SD)	21.64 (2.20)
Gender	
Male	153 (53.9)
Female	131 (46.1)
Program	
Nursing	146 (51.4)
Pharmacy	80 (28.2)
Clinical Laboratory Science	58 (20.4)
Year level	
2nd year	104 (36.6)
3rd year	101 (35.6)
4th year	79 (27.8)
Type of community	
Urban	149 (52.5)
Rural	135 (47.5)
Awareness about the term antibiotic resistance	
No	80 (28.2)
Yes	204 (71.8)
Learned about antibiotic resistance problems during course study	
No	107 (37.7)
Yes	177 (62.3)
Attended Pharmacology course in college	
No	121 (42.6)
Yes	163 (57.4)
Attendance of seminars/ trainings about antibiotic resistance in the last year	
No	134 (47.2)
Yes	150 (52.8)
Do you believe that antibiotic resistance is a serious healthcare problem?	
No	49 (17.3)
Yes	235 (82.7)
Awareness about the WHO agenda about antibiotic resistance	
No	103 (36.3)
Yes	181 (63.7)

^a Range = 18-30.

Table 2. Descriptive analyses on the knowledge and use scores (n = 284).

Variable	Incorrect n (%)	Correct n (%)
Knowledge on antibiotic		
Amoxicillin and penicillin are antibiotics	68 (23.9)	216 (76.1)
Paracetamol is an antibiotic	164 (57.7)	120 (42.3)
For viral infection, antibiotics are effective	198 (69.7)	86 (30.3)
For bacterial infection, antibiotics are effective	48 (16.9)	236 (83.1)
Antibiotics can be used as a substitute for anti-inflammatory drugs for any kind of pain and inflammation	167 (58.8)	117 (41.2)
The use of antibiotics increases the recovery from cough and colds	189 (66.5)	95 (33.5)
It is appropriate to stop taking the antibiotics once the symptoms are relieved	164 (57.7)	120 (42.3)
Our body has good bacteria	48 (16.9)	236 (83.1)
Antibiotics can kill the good bacteria of the microflora of our body	100 (35.2)	184 (64.8)
Antibiotics can cause allergic reactions	68 (23.9)	216 (76.1)
Knowledge on antibiotic use		
Antibiotics are preferred to be used for fever	185 (65.1)	99 (34.9)
Antibiotics are preferred to be used for common colds	177 (62.3)	107 (37.7)
Antibiotics are preferred to be used for cough	181 (63.7)	103 (36.3)
Once the patient feels better, stop the use of antibiotics	161 (56.7)	13 (43.3)
Antibiotic therapy is safe to use for any ailment without consulting the doctor	142 (50.0)	142 (50.0)
Knowledge on antibiotic resistance		
Antibiotic resistance is a phenomenon in which bacteria resist the effect of antibiotic to which it was sensitive before	68 (23.9)	216 (76.1)
Antibiotic resistance problem is a worldwide problem	80 (28.2)	204 (71.8)
Antibiotic resistance is also a problem in Saudi Arabia	74 (26.1)	210 (73.9)
Misuse of antibiotics is the leading cause of antibiotic resistance	83 (29.2)	201 (70.8)
Frequent use of antibiotic leads to the loss of sensitivity of antibiotic towards a specific pathogenic bacteria	96 (33.8)	188 (66.2)
It is necessary to get more knowledge about the judicious use of antibiotics	86 (30.3)	198 (69.7)
During antibiotic treatment, skipping off some doses does not contribute to the development of antibiotic resistance	191 (67.3)	93 (32.7)
It is essential to complete the course of antibiotic therapy even disease symptoms are relieved	82 (28.9)	202 (71.1)

Table 3. Factors associated with the students' knowledge of antibiotics (n=284).

Predictor variables	B	SE	Beta	t	p	95% CI	
						Lower	Upper
Age	-0.04	0.07	-0.05	-0.58	0.566	-0.17	0.09
Gender	0.55	0.21	0.16	2.60	0.010*	0.13	0.96
Program (Reference group: Nursing)							
Pharmacy	-1.19	0.28	-0.32	-4.22	< 0.001***	-1.74	-0.63
Clinical Laboratory Science	-0.27	0.27	-0.07	-1.02	0.308	-0.79	0.25
Level (Reference group: 4th year)							
2nd year	-0.51	0.31	-0.15	-1.67	0.097	-1.11	0.09
3rd year	-0.22	0.25	-0.06	-0.89	0.374	-0.71	0.27
Type of community	0.15	0.19	0.04	0.78	0.439	-0.23	0.52
Awareness about the term antibiotic resistance	0.28	0.22	0.08	1.28	0.201	-0.15	0.72
Learned about antibiotic resistance problems during course study	0.07	0.20	0.02	0.33	0.743	-0.33	0.47
Attended Pharmacology course in the college	0.08	0.23	0.02	0.34	0.731	-0.37	0.53
Attendance on seminars/trainings about antibiotic resistance in the last year	-0.14	0.20	-0.04	-0.67	0.501	-0.53	0.26
Do you believe that antibiotic resistance is a serious healthcare problem?	0.61	0.25	0.14	2.41	0.016*	0.11	1.10
Awareness about the WHO agenda about antibiotic resistance	-0.32	0.21	-0.09	-1.50	0.134	-0.74	0.10

The students' knowledge on antibiotics was the dependent variable. β is the unstandardized coefficients; SE-b is the Standard error. Beta is the standardized coefficients. $R^2 = 0.199$; Adjusted $R^2 = 0.161$; * $p < 0.05$, *** $p < 0.001$.

The scores of students who believed that antibiotic resistance is a serious problem were 0.61 ($t = 2.41, p = 0.016, 95\% \text{ CI} = 0.11 - 1.10$) higher than those who did not believe on the seriousness of the problem.

Knowledge about Antibiotic Use

The mean score of the students was 2.02 (SD = 1.59, range = 0–5). The majority of the respondents know that antibiotics are preferred for fever (65.1%), common colds (62.3%), and cough (63.7%). Most of the students thought that antibiotic use could be discontinued once the patient feels better (56.7%), whereas half of them thought that antibiotics could safely be used for any ailment without consulting the doctor (50.0%) (Table 2).

In Table 4, a year increase in the respondents’ age corresponded to a 0.14 point ($t = -2.51, p = 0.013, 95\% \text{ CI} = -0.25 - -0.03$) decrease in the knowledge on antibiotic use mean score. The scores of pharmacy students were lower than those of nursing students ($\beta = -1.46, t = -6.00, p < 0.001, 95\% \text{ CI} = -1.94 - -0.98$). The scores of junior students were lower than those of senior students by 0.59 points ($t = -2.75, p = 0.006, 95\% \text{ CI} = -1.01 - -0.17$).

Knowledge about Antibiotic Resistance

The mean score of the students was 5.32 (SD = 1.62, range = 1–8). As summarized in Table 2, all the items were answered correctly by most respondents, except

for the item “during antibiotic treatment, skipping off some doses does not contribute to the development of antibiotic resistance” (67.3%).

As indicated in Table 5, females recorded higher scores than males ($\beta = 0.83, t = 4.30, p < 0.001, 95\% \text{ CI} = 0.45 - 1.20$). Pharmacy students had higher scores compared with nursing students ($\beta = 0.61, t = 2.36, p = 0.019, 95\% \text{ CI} = 0.10 - 1.11$). Students who knew the term antibiotic resistance ($\beta = 0.79, t = 3.91, p < 0.001, 95\% \text{ CI} = 0.39 - 1.19$), who had attended seminars/training about antibiotic resistance in the past year ($\beta = 0.45, t = 2.44, p = 0.015, 95\% \text{ CI} = 0.09 - 0.81$), and who believed that antibiotic resistance is a serious healthcare problem ($\beta = 0.59, t = 2.56, p = 0.011, 95\% \text{ CI} = 0.14 - 1.04$) had higher knowledge scores compared with those who were not aware about antibiotic resistance, who had not attended similar activities, and who did not believe of the seriousness of the problem, respectively.

Discussion

This study investigated the knowledge of clinical laboratory, nursing, and pharmacy students of a Saudi university on antibiotics and their uses and antibiotic resistance. The knowledge level on the different assessed areas and the factors associated with the knowledge are discussed in this section.

The study found that students have above average general knowledge on antibiotics and antibiotic

Table 4. Factors associated with the students’ knowledge of antibiotic use (n =284).

Predictor variables	β	SE	Beta	t	p	95% CI	
						Lower	Upper
Age	-0.14	0.06	-0.19	-2.51	0.013*	-0.25	-0.03
Gender	0.22	0.18	0.07	1.22	0.224	-0.14	0.58
Program (Reference group: Nursing)							
Pharmacy	-1.46	0.24	-0.41	-6.00	< 0.001***	-1.94	-0.98
Clinical Laboratory Science	-0.39	0.23	-0.10	-1.69	0.092	-0.84	0.06
Level (Reference group: 4th year)							
2nd year	-0.51	0.26	-0.15	-1.92	0.056	-1.03	0.01
3rd year	-0.59	0.21	-0.18	-2.75	0.006**	-1.01	-0.17
Type of community	0.03	0.16	0.01	0.17	0.863	-0.29	0.35
Awareness about the term antibiotic resistance	-0.12	0.19	-0.03	-0.63	0.527	-0.50	0.26
Learned about antibiotic resistance problems during course study	-0.04	0.18	-0.01	-0.25	0.805	-0.39	0.30
Attended Pharmacology course in the college	0.01	0.20	0.00	0.06	0.950	-0.38	0.40
Attendance on seminars/trainings about antibiotic resistance in the last year	-0.12	0.18	-0.04	-0.67	0.503	-0.46	0.23
Do you believe that antibiotic resistance is a serious healthcare problem?	-0.24	0.22	-0.06	-1.11	0.268	-0.67	0.19
Awareness about the WHO agenda about antibiotic resistance	-0.12	0.19	-0.04	-0.67	0.507	-0.49	0.24

The students’ knowledge on antibiotic use was the dependent variable. β is the unstandardized coefficients; SE-b is the Standard error. Beta is the standardized coefficients. $R^2 = 0.332$; Adjusted $R^2 = 0.300$; * $p < 0.05$, ** $p < 0.01$, *** $p < 0.001$.

resistance, whereas their knowledge of antibiotic use was inadequate. Similar findings were reported in previous studies conducted among university students in the United Arab Emirates and Ethiopia [20,21]. Some concerning findings were revealed by the study in terms of knowledge of antibiotics. For instance, most of the students erroneously responded that paracetamol is an antibiotic. This finding is alarming considering that this error could cause misuse of antibiotics and lead to inappropriate use of paracetamol for bacterial infections. The findings also reflected that the majority thought that antibiotics are effective against infections caused by viruses and could aid in the recovery from cough and colds. This result is similar to the findings reported in previous studies [7,20]. However, the current finding is somewhat more promising than that reported among Italian medical students, where 83.2% thought antibiotics could be used to treat viral infections [7]. Moreover, most students thought that antibiotics could be used as substitutes to anti-inflammatory medications for pain and inflammation. They also erroneously thought that antibiotics could be stopped once the symptoms are gone. In terms of antibiotic use, all items were responded incorrectly by the majority of the students. Most of them thought that antibiotics could be utilized for fever, common colds, and cough. A previous study presented a contrary result where most of the nursing students sampled in Spain reported good knowledge that antibiotics could not treat pain,

inflammation, cough, and colds [22]. The same study found good nursing students’ knowledge on the importance of adhering to the prescribed duration of the antibiotic therapy and to not discontinue the antibiotic therapy once the signs and symptoms of the infection diminished [22]. However, the present findings revealed that students thought antibiotic therapy could be stopped once the patient feels better and that antibiotics could safely be used for any ailments without consulting the doctor. This inadequacy of knowledge is alarming considering that health-related professionals are responsible for educating patients about the responsible use of antibiotics. If left uncorrected, these future healthcare workers may provide wrong information to patients, leading to future severe problems of antibiotic resistance and self-medication practices. These findings indicate the need to improve the education of clinical laboratory, nursing, and pharmacy students in terms of antibiotics. Inadequate knowledge of antibiotics could lead to incorrect usage, which could increase the cases of antibiotic resistance.

The findings also revealed that female students had better knowledge of antibiotics and antibiotic resistance, which contrasts with the results reported among medical students in Nigeria reporting better knowledge among males than females [23]. The gender differences revealed in this study may be related to the gender segregation in universities in the country.

Table 5. Factors associated with the students’ knowledge of antibiotic resistance (n =284).

Predictor variables	β	SE	Beta	t	p	95% CI	
						Lower	Upper
Age	0.02	0.06	0.02	0.27	0.790	-0.10	0.13
Gender	0.83	0.19	0.26	4.30	< 0.001***	0.45	1.20
Program (Reference group: Nursing)							
Pharmacy	0.61	0.26	0.17	2.36	0.019*	0.10	1.11
Clinical Laboratory Science	-0.26	0.24	-0.07	-1.08	0.282	-0.74	0.22
Level (Reference group: 4th year)							
2nd year	0.02	0.28	0.01	0.08	0.936	-0.53	0.57
3rd year	0.11	0.23	0.03	0.48	0.633	-0.34	0.55
Type of community	0.07	0.17	0.02	0.38	0.704	-0.28	0.41
Awareness about the term antibiotic resistance	0.79	0.20	0.22	3.91	< 0.001***	0.39	1.19
Learned about antibiotic resistance problems during course study	0.01	0.19	0.00	0.04	0.965	-0.36	0.37
Attended Pharmacology course in the college	0.19	0.21	0.06	0.89	0.376	-0.23	0.60
Attendance on seminars/trainings about antibiotic resistance in the last year	0.45	0.19	0.14	2.44	0.015*	0.09	0.81
Do you believe that antibiotic resistance is a serious healthcare problem?	0.59	0.23	0.14	2.56	0.011*	0.14	1.04
Awareness about the WHO agenda about antibiotic resistance	0.16	0.20	0.05	0.83	0.405	-0.22	0.55

The students’ knowledge on antibiotic resistance was the dependent variable. β is the unstandardized coefficients; SE-b is the Standard error. Beta is the standardized coefficients. R² = 0.276; Adjusted R² = 0.241; *p < 0.05, **p < 0.01, *** p < 0.001.

Although a university uses a similar curriculum and course contents, different professors teach the same course for each gender-based college. Different approaches and strategies of teaching the courses may impact the level of learning of students. This finding could be supported by previous studies conducted in Saudi Arabia, which reported gender differences in knowledge of infection control and prevention [24,25].

Furthermore, pharmacy students reported lower knowledge of antibiotics and antibiotic use compared with nursing students. However, pharmacy students reported better knowledge of antibiotic resistance compared with nursing students. Although the comparison between different programs in terms of the studied variables is unpopular in the literature, several studies focusing on each sample group support the current findings. For instance, a study conducted among pharmacy students in Malaysia reported that only 59.5% (N = 346) had good knowledge of antibiotic use; however, 84.4% had good knowledge of antibiotic resistance [26]. In another investigation performed among student nurses in Spain, the surveyed students generally had good knowledge of antibiotics but poor knowledge regarding antibiotic resistance [22]. The differences reported in the present study may be due to the differences in the curricular contents and coverage of the topics on antibiotics and their uses, as well as antibiotic resistance in each program. This finding may provide a basis for curricular review and enhancement to provide more content on the inadequately covered topics. For example, the university's pharmacy program may enhance its curricular contents related to general information and correct usage of antibiotics. The topic of antibiotic resistance in the nursing program must be stressed more in the curriculum to provide more information to nursing students.

Awareness of antibiotic resistance and belief that it is a serious healthcare problem positively influenced the students' knowledge of antibiotic resistance. Students who have heard about antibiotic resistance and believed that it is a serious problem answered most items on antibiotic resistance correctly compared with those who did not have similar awareness and beliefs. Other studies have reported a high percentage of health-related students being aware of antibiotic resistance [26,27]. A Sri Lankan study reported a high awareness of antibiotic resistance among trainee nurses, although this did not translate to an accurate understanding of antibiotic resistance. The study explained that although the trainee nurses knew about antibiotic resistance, some defined antibiotic resistance erroneously [28]. However, the present finding showed that the students

who had awareness about antibiotic resistance were most likely to have good knowledge of antibiotic resistance. This difference may be explained by how the students were made aware of the concept of antibiotic resistance. Respondents in the present study might have gained information about antibiotic resistance in their courses, which provides more accurate information about this concept. Furthermore, believing that antibiotic resistance is a serious healthcare concern could prompt students to study more about this phenomenon, thereby increasing their knowledge. This phenomenon may have served as their motivation to increase their knowledge about antibiotic resistance; hence, students who believed that antibiotic resistance is a serious problem had better knowledge of this concept than those who did not have a similar belief.

Finally, attendance to seminars and training on antibiotic resistance in the past year increased the students' level of knowledge on antibiotic resistance. Although the present study did not clarify the details of the seminars/training attended, previous investigations support the beneficial contributions of educational interventions in increasing the knowledge on the topics. For instance, a 17% increase in the posttest score on knowledge regarding antibiotic use was reported by medical trainees after an educational intervention [29]. Another study in Egypt concluded a significant increase in antibiotic use knowledge among physicians and pharmacists who were provided with an educational intervention in promoting the correct use of antibiotics [30]. Attendance at seminars and training about this topic provides additional educational resources and learning opportunities to students. Knowledge regarding antibiotic resistance that students have learned in their formal studies may be augmented by additional information from attending these activities, thereby enriching their knowledge on this area.

Some limitations of the study must be considered when interpreting the results and will also guide future investigations. The design used in this study was cross-sectional, which limited the causal investigation of variables. The investigation only involved a single university in the country; hence, multi-university or national study is recommended to improve the generalizability of results. The study failed to include other health-related students, such as medical students, due to the inability of the researchers to gain permission to collect data from them. We recommend that studies involving medical students and other health-related students will be conducted in the future. Furthermore, the study only focused on assessing the students' knowledge. Future studies may also consider assessing

the students' attitudes, behaviors, and practices about antibiotics, antibiotic use, and antibiotic resistance.

Conclusions

The present study assessed the knowledge of CLS, nursing, and pharmacy students on antibiotics, antibiotic use, and antibiotic resistance. The findings suggest that the knowledge of students in these areas should be improved. Misconceptions are prominent in certain areas, such as in the concept of antibiotics and their uses. Several factors, including gender, program, academic level, awareness about antibiotic resistance, attendance to seminars/training, and belief on the seriousness of antibiotic resistance problem, affect students' knowledge. The findings prompt immediate interventions to improve students' knowledge regarding antibiotics and antibiotic resistance. Considering that antibiotic resistance is a serious and growing problem in Saudi Arabia and around the world, health-related programs should prepare their students to become competent healthcare workers capable of solving this problem. Curricular contents must be reviewed and enhanced to suit the specific learning needs of students in terms of these concepts. Additional seminars and training must be provided to these students to further improve their awareness and knowledge of antibiotics.

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