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Rational antibiotic use among university students a study on knowledge, attitudes, and practices (KAP)

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To examine the associations between antibiotic use behaviors and knowledge, attitudes, and practices (KAP), digital health literacy, general health literacy, and medication-related beliefs among university students. A cross-sectional study was conducted among 1,012 university students using a structured online questionnaire. Data on KAP, eHealth literacy (eHEALS), general health literacy (HLS-EU-Q6), and beliefs about medicines (BMQ) were collected. Non-parametric tests, correlation analyses, and multivariate logistic regression were performed to identify factors associated with non-prescription antibiotic use. The prevalence of non-prescription antibiotic use was 13.9%. Knowledge scores increased across academic years ($p < 0.001$) but were not associated with reduced risky behaviors. Attitude scores were negatively associated with non-prescription antibiotic use (OR = 0.536, $p = 0.006$), whereas risky behavior score was the strongest positive predictor (OR = 2.344, $p < 0.001$). Prior health literacy training was associated with increased odds of non-prescription use (OR = 1.814, $p = 0.038$). Knowledge and general health literacy were not significant predictors. Correlation analysis showed a moderate association between knowledge and attitudes (ρ = 0.415) and a negative association between attitudes and risky behaviors (ρ = −0.390). Antibiotic misuse among university students was more strongly associated with behavioral and attitudinal factors than with knowledge levels. These findings highlight the limitations of knowledge-based interventions and support the need for integrated strategies incorporating behavioral approaches and critical health literacy skills to reduce inappropriate antibiotic use.

Keywords Antimicrobial resistance, Antibiotic misuse, Health literacy, eHealth literacy, Knowledge–attitude–practice, University students, Self-medication

Antimicrobial resistance (AMR) has emerged as one of the most pressing global public health threats of the 21st century, with inappropriate and excessive antibiotic use recognized as a major contributing factor in both clinical and community settings. Recent estimates indicate that bacterial AMR was associated with approximately 4.95 million deaths globally in 2019, underscoring the urgent need for coordinated interventions to promote rational antibiotic use[1]. Among the key contributors to this growing burden is the widespread practice of non-prescription antibiotic use, particularly in low- and middle-income countries but increasingly observed across diverse healthcare systems[2]. Previous large-scale international analyses based on antibiotic consumption data collected between 2000 and 2015 demonstrated a sustained increase in antibiotic consumption and convergence across regions, highlighting the urgency of addressing inappropriate use patterns at both individual and system levels[3].

Inappropriate antibiotic use encompasses a range of behaviors, including self-medication, premature discontinuation of therapy, dose modification, and the reuse of leftover antibiotics. These practices not only reduce treatment efficacy but also accelerate the selection of resistant bacterial strains, thereby compromising future therapeutic options[4,5]. Systematic reviews have shown that self-medication with antibiotics remains highly

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prevalent across different populations, with behavioral and contextual factors playing a central role in shaping misuse patterns[6]. Despite global awareness campaigns and antimicrobial stewardship initiatives, such behaviors remain common, especially among young adults and university students, who often exhibit high access to health information but variable levels of critical appraisal and appropriate application[7,8].

Understanding antibiotic use behaviors requires a multidimensional framework that extends beyond knowledge alone. The Knowledge–Attitude–Practice (KAP) model has been widely employed to assess public health behaviors; however, emerging evidence suggests that knowledge does not consistently translate into appropriate practices, highlighting the mediating role of attitudes and behavioral tendencies[9,10]. In parallel, health literacy—defined as the capacity to access, understand, and use health information—has been recognized as an important factor associated with health-related decision-making[11]. More recent conceptual developments emphasize that health literacy is not only an individual skill but also a dynamic and context-dependent construct shaped by social and environmental factors[12]. Furthermore, digital health literacy (eHealth literacy) has gained increasing importance in the context of widespread reliance on online health information, particularly among younger populations, where the ability to critically evaluate and apply information remains variable[13,14]. Individuals with limited health literacy may experience difficulties in understanding appropriate indications for antibiotic use, interpreting medical advice, and evaluating treatment-related information. Similarly, inadequate eHealth literacy may increase susceptibility to misinformation obtained through online sources, potentially contributing to inappropriate self-medication and antibiotic misuse. Therefore, both general and digital health literacy may be associated with antibiotic-related decision-making beyond factual knowledge alone.

Despite the growing body of literature, important gaps remain. First, the relationship between general health literacy and antibiotic-specific behaviors is not fully elucidated, with some studies reporting weak or inconsistent associations[15]. Second, the role of medication-related beliefs, such as perceived necessity and concerns about overuse, has been less frequently explored in the context of antibiotic misuse[16]. Third, there is limited integrative research simultaneously examining KAP dimensions, digital health literacy, general health literacy, and medication beliefs within a single analytical framework.

University students represent a particularly relevant population for such investigations. As future healthcare professionals and informed members of society, understanding their antibiotic use behaviors is important in the context of both personal health outcomes and broader public health trends. Moreover, the transition to independent healthcare decision-making during university years increases the likelihood of self-medication practices and exposure to informal sources of medical advice[17]. In addition, recent studies suggest that inappropriate antibiotic use among students is often associated with a combination of social norms, perceived knowledge, and behavioral habits rather than objective knowledge alone[18]. In the present study, KAP dimensions, health literacy, eHealth literacy, and medication beliefs were conceptualized as complementary factors associated with antibiotic-related behaviors. Knowledge reflects factual understanding, attitudes represent evaluative orientations toward antibiotic use, while health literacy and eHealth literacy are related to individuals' capacity to access, interpret, and apply health information. Medication beliefs may further be associated with behavioral decisions regarding medicine use. Rather than assuming a sequential causal pathway, these constructs were examined as potentially interrelated correlates of antibiotic use behaviors within a multidimensional framework.

To provide a clearer theoretical context for the present study, a conceptual framework was developed to illustrate the relationships among demographic characteristics, health literacy, eHealth literacy, medication beliefs, knowledge, attitudes, and antibiotic use practices (Fig. 1). The framework was intended to guide interpretation of the observed associations rather than to imply causal pathways.

Therefore, the present study aimed to provide a comprehensive evaluation of antibiotic use behaviors among university students by integrating KAP components with digital health literacy, general health literacy, and medication beliefs. Specifically, the study sought to (i) assess knowledge, attitudes, and practices related to antibiotic use; (ii) examine the role of health literacy and eHealth literacy; and (iii) identify key predictors of non-prescription antibiotic use through multivariate analysis. By adopting a multidimensional approach, this study aims to contribute to the development of targeted interventions for promoting rational antibiotic use and combating antimicrobial resistance.

Methods

Study design and setting

This cross-sectional, descriptive study was conducted to evaluate antibiotic-related knowledge, attitudes, and practices (KAP), along with digital health literacy, general health literacy, and medication beliefs among university students. Data were collected using a structured online questionnaire administered via Google Forms.

Participants and sampling

The study population consisted of university students enrolled in various academic programs. Participation was voluntary and anonymous. A total of 1,161 responses were received. After excluding duplicate entries ($n = 25$) and participants who failed the attention check question ($n = 124$), the final sample included 1,012 respondents.

Participants were recruited using convenience sampling through university communication channels, including institutional e-mail groups and student social media networks. Participation was voluntary, and no incentives were offered. Because recruitment relied on voluntary online participation, selection bias and overrepresentation of students with greater interest in health-related topics cannot be excluded.

Inclusion criteria comprised being an active university student and providing informed consent. Responses with incomplete key sections or failed attention checks were excluded to ensure data quality.

Data collection instrument

The questionnaire consisted of 54 items organized into eight sections:

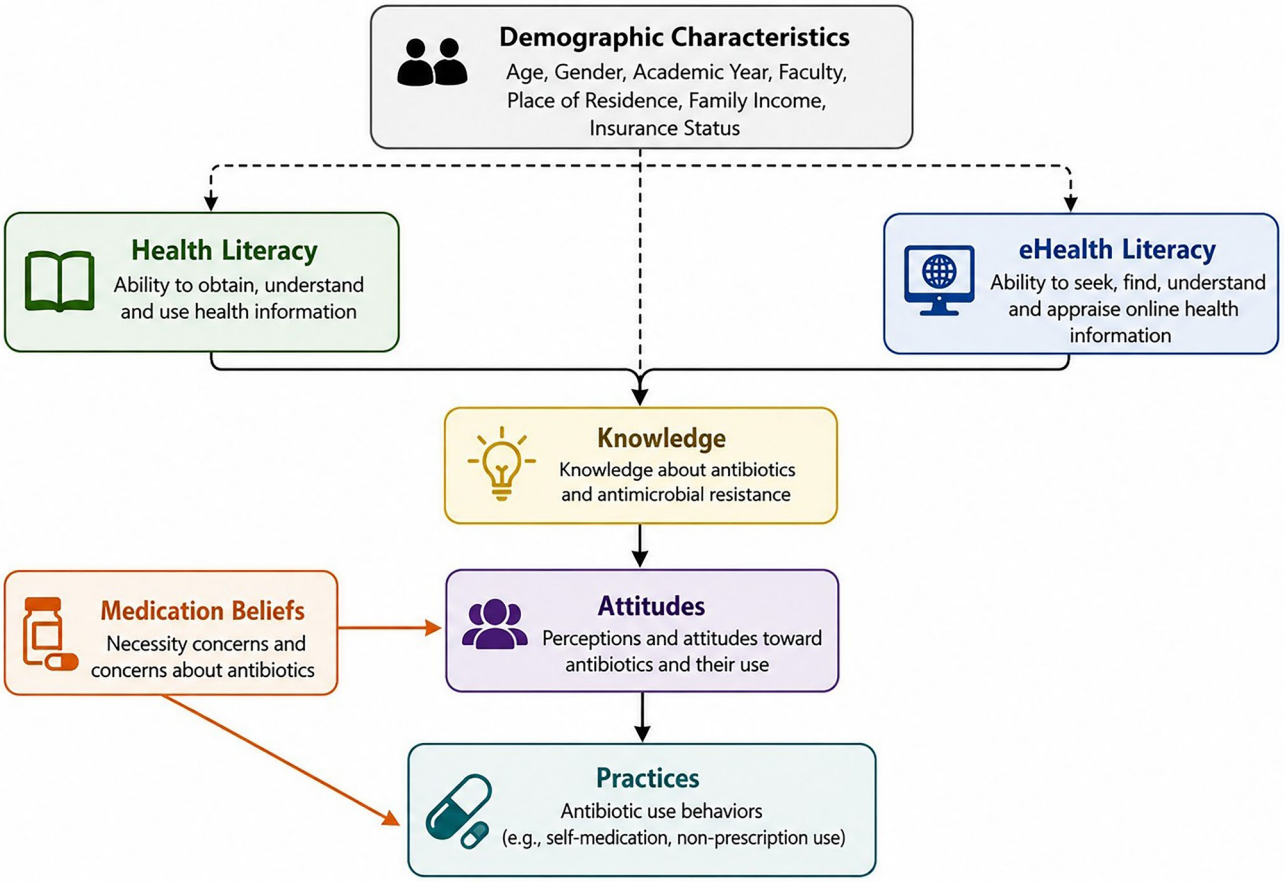


Fig. 1. Conceptual framework illustrating the theoretical relationships among demographic characteristics, health literacy, eHealth literacy, medication beliefs, knowledge, attitudes, and antibiotic use practices examined in the present study. The framework illustrates theoretical relationships among the study variables and was developed to guide interpretation of the observed associations. The proposed pathways are theoretical and do not imply causal relationships.

- Demographics (Items 1–8): Age, gender, academic program, year of study, antibiotic use within the past 12 months, non-prescription use, chronic disease status, and prior health literacy training.
- Attention check (Item 9): Included to ensure response validity.
- Knowledge (Items 10–17): Eight items adapted from previously validated KAP studies[19,20]. Responses were coded as correct[1] or incorrect/uncertain (0), yielding a total score ranging from 0 to 8. An example item was: "Antibiotics are effective in viral infections such as influenza and the common cold.
- Attitudes (Items 18–24): Seven items measured on a 5-point Likert scale[1–5]. Negatively worded items were reverse-coded, with higher scores indicating more appropriate attitudes. In this study, "appropriate attitudes" refer to favorable evaluations of evidence-based antibiotic use, including adherence to prescribed treatments, avoidance of self-medication, and recognition of antimicrobial resistance risks. Therefore, higher scores indicate attitudes more consistent with recommended antibiotic stewardship principles. An example item was: "I think it is wrong to use antibiotics recommended by family members or friends."
- Practices (Items 25–31): Seven dichotomous (yes/no) items assessed antibiotic use behaviors. A risky behavior index was constructed using six predefined inappropriate antibiotic use behaviors: (i) non-prescription antibiotic use, (ii) reuse of leftover antibiotics, (iii) antibiotic use based on family or friends' recommendations, (iv) dose modification without professional consultation, (v) failure to adhere to recommended dosing intervals, and (vi) failure to read the medication leaflet before use. Each behavior was scored as 1 if present and 0 if absent, generating a total score ranging from 0 to 6, with higher scores indicating greater engagement in risky antibiotic-related practices. The item assessing adverse effects during antibiotic use was analyzed separately and was not included in the risky behavior index. An example item was: "I reused leftover antibiotics kept at home."
- eHealth Literacy (Items 32–39): Adapted from the eHEALS scale (Norman & Skinner, 2006). In the present study, the items were administered using a dichotomous response format (agree/disagree) to reduce respondent burden and facilitate interpretation within the broader questionnaire. Responses were scored as 0–1, yielding a total score ranging from 0 to 8. Although this approach differs from the original Likert-based

format, internal consistency remained high (KR-20 = 0.853), indicating acceptable reliability in the present sample. An example item was: "I know how to find health-related information on the internet."

- General Health Literacy (Items 40–45): Based on the HLS-EU-Q6 short form (Pelikan et al., 2014), scored on a 4-point scale. A standardized index was calculated using the formula: (mean − 1) / 3 × 50 (range: 0–50).
- Medication Beliefs (Items 46–53): Adapted from the Beliefs about Medicines Questionnaire (BMQ)[16], comprising two subscales: Overuse and Necessity (range: 0–4 each). An example item was: "People use too many medicines."

An open-ended question (Item 54) was included to capture additional participant perspectives.

Ethical considerations

Participation was voluntary and anonymous. Informed consent was obtained electronically prior to data collection. The study was conducted in accordance with the principles of the Declaration of Helsinki. Ethical approval was obtained from the Institutional Review Board (IRB) of Fenerbahçe University (Approval No: 110.2025fbu; Date: 21 October 2025).

Statistical analysis

All statistical analyses were performed using Python (version 3.12) with the pandas (v2.2), NumPy (v1.26), and SciPy (v1.13) libraries. Statistical significance was set at $p < 0.05$.

Internal consistency of the scales was assessed using Kuder–Richardson Formula 20 (KR-20) for dichotomous variables and Cronbach's alpha for Likert-type scales.

Normality of continuous variables was evaluated using the Shapiro–Wilk and Kolmogorov–Smirnov tests. As the data did not meet normal distribution assumptions, non-parametric tests were applied. Differences between two independent groups were analyzed using the Mann–Whitney U test, while comparisons among three or more groups were conducted using the Kruskal–Wallis H test. Effect sizes were calculated as r ($|Z|/\sqrt{n}$) for Mann–Whitney U and η^2 for Kruskal–Wallis tests, interpreted according to Cohen's criteria.

Associations between categorical variables were examined using the chi-square test, with effect size reported as Cramér's V. Relationships among continuous variables were assessed using Spearman's rank correlation coefficient (ρ), with 95% confidence intervals estimated via bootstrap resampling (1,000 iterations). Missing data were assumed to be missing at random, and pairwise deletion was applied in analyses involving incomplete observations.

Binary logistic regression analysis was performed to identify predictors of non-prescription antibiotic use. Model fit was evaluated using the Hosmer–Lemeshow goodness-of-fit test and Nagelkerke R^2. Multicollinearity was assessed using variance inflation factor (VIF), with values below 5 indicating acceptable levels.

Results

Sample characteristics

A total of 1,161 responses were collected. After excluding duplicate entries ($n = 25$) and participants failing the attention check ($n = 124$), analyses were conducted on 1,012 respondents. Approximately 8% missing data were identified in the knowledge and attitude domains and were associated with academic year ($p < 0.001$); therefore, pairwise deletion was applied.

Participant profile

The mean age was 21.98 ± 6.51 years (median = 20). The majority of participants were female (71.8%), enrolled in health-related programs (62.7%), and in their first or second year of study (74.1%). Antibiotic use within the past 12 months was reported by 64.2% of participants, while 13.9% ($n = 141$) reported non-prescription use. Chronic disease prevalence was 9.8%, and 17.6% had received prior health literacy training. A detailed summary of participant characteristics is presented in Table 1.

Reliability analysis

Scale reliability coefficients are presented in Table 1. Internal consistency was high for eHEALS (KR-20 = 0.853) and HLS-EU-Q6 (Cronbach's α = 0.825), and acceptable for the knowledge scale (KR-20 = 0.716). The attitude scale demonstrated borderline reliability (α = 0.669), whereas the BMQ Overuse subscale showed low reliability (KR-20 = 0.420).

Antibiotic knowledge

The mean knowledge score was 4.96 ± 2.05 ($n = 920$). The highest correct response rates were observed for items related to disruption of gut flora (86.9%) and the non-analgesic nature of antibiotics (82.9%). In contrast, knowledge gaps were evident for items regarding ineffectiveness against viral infections (35.4%) and specificity for bacterial pathogens (36.1%).

Attitudes toward antibiotic use

The overall attitude score was high (mean = 4.23 ± 0.55, $n = 924$). The highest agreement levels were observed for items 20 (M = 4.50) and 22 (M = 4.49), whereas the lowest score was related to completing the full course of treatment (item 21; M = 3.83).

Variable	Value
Sample size	1,012
Age, mean ± SD	21.98 ± 6.51
Age, median	20
Female, n (%)	727 (71.8)
Health-related students, n (%)	635 (62.7)
1st–2nd year students, n (%)	750 (74.1)
Antibiotic use (last 12 months), n (%)	650 (64.2)
Non-prescription use, n (%)	141 (13.9)
Chronic disease, n (%)	99 (9.8)
Health literacy training, n (%)	178 (17.6)
Reliability of scales	
Scale	**Coefficient**
eHEALS	0.853
HLS-EU-Q6	0.825
Knowledge	0.716
Attitude	0.669
BMQ Overuse	0.420

Table 1. Demographic characteristics of participants and reliability coefficients of study scales. SD, standard deviation.

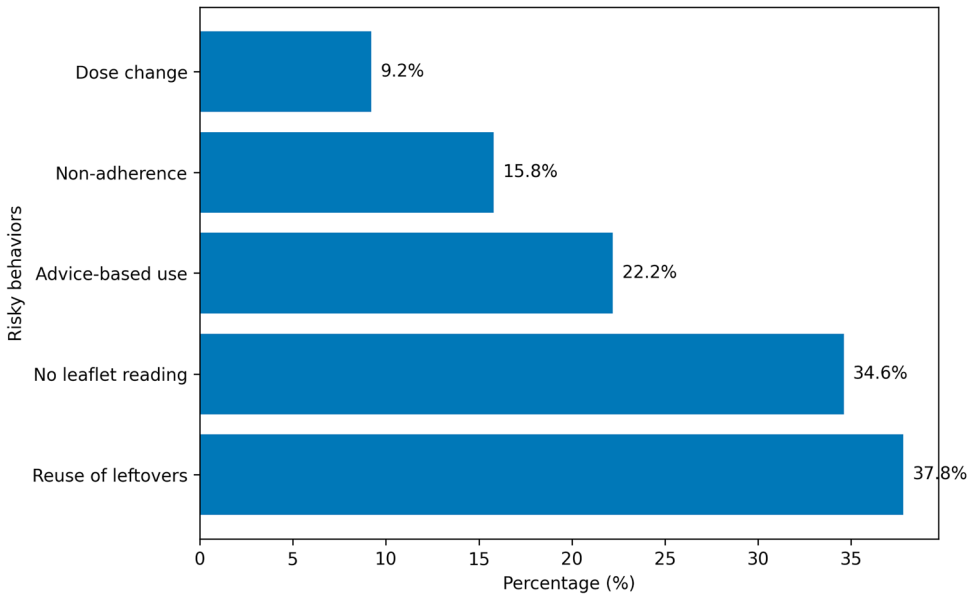


Fig. 2. Prevalence of risky antibiotic use behaviors among participants. The most frequently reported behaviors included reuse of leftover antibiotics, failure to read medication leaflets, and antibiotic use based on informal advice. Percentages represent the proportion of participants reporting each behavior.

Antibiotic use practices

Most participants (84.9%) reported that all antibiotics used were prescribed. However, several risky behaviors were identified, including reuse of leftover antibiotics (37.8%), use based on advice without prescription (22.2%), dose modification (9.2%), non-adherence to dosing intervals (15.8%), and failure to read medication leaflets (34.6%). Adverse effects were reported by 20.4% of participants. The mean risky behavior score was 1.35 ± 1.50.

The distribution of risky antibiotic use behaviors is presented in Fig. 2.

eHealth literacy, health literacy, and medication beliefs

The mean eHEALS score was 5.58 ± 2.54, with the highest agreement for accessing health information (78.7%) and the lowest for applying information to decision-making (51.6%). The HLS-EU-Q6 index was 28.72 ± 8.54, with 38.8% of participants classified as having inadequate and 29.7% problematic health literacy (total 68.5%). The most challenging domain was decision-making related to health (72.2% reporting difficulty).

Variable	Outcome	*p*-value	Effect size
Gender (female vs. male)	Attitude higher in females	< 0.001	$r = 0.096–0.158$
	Risky behavior lower in females	< 0.001	
	eHEALS higher in males	0.002	
Non-prescription use	Attitude lower	< 0.001	$r = 0.250$
	Risky behavior higher	< 0.001	$r = 0.425$
Health literacy training	Knowledge higher	< 0.001	$r = 0.213$
	Attitude higher	< 0.001	
	Risky behavior lower	0.039	
Field of study (health vs. non-health)	Knowledge higher	< 0.01	$r = 0.157$
	Attitude higher	< 0.01	$r = 0.204$
Academic year	Knowledge increases	< 0.001	$\eta^2 = 0.140$
	Attitude increases	< 0.001	
	Risky behavior	0.825	$p > 0.05$

Table 2. Comparison of knowledge, attitude, and risky behavior scores across participant characteristics. r, effect size; η^2, eta squared.

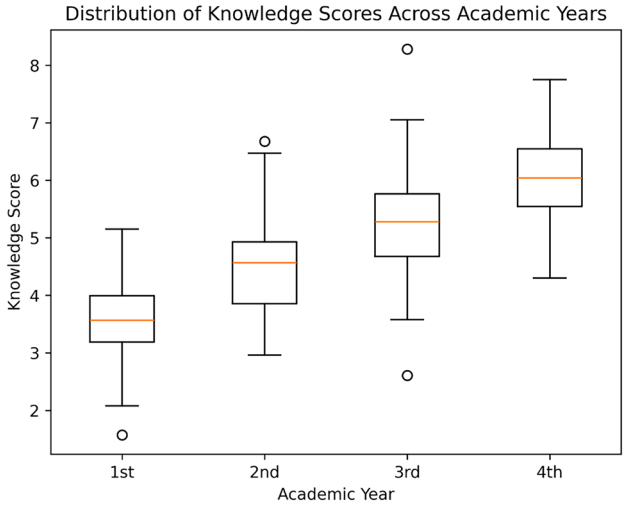


Fig. 3. Distribution of antibiotic knowledge scores across academic years. A statistically significant difference was observed between groups (Kruskal–Wallis $H = 140.26$, $p < 0.001$, $\eta^2 = 0.140$). Knowledge scores increased across academic levels from first to fourth year. Detailed comparisons are presented in Table 2.

For medication beliefs, the Necessity score (3.45 ± 0.94) exceeded the Overuse score (2.51 ± 0.97), with a mean differential of -0.93 ± 1.43.

Group comparisons

Detailed comparisons are summarized in Table 2. Given the imbalance in group sizes (e.g., 727 females vs. 276 males), effect sizes were interpreted alongside statistical significance.

Females demonstrated significantly more positive attitudes and lower risky behavior scores compared to males (both $p < 0.001$), whereas males had higher eHEALS scores ($p = 0.002$). Effect sizes were small ($r = 0.096–0.158$), and no significant difference was observed in knowledge scores.

Participants reporting non-prescription antibiotic use exhibited significantly lower attitude scores ($p < 0.001$, $r = 0.250$) and higher risky behavior scores ($p < 0.001$, $r = 0.425$), with no difference in knowledge levels.

Participants with prior health literacy training had significantly higher knowledge, attitude, eHEALS, and HLS scores (all $p \leq 0.004$), along with lower risky behavior scores ($p = 0.039$).

Students enrolled in health-related programs demonstrated higher knowledge ($r = 0.157$), attitude ($r = 0.204$), and eHEALS scores ($r = 0.099$), as well as lower risky behavior scores (all $p < 0.01$).

Knowledge scores differed significantly across academic years ($H = 140.26$, $p < 0.001$, $\eta^2 = 0.140$), showing a progressive increase from first to fourth year (Fig. 3). Attitude and eHEALS scores also increased across academic levels (both $p < 0.001$), whereas risky behavior scores did not differ significantly ($p = 0.825$).

Variable	Knowledge	Attitude	Risky behavior	eHEALS	HLS
Knowledge	1	0.415	− 0.119	–	− 0.001
Attitude	0.415	1	− 0.390	–	− 0.014
Risky behavior	− 0.119	− 0.390	1	–	–
eHEALS	–	–	–	1	0.291
HLS	− 0.001	− 0.014	–	0.291	1

Table 3. Spearman correlation coefficients among key variables. Values represent Spearman's ρ.

Variable	OR	95% CI	*p*-value
Risky behavior score	2.344	2.016–2.727	< 0.001
Attitude score	0.536	0.345–0.832	0.006
Health literacy training	1.814	1.032–3.187	0.038
Knowledge score	1.052	–	0.420
eHEALS	–	–	> 0.05
HLS index	–	–	> 0.05
BMQ subscales	–	–	> 0.05
Age	–	–	> 0.05
Gender	–	–	> 0.05

Table 4. Logistic regression analysis of predictors of non-prescription antibiotic use. OR, odds ratio; CI, confidence interval.

Correlation analysis

The correlation matrix is presented in Table 3. The strongest associations were observed between knowledge and attitude (ρ = 0.415, 95% CI [0.354–0.473]) and between attitude and risky behavior (ρ = −0.390, 95% CI [− 0.445 to − 0.331]). The relationship between knowledge and risky behavior was weak (ρ = −0.119).

A moderate correlation was found between eHEALS and HLS (ρ = 0.291). In contrast, the HLS index showed negligible correlations with knowledge (ρ = −0.001) and attitude (ρ = −0.014).

Predictors of non-prescription antibiotic use

Logistic regression results are presented in Table 4 (n = 929; non-prescription users: 139, 15.0%). The model was statistically significant (χ^{2}_{12}= 228.71, p < 0.001), with good fit (Hosmer–Lemeshow χ^{2}_{8}= 6.216, p = 0.623), explaining 38.3% of the variance (Nagelkerke R^2 = 0.383) and achieving 86.8% classification accuracy. Multicollinearity was not detected (VIF: 1.04–1.51).

Three significant predictors were identified: risky behavior score (OR = 2.344, 95% CI [2.016–2.727], p < 0.001), attitude score (OR = 0.536, 95% CI [0.345–0.832], p = 0.006), and prior health literacy training (OR = 1.814, 95% CI [1.032–3.187], p = 0.038). The relative contribution and precision of these predictors are illustrated in Fig. 4.

Knowledge score (OR = 1.052, p = 0.420), eHEALS, HLS index, BMQ subscales, age, gender, and field of study were not significant predictors. No significant associations were found between demographic variables and non-prescription antibiotic use in chi-square analyses (all p > 0.05).

Discussion

This study provides a comprehensive evaluation of antibiotic use behaviors among university students by integrating knowledge, attitudes, and practices (KAP) with digital health literacy, general health literacy, and medication-related beliefs. The findings demonstrate that inappropriate antibiotic use remains prevalent within this population and, more importantly, that behavioral and attitudinal factors play a more decisive role than knowledge alone in shaping antibiotic use practices. These results align with growing evidence suggesting that behavioral and contextual factors are more strongly associated with antibiotic misuse than knowledge deficits alone[6,18]. This issue is particularly pronounced in settings where structural and healthcare system constraints further exacerbate irrational antibiotic use and resistance patterns[21].

One of the most notable findings of this study is the weak association between knowledge and risky antibiotic use, despite a moderate positive relationship between knowledge and attitudes. This observation reinforces previous evidence suggesting that increased knowledge does not necessarily translate into appropriate health behaviors[10]. Similar patterns have been reported among university students and healthcare trainees, where awareness of antibiotics is relatively high, yet misconceptions—especially regarding viral infections— continue to coexist with inappropriate antibiotic use[7,8]. These findings highlight the existence of a persistent "knowledge–behavior gap," suggesting that interventions focused solely on information dissemination may be insufficient. Contemporary behavioral research further supports this perspective, suggesting that health-related decision-making is closely associated with cognitive biases, social norms, and habitual behaviors rather than objective knowledge alone[22].

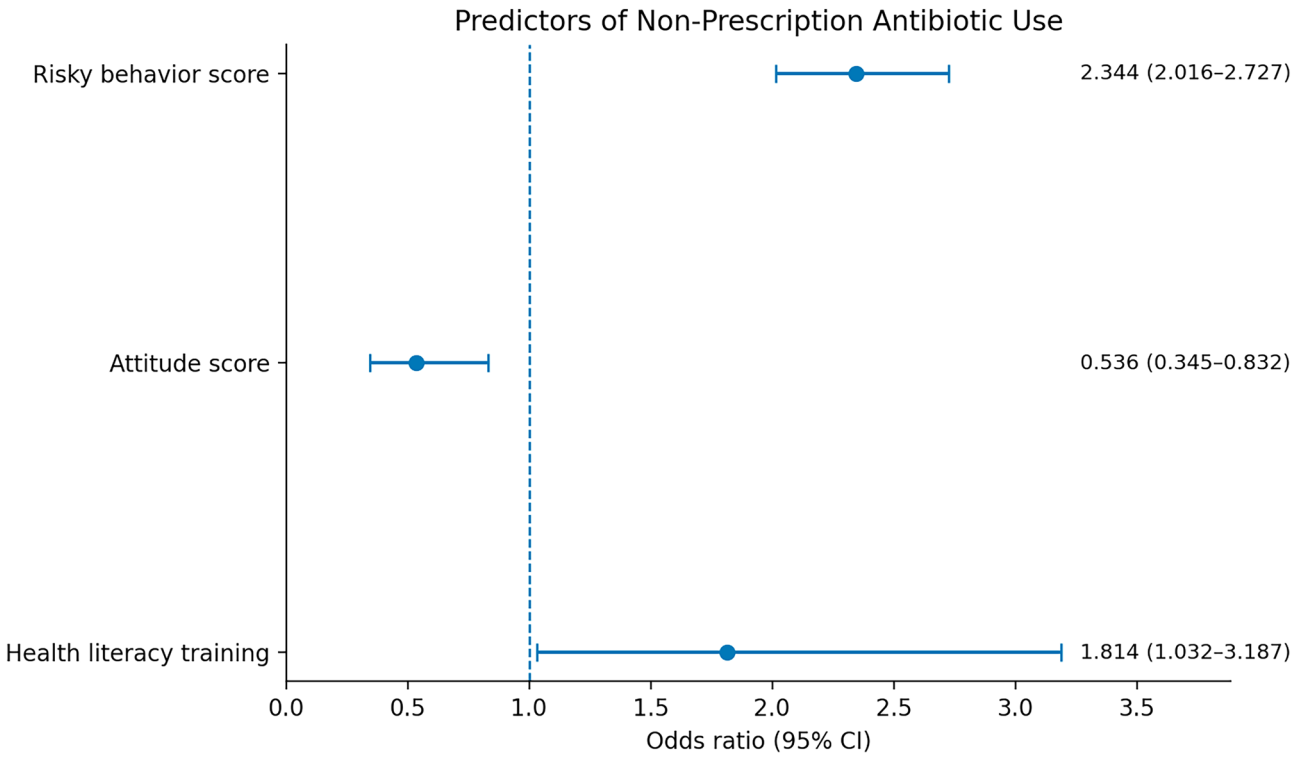


Fig. 4. Forest plot displaying odds ratios (OR) with 95% confidence intervals (CI) for predictors of non-prescription antibiotic use derived from multivariate logistic regression analysis. Risky behavior score was identified as the strongest positive predictor, whereas higher attitude scores were associated with reduced odds of non-prescription use. Prior health literacy training was also significantly associated with increased likelihood of non-prescription antibiotic use. Detailed regression results are presented in Table 4.

In contrast, attitudes emerged as a key correlate of antibiotic-related behaviors. Higher attitude scores were significantly associated with lower odds of non-prescription antibiotic use, indicating a protective effect. This finding is consistent with the Theory of Planned Behavior, which identifies attitudes as central predictors of both behavioral intention and actual behavior[9]. Furthermore, the observed inverse relationship between attitudes and risky practices is supported by empirical studies demonstrating that beliefs regarding medication necessity and concerns about misuse are more strongly associated with antibiotic behaviors than knowledge alone[16,23]. Similar findings have recently been reported among young adults, where attitudes and perceived risks were more strongly associated with appropriate antibiotic use behaviors than knowledge levels alone[24]. Importantly, recent intervention studies have shown that strategies targeting behavioral change—rather than knowledge alone—are more effective in reducing inappropriate antibiotic use. In particular, large-scale randomized controlled trials have demonstrated that social norm–based interventions can significantly reduce inappropriate antibiotic prescribing practices[25].

Another important finding is the strong predictive role of risky behavior patterns, suggesting that inappropriate antibiotic practices tend to cluster rather than occur independently. Behaviors such as the reuse of leftover antibiotics and self-medication based on informal advice were commonly reported and often co-occurred. This clustering effect has also been documented in previous studies, suggesting that such practices frequently co-occur and are associated with sustained patterns of antibiotic misuse[17,26]. These findings underscore the importance of targeting behavioral patterns as a whole, rather than addressing individual actions in isolation, within antimicrobial stewardship interventions.

Interestingly, prior health literacy training was associated with increased odds of non-prescription antibiotic use, a finding that may initially appear counterintuitive. However, this can be explained by distinguishing between access to information and the ability to critically evaluate and appropriately apply that information. Previous studies have suggested that individuals with higher perceived competence in accessing health information may develop increased confidence in making independent treatment decisions, including self-medication[15]. In the present study, although eHealth literacy scores were relatively high, participants reported lower confidence in applying information to decision-making. This indicates a disconnect between information acquisition and effective utilization. An alternative explanation is that students who actively seek health-related education may simultaneously exhibit greater confidence in self-managing minor illnesses. Such confidence may encourage self-medication behaviors despite higher knowledge levels. Moreover, the cross-sectional design prevents determination of whether training preceded or followed the development of these behaviors. Supporting this interpretation, recent literature emphasizes that digital health literacy is not consistently associated with appropriate health behaviors unless accompanied by critical appraisal and decision-making skills[14].

In contrast, general health literacy (HLS-EU-Q6) showed minimal association with antibiotic-specific knowledge and attitudes, suggesting that general health literacy measures may not adequately capture domain-specific competencies. This finding aligns with previous research indicating that health literacy is context-dependent and that disease- or medication-specific literacy tools may provide more accurate insights into health-related behaviors[11,12]. Similarly, medication beliefs assessed through the BMQ did not emerge as significant predictors in the regression model, indicating that general beliefs about medicines may not directly translate into antibiotic-specific decision-making.

The observed increase in knowledge scores across academic years is consistent with higher levels of antibiotic-related awareness among students in more advanced years of study. However, the absence of a corresponding decrease in risky behaviors suggests that educational progression alone is insufficient to modify behavior. This reinforces the need for integrated educational strategies that combine knowledge acquisition with behavioral and attitudinal components. Similar discrepancies between improvements in knowledge and actual behavioral change have been reported in recent studies across different educational settings[7,27].

Overall, these findings suggest that effective interventions to promote rational antibiotic use should move beyond traditional knowledge-based approaches and instead incorporate behavioral insights, social norm strategies, and skills-based health literacy training. Such multidimensional approaches may be more effective in addressing factors associated with antibiotic misuse and may contribute to efforts aimed at combating antimicrobial resistance. These findings have important implications for antimicrobial stewardship programs targeting young adult populations.

Strengths and limitations

This study has several strengths, including a large sample size, the simultaneous assessment of knowledge, attitudes, practices, health literacy, eHealth literacy, and medication beliefs, and the use of multivariate analytical approaches. However, several limitations should be considered when interpreting the findings. First, the cross-sectional design precludes causal inference. Second, data were self-reported and may be subject to recall bias and social desirability bias, potentially resulting in underreporting of inappropriate antibiotic use behaviors. Third, convenience sampling may limit the generalizability of the results. Fourth, approximately 8% missing data were present in some domains. Because missingness was associated with academic year, some degree of bias may have been introduced into the analyses. Finally, although previously validated instruments were employed, exploratory or confirmatory factor analyses were not performed because the primary objective of the study was not instrument development or validation. Instead, internal consistency indices were calculated to evaluate reliability within the study sample.

Data availability

Data Availability Statement: The datasets generated and/or analyzed during the current study are not publicly available due to ethical and privacy restrictions but are available from the corresponding author on reasonable request.

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Author contributions
M.M. conceived and designed the study, performed data analysis, and wrote the main manuscript. A.K.T. contributed to study design, data interpretation, and critical revision of the manuscript. M.O.D. assisted in data analysis and interpretation. G.S. contributed to statistical analysis and reviewed the manuscript. Ş.M. contributed to data collection and manuscript revision. All authors read and approved the final manuscript.

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Declarations

Competing interests
The authors declare no competing interests.

Ethical approval
The study was conducted in accordance with the principles of the Declaration of Helsinki. Ethical approval was obtained from the Institutional Review Board of Fenerbahçe University (Approval No: 110.2025fbu; Date: 21 October 2025). Participation was voluntary and anonymous, and informed consent was obtained electronically from all participants prior to data collection.

Declaration of generative AI and AI-assisted technologies in the manuscript preparation process
During the preparation of this work, the authors used AI-assisted tools to improve language clarity and readability. After using these tools, the authors carefully reviewed and edited the content and take full responsibility for the accuracy and integrity of the manuscript.

Additional information
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