

Impact of Antibiotic Self-Medication on Liver and Kidney Biochemical Parameters (LFTs) and Oxidative Stress Markers Among University Students in Peshawar

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ABSTRACT

Background: Antibiotic self-medication among university students may contribute to antimicrobial resistance and adverse hepatic, renal, and oxidative effects, warranting biochemical assessment and stewardship education.

Objective: To evaluate the relationship between antibiotic self-medication and liver and kidney biochemical parameters and some oxidative stress markers in university students of Peshawar.

Methods: This comparative analytical cross-sectional study included 100 university students at Khyber Medical College, Peshawar, from September 2025 to June 2026. Participants were equally divided into antibiotic self-medication and non-self-medication groups. Questionnaire data and biochemical parameters assessing hepatic, renal, oxidative stress, and antioxidant status were analyzed using SPSS version 26.0. Independent-samples t-tests and chi-square tests were applied, and a two-tailed p-value of less than 0.05 was considered statistically significant.

Results: The mean age for the self-medication group being 24.82 ± 5.31 years, and for the non-self-medication group being 24.36 ± 5.08 years. The mean levels of ALT, AST, ALP, serum creatinine and blood urea were higher in the self-medication group compared to the non-self-medication group. ALT (35.84 ± 9.21 vs. 28.46 ± 7.18 U/L; $p < 0.001$), AST (32.76 ± 8.42 vs. 27.18 ± 6.37 U/L; $p = 0.001$), ALP (118.62 ± 21.54 vs. 105.48 ± 18.76 U/L; $p = 0.002$), serum creatinine (0.96 ± 0.18 vs. 0.86 ± 0.14 mg/dL; $p = 0.002$), and blood urea (31.84 ± 7.62 vs. 27.56 ± 6.13 mg/dL; $p = 0.002$) were significantly higher in the self-medication group. The participants who self-medicated with antibiotics showed significant increases in MDA and significant decreases in GSH, SOD and CAT ($p < 0.001$ for each).

Conclusion: Antibiotic self-medication was associated with differences in hepatic, renal, and oxidative stress parameters, highlighting the need for antimicrobial stewardship and prospective studies.

Keywords: Self-Medication; Anti-Bacterial Agents; Liver Function Tests; Kidney Function Tests; Oxidative Stress.

INTRODUCTION

Antibiotics are essential medicines for the treatment of bacterial infections and have substantially reduced morbidity and mortality associated with infectious diseases. Inappropriate antibiotic use is however an important global public-health issue because the unnecessary and incorrect use of antibiotics not only leads to antimicrobial resistance, but also to failure to treat and to adverse effects of antibiotics, unnecessary cost of care and loss of life. Inappropriate use of antimicrobials is a major contributor to antimicrobial resistance and responsible use and stewardship of antimicrobials is a priority for WHO.1 Self-medication is the use of medicines to treat an illness that the user is aware of without the advice of a qualified health care professional. The use of antibiotics for non-bacterial infections is particularly problematic, as is the wrong antibiotic, dosage, length of

treatment, and premature cessation of antibiotics. 2 University students are an important group to study in relation to self-medication because they have access to medicines, they have had previous experience of some common illnesses, the influence of peers and academic pressures and have confidence in their ability to treat minor illnesses themselves. A systematic review and meta-analysis of 89 studies with 60,938 university students found an overall prevalence of self-medication to be 70.1% with significant heterogeneity among the included studies. 3 Antibiotic self-medication has also been reported in Pakistan. The antibiotic self-medication rates reported by Shah et al. (47.6% in Karachi). 4 and by Gillani et al. (62.5% in Punjab, Pakistan). 5 show that inappropriate antibiotic use is still a problem among young adults in Pakistan. There is no difference between healthcare-related students and other students in terms of practicing antibiotic self-medication, even though the latter are exposed to more medical



information. High rates of antibiotic self-medication were reported in a study conducted among nursing students in Karachi, Pakistan, with 77.8% of them buying antibiotics, and in a more recent study of healthcare students in Pakistan, where 68.8% of the students had engaged in self-medication with antibiotics; the most commonly purchasing antibiotics included amoxicillin and azithromycin.^{6,7} While antimicrobial resistance is the biggest problem at the population level, antibiotics can also cause adverse effects on the individual level. The liver is relevant in particular since a large number of antimicrobial agents are metabolized in the liver and some classes of antibiotics have been linked to drug-induced liver damage. This injury may be reflected by an increase in amino-transferases, alkaline phosphatase, bilirubin or a mixture of these parameters.⁸ The risk is dependent upon the antimicrobial agent, dose, duration, patient factors, and co-exposures.¹⁰ Macrolide antibiotics (such as azithromycin and clarithromycin) are also known to cause clinically apparent liver damage. Another organ system that plays an important role in the elimination of drugs is the kidneys. Some antibiotics, especially the aminoglycosides, are known to be nephrotoxic by damaging the tubular cells. Serum creatinine and blood urea are commonly measured parameters of renal function; however, these traditional tests may not reflect subtle or early renal injury.¹¹ Oxidative stress has also been proposed as one possible pathway involved in antibiotic-associated cellular effects. Experimental research has demonstrated mitochondrial dysfunction and oxidative damage following exposure to selected bactericidal antibiotics.¹² Nevertheless, the relationship between antibiotic exposure and oxidative stress is complex, and findings from experimental models should not automatically be extrapolated to healthy human populations. MDA is commonly used as an indicator of lipid peroxidation, whereas GSH, SOD, and CAT represent important components of endogenous antioxidant defense. An increase in MDA accompanied by reduced antioxidant activity may indicate an altered oxidant-antioxidant balance. Despite the widespread practice of antibiotic self-medication, limited local research has simultaneously evaluated hepatic, renal, and oxidative stress parameters among university students in Peshawar. Therefore, the present study was conducted to compare liver and kidney biochemical parameters and oxidative stress markers between university students who practiced antibiotic self-medication and those who did not.

METHODOLOGY

A comparative cross-sectional study was conducted among 100 university students aged 15–45 years in Peshawar, Pakistan. Participants were divided equally into two groups: Group I comprised 50 students with a history of antibiotic self-medication, whereas Group II included 50 students without such a history. Participants were eligible if they were willing to participate, provided informed consent, completed the study questionnaire, and submitted the required blood sample. Individuals with established chronic liver or kidney disease, diabetes mellitus, pregnancy, major systemic diseases, or current use of medications that could significantly affect the biochemical parameters under investigation were excluded. Participants were classified according to their history of antibiotic use without a current prescription or consultation with a qualified healthcare professional for the relevant illness episode. Demographic characteristics and antibiotic-use practices, including age, sex, academic background, frequency and duration of self-medication, antibiotic type, indication, source, and completion of the antibiotic course, were recorded using a structured questionnaire. Venous blood samples were collected under aseptic conditions, and serum was separated using standard laboratory procedures. Liver function was assessed by measuring

alanine aminotransferase, aspartate aminotransferase, alkaline phosphatase, and total bilirubin. Renal function was evaluated through serum creatinine and blood urea measurements. Oxidative stress and antioxidant status were assessed using malondialdehyde, reduced glutathione, superoxide dismutase, and catalase. Biochemical analyses were performed at the Department of Biochemistry, Khyber Medical College, Peshawar, using standard procedures and commercially available assay kits according to the manufacturers' instructions. Data were analyzed using SPSS version 26.0. Continuous variables were expressed as mean $\pm$ standard deviation and categorical variables as frequencies and percentages. Normality was assessed using the Shapiro–Wilk test. Independent-samples t-tests and chi-square tests were used for between-group comparisons, as appropriate. All tests were two-tailed, and p values below 0.05 were considered statistically significant.

RESULTS

In total, 100 students of the University (15–45 years) were included. The antibiotic self-medication group consisted of 50 individuals while the non-self-medication group comprised 50 individuals.

The mean age was 24.82 ± 5.31 years in Group I and 24.36 ± 5.08 years in Group II. No statistically significant difference was found in the mean age between the two groups ($p=0.660$).

Table 1. Demographic characteristics and antibiotic-use profile of study participants

Variable	Self-medication Group (n=50)	Non-self-medication Group (n=50)	p-value
Mean age, years $\pm$ SD	24.82 ± 5.31	24.36 ± 5.08	0.660
Age group, years			
15–25	29 (58.0%)	30 (60.0%)	0.834
26–35	16 (32.0%)	15 (30.0%)	
36–45	5 (10.0%)	5 (10.0%)	
Sex			
Male	27 (54.0%)	25 (50.0%)	0.689
Female	23 (46.0%)	25 (50.0%)	
Previous antibiotic use	50 (100%)	31 (62.0%)	<0.001
Antibiotic obtained without prescription	50 (100%)	0 (0%)	<0.001
Incomplete antibiotic course	18 (36.0%)	7 (14.0%)	0.014

Data are presented as frequency (%) or mean $\pm$ SD. SD = standard deviation. Group I = antibiotic self-medication group; Group II = non-self-medication group. A p-value <0.05 was considered statistically significant. Respiratory symptoms, sore throat, fever, and gastrointestinal complaints were the most common indications of antibiotic self-medication among those who participated in Group I. Amoxicillin/amoxicillin-clavulanate, azithromycin and ciprofloxacin were all commonly reported antibiotics. Previous experience with similar illness, easy availability of antibiotics, symptom perceived mildness and avoidance of consultation cost were the most frequently reported reasons for self-medication.

Table 2. Comparison of liver and renal biochemical parameters between the study groups

Parameter	Self-medication Group (n=50)	Non-self-medication Group (n=50)	Mean Difference	p-value
ALT (U/L)	35.84 ± 9.21	28.46 ± 7.18	7.38	<0.001
AST (U/L)	32.76 ± 8.42	27.18 ± 6.37	5.58	0.001
ALP (U/L)	118.62 ± 21.54	105.48 ± 18.76	13.14	0.002
Total bilirubin (mg/dL)	0.89 ± 0.24	0.82 ± 0.20	0.07	0.118
Serum creatinine (mg/dL)	0.96 ± 0.18	0.86 ± 0.14	0.10	0.002
Blood urea (mg/dL)	31.84 ± 7.62	27.56 ± 6.13	4.28	0.002

ALT = alanine aminotransferase; AST = aspartate aminotransferase; ALP = alkaline phosphatase; SD = standard deviation. Data are expressed as mean ± SD. Independent-samples t-test was used. The level of p-value < 0.05 was taken as statistically significant. The levels of ALT, AST and ALP were significantly higher in the self-medication group as compared with the non-self-medication group. ALT was 35.84 ± 9.21 U/L in Group I compared with 28.46 ± 7.18 U/L in Group II (p<0.001). AST was also significantly higher in Group I (32.76 ± 8.42 vs. 27.18 ± 6.37 U/L; p=0.001). Similarly, ALP was significantly higher in the self-medication group (118.62 ± 21.54 vs. 105.48 ± 18.76 U/L; p=0.002). Total bilirubin was more in Group I than Group II, but this difference was not significant (p=0.118). In terms of renal parameters, the serum creatinine level was significantly higher in the self-medication group than in the non-self-medication group (0.96 ± 0.18 vs. 0.86 ± 0.14 mg/dL; p=0.002). Participants who self-medicated with antibiotics also had significantly elevated blood urea levels (31.84 ± 7.62 vs 27.56 ± 6.13 mg/dL; p=0.002).

Table 3. Comparison of oxidative stress and antioxidant parameters between study groups

Parameter	Self-medication Group (n=50)	Non-self-medication Group (n=50)	Mean Difference	p-value
MDA (nmol/mL)	4.82 ± 0.91	3.61 ± 0.72	1.21	<0.001
GSH (μmol/L)	6.84 ± 1.22	8.17 ± 1.35	-1.33	<0.001
SOD (U/mL)	82.46 ± 12.18	94.72 ± 13.64	-12.26	<0.001
CAT (U/mL)	46.38 ± 8.76	53.92 ± 9.14	-7.54	<0.001

Data are presented as mean ± SD, MDA = malondialdehyde; GSH = reduced glutathione; SOD = superoxide dismutase; CAT = catalase. Data are reported as mean ± SD. The t-test for independent samples was performed. The statistical significance was determined by p value <0.05.

The self-medication group had significantly higher levels of MDA (4.82 ± 0.91 vs. 3.61 ± 0.72 nmol/mL; p<0.001) than the non-self-medication group. In contrast, GSH concentration was significantly lower in Group I (6.84 ± 1.22 vs. 8.17 ± 1.35 μmol/L; p<0.001). Likewise, the self-medication group showed significantly reduced SOD activity as compared to the non-self-medication group (82.46 ± 12.18 vs 94.72 ± 13.64 U/mL;

p<0.001). CAT activity was also significantly lower in Group I (46.38 ± 8.76 vs. 53.92 ± 9.14 U/mL; p<0.001). Overall, participants who reported antibiotic self-medication demonstrated higher hepatic and renal biochemical values together with a pattern of increased lipid peroxidation and reduced antioxidant activity.

DISCUSSION

The present study compared 50 university students who reported antibiotic self-medication with 50 students who did not report this practice. The age of the children was similar in both groups. The results revealed that the serum ALT, AST, ALP, serum creatinine and blood urea levels were elevated in the self-medication group while the levels of MDA were elevated and the levels of GSH, SOD and CAT were decreased in the same group. The case of self-medication with antibiotics in the present study was similar to the previous study conducted among university students. Several studies in Pakistan have also shown high prevalence of self-medication with antibiotics among university students with significant variation among populations.^{12,13} The factors cited in the present study such as previous experience, easy availability of antibiotics, perceived mild illness and avoidance of consultation costs are similar to those mentioned in earlier studies conducted in Pakistan. Among the nursing students of Karachi, convenience and knowledge of medicine were noted as a significant reason for self-medication with antibiotics.¹⁴ In the present study, the participants who engaged in antibiotic self-medication showed significantly higher levels of ALT, AST and ALP levels. Drug-induced liver injury is an important reason for antibiotic use, but the risk of liver injury varies significantly among different classes of antibiotics. Treatment courses are generally brief, and primary infections can also cause liver abnormalities, making the diagnosis of AALD challenging. Stine and Lewis explained.¹⁵ The present results suggest biological plausibility for the hepatic differences exhibited in the present study, as amoxicillin-clavulanate is a known cause of clinically apparent liver injury, with three patterns of biochemical injury described: hepatocellular, cholestatic or mixed, and macrolide antibiotics, such as azithromycin and clarithromycin, have also been described as causes of clinically apparent liver injury. But the present cross-sectional design does not allow the inference that the enzyme differences are due to antibiotic self-medication. There was no significant difference between the two groups in terms of total bilirubin. This finding may suggest that the biochemical differences in liver function noted between the groups were relatively minor and that there was not a significant rise in bilirubin. Elevated aminotransferase levels may be present in the absence of clinically significant change in liver function or jaundice. The study also found that self-medicating with antibiotics had significantly more serum creatinine and blood urea levels. Experimental models have shown that renal toxicity induced by gentamicin can include oxidative stress, lipid peroxidation and alterations in antioxidant defense mechanisms.¹⁸ The renal parameters were statistically different, but not necessarily clinically significant kidney injury. There are multiple physiological factors that affect serum creatinine such as hydration status and muscle mass. Greater sensitivity of renal biomarkers and repeated measurements would yield more robust evidence of renal injury. The oxidative stress results were consistent. The levels of MDA increased significantly in self-medicated group, whereas GSH, SOD, and CAT decreased significantly in the same group. MDA is an indicator of lipid peroxidation, while GSH, SOD and CAT are important components of antioxidant defense system. Experimental studies have shown that specific antibiotic antibiotics could cause mitochondrial

dysfunction and oxidative damage in mammalian cells.²⁰ This offers a biological foundation to examine the potential of oxidative stress in populations exposed to antibiotics. But the settings in which such studies are conducted are very different from those in actual antibiotic exposure by normal university students. Experimental exposure to gentamicin has also shown oxidative stress and renal injury, which included changes in lipid peroxidation and antioxidant defense, after gentamicin exposure; a similar relationship has been suggested for the use of tigecycline and gentamicin together.²² These results suggest a possible biological association but should not be directly extrapolated to human students. The link between antibiotic exposure and ROS is still quite complicated. Killing by bactericidal antibiotics was not dependent on production of reactive oxygen species, countering a generalized ROS-mediated antibiotic killing mechanism, as reported by Keren et al.²³⁻²⁶ It is important to interpret the changes in oxidative stress observed in the present study as biochemical associations that may or may not represent a specific molecular mechanism. There are a number of cautions that should be taken into account. The cross-sectional design is not temporal and/or causal. Second, the information on antibiotic exposure was partially self-reported, and may thus be subject to recall bias. Third, it was a small sample of 100 participants from one study site. Fourth, biochemical parameters can be affected by diet, fluid intake, exercise, illness, smoking, other drugs and medical conditions.

CONCLUSION

The present comparative study evaluated 100 university students aged 15–45 years, equally divided into an antibiotic self-medication group and a non-self-medication group. The mean values of AST, ALT, ALP, serum creatinine and blood urea were higher in the participants who reported self-medicating with antibiotics. They were also observed as having increased levels of MDA and decreased levels of GSH, SOD and CAT. The results suggest a relationship between antibiotic self-medication and the selected parameters of the liver, kidneys and oxidative stress. This cross-sectional design does not allow for causal inference, however, a biochemical difference could not be assumed to be clinically significant organ damage unless it is statistically significant. The results corroborate the necessity to use the antibiotic rationally, provide education on antimicrobial stewardship and call for professional advice before taking antibiotics. It is recommended that more detailed biochemical measures and more detailed antibiotic exposure be assessed in larger prospective studies.

Ethical Approval

Ethical approval for this study was obtained from the Institutional Review/Ethics Committee of Khyber Medical College, Peshawar, before commencement of the research. The study was conducted in accordance with institutional ethical guidelines and the principles of the Declaration of Helsinki. Written informed consent was obtained from all participants before enrollment.

Data Availability

The data supporting the findings of this study are available from the corresponding author upon reasonable request, subject to institutional and ethical restrictions.

Author Contributions

Natasha Junaid: Conceptualization, study design, data acquisition, interpretation of results, manuscript drafting, critical revision, final approval, and accountability for the work.

Zahid Sarfraz Khan: Study conception and design, supervision, interpretation of findings, critical revision of the manuscript, final approval, and accountability for the work.

Bibi Hajira Ishaq: Laboratory investigations, data acquisition, biochemical analysis, interpretation of results, critical revision, final approval, and accountability for the work.

Muhammad Umar Faraz: Methodology, data acquisition, interpretation of findings, critical revision of the manuscript, final approval, and accountability for the work.

Kashif ur Rehman Khalid: Data analysis, interpretation of results, manuscript review, critical revision, final approval, and accountability for the work.

Hamza Shahzad: Data collection, literature review, manuscript drafting, critical revision, final approval, and accountability for the work.

All authors contributed substantially to the study, reviewed the manuscript critically, approved the final version, and agreed to be accountable for all aspects of the work.

Informed Consent

Written informed consent was obtained from all participants before enrollment.

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Conflict of Interest

The authors declare that they have no conflict of interest.

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Declaration of AI-Assisted Language Editing

Grammarly AI was used for language and grammar correction.

REFERENCES

1. Murray CJL, Ikuta KS, Sharara F, Swetschinski L, Robles Aguilar G, Gray A, et al. Global burden of bacterial antimicrobial resistance in 2019: a systematic analysis. *Lancet*. 2022;399(10325):629-55. doi:10.1016/S0140-6736(21)02724-0.
2. World Health Organization. Antimicrobial stewardship programmes in health-care facilities in low- and middle-income countries: a WHO practical toolkit. *JAC Antimicrob Resist*. 2019;1(3). doi:10.1093/jacamr/dlz072.
3. Behzadifar M, Behzadifar M, Aryankhesal A, Ravaghi H, Baradaran HR, Sajadi HS, et al. Prevalence of self-medication in university students: systematic review and meta-analysis. *East Mediterr Health J*. 2020;26(7):846-57. doi:10.26719/emhj.20.052.
4. Shah SJ, Ahmad H, Rehan RB, Najeeb S, Mumtaz M, Jilani MH, et al. Self-medication with antibiotics among non-medical university students of Karachi: a cross-sectional study. *BMC Pharmacol Toxicol*. 2014; 15:74. doi:10.1186/2050-6511-15-74.
5. Gillani AH, Ji W, Hussain W, Imran A, Chang J, Yang C, et al. Antibiotic self-medication among non-medical university students in Punjab, Pakistan: a cross-sectional survey. *Int J Environ Res Public Health*. 2017;14(10):1152. doi:10.3390/ijerph14101152.
6. Limaye D, Saeed F, Ahmad M, Pitani RS, Fortwengel G. Self-medication practices among university students from Karachi, Pakistan. *Int J Community Med Public Health*. 2017;4(8):2741-7. doi:10.18203/2394-6040.ijcmph20173635.
7. Rehman S, Sarfraz MR, Tariq H, Ismail A, Mansoor M, Salman A, et al. Antibiotic self-medication among healthcare students in Pakistan: a dual-center cross-sectional study. *Work*. 2026;83(3):713-24. doi:10.1177/10519815251382367.
8. Stine JG, Lewis JH. Hepatotoxicity of antibiotics: a review and update for the clinician. *Clin Liver Dis*. 2013;17(4):609-42. doi:10.1016/j.cld.2013.07.008.

9. Robles M, Toscano E, Cotta J, Lucena MI, Andrade RJ. Antibiotic-induced liver toxicity: mechanisms, clinical features and causality assessment. *Curr Drug Saf.* 2010;5(3):212-22. doi:10.2174/157488610791698307.
10. Serranti D, Montagnani C, Indolfi G, Chiappini E, Galli L, de Martino M. Antibiotic induced liver injury: what about children? *J Chemother.* 2013;25(5):255-72. doi:10.1179/1973947813Y.0000000090.
11. Le TA, Hiba T, Chaudhari D, Preston AN, Palowsky ZR, Ahmadzadeh S, et al. Aminoglycoside-related nephrotoxicity and ototoxicity in clinical practice: a review of pathophysiological mechanism and treatment options. *Drugs Ther Perspect.* 2024;40(4):1357-65. doi:10.1007/s12325-023-02436-x.
12. Kalghatgi S, Spina CS, Costello JC, Liesa M, Morones-Ramirez JR, Slomovic S, et al. Bactericidal antibiotics induce mitochondrial dysfunction and oxidative damage in mammalian cells. *Sci Transl Med.* 2013;5(192):192ra85. doi:10.1126/scitranslmed.3006055.
13. Shabbir MZ, Ashraf MA, Rasool N, et al. Modeling antibiotic self-medication among health sciences students in Pakistan using path mediation and machine learning. *Sci Rep.* 2026. doi:10.1038/s41598-026-71214-w.
14. Khan HT, Murad S, Afridi S, Sajjad M, Malik L. Assessment of self-medication and non-compliance of antibiotics among health majored students in Peshawar. *J Health Wellness Community Res.* 2026. doi:10.61919/mg1x1t59.
15. Rehman S, Sarfraz MR, Bano S, Ismail A, Naveed A, Malik A. Assessing the impact of self-medication with antibiotics among medical students. *Pak J Health Sci.* 2024;5(2):35-9. doi:10.54393/pjhs.v5i02.1242.
16. Keren I, Wu Y, Inocencio J, Mulcahy LR, Lewis K. Killing by bactericidal antibiotics does not depend on reactive oxygen species. *Science.* 2013;339(6124):1213-6. doi:10.1126/science.1232688.
17. Kandeel M, Abdelaziz I, Elhabashy N, Hegazy H, Tolba Y. Nephrotoxicity and oxidative stress of single large dose or two divided doses of gentamicin in rats. *Pak J Biol Sci.* 2011;14(11):627-33. doi:10.3923/pjbs.2011.627.633.
18. Elgazzar D, Aboubakr M, Bayoumi H, et al. Tigecycline and gentamicin-combined treatment enhances renal damage: oxidative stress, inflammatory reaction, and apoptosis interplay. *Pharmaceuticals (Basel).* 2022;15(6):736. doi:10.3390/ph15060736.
19. Xiao Y, Xiong T, Meng X, Yu D, Xiao Z, Song L. Different influences on mitochondrial function, oxidative stress and cytotoxicity of antibiotics on primary human neuron and cell lines. *J Biochem Mol Toxicol.* 2019;33(4). doi:10.1002/jbt.22277.
20. Albusalih FA, Naqvi AA, Ahmad R, Ahmad N. Prevalence of self-medication among students of pharmacy and medicine colleges of a public sector university in Dammam city, Saudi Arabia. *Pharmacy (Basel).* 2017;5(3):51. doi:10.3390/pharmacy5030051.
21. Baddal B, Lajunen TJ, Sullman MJM. Knowledge, attitudes and behaviours regarding antibiotics use among Cypriot university students: a multi-disciplinary survey. *BMC Med Educ.* 2022;22:847. doi:10.1186/s12909-022-03853-2.
22. Alghadeer S, Aljuaydi K, Babelghaith S, Alhammad A, Alarifi MN. Self-medication with antibiotics in Saudi Arabia. *Saudi Pharm J.* 2018;26(5):719-24. doi:10.1016/j.jsps.2018.02.018.
23. Rathod P, Sharma S, Ukey U, Sonpimpale B, Ughade S, Narlawar U, et al. Prevalence, pattern, and reasons for self-medication: a community-based cross-sectional study from Central India. *Cureus.* 2023;15(1). doi:10.7759/cureus.33917.
24. Bhattacharya S, Gupta N, Dutta A, Bonomo MG, Milella L, Sarker SD, Nahar L. Mitigating ROS signalling pathway-mediated defence mechanism: a novel approach to counteract bacterial resistance using natural antioxidant-based antibiotics. *Phytochemistry Reviews.* 2025 Sep 15:1-33.
25. Basu S, Valente M, Banik BK. The Role of Beta-Lactam Antibiotics in Reactive Oxygen Species Generation and Therapeutic Implications. *Current Medicinal Chemistry.* 2025.
26. Anwer EK, Ajagbe M, Sherif M, Musaibah AS, Mahmoud S, ElBanbi A, Abdelnaser A. Gut microbiota secondary metabolites: key roles in GI tract cancers and infectious diseases. *Biomedicine.* 2025 Jan 3;13(1):100.