



ORIGINAL ARTICLE / ОРИГИНАЛНИ РАД

Knowledge and attitudes of biomedical science students about antibiotic resistance

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SUMMARY

Introduction/Objective Antibiotics are essential drugs for treating bacterial infections; however, inappropriate use contributes to antibiotic resistance. This study aimed to assess the knowledge and attitudes of biomedical science students regarding risks associated with antibiotic use and the emergence of antibiotic resistance.

Methods This cross-sectional study was conducted using a questionnaire-based survey. A total of 195 biomedical science students participated, including 65 students each from medicine, pharmacy, and dentistry at the Faculty of Medical Sciences, University of Kragujevac. Participants anonymously completed a 15-item questionnaire covering sociodemographic characteristics and knowledge and attitudes related to antibiotic use and resistance. Data were analyzed using IBM SPSS Statistics for Windows, Version 22.0. (IBM Corp., Armonk, NY, USA).

Results The mean age of participants was 24.06 ± 1.1 years, and most respondents were female (80.5%). Nearly all students were familiar with the definition of antibiotics (98.5%), types of antibiotics (89.2%), and the concept of antimicrobial resistance (99.5%). The majority (75.9%) recognized antibiotic resistance as a major global health problem. Statistically significant differences were observed between medical and dental students, as well as between pharmacy and dental students. Concern about the impact of antibiotic resistance on personal health varied significantly among groups; 55.4% reported concern, while 33.3% were not concerned. Most respondents (96.4%) strongly agreed that responsible antibiotic use is a collective responsibility.

Conclusion Students across all study programs demonstrated good knowledge of antibiotic use and resistance but expressed a need for additional education. Curriculum revision during clinical training may improve application of knowledge in future clinical practice.

Keywords: antibiotics; resistance; students

INTRODUCTION

Antimicrobial resistance (AMR) is a significant public health problem worldwide [1, 2], defined as the ability of microorganisms to resist antimicrobial agents to which they were previously susceptible [3]. AMR represents a growing global public health challenge, arising from a range of complex processes such as genetic mutations, horizontal gene transfer, and bacterial adaptations including biofilm development and increased efflux pump activity. These processes hasten the evolution and dissemination of resistant strains, further shaped by genetic context, mobile genetic elements, and environmental pressures [4]. Various factors contribute to the spread of AMR, including self-medication or the use of antibiotics without a prescription and the over prescription of antibiotics [5, 6]. Studies have shown a global increase in antibiotic prescribing in recent decades [1–7]. This problem is often attributed to inappropriate guidelines for antibiotic prescribing and the empirical use of antibiotics without identifying the causative agent of the infection. The issue is particularly prevalent in low- and

middle-income countries [8]. Additionally, insufficient knowledge regarding the indications for specific antibiotic groups coupled with the lack of clear protocols during and after the COVID-19 pandemic, has exacerbated the irrational use of antibiotics, potentially leading to a further rise in antibiotic resistance [9]. AMR has numerous consequences, including severe illness, increased hospital admissions, higher costs of second-line drugs, elevated overall healthcare expenses, and increased mortality rates [10]. AMR ranks among the major global causes of mortality, disproportionately affecting low-resource regions [11].

Serbia is among the European countries with the highest rates of antibiotic resistance and consumption [12, 13]. According to the 2020 Central Asia and Europe Antimicrobial Resistance Surveillance Network (CAESAR) report, which includes data from 18 countries and territories outside the European Union, high resistance rates in *P. aeruginosa*, *Acinetobacter spp.*, and *E. faecium* in Serbia are particularly concerning. Additionally, there is moderately high resistance to third-generation cephalosporins, aminoglycosides,

Received • Примљено:
March 20, 2026

Revised • Ревизија:
April 15, 2026

Accepted • Прихваћено:
April 22, 2026

Online first: May 14, 2026

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and fluoroquinolones in *E. coli*, as well as to penicillin and macrolides in *S. pneumoniae* [12]. With an antibiotic consumption rate of 31.57 defined daily doses (DDD) per 1000 inhabitants per day, Serbia ranks among the three European countries with the highest total antibiotic consumption, alongside Greece (33.85 DDD) and Turkey (38.18 DDD), according to the European Antimicrobial Network Report on Medicines Consumption for the period 2016–2018 [13]. The Republic of Serbia has implemented a National Antimicrobial Resistance Control Program for 2019–2023, which emphasizes, among other strategies, raising awareness among healthcare professionals who prescribe antimicrobials [14]. As a middle-income country, Serbia reports that 80% of all antibiotics are prescribed for outpatient conditions [15]. Serbia is also a member of the CAESAR network and it ranks among the European countries with the highest percentage of resistant isolates [16]. More robust interventions are essential to facilitate the prudent and evidence-based use of antibiotics. Additionally, research is needed to explore and understand the knowledge, attitudes, and behaviors of the general population regarding antibiotic use [17].

Considering that the knowledge, attitudes, and behaviors of individuals are crucial for establishing and ensuring the rational use of antibiotics, the indications for their prescription must be defined responsibly [16]. In Serbia, the medical education curricula for future doctors, dentists, and pharmacists include courses in pharmacology and microbiology but lack dedicated courses on antimicrobial use and resistance.

Recent global reports continue to highlight AMR as one of the leading threats to public health, with projections indicating a further increase in morbidity and mortality if current trends persist [18]. In addition, growing evidence emphasizes the importance of educating future healthcare professionals as a key strategy in antimicrobial stewardship programs [19]. Therefore, assessing knowledge and attitudes among biomedical students remains essential for designing targeted educational interventions.

The aim of this study was to assess the knowledge and attitudes of biomedical science students at the Faculty of Medical Sciences, University of Kragujevac, regarding their perception of risks associated with antibiotic use and the emergence of antibiotic resistance.

METHODS

Study design

The study was designed as a cross-sectional study based on the use of a questionnaire. It was conducted at the Faculty of Medical Sciences, University of Kragujevac from November to December 2023. The study population comprised a total of 195 biomedical science students (65 final year students of medicine, 65 final year students of pharmacy and 65 third, fourth and final year students of dentistry). The selected groups of students are future healthcare professionals who will be allowed to prescribe

or sell antibiotics in the Republic of Serbia. Inclusion criteria: students of biomedical sciences (medicine, pharmacy, and dentistry) who have passed the pharmacology exam. Exclusion criteria: students of other faculties and students who have not passed the pharmacology exam yet.

Questionnaire design

The questionnaire was adapted from previously published instruments originally developed by Golhar et al. [20] and aligned with the World Health Organization recommendations on AMR awareness. Prior to the study, the questionnaire was reviewed by experts in pharmacology and public health to ensure content validity. A pilot test was conducted on a small group of students to assess clarity and comprehensibility, and minor modifications were made accordingly.

The final questionnaire consisted of 15 items divided into two domains: knowledge (two questions) and attitudes (13 questions). All questions were close-ended with three response options. The questionnaire also included sociodemographic variables such as sex, year of birth, study program, and year of study.

Data analysis

Data were analyzed using IBM SPSS Statistics for Windows, Version 22.0. (IBM Corp., Armonk, NY, USA). Descriptive statistics were expressed as frequencies, percentages, means, and standard deviations. The normality of data distribution was assessed using the Kolmogorov–Smirnov test. As the data did not follow a normal distribution, non-parametric tests were applied.

Differences between two independent groups were analyzed using the Mann–Whitney U test, while comparisons among three groups were performed using the Kruskal–Wallis test. Categorical variables were analyzed using the χ^2 test. A $p < 0.05$ was considered statistically significant.

Ethics: This study was approved by the Ethics Committee of the University of Kragujevac, Medical Sciences (No: 09-666/3, February 13, 2025).

RESULTS

A total of 195 biomedical sciences students were included in the study, with 65 participants in each academic group. Female students predominated in all three groups, accounting for 80.5% of the total sample. Demographic characteristics are presented in Table 1. A statistically significant difference in age was observed among the groups ($p < 0.001$), with the highest mean age recorded in medical students and the lowest in dental students.

The overall distribution of respondents' knowledge and attitudes toward antibiotic use and antibiotic resistance is presented in Table 2, whereas between-group comparisons are shown in Table 3. Overall, the respondents demonstrated a high level of knowledge regarding antibiotics. Almost

Table 1. Demographic data of the respondents

Variables		IASM n (%)	IASPH n (%)	IASD n (%)
Sex n (%)	Male	15 (23.1)	7 (10.8)	16 (24.6)
	Female	50 (76.9)	58 (89.2)	49 (75.4)
Total		65 (100)	65 (100)	65 (100)
*Agea (X ± SD)		25.1 ± 0.1	24 ± 0.1	23.1 ± 0.1

IASM – integrated academic studies of medicine; IASPH – integrated academic studies of pharmacy; IASD – integrated academic studies of dentistry; n – number of the respondents; % – percent of the respondents; X – mean value; SD – standard deviation;

*p < 0.001;

*Kruskal–Wallis test

all participants correctly identified that antibiotics may exert both bacteriostatic and bactericidal effects (98.5%), 89.2% correctly recognized the group consisting exclusively of antibiotics, and 99.5% reported being familiar with the term antibiotic resistance.

With respect to antibiotic-use practices, 69.7% of respondents reported having used antibiotics without a prescription, with no significant differences among the academic groups ($p = 0.528$). In addition, 86.7% stated that they always take antibiotics exactly as prescribed, and 89.2% reported that they do not discontinue antibiotic therapy once symptoms begin to improve; neither variable differed significantly between groups ($p = 0.627$ and $p = 0.577$, respectively). Furthermore, 62.1% considered it unacceptable to take an antibiotic from a family member or friend without prior consultation with a physician, although this attitude did not significantly differ across groups ($p = 0.261$).

Regarding recent antibiotic exposure, 54.4% of participants reported not having used antibiotic therapy in the previous six months, with no statistically significant difference among the groups ($p = 0.182$). In relation to agriculture, 59.5% of respondents believed that antibiotics are used extensively in this sector, while 59% believed that such use should be reduced. Although perceptions of extensive agricultural use did not differ significantly between groups ($p = 0.056$), attitudes toward reducing antibiotic use in agriculture did show a significant difference ($p = 0.009$). Agreement with reducing such use was higher among medical and pharmacy students (66.2% in both groups) than among dental students (44.6%).

Most respondents (76.9%) believed that antibiotic resistance does not receive sufficient attention at universities, in professional literature, or in the media, with no significant between-group difference ($p = 0.345$). In total, 75.9% agreed that antibiotic resistance is one of the leading global problems; however, this perception differed significantly across groups ($p < 0.001$), with greater agreement among pharmacy students (92.3%) and medical students (83.1%) than among dental students (52.3%). A significant between-group difference was also observed regarding concern about the impact of antibiotic resistance on personal and family health ($p = 0.030$), with pharmacy students expressing the highest level of concern (66.1%) and dental students the lowest (41.5%). Finally, 96.4% of respondents agreed that the responsible use of antibiotics

is a collective responsibility, with no statistically significant difference among the groups ($p = 0.087$).

DISCUSSION

This is the first study to examine this topic among students at the University of Kragujevac, rather than the general population in Serbia. Our research revealed that the surveyed students possess good knowledge about antibiotics and antibiotic resistance, with the percentage of students demonstrating adequate knowledge being slightly higher than that observed in the general population in Serbia [17]. A total of 89.23% of the surveyed students reported not discontinuing antibiotics as soon as they noticed improvement, indicating adherence to the prescribed duration of therapy. These findings align with those of a study conducted in the USA, where nearly all interviewed medical students were aware that the inappropriate use of antibiotics could harm patients and contribute to the spread of resistant bacterial strains [21]. In contrast, a study by Horvat et al. [17] found that approximately 22% of dental and veterinary students and 10% of medical students discontinued antibiotics once their symptoms resolved.

A study by Sobierajski et al. [22] demonstrated that students are aware of the dangers of antibiotic resistance, identifying the misuse of antibiotics as its primary cause. Additionally, students emphasized the need for more classes on antibiotic therapy to be integrated into the curriculum of the Medical University of Warsaw, and this viewpoint was shared by 76.92% of our respondents. In a study by Jackson et al. [23], the majority of participants, Nigerian students (94.3%), exhibited above-average knowledge about antibiotics and antibiotic resistance and recognized AMR as a global problem, though their understanding of proper antibiotic use was inadequate. These findings are consistent with our results, which showed that students had strong theoretical knowledge, with 98.46% correctly identifying the definition of antibiotics and 89.23% providing the correct response to the question about which drug belongs to the group of antibiotics. Compared to similar studies conducted in Europe and developing countries, our findings indicate a relatively high level of theoretical knowledge; however, important gaps remain in practical attitudes and behaviors, particularly regarding self-medication and inappropriate antibiotic use [24, 25].

Kose et al. [26] examined the knowledge of final-year medical students and doctors in their study. Doctors were more hesitant during the undergraduate period and more confident in the postgraduate period in their decision to start antibiotic treatment. One of the greatest concerns was that doctors tend to forget their theoretical knowledge about antibiotics over time and are unable to keep up with current developments after graduation. The most significant concern during the undergraduate period was the choice of antibiotics from the wrong group, while in the postgraduate period, the fear of an unproven infection being present was more prominent. Doctors' habits, attitudes, and behavior in prescribing antibiotics vary before

Table 2. Knowledge and attitudes of the respondents related to antibiotic use and resistance

Question	n (%)	p ^a
The mechanism of action of antibiotics is: bacteriostatic effect bactericidal effect bacteriostatic and bactericidal effect	0 (0) 3 (1.5) 192 (98.5)	0.000*
Select the response that includes exclusively antibiotics: tafluprost, amikacin, clarithromycin gentamicin, ciprofloxacin, favipiravir azithromycin, doxycycline, teicoplanin	3 (1.5) 18 (9.2) 174 (89.2)	0.000*
Have you ever used antibiotics without a prescription? yes no not sure	136 (69.7) 18 (9.2) 8 (4.1)	0.000*
Do you always take antibiotics exactly as prescribed (dose, dosing schedule, etc.)? yes no not sure	169 (86.7) 25 (12.8) 1 (0.5)	0.000*
Do you discontinue antibiotic therapy once your symptoms begin to improve? yes no not sure	20 (10.3) 174 (89.2) 1 (0.5)	0.000*
Do you consider it acceptable to take an antibiotic from a family member or friend, if it is indicated for your condition, without prior consultation with a doctor? yes no not sure	6 5 (33.3) 121 (62.1) 9 (4.6)	0.000*
Have you used antibiotic therapy in the last six months? yes no not sure	86 (44.1) 106 (54.4) 3 (1.5)	0.000*
Are you familiar with the term antibiotic resistance? yes no not sure	194 (99.5) 0 (0) 1 (0.5)	0.000*
Do you think that antibiotics are used extensively in agriculture (primarily in animal farming)? yes no not sure	116 (59.5) 6 (3.1) 73 (37.4)	0.000*
Do you think that antibiotic resistance receives enough attention (at university, in professional literature, and in the media)? yes no not sure	35 (17.9) 150 (76.9) 10 (5.1)	0.000*
Antibiotic resistance is one of the leading global problems yes no not sure	148 (75.9) 15 (7.7) 32 (16.4)	0.000*
I think healthcare professionals should prescribe antibiotics only when it is truly necessary yes no not sure	184 (94.4) 10 (5.1) 1 (0.5)	0.000*
I believe that the use of antibiotics in agriculture should be reduced yes no not sure	115 (59) 11 (5.6) 69 (35.4)	0.000*
I am concerned about the impact of antibiotic resistance on my health and the health of my family yes no not sure	108 (55.4) 65 (33.3) 22 (11.3)	0.000*
Responsible use of antibiotics is a collective responsibility yes no not sure	188 (96.4) 3 (1.5) 4 (2.1)	0.000*

n – number of respondents; % – percent of respondents; p – significance;
a – χ^2 test; * – statistical significance

and after graduation. Continuous education on antibiotic use for doctors after graduation could positively contribute to reducing the rate of AMR and increasing awareness of rational antibiotic use.

Knowledge, attitudes, and practices vary greatly depending on the university, training cycle, and socioeconomic status.

A significant proportion of students consider the standard of education on antibiotics and bacterial resistance at their university to be poor or mediocre. These findings indicate that there is a need to strengthen the curriculum and programs for medical students on antibiotics, the mechanisms of antibiotic resistance, and the prudent use of antibiotics. This is an important strategy to combat the public health problem of resistance, especially in endemic countries [27].

The findings from the study, conducted by Mayers et al. [28], demonstrate that short-term international programs integrating hands-on microbiology training with AMR-focused education can effectively enhance students' technical competencies, awareness of AMR, and professional confidence. Moreover, the workshop's cross-cultural and English-based collaborative framework highlights its value in fostering global perspectives and partnerships essential for addressing AMR as a shared public health challenge [28].

The systematic review and thorough meta-analysis by Jahromi et al. [29] reveal considerable deficiencies in healthcare workers' knowledge, attitudes, and practices concerning AMR worldwide. Overall, it appears that the levels of knowledge and attitudes and consequently good practice among healthcare workers, including students, particularly in less developed countries, remain far from satisfactory [29].

The majority of students in the study by Baddal et al. [30] had sufficient basic knowledge about antibiotics, but there were areas of concern. All groups of students were aware of how antibiotic resistance develops and their roles as healthcare professionals in implementing measures against resistance. These results are consistent with our findings, where the majority of respondents believe that antibiotic resistance is one of the leading global problems.

This study has several limitations, including being conducted at a single institution, which may limit the generalizability of the findings, and the use of self-reported questionnaires that may introduce response bias. Additionally, the cross-sectional design prevents establishing causal relationships between knowledge and attitudes.

Nevertheless, the study provides important insights into the current level of awareness

Table 3. Knowledge and attitudes between groups of the respondents related to antibiotic use and resistance

Question	IASM n (%)	IASPH n (%)	IASD n (%)	<i>p</i> ^a
The mechanism of action of antibiotics is: bacteriostatic effect bactericidal effect bacteriostatic and bactericidal effect	0 (0) 1 (1.5) 64 (98.5)	0 (0) 0 (0) 65 (100)	0 (0) 2 (3.1) 63 (96.9)	0.447
Select the response that includes exclusively antibiotics: tafluprost, amikacin, clarithromycin gentamicin, ciprofloxacin, favipiravir azithromycin, doxycycline, teicoplanin	1 (1.5) 7 (10.8) 57 (87.7)	0 (0) 0 (0) 65 (100)	2 (3.1) 11 (16.9) 52 (80)	0.159
Have you ever used antibiotics without a prescription? yes no not sure	46 (70.8) 18 (27.7) 1 (1.5)	44 (67.7) 19 (29.2) 2 (3.1)	46 (70.8) 14 (21.5) 5 (7.7)	0.528
Do you always take antibiotics exactly as prescribed (dose, dosing schedule, etc.)? yes no not sure	57 (87.7) 8 (12.3) 0 (0)	53 (81.6) 11 (16.9) 1 (1.5)	59 (90.8) 6 (9.2) 0 (0)	0.627
Do you discontinue antibiotic therapy once your symptoms begin to improve? yes no not sure	8 (12.3) 56 (86.2) 1 (1.5)	7 (10.8) 58 (89.2) 0 (0)	5 (7.7) 60 (92.3) 0 (0)	0.577
Do you consider it acceptable to take an antibiotic from a family member or friend, if it is indicated for your condition, without prior consultation with a doctor? yes no not sure	21 (32.3) 41 (63.1) 3 (4.6)	16 (24.6) 46 (70.8) 3 (4.6)	28 (43.1) 34 (52.3) 3 (4.6)	0.261
Have you used antibiotic therapy in the last six months? yes no not sure	24 (36.9) 40 (61.5) 1 (1.5)	29 (44.6) 26 (55.4) 0 (0)	33 (50.8) 30 (46.2) 2 (3.1)	0.182
Are you familiar with the term antibiotic resistance? yes no not sure	65(100) 0 (0) 0 (0)	65 (100) 0 (0) 0 (0)	64 (98.5) 0 (0) 1 (1.5)	0.221
Do you think that antibiotics are used extensively in agriculture (primarily in animal farming)? yes no not sure	43 (66.2) 1 (1.5) 21 (32.3)	41 (63.1) 3 (4.6) 21 (32.3)	32 (49.2) 2 (3.1) 31 (47.7)	0.056
Do you think that antibiotic resistance receives enough attention (at university, in professional literature, and in the media)? yes no not sure	11 (16.9) 52 (80) 2 (3.1)	14 (21.5) 49 (75.4) 2 (3.1)	10 (15.4) 49 (75.4) 6 (9.2)	0.345
Antibiotic resistance is one of the leading global problems yes no not sure	54 (83.1) 5 (7.7) 6 (9.2)	60 (92.3) 3 (4.6) 2 (3.1)	34 (52.3) 7 (10.8) 24 (36.9)	0.000*
I think healthcare professionals should prescribe antibiotics only when it is truly necessary yes no not sure	60 (92.3) 4 (6.2) 1 (27.7)	63 (96.9) 2 (3.1) 0 (0)	61 (93.8) 4 (6.2) 0 (0)	0.502
I believe that the use of antibiotics in agriculture should be reduced yes no not sure	43 (66.2) 4 (6.2) 18 (27.7)	43 (66.2) 3 (4.6) 19 (29.2)	29 (44.6) 4 (6.2) 32 (49.2)	0.009*
I am concerned about the impact of antibiotic resistance on my health and the health of my family yes no not sure	38 (58.5) 21 (32.3) 6 (9.2)	43 (66.1) 18 (27.7) 4 (6.2)	27 (41.5) 26 (40) 12 (18.5)	0.030*
Responsible use of antibiotics is a collective responsibility yes no not sure	64 (98.5) 1 (1.5) 0 (0)	63 (97) 1 (1.5) 1 (1.5)	61 (93.9) 1 (1.5) 3 (4.6)	0.087

IASM – integrated academic studies of medicine; IASPH – integrated academic studies of pharmacy; IASD – integrated academic studies of dentistry;
n – number of respondents; % – percent of respondents; *p* – significance; a – χ^2 test; * – statistical significance

among future healthcare professionals and highlights the need for continuous education and curriculum improvement.

CONCLUSION

Based on our results, we can conclude that students from all study groups are educated about antibiotic resistance, as well as the use and application of antibiotics in treatment, but students expressed a desire for additional education. A

possible solution to this problem is to change the curriculum in the clinical years of the faculty in order for students to expand their knowledge that they will implement in their daily clinical practice after their studies. This way, they would more clearly define the indications for the use of antibiotics to prevent improper prescribing of antibiotics and the development of AMR with global economic and health consequences.

Conflict of interest: None declared.

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Знања и ставови студената биомедицинских наука о антибиотској резистенцији

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САЖЕТАК

Увод/Циљ Антибиотици су значајни лекови у борби против бактеријских инфекција, међутим неадекватна употреба доприноси развоју антибиотске резистенције. Циљ ове студије био је да се процене знања и ставови студената биомедицинских наука о ризицима повезаним са употребом антибиотика и појавом антибиотске резистенције.

Методе Студија је дизајнирана као студија пресека базирана на коришћењу упитника. У истраживању је учествовало укупно 195 студената биомедицинских наука, по 65 студената медицине, фармације и стоматологије са Факултета медицинских наука Универзитета у Крагујевцу. Испитаници су анонимно попунили упитник од 15 питања који је обухватао социодемографске карактеристике, као и питања о знању и ставовима у вези са употребом антибиотика и резистенцијом. Подаци су статистички обрађени у програму *IBM SPSS Statistics for Windows*, верзија 22.0. (*IBM Corp.*, Армонк, Њујорк, САД).

Резултати Просечна старост испитаника била је $24,06 \pm 1,1$ година, а већину су чиниле жене (80,5%). Готово сви сту-

денти познавали су дефиницију антибиотика (98,5%), врсте антибиотика (89,2%) и појам антимикробне резистенције (99,5%). Већина испитаника (75,9%) сматрала је да је антибиотска резистенција велики глобални здравствени проблем. Утврђене су статистички значајне разлике између студената медицине и стоматологије, као и између студената фармације и стоматологије. Забринутост због утицаја антибиотске резистенције на лично здравље показала је статистички значајну разлику; 55,4% је изразило забринутост, док 33,3% није било забринуто. Већина испитаника (96,4%) у потпуности се сложила да је одговорна употреба антибиотика колективна одговорност.

Закључак Студенти свих студијских програма показали су добро знање о употреби антибиотика и антибиотској резистенцији, али су нагласили потребу за додатном едукацијом. Измена информатора предмета на клиничким годинама студија могла би унапредити примену стеченог знања у будућој клиничкој пракси.

Кључне речи: антибиотици; резистенција; студенти