Original Research Paper

Volume - 16 | Issue - 09 | September - 2026 | PRINT ISSN No. 2249 - 555X | DOI : 10.36106/ijar

Pharmacology

ANTIMICROBIAL RESISTANCE AND ANTIMICROBIAL STEWARDSHIP AMONG UNDERGRADUATE MEDICAL STUDENTS: A COMPREHENSIVE MULTICENTRIC CROSS-SECTIONAL ASSESSMENT OF KNOWLEDGE, ATTITUDE, PRACTICES, PRESCRIBING CONFIDENCE AND STEWARDSHIP READINESS

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ABSTRACT **Background:** Antimicrobial resistance (AMR) is a major global public health challenge, and strengthening antimicrobial stewardship (AMS) competencies among future physicians is essential for promoting rational antibiotic use. This study assessed knowledge, attitudes, practices, prescribing confidence, stewardship readiness, and educational needs regarding AMR and AMS among undergraduate medical students. **Methods:** A multicentric cross-sectional questionnaire-based study was conducted among undergraduate medical students from government medical colleges in North India. A validated structured questionnaire evaluated demographic characteristics, knowledge, attitudes, antibiotic-use practices, prescribing confidence, stewardship readiness, and perceived educational adequacy. Composite domain scores were calculated, and comparisons between students with and without formal AMR/AMS training were performed using appropriate statistical tests. Correlation analysis was conducted using Spearman's rank correlation coefficient. **Results:** A total of 652 students participated (mean age 21.27±2.45 years; 57.7% males), of whom 47.2% had received formal AMR/AMS training. Knowledge (82.1%), attitude (79.8%), and practice (77.5%) scores were satisfactory, whereas prescribing confidence was the weakest domain (50.6%). Nearly 88% of participants supported additional AMR/AMS training during MBBS, with clinical case-based learning identified as the highest educational priority (43.9%). Students who had received formal training demonstrated significantly higher scores across all domains (all $p<0.001$). Educational adequacy showed a strong positive correlation with stewardship readiness ($\rho=0.721$), while prescribing confidence correlated positively with stewardship readiness ($\rho=0.584$). **Conclusion:** Undergraduate medical students demonstrated good awareness of AMR but insufficient prescribing confidence and stewardship preparedness. Structured, competency-based, longitudinal AMR/AMS training incorporating case-based learning, microbiology interpretation, simulation, and supervised prescribing should be integrated into undergraduate medical curricula to strengthen antimicrobial stewardship competencies and support rational antibiotic prescribing.

KEYWORDS : Antimicrobial resistance; Antimicrobial stewardship; Medical students; Knowledge, Attitudes and Practices.

INTRODUCTION

Antimicrobial resistance (AMR) has emerged as one of the most critical threats to global public health, undermining decades of progress in the prevention and treatment of infectious diseases. The Global Research on Antimicrobial Resistance study estimated that bacterial AMR directly caused approximately 1.27 million deaths and was associated with 4.95 million deaths worldwide in 2019, highlighting its enormous clinical and economic impact [1]. The rapid emergence and dissemination of resistant microorganisms are driven by inappropriate prescribing, irrational antimicrobial use, self-medication, over-the-counter availability of antibiotics, inadequate infection prevention, and insufficient antimicrobial stewardship (AMS) interventions [2,3]. Recognizing this urgency, the World Health Organization has identified education and training of healthcare professionals as a cornerstone of the Global Action Plan on AMR, emphasizing that rational antimicrobial prescribing should begin during undergraduate medical education [2].

Antimicrobial stewardship encompasses coordinated interventions that promote the appropriate selection, dose, route, and duration of antimicrobial therapy to optimize patient outcomes while minimizing resistance [3]. Traditionally, stewardship initiatives have focused on practicing clinicians; however, prescribing behaviors and confidence begin developing during undergraduate training, making medical students an essential target for early educational interventions [4]. Efthymiou et al., in a review of medical students' knowledge, attitudes, and perceptions, showed that students generally recognize AMR as a major public-health issue but have persistent gaps in prescribing knowledge and preparedness for antimicrobial stewardship [4]. Silverberg et al. similarly reported wide heterogeneity in stewardship training across medical curricula and highlighted the need for structured, competency-based AMS education with measurable learning outcomes [5].

Several cross-sectional studies across countries have evaluated knowledge, attitudes, and practices (KAP) of healthcare students regarding antibiotic use and AMR. Haque et al. in Malaysia, Homsi et al. in Jordan, Saadeh et al. in Lebanon, Sefah et al. in Ghana, Akande-Sholabi and Ajamu in Nigeria, Sannathimmappa et al. in Oman, Shrestha in Nepal, Yang et al. in China, and Al-Shami et al. in Libya consistently reported good general awareness but persistent deficiencies in prudent antibiotic selection, culture and susceptibility interpretation, treatment duration, and prescribing confidence [6-14]. These studies also indicate that positive attitudes toward rational antibiotic use do not always translate into appropriate prescribing practices, suggesting a disconnect between theoretical knowledge and practical competence [6,7,11].

India is one of the countries most affected by AMR because of its high infectious disease burden, extensive antibiotic consumption, widespread self-medication, and heterogeneous prescribing practices [15-18]. Although the National Action Plan on AMR and the Competency-Based Medical Education curriculum advocate rational antimicrobial prescribing and stewardship, Gopichandran and Vijayaraghavan reported that AMR- and AMS-related competencies occupy only a limited proportion of the revised Indian undergraduate curriculum [15]. Indian studies by Gupta et al., Khan et al., Sharma et al., Dutt et al., Varshney et al., Janagond et al., and Deogaonkar and Dawane continue to show deficiencies in antibiotic-use knowledge, prescribing behavior, and stewardship preparedness among undergraduate medical students despite increasing awareness of AMR [16-22].

Recent educational interventions and assessment tools further support the need for structured undergraduate stewardship reforms. Varghese and Kwatra demonstrated improvement after a self-directed learning module on AMR, Mittal et al. described a competency-based elective on rational antimicrobial prescribing, and Vijayaraghavan et al. reported improved awareness after the SOS-AMR sensitization initiative among Indian medical students [23-25]. Rajopadhye et al. highlighted the value of community-awareness initiatives led by medical undergraduates, while Sumana et al. showed that game-based learning can improve rational antimicrobial-use competencies among healthcare learners [26,27]. Psychometrically validated tools such as PATARAS and questionnaire-validation studies by Kusuma et al. and Vázquez-Cancela et al. provide additional frameworks for assessing

stewardship readiness and educational adequacy [28,29].

Despite this growing literature, multicentric Indian evidence evaluating knowledge, attitudes, antibiotic-use practices, prescribing confidence, stewardship readiness, and perceived educational adequacy among undergraduate medical students remains limited. Most available studies are institution-specific and use heterogeneous assessment tools, limiting comparison across settings. Therefore, the present multicentric cross-sectional study was undertaken to comprehensively assess undergraduate medical students' knowledge, attitudes, practices, prescribing confidence, stewardship readiness, and educational needs regarding AMR and AMS using a structured questionnaire. The findings are expected to identify competency gaps and provide evidence for strengthening undergraduate stewardship education, thereby promoting rational antimicrobial prescribing and supporting national and global strategies to combat AMR.

MATERIALS AND METHODS

This multicentric cross-sectional questionnaire-based study was conducted among undergraduate medical students from government medical colleges in North India after obtaining approval from the respective Institutional Ethics Committees. Medical students from all professional years who provided informed electronic consent were eligible to participate. The survey was administered online using a structured Google Forms questionnaire between the study period, and participation was voluntary and anonymous. Responses with incomplete data or duplicate entries were excluded from the final analysis. A total of 652 valid responses were included for statistical analysis.

The study instrument was a pre-validated, self-administered questionnaire developed to assess antimicrobial resistance (AMR) and antimicrobial stewardship (AMS)-related competencies. The questionnaire comprised four sections: Section 1 collected Future Healthcare Professional Profile and previous exposure to formal AMR/AMS training; Section 2 evaluated knowledge and attitudes regarding AMR and AMS using multiple-choice and five-point Likert-scale items; Section 3 assessed antibiotic-use practices and prescribing confidence; and Section 4 evaluated stewardship readiness, perceived adequacy of undergraduate education, need for additional AMR/AMS training, and preferred educational interventions. Composite domain scores for knowledge, attitude, practice, prescribing confidence, stewardship readiness, and educational adequacy were calculated by summing item scores within each domain and converting them to percentage scores for comparison. Internal consistency of the domains was assessed using Cronbach's alpha.

Data were entered into Microsoft Excel and analysed using IBM SPSS Statistics version 26.0 (IBM Corp., Armonk, NY, USA). Continuous variables were expressed as mean ± standard deviation (SD) or median (interquartile range), whereas categorical variables were summarized as frequencies and percentages. Comparisons between students with and without formal AMR/AMS training were performed using the independent-samples t-test for continuous variables and the Chi-square test for categorical variables. Cohen's d was calculated to determine effect sizes for group comparisons. Associations between composite domain scores were evaluated using Spearman's rank correlation coefficient (ρ). All statistical tests were two-tailed, and a p-value <0.05 was considered statistically significant.

RESULTS

The study included 652 undergraduate medical students, and the results are presented sequentially according to the questionnaire sections. Descriptive statistics were used to summarize participant characteristics and questionnaire responses, while inferential statistics evaluated associations between formal AMR/AMS training and composite domain scores. Correlation analysis was performed to examine relationships among knowledge, attitude, practice, confidence, and stewardship readiness.

Table 1. Future Healthcare Professional Profile (n = 652).

Variable	Category	n (%) / Summary
Age (years)	Mean ± SD	**21.27 ± 2.45**
Gender	Male	**376 (57.7)**
	Female	**276 (42.3)**
	Prefer not to say	**0 (0.0)**
Formal AMR/AMS training	Yes	**308 (47.2)**
	No	**285 (43.7)**
	Not sure	**59 (9.0)**

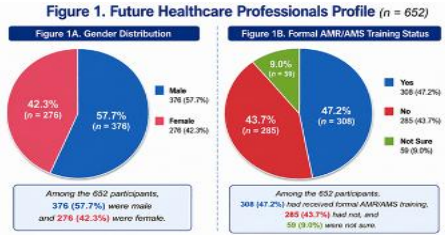

Figure 1. Future Healthcare Professionals Profile. (A) Pie chart showing the gender distribution among the 652 undergraduate medical students included in the study, with males constituting 57.7% and females 42.3% of the study population. (B) Pie chart illustrating previous exposure to formal antimicrobial resistance (AMR) and antimicrobial stewardship (AMS) training, showing that 47.2% of participants had received formal training, 43.7% had not, and 9.0% were unsure of their training status.

The mean age of participants was 21.27 ± 2.45 years. Male students constituted 57.7% (376/652) of the study population, while 42.3% (276/652) were female. Nearly half of the participants (47.2%) reported having received formal AMR/AMS training, whereas 43.7% had not and 9.0% were uncertain about prior training (Table 1). Figure 1A illustrates the gender distribution of participants, while Figure 1B depicts the distribution according to formal AMR/AMS training status, showing an almost equal proportion of trained and untrained students.

Table 2. Knowledge regarding antimicrobial resistance and antimicrobial stewardship (n = 652)

Knowledge item	Correct n (%)	Incorrect n (%)	Don't know n (%)
Antibiotics are effective against viral infections (False)	**530 (81.3)**	98 (15.0)	24 (3.7)
Inappropriate antibiotic use contributes to AMR	**556 (85.3)**	64 (9.8)	32 (4.9)
Stopping antibiotics early contributes to AMR	**474 (72.7)**	123 (18.9)	55 (8.4)
Culture & sensitivity guides therapy	**583 (89.4)**	25 (3.8)	44 (6.7)
AMS improves outcomes while reducing AMR	**534 (81.9)**	31 (4.8)	87 (13.3)

Participants demonstrated generally good knowledge regarding antimicrobial resistance. The highest proportion of correct responses was observed for the role of culture and antimicrobial susceptibility testing in guiding therapy (89.4%), followed by awareness that inappropriate antibiotic use contributes to AMR (85.3%) and that antibiotics are ineffective against viral infections (81.3%). (Table 2) Knowledge regarding completion of antibiotic therapy was comparatively lower (72.7%), indicating an important educational gap despite overall satisfactory awareness.

Table 3. Attitudes towards antimicrobial resistance and antimicrobial stewardship (n = 652)

Statement	Agree/Strongly Agree	Neutral	Disagree	Mean Score
AMR is a global public-health challenge	528 (81.0)	66 (10.1)	58 (8.9)	4.07
Medical students have a role in combating AMR	497 (76.2)	106 (16.3)	49 (7.5)	3.94
AMS should be mandatory in MBBS curriculum	493 (75.6)	111 (17.0)	48 (7.4)	3.95

Overall attitudes toward antimicrobial resistance and stewardship were highly positive. More than three-fourths of respondents agreed that AMR represents a major global public health challenge (81.0%), that medical students have an important role in combating AMR (76.2%), and that antimicrobial stewardship should be incorporated into the MBBS curriculum (75.6%). Mean attitude scores ranged from 3.94 to 4.07, reflecting a favourable perception toward responsible antibiotic use (Table 3).

Table 4. Antibiotic-use practices and prescribing confidence (n = 652)

Indicator	Favourable n (%)	Intermediaten (%)	Poor n (%)
Consult healthcare professional before antibiotics	413 (63.3)	196 (30.1)	43 (6.6)

Complete full antibiotic course	480 (73.6)	129 (19.8)	43 (6.6)
Never self-medicated with antibiotics	237 (36.3)	385 (59.0)	30 (4.6)
High confidence selecting antibiotic	119 (18.3)	246 (37.7)	287 (44.0)
High confidence deciding duration	92 (14.1)	198 (30.4)	362 (55.5)
High confidence interpreting AST	141 (21.6)	194 (29.8)	317 (48.6)

Although participants reported generally favourable antibiotic practices, prescribing confidence remained relatively low. Approximately 73.6% completed the full antibiotic course and 63.3% sought professional advice before antibiotic use. However, only 18.3% expressed high confidence in selecting empirical antibiotics, 14.1% were confident in determining treatment duration, and 21.6% reported confidence in interpreting antimicrobial susceptibility reports, highlighting deficiencies in practical prescribing competencies (Table 4).

Table 5. Stewardship Readiness & Educational Needs (n = 652)

Question	Most favourable response n (%)	Intermediate response n (%)	Least favourable response n (%)
Preparedness to apply antimicrobial stewardship principles during future clinical practice	162 (24.8)	245 (37.6)	245 (37.6)
Preparedness to interpret culture and antimicrobial susceptibility reports for clinical decision-making	151 (23.2)	214 (32.8)	287 (44.0)
Preparedness to make responsible antibiotic prescribing decisions after graduation	176 (27.0)	215 (33.0)	261 (40.0)
Undergraduate preparation for rational antibiotic use	194 (29.8)	242 (37.1)	216 (33.1)
Undergraduate preparation for antimicrobial stewardship practices	170 (26.1)	238 (36.5)	244 (37.4)
Confidence that current medical education will enable responsible future prescribing	183 (28.1)	208 (31.9)	261 (40.0)
Additional AMR/AMS training required during MBBS	573 (87.9)	46 (7.1)	33 (5.1)
Highest priority area for undergraduate medical training	Clinical case-based antibiotic decision making– 286 (43.9)	AMS principles – 183 (28.0)	Others – 183 (28.1)

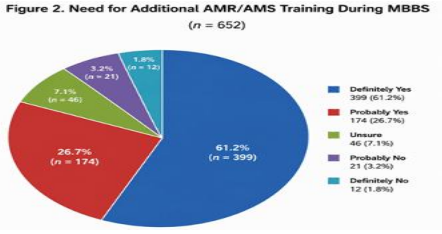

Figure 2. Need for additional AMR/AMS training during MBBS. Distribution of participant responses regarding the need for additional antimicrobial resistance and antimicrobial stewardship training during undergraduate medical education. A majority of respondents (87.9%) supported the inclusion of additional AMR/AMS training in the MBBS curriculum.

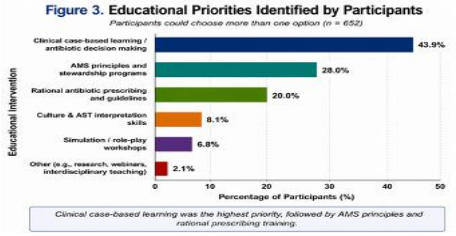

Figure 3. Educational priorities identified by participants.

Preferred educational interventions for strengthening undergraduate AMR/AMS education. Clinical case-based learning and antibiotic decision-making was the highest-ranked educational priority, followed by antimicrobial stewardship principles and rational antibiotic prescribing.

Participants reported moderate preparedness for antimicrobial stewardship activities but expressed a strong desire for additional educational support. Less than one-third considered themselves adequately prepared to apply stewardship principles or interpret culture reports independently. Notably, 87.9% believed that additional AMR/AMS training should be incorporated into the undergraduate curriculum (Table 5). Clinical case-based antibiotic decision-making was identified as the highest educational priority (43.9%), followed by stewardship principles (28.0%). These findings are further illustrated in Figure 2, which demonstrates overwhelming support for additional AMR/AMS training during MBBS, and Figure 3, which ranks the preferred educational interventions among participants.

Table 6. Composite domain scores (n = 652)

Domain	Mean ± SD	Median	#Mean %	Cronbach α
Knowledge	4.11 ±1.20	5	82.1	0.63
Attitude	11.96 ±2.78	12	79.8	0.87
Practice	10.85 ±2.26	11	77.5	0.67
Prescribing confidence	7.59 ±2.75	7	50.6	0.80
AMS readiness	7.56 ±2.53	8	63.0	0.83
Educational adequacy	8.02 ±2.53	8	66.8	0.86

#Mean % = percentage of maximum obtainable score

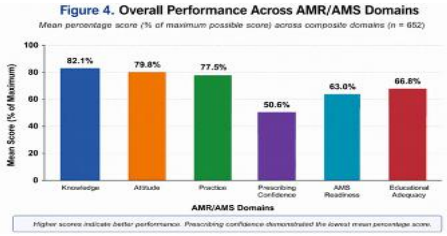

Figure 4. Overall performance across AMR/AMS domains. Mean percentage scores across the six composite AMR/AMS domains. Knowledge, attitude, and practice demonstrated the highest scores, whereas prescribing confidence showed the lowest overall performance.

Composite score analysis demonstrated the highest performance in the knowledge domain (82.1%), followed by attitude (79.8%) and practice (77.5%). Educational adequacy (66.8%) and stewardship readiness (63.0%) showed intermediate performance, whereas prescribing confidence (50.6%) represented the weakest domain. Reliability analysis showed acceptable to good internal consistency across domains (Cronbach's α = 0.63–0.87) (Table 6). The comparative performance of all composite domains is presented in Figure 4, which highlights prescribing confidence as the principal area requiring improvement.

Table 7. Factors associated with AMR/AMS scores (n = 652)

Outcome	Training Yes	Training No	*p value	Effect size
Knowledge	4.55 ±0.87	3.68 ±1.28	<0.001	0.79
Attitude	12.71 ±2.39	11.18 ±3.01	<0.001	0.57
Practice	11.29 ±2.12	10.39 ±2.31	<0.001	0.40
Confidence	8.09 ±2.66	7.12 ±2.76	<0.001	0.36
AMS readiness	8.40 ±2.40	6.72 ±2.44	<0.001	0.70
Educational adequacy	8.96 ±2.34	7.08 ±2.39	<0.001	0.79
Female vs Male Practice	11.12	10.65	0.007	Female higher
Male vs Female Confidence	7.93	7.13	<0.001	Male higher

Values are Mean ± SD. Independent-samples t test used. *P <0.05 statistically significant. Effect size expressed as Cohen's d.

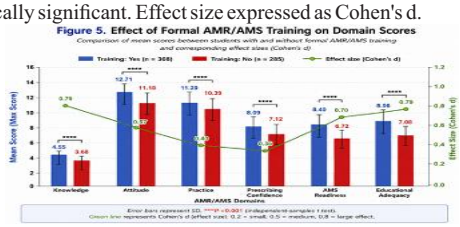

Figure 5. Effect of formal AMR/AMS training on domain scores.

Comparison of composite domain scores between students who had and had not received formal AMR/AMS training. Participants with previous formal training demonstrated significantly higher scores across all domains, with moderate-to-large effect sizes (Cohen's *d*).

Students who had received formal AMR/AMS training achieved significantly higher scores across all assessed domains compared with untrained students (all $p < 0.001$). The greatest effect sizes were observed for knowledge (Cohen's $d = 0.79$) and educational adequacy ($d = 0.79$), followed by AMS readiness ($d = 0.70$) (Table 7). Female students demonstrated significantly better practice scores ($p = 0.007$), whereas male students reported greater prescribing confidence ($p < 0.001$). These differences are visually summarized in Figure 5, which illustrates the consistent positive effect of formal AMR/AMS training across all domains.

Table 8. Correlation analysis

Variables	#Spearman ρ	*p value
Knowledge vs Attitude	0.409	<0.001
Knowledge vs Practice	0.302	<0.001
Knowledge vs Confidence	0.150	<0.001
Confidence vs AMS readiness	0.584	<0.001
AMS readiness vs Educational adequacy	0.721	<0.001
Attitude vs Educational adequacy	0.295	<0.001
Age vs Knowledge	0.174	<0.001
Age vs Confidence	0.117	0.003

#Spearman correlation coefficient (ρ); all tests two-tailed. *P <0.05 statistically significant.

Significant positive correlations were observed among all major AMR/AMS domains. Knowledge showed moderate positive correlations with attitude ($\rho = 0.409$) and practice ($\rho = 0.302$), while confidence demonstrated a strong association with stewardship readiness ($\rho = 0.584$) (Table8). The strongest correlation was identified between AMS readiness and educational adequacy ($\rho = 0.721$), suggesting that perceived quality of undergraduate education substantially influences preparedness for stewardship activities. Age demonstrated weak but statistically significant positive correlations with both knowledge ($\rho = 0.174$) and confidence ($\rho = 0.117$).

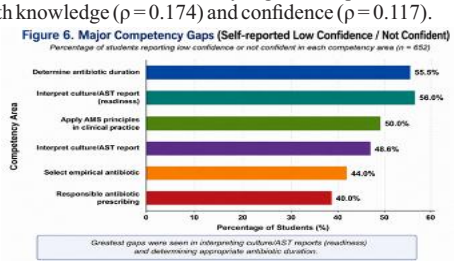

Figure 6. Major competency gaps among participants. Percentage of participants reporting low confidence across key antimicrobial stewardship competencies. The greatest competency gaps were observed in interpreting culture and antimicrobial susceptibility reports, determining appropriate antibiotic duration, and applying stewardship principles in clinical practice.

Overall, the findings indicate that undergraduate medical students possess satisfactory knowledge, attitudes, and antibiotic-use practices regarding AMR; however, important deficiencies persist in prescribing confidence and stewardship readiness. Formal AMR/AMS training was consistently associated with superior performance across all evaluated domains, and the majority of participants expressed a clear need for enhanced stewardship-focused education during the MBBS curriculum. The competency gaps highlighted in Figure 6 further emphasize the need for targeted educational interventions, particularly in antimicrobial susceptibility interpretation, antibiotic duration selection, and responsible prescribing.

DISCUSSION

The present multicentric study evaluated knowledge, attitudes, practices, prescribing confidence, stewardship readiness, and educational needs regarding AMR and AMS among undergraduate medical students. Overall, participants demonstrated satisfactory knowledge, positive attitudes, and generally appropriate antibiotic-use practices. However, important deficiencies were observed in prescribing confidence, interpretation of microbiological reports, and stewardship readiness, indicating that theoretical knowledge alone may not translate into clinical competence.

The overall knowledge score of 82.1% observed in the present study is consistent with reports from India and other countries, where undergraduate medical students generally possess good awareness regarding the causes and consequences of AMR. Varshney et al. and Janagond et al. similarly reported satisfactory theoretical knowledge among Indian medical students, although deficiencies persisted regarding rational antibiotic prescribing and resistance mechanisms [20,21]. Comparable findings have been reported by Sefah et al. in Ghana, Homsi et al. in Jordan, Saadeh et al. in Lebanon, and Abdu-Aguye et al. in Nigeria, suggesting that awareness of AMR has improved globally following increased public-health emphasis on antimicrobial stewardship [7-10,30].

Participants in the present study demonstrated highly favorable attitudes toward responsible antibiotic use and overwhelmingly acknowledged AMR as a major public-health problem. These findings are comparable to those of Efthymiou et al., whose review concluded that medical students widely recognize the importance of AMR despite variability in preparedness for clinical prescribing [4]. Similar positive attitudes have also been reported by Sannathimmappa et al. in Oman, Shrestha in Nepal, Deo et al. in Nepal, and Sharma et al. in India [11,12,17,31]. Nevertheless, positive attitudes alone cannot ensure rational prescribing unless accompanied by adequate clinical exposure and stewardship training.

Although antibiotic-use practices were generally appropriate, prescribing confidence emerged as the weakest domain in the present study. Less than one-fourth of participants expressed confidence in selecting empirical antibiotics, interpreting antimicrobial susceptibility reports, or determining appropriate treatment duration. Similar deficiencies were described by Haque et al. among Malaysian medical students, Saadeh et al. among Lebanese students, and Homsi et al. among Jordanian healthcare students, all of whom identified inadequate confidence despite satisfactory theoretical knowledge [6-8]. Min et al. further demonstrated that knowledge correlates with attitude and practice but does not eliminate inappropriate prescribing behavior, emphasizing the importance of experiential learning [32].

Formal AMR/AMS training showed a significant positive association with all composite domains in the present study, with the greatest improvements observed in knowledge, educational adequacy, and stewardship readiness. These findings agree with Akande-Sholabi and Ajamu, who demonstrated higher AMR knowledge among healthcare students exposed to formal antimicrobial education [10]. Homsi et al. also reported that structured educational exposure predicted better knowledge and practices [7]. Educational intervention studies by Varghese and Kwatra, Mittal et al., and Sumana et al. further demonstrated that self-directed learning, competency-based modules, and game-based learning can improve stewardship knowledge, clinical reasoning, and rational antimicrobial prescribing [23,24,27].

An important observation of the present study was that nearly 88% of participants expressed the need for additional AMR/AMS training during MBBS, while clinical case-based learning emerged as the preferred educational intervention. These findings support Silverberg et al., who concluded that stewardship teaching remains heterogeneous worldwide and requires structured competency-based integration [5]. Gopichandran and Vijayaraghavan similarly demonstrated that AMR competencies occupy only a small proportion of the revised Indian undergraduate curriculum, highlighting an important curricular deficiency [15]. The recent review by Rana et al. also identified persistent gaps between theoretical knowledge and practical application of stewardship principles among Indian healthcare professionals and students [33].

Correlation analysis in the present study demonstrated strong positive relationships between educational adequacy, stewardship readiness, prescribing confidence, and knowledge, indicating that improvements in undergraduate education are likely to enhance future prescribing competence. Similar interrelationships between knowledge, attitudes, and prescribing practices have been reported by Min et al. in China, Homsi et al. in Jordan, Yang et al. among Chinese nursing students, and Kusuma et al. during validation of the PATARAS stewardship assessment tool [7,13,28,32]. These findings collectively reinforce the importance of comprehensive competency-based AMS education rather than isolated theoretical teaching sessions.

The strengths of the present study include its multicentric design, large sample size, comprehensive assessment of multiple stewardship

domains, and inclusion of composite domain scores with effect-size and correlation analyses. Nevertheless, certain limitations should be acknowledged. The cross-sectional design precludes causal inference, self-reported responses may be influenced by recall and social desirability bias, and the participating institutions may not represent all Indian medical colleges. Furthermore, actual prescribing behavior was not objectively assessed. Overall, the present study demonstrates that while undergraduate medical students possess satisfactory knowledge and favorable attitudes toward AMR, significant gaps remain in prescribing confidence and stewardship readiness. These findings emphasize the need for structured, longitudinal, competency-based AMR and AMS training incorporating case-based discussions, simulation, microbiology laboratory interpretation, and supervised clinical prescribing exercises throughout undergraduate medical education.

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