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Knowledge, attitude, and practice of antifungal resistance and stewardship among pharmacy students in Zambia: a cross- sectional study to inform antifungal stewardship programs

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Background: Antifungal resistance (AFR) is a growing global health threat, particularly in low- and middle-income countries such as Zambia, where antifungals are often accessed without prescription. Antifungal stewardship (AFS) programs aim to optimise antifungal use, yet limited data exist on pharmacy students' knowledge, attitudes, and practices (KAP) toward AFR and AFS. This study evaluated pharmacy students' knowledge, attitudes, and practices (KAP) toward AFR and AFS in Zambia.

Methods: A descriptive cross-sectional survey was conducted among 288 randomly selected pharmacy students between August and September 2024 using a structured questionnaire. Descriptive statistics summarised demographics and KAP responses. Associations were analysed using Chi-square and Fisher's Exact Tests, while multivariable logistic regression identified predictors of good KAP ($p < 0.05$).

Results: Among respondents (55.2% female; 76.7% aged 18–25 years), most students (94.1%) knew how to define AFR, and 90.3% recognized antifungal misuse as a factor driving resistance. Nevertheless, only 18.1% showed good knowledge, 67.7% held positive attitudes (especially among fourth-year students, $p < 0.001$), and merely 2.4% practiced appropriately. Multivariable analysis found that being a fourth-year student increased the likelihood of a good attitude (aOR = 5.10, 95% CI: 2.28–11.43). Married students were more likely to demonstrate good practices (aOR = 2.75, 95% CI: 1.13–6.68) towards AFR and antifungal stewardship (AFS) compared to unmarried ones. Additionally, age above 33 years was not significantly associated with better knowledge (aOR = 1.29, 95% CI: 0.32–5.18).

Conclusion: Pharmacy students in Zambia demonstrated positive attitudes towards AFR and AFS, but significant gaps in knowledge and practice remain. Strengthening AFR and AFS-related content and experiential training within the pharmacy curriculum is urgently needed to improve preparedness for clinical practice.

KEYWORDS

antifungal resistance, antifungal stewardship, antifungal stewardship programs, antimicrobial resistance, fungal infections, pharmacy students, Zambia

1 Introduction

Antifungal resistance (AFR), which is part of antimicrobial resistance (AMR), is classically defined as the reduction in susceptibility of fungal pathogens to antifungal agents due to intrinsic or acquired mechanisms, leading to clinical treatment failure, prolonged infection, or increased mortality (Gupta et al., 2021; Pai et al., 2018; Perea and Patterson, 2002). AFR is a global public health problem that has contributed to increased morbidity and mortality, alongside negative economic implications (Arastehfar et al., 2020; Stevenson et al., 2022; van Rhijn et al., 2024; Wiederhold, 2017). Consequently, AFR has been largely neglected and lags behind antibiotic resistance regarding its implementation, diagnostics, pharmaceutical industry, research, awareness, evidence base, resources, and perceived importance (Ananda-Rajah et al., 2012; Mudenda, 2024; van Rhijn et al., 2024; Whitney et al., 2022). Among the earliest reported cases of drug resistance of dermatophytes to antifungals was against griseofulvin (Lenhart, 1968). However, recent findings have demonstrated high prevalence and resistance of *Candida* species to antifungal drugs (Arastehfar et al., 2021; Lee et al., 2021; Nucci et al., 2021; Sahu et al., 2023). This problem has been worsened by a lack of newer antifungal agents in the drug development pipeline (McCarty and Pappas, 2021; Oshero and Kontoyiannis,

2017; Stover et al., 2023; Vitiello et al., 2023). There is a growing need for antifungal stewardship (AFS); however, limited information exists regarding the knowledge, attitudes, and practices (KAP) of health sciences students toward AFR in Zambia (Mudenda et al., 2023b).

Globally, fungal infections account for approximately 150 million cases and up to 3.8 million deaths annually, with a notable increase from 1.7 million deaths in previous years to over 3.8 million by 2023 (Mudenda, 2024). The high prevalence of fungal infections has contributed to the overuse and misuse of antifungal agents, thereby fueling the emergence and spread of AFR (Mudenda, 2024). AFR continues to be a considerable challenge in the sub-Saharan African region, especially among immunocompromised patients (Africa and Abrantes, 2017; Mudenda, 2024; Oliveira et al., 2023). Historically, AFR has not been recognised as a significant public health threat (Fisher et al., 2022). However, this is changing as more is known about AFR and its implications (Mudenda, 2024; Vitiello et al., 2023). Every year, it is estimated that more than 300 million people suffer from severe fungal infections worldwide, with an estimated 1.5–2.5 million annual deaths due to *Candida* and *Aspergillus* infections, with considerable economic costs for the health care system (Denning, 2024; Jamiu et al., 2021; Khalifa et al., 2022). Overall, infections due to *Candida* and *Aspergillus*

species have appreciable public health consequences, and resistance to these fungal pathogens needs to be avoided where possible (Paiva Macedo and Dias, 2024; Revie et al., 2018).

Drivers of AFR are complex and include the inappropriate use of antifungal drugs coupled with access to these agents without a prescription (Ferris et al., 2002; Hassoun et al., 2023; Khairy et al., 2021; Langfeldt et al., 2022; Papadimitriou-Olivgeris et al., 2020). Alongside this, the lack of access to a variety of antifungal drugs to treat fungal infections has also contributed to the growing rates of AFR and associated consequences (Denning, 2022; Kneale et al., 2016). Evidence has shown that clinical AFR is due to incorrect diagnosis, which can be divided into two categories: (i) misdiagnosis or polymicrobial disease when empirical and pre-emptive strategies are employed; (ii) immune reconstitution inflammatory syndromes in patients receiving cytotoxic, biologic, or antiretroviral therapy (Kanafani and Perfect, 2008). Alongside this, few laboratories conduct routine antifungal susceptibility testing, especially in African countries (Achilonu et al., 2023). Typically, patients with immunosuppressive conditions are highly prone to fungal infections and AFR (Kainz et al., 2020; Perlin, 2015; Reddy et al., 2022; Xia et al., 2022). These drivers have contributed to the rising cases of drug-resistant fungal infections in recent years (Arendrup and Patterson, 2017; Hassoun et al., 2023; Lockhart et al., 2023; Mudenda, 2024).

Drug-resistant fungal infections may arise due to genetic variations affecting how antifungal medications are metabolised or from inadequate absorption of the drugs into the body (Ghannoum and Rice, 1999). Consequently, it is important to be vigilant with antifungal dosages, especially in the pediatric population (Watt et al., 2011). A suboptimal length of treatment often predicts failure for most mycoses, and compliance is a potential problem for successful therapy (Kanafani and Perfect, 2008). The other appreciable challenge to successful fungal therapy is patients' underlying diseases, including tuberculosis, Human Immunodeficiency Virus (HIV), cancer, diabetes, and cardiovascular diseases (Reddy et al., 2022). This is because of inadequate knowledge of drug-to-drug interactions, which can result from the administration of multiple medications with antifungal agents (Mufwambi et al., 2021). It is for this reason that AFR should be addressed and antifungal stewardship programs (AFSPs) instigated (Mudenda, 2024; Rabaan et al., 2023). These programs are critical in reducing the consumption of antifungal agents across various populations (Albahar et al., 2024; Hart et al., 2019; Jacob et al., 2025; Whitney et al., 2022).

Overall, AFR is responsible for high morbidity and mortality rates across Africa (Africa and Abrantes, 2017). An estimated 25.8 million people in the sub-Saharan region are HIV-infected, driving a surge in opportunistic mycoses and associated resistance mechanisms in low and middle-income countries (LMICs) (Africa and Abrantes, 2017). In view of this, multiple AFSPs must be instigated to address AFR (Micallef et al., 2014, 2017; Ray et al., 2023; Zhang et al., 2024). AFSPs are coordinated measures employed to maximise therapeutic results, reduce side effects and selective pressure, and oversee the proper administration of antifungal medications (Hamdy et al., 2017; Kara et al., 2021; Ruhnke, 2014). To be effective, AFSPs must be implemented by a multidisciplinary team involving all healthcare professionals (HCPs) (Agrawal et al., 2016). There

have been concerns with instigating antimicrobial stewardship programs (ASPs), including AFSPs, among LMICs due to resource and personnel issues (Cox et al., 2017). However, this is now changing, and there is an increasing number of ASPs, including AFSPs, undertaken in LMICs alongside high-income countries, including those orchestrated by pharmacists (Johnson et al., 2020; Otieno et al., 2022; Siachalinga et al., 2022). Overall, a multidisciplinary approach is typically needed for AFSPs to be effective (Agrawal et al., 2016; Hamdy et al., 2017; Johnson et al., 2020; Ray et al., 2023; Valerio et al., 2015).

Despite increasing global attention to AMR, AFR remains underexplored, particularly in low- and middle-income countries such as Zambia. While antifungal misuse and over-the-counter access are recognised contributors to resistance (Mudenda et al., 2023b, 2023d), there is limited evidence on the preparedness of future healthcare professionals to address these challenges. Pharmacy students, as future prescribers and stewards of antimicrobial use, play a critical role in AFS implementation (Alshehri and Khawagi, 2025; Khan et al., 2021; Maqbool et al., 2026; Mudenda et al., 2022). However, there is a paucity of Zambia-specific data assessing their KAP regarding AFR and AFS. Addressing this gap is essential for informing targeted educational interventions and strengthening AFSPs. Therefore, this study aimed to evaluate the knowledge, attitudes, and practices of pharmacy students in Zambia regarding AFR and AFS.

2 Materials and methods

2.1 Study design, setting, and population

This is a cross-sectional study conducted among undergraduate pharmacy students at the Levy Mwanawasa Medical University (LMMU) from August 2024 to September 2024. The University was chosen for this research as it is located in Lusaka and offers the following programs: Biomedical Sciences, Environmental Health, Physiotherapy, Public Health, Public Health Nutrition, Nursing, Medicine, Pharmacy, Radiography, and Nutrition and Dietetics. Pharmacy is a five-year degree program with first-year pre-requisite courses that include Biology, Chemistry, Mathematics, and Physics. Another reason why this site was chosen is that no study had been conducted at LMMU before this survey. The study population included all pharmacy students registered at LMMU in Lusaka who consented to be part of the study and were willing to respond to the questionnaire. This study excluded all pharmacy students who were not available during the data collection period.

2.2 Sample size determination

The sample size was determined using Taro Yamane's formula [69]. The population of pharmacy students included 215 s-year students, 160 third-year students, 176 fourth-year students, and 36 fifth-year students, resulting in a total of 587 undergraduate pharmacy students. The margin of error was assumed to be 5% at a 95% confidence level. A 10% non-response rate was taken into consideration. The final sample size was estimated to be

238 undergraduate pharmacy students. A stratified random sampling approach was employed, with strata defined based on the year of study (second to fifth year). Proportional allocation was used to determine the number of participants selected from each stratum relative to their population size. Within each stratum, participants were randomly selected using a simple random sampling technique to ensure equal representation and minimise selection bias.

2.3 Data collection and instrument development

Data were collected using a questionnaire adopted from a previously validated tool that assessed AFR and AFS among pharmacy students (Mudenda et al., 2023d). The questionnaire comprised four sections: Section A had five questions on the participants' sociodemographic characteristics; Section B included 10 questions evaluating knowledge of AFR and AFS; Section C consisted of 10 questions exploring attitudes toward AFR and AFS; and Section D contained 10 questions on practices related to AFR and AFS.

After providing written consent to participate in the study, participants were recruited and provided with a face-to-face self-administered questionnaire, which they returned to the data collectors upon completion. Data collection was carried out by three trained individuals (S.M., B.C. and P.N.N) and took approximately 20–30 min per participant. Given the use of self-administered questionnaires, there is potential for response bias and social desirability bias, where participants may provide answers they perceive as acceptable rather than reflective of actual behaviour. Measures such as anonymity and voluntary participation were implemented to minimise these biases.

2.4 Validity and reliability

The questionnaire underwent face and content validity assessment by three public health experts to ensure clarity, relevance, and comprehensiveness. A pilot study involving 20 pharmacy students was conducted to refine the tool and enhance its robustness. Participants in the pilot study were excluded from the main study. Internal consistency was assessed using Cronbach's alpha, which yielded a value of 0.827, indicating acceptable reliability.

2.5 Statistical analysis

Data from questionnaires were entered into Stata/BE version 18 (Stata Corporation, College Station, TX, USA) for statistical analysis. Categorical variables were reported as frequencies and percentages. Associations between putative predictor variables and outcome variable(s) were assessed in univariable analysis using a Pearson Chi-square test and Fisher's Exact Test, as appropriate. For instance, associations between the years of study and KAP regarding AFR were assessed using a Pearson Chi-square test and Fisher's Exact Test, as appropriate. The

KAP scores were computed by assigning one point for each correct response and zero for incorrect or neutral responses. A Bloom's cut-off value of 80% was applied to categorise respondents into "good" ($\geq 80\%$) and "poor" ($< 80\%$) levels of KAP on AFR and AFS. Variable definitions were standardised before analysis to ensure consistency and reproducibility (Mudenda et al., 2023d).

Multivariable logistic regression analysis was performed to assess factors independently contributing to KAP towards AFR, adjusting for confounders. Only variables with a p -value less than 0.20 from the Chi-Square or Fisher's exact test and clinically relevant based on previous studies were included in the multivariable model. The Hosmer-Lemeshow test was used to test the model for goodness-of-fit. We reported the odds ratios with respective 95% Confidence intervals at a significance level of alpha less than 0.05 (two-tailed).

2.6 Ethical approval

Ethical approval was obtained from the University of Zambia Health Sciences Research Ethics Committee (Approval ID: 20231270124) and the National Health Research Authority (Approval ID: A042/25/7/2024). Written informed consent was obtained from all participants prior to data collection. Participation was voluntary, and all responses were anonymised to ensure confidentiality.

3 Results

3.1 Socio-demographic characteristics of participants

Table 1 shows the socio-demographic characteristics of study participants. A total of 300 questionnaires were distributed, of which 288 were completed and included in the analysis, yielding a response rate of 96%. The largest proportion, 159 (55.2%), were females, 126 (43.8%) were in the third year of study, and 221 (76.7%) were aged between 18 and 25. The majority of the respondents were not married, and most of them resided in urban areas (Table 1).

3.2 KAP of antifungal resistance and stewardship among study participants

The overall KAP for AFR and AFS is presented in Figure 1. The proportion of respondents with good knowledge of AFR was 18.1% [95% confidence interval (CI): 13.8%–23.0%], being numerically highest, 19.1% (95% CI: 12.6%–27.0%), among students in the third year of study. Additionally, 2.4% (95% CI: 0.1%–4.9%) of the respondents had good practices towards AFR, which was numerically the highest, at 3.8% (95% CI: 0.8%–10.8%) among fourth-year students. Furthermore, 67.7% (95% CI: 62.0%–73.1%) of respondents had a good attitude towards AFR, with fourth-year students reporting the highest proportion at 84.6% (95% CI: 74.7%–91.8%), which was statistically significant ($p < 0.001$).

3.3 Responses to knowledge, attitude, and practice statements on AFR and AFS among study participants

Responses to KAP statements are presented in Table 2. The majority of respondents demonstrated a strong understanding of AFR concepts, including its definition, causes, and

consequences. Most of the respondents reported that AFR is a significant public health problem; nevertheless, 39.9% did not think that the current training on AFR in the university was sufficient. Notably, most of the respondents reported that formal learning on the proper usage of antifungals among healthcare students is an intervention that may minimise AFR going forward.

3.4 Factors influencing good knowledge, attitude and practice regarding AFR and AFS among study participants

Table 3 shows results from the multiple logistic regression model. The Hosmer-Lemeshow test suggested a good fit for the final model. Participants in their fourth year [adjusted odds ratio (aOR) = 5.10, 95% CI: 2.28–11.43] of the study were more likely to have a good attitude towards AFR and AFS than those in their second year. Furthermore, married participants (aOR = 2.75, 95% CI: 1.13–6.68) were more likely to have good practices towards AFR and AFS.

4 Discussion

This study assessed pharmacy students' knowledge, attitudes, and practices (KAP) toward AFR and AFSPs in Zambia. Understanding these aspects in future healthcare professionals is crucial, as they will play a pivotal role in combating the growing threat of AMR, including AFR.

TABLE 1 Socio-demographic characteristics of study participants, $N = 288$.

Variables	Category	Frequency	Percentage %
Age (years)	18–25	221	76.7
	26–33	47	16.3
	Above 33	20	7.0
Gender	Female	159	55.2
	Male	129	44.8
Year of Study	Second	62	21.5
	Third	126	43.8
	Fourth	78	27.1
	Fifth	22	7.6
Marital Status	Unmarried	253	87.8
	Married	35	12.2
Residence	Urban	213	74.0
	Rural/peri-urban	75	26.0

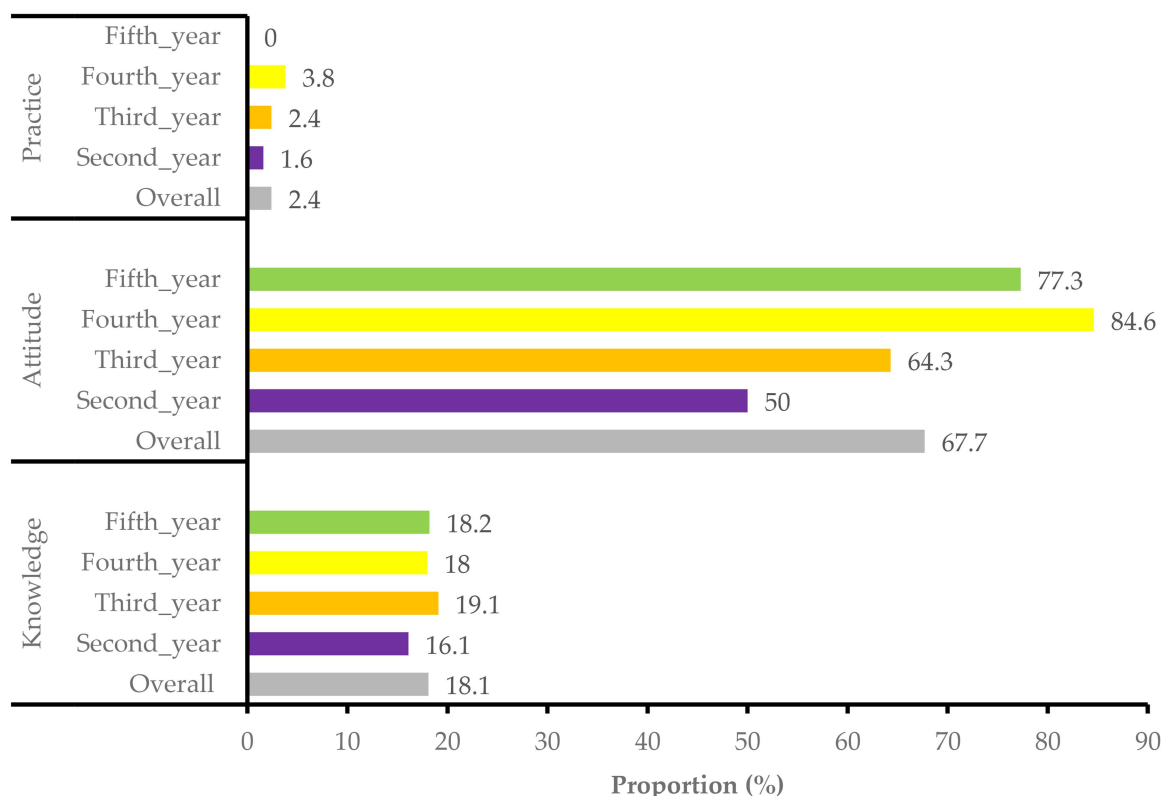


FIGURE 1

Proportion of respondents with good knowledge, attitude and practice regarding AFR and AFS.

TABLE 2 Participants' responses about knowledge, attitude and practice statements.

Competency	Yes		No		Neutral	
	<i>n</i>	%	<i>n</i>	%	<i>N</i>	%
Knowledge statements						
Antifungal Resistance is a phenomenon where fungi become less responsive to antifungal medications	271	94.1	9	3.1	8	2.8
Fluconazole, Amphotericin B, and Itraconazole are examples of common antifungal medications	251	87.2	15	5.2	22	7.6
Misuse or overuse of antifungal medications contributes to the development of antifungal resistance	260	90.3	19	6.6	9	3.1
Antifungal resistance could lead to prolonged illnesses and higher mortality rates.	254	88.2	17	5.9	17	5.9
Only bacterial infections can develop resistance; fungal infections cannot	30	10.4	236	81.9	22	7.7
It's important to complete the full course of prescribed antifungal treatment, even if symptoms improve earlier.	278	96.5	7	2.5	3	1.0
Antifungal stewardship programs aim to improve the use of these drugs	265	92.0	8	2.8	15	5.2
Over-the-counter antifungal medications cannot lead to antifungal resistance	47	16.3	203	70.5	38	13.2
Patient adherence to the prescribed antifungal regimen is crucial for effective treatment	256	88.9	21	7.3	11	3.8
Regular diagnostics are not necessary when prescribing antifungal treatment	43	14.9	212	73.6	33	11.5
Attitude statements						
Antifungal resistance is a significant public health concern	251	87.2	20	6.9	17	5.9
The current training and education about the proper use of antifungals and antimicrobial resistance are sufficient	115	39.9	123	42.7	50	17.4
It is okay to prescribe antifungal medication even without a confirmed fungal infection	20	6.9	254	88.2	14	4.9
All healthcare students should participate in antifungal stewardship programs	255	88.5	8	2.8	25	8.7
Patient non-compliance with antifungal medicines contributes to the occurrence of antifungal resistance	245	85.1	25	8.7	18	6.2
Overuse or misuse of antifungal medications in healthcare practices is a public health concern	254	88.2	24	8.3	10	3.5
The proper use of antifungal medicines is a critical part of effective patient care	270	93.8	10	3.5	8	2.7
It's necessary to discuss antifungal resistance and its implications with patients.	278	96.6	5	1.7	5	1.7
I believe that more research is needed in the field of antifungal resistance	264	91.7	9	3.1	15	5.2
Preventive measures, such as infection control and prophylaxis, are important in managing antifungal resistance	255	88.5	19	6.3	14	4.9
Practice statements						
I bought antifungal medicines without a prescription	112	38.9	151	52.4	25	8.7
When my family/friends are sick, I recommend buying antifungals.	55	19.1	208	72.2	25	8.7
I use antifungals because of advice from friends and family	54	18.8	204	70.8	30	10.4
I use antifungals when I have a urinary tract infection	80	27.8	180	62.5	28	9.7
I use antifungal medicines when I have a cold	14	4.9	268	93.0	6	2.1
I seek additional education or training on antifungal medications and resistance	242	84.0	27	9.4	19	6.6
Prescribing physicians and students are the only professionals who need to understand antifungal stewardship	61	21.2	205	71.1	22	7.6
I participate in antifungal stewardship and awareness programs	98	34.0	152	52.8	38	13.2
I keep myself updated about the latest research and guidelines regarding antifungal medications and antimicrobial resistance	118	41.0	112	38.9	58	20.1
Formal teaching on the proper usage of antifungals among healthcare students is an intervention that may minimise the phenomenon of antifungal resistance	264	91.6	15	5.2	9	3.1

The findings of the present study revealed a diverse and mixed landscape of KAP among the pharmacy students overall. While a substantial majority of respondents demonstrated good attitudes towards AFR and AFS (67.7%), the proportion with good knowledge (18.1%) and, more critically, good practices (2.4%) was notably low. This discrepancy between a positive attitude and lagging knowledge and practice is a common challenge observed in various healthcare education settings regarding AFSPs (Shrestha, 2019). It suggests that while students appreciate the

importance of AFR/AFS, there may be gaps in the depth of their understanding or the translation of knowledge and positive intent into appropriate behaviours. Contrary to our findings, most health students in India had good knowledge regarding AFR (Pandey et al., 2026). The observed differences could be attributed to a difference in sample size between the one used in our study and the 752 students included in the Indian study.

The high level of awareness regarding the definition of AFR (94.1%) and its consequences, such as prolonged illnesses and

TABLE 3 Factors influencing knowledge, attitude and practice towards antifungal resistance and stewardship.

Characteristic	Knowledge		Attitude		Practice	
	Adjusted OR(95% CI)	p-value	Adjusted OR(95% CI)	p-value	Adjusted OR(95% CI)	p-value
Year of study						
Second	Ref		Ref		Ref	
Third	1.22 (0.54–2.77)	0.636	1.78 (0.95–3.32)	0.070	1.45 (0.14–14.75)	0.756
Fourth	1.05 (0.39–2.84)	0.921	5.10 (2.28–11.43)	<0.001	2.49 (0.24–26.33)	0.449
Fifth	1.03 (0.27–3.93)	0.960	3.08 (0.98–9.67)	0.054	–	
Sex						
Female	Ref				Ref	
Male	1.07 (0.56–2.02)	0.847			0.29 (0.05–1.68)	0.166
Marital status						
Unmarried	Ref		Ref		Ref	
Married	1.37 (0.44–4.25)	0.587	2.05 (0.73–5.75)	0.171	2.75 (1.13, 6.68)	0.026
Residence						
Rural/peri-urban	Ref		Ref		Ref	
Urban	0.95 (0.47–1.92)	0.893	1.51 (0.84–2.73)	0.172	0.11 (0.02–0.61)	0.011
Age						
18–25	Ref		–	–	–	–
26–33	0.86 (0.30–2.48)	0.781				
Above 33	1.29 (0.32–5.18)	0.717				

OR = odds ratio, 95% CI = 95% confidence intervals, boldface (statistical significance at 5%). Good knowledge, practice and attitude were scores of $\geq 80\%$.

increased mortality (88.2%), is encouraging. This foundational understanding indicates that the essential concepts of resistance are being effectively incorporated into the curriculum. Furthermore, the recognition that antifungal misuse contributes to AFR (90.3%) and that AFSPs are intended to optimise drug utilisation (92.0%) reflects a strong theoretical comprehension of the problem and its corresponding interventions. However, a significant proportion (39.9%) of students felt that the current university training on AFR was insufficient. This finding was echoed by another study that was conducted at the University of Zambia, where more than half of the students indicated that they felt the training they were currently receiving in AFR and AFS was insufficient (Mudenda et al., 2023d). This perception aligns with the low overall good knowledge scores. It highlights a critical area for curriculum enhancement, emphasising the need for more comprehensive and practical education on AFR and AFS (Godman et al., 2021). Formal teaching on proper antifungal usage (91.6%) was overwhelmingly endorsed as a key intervention, reinforcing the students' desire for improved training. This approach is key in ensuring graduates from institutions of higher learning are ready to face the challenges of AFR and AFS early in their formative working careers. This assertion was also highlighted in a previous study to investigate the KAP on AFR and AFS in Lusaka, Zambia (Mudenda et al., 2023d).

The overwhelmingly positive attitude towards AFR as a significant public health concern (87.2%), coupled with the belief that AFSPs improve clinical outcomes and reduce resistance, as implied by the strong agreement with related statements, is a

major strength of the present study. Similar findings were reported in India, in which health sciences students had positive attitudes towards AFR and AFS (Pandey et al., 2026). This positive disposition provides a fertile ground upon which to build more effective educational and practical interventions (Mendelson and Matsoso, 2015). Students' strong agreement that all healthcare students should participate in AFSPs (88.5%) further underscores their recognition of the multidisciplinary nature of stewardship. A previous study conducted in Zambia also found that most pharmacy students were willing to participate in AFSPs (Mudenda et al., 2023d). These findings must be actualised by the implementation of AFSPs as stipulated in other studies and recommendations (Alegria and Patel, 2021; Johnson et al., 2020; Ray et al., 2023). Alongside this, the findings are encouraging and good to see the increasing implementation of AFSPs in LMICs and the growing role of pharmacists (Kara et al., 2021; Ruhnke, 2014; Samura et al., 2020).

The present study found an alarmingly low proportion of good practices (2.4%) towards AFR and AFS among pharmacy students. This is particularly evident in the self-reported behaviours, with 38.9% of pharmacy students admitting to buying antifungals without a prescription, 19.1% recommending antifungals to friends/family, and 27.8% using antifungals for urinary tract infections (UTIs), which are predominantly bacterial. These practices reflect a dangerous gap between theoretical understanding and real-world application, potentially driven by accessibility, societal norms, or a lack of confidence in alternative approaches, similar to other findings (Khairy et al.,

2021). In line with our study, the findings in India also revealed that health sciences students had poor practices towards AFR and AFS (Pandey et al., 2026). Similar findings were reported in other studies in which most of the HCPs had poor practices towards AFR (Gómez-Chaves et al., 2025; Ibrahim et al., 2023). In the present study, the use of antifungals for infectious conditions, including UTIs or colds (4.9%), indicates a fundamental misunderstanding of the appropriate indications for these medications, highlighting the urgent need for robust diagnostic stewardship education regarding both the appropriate use of antifungals and antibiotics. While 84.0% of students reported pursuing additional education, and 41.0% indicated that they stay updated on guidelines, these individual efforts are clearly insufficient to overcome systemic challenges or ingrained behaviours. These findings indicate gaps in practices and the use of antifungal agents among pharmacy students. Hence, implementation of AFSPs and educational interventions is pertinent in addressing these gaps and promoting the rational use of antifungal agents (Albahar et al., 2024; Johnson et al., 2020; Kara et al., 2021; Mudenda et al., 2023d; Nguyen et al., 2025; Talento et al., 2021; Urbancic et al., 2018).

The multiple logistic regression analysis provides valuable insights into factors influencing KAP. Students in their fourth year of study were significantly more likely to have a good attitude towards AFR and AFS compared to second-year students. A similar study also reported higher knowledge and attitudes in the fourth-year students among students at the University of Zambia (Mudenda et al., 2023c). This suggests a progressive development of positive attitudes as students advance through their academic program, likely due to increased exposure to clinical rotations, pharmacology, and infectious disease modules. This finding underscores the importance of integrating comprehensive AFS education throughout the pharmacy curriculum, not just in later years, to foster positive attitudes earlier.

Interestingly, married participants were more likely to exhibit good practices than unmarried individuals. Our findings are in agreement with a similar study that was conducted at the University of Zambia among Pharmacy students, which found that married participants were more likely to exhibit good practices towards AFS (Mudenda et al., 2023d). This could potentially be attributed to factors such as increased maturity, greater personal responsibility, or different social influences and health-seeking behaviours within a family unit. Further qualitative research could explore the underlying reasons for this association.

Conversely, participants residing in urban areas were less likely to have good practices compared to those in rural/peri-urban areas. This finding is somewhat counterintuitive, as urban areas typically have better access to information and healthcare facilities. However, it might be explained by easier access to over-the-counter medications in urban pharmacies, potentially leading to higher rates of self-medication and less adherence to professional prescribing norms without a prescription. A previous study reported lower positive attitudes towards AFS in urban areas compared to rural areas (Mudenda et al., 2023d). Other evidence indicates that it could also reflect differing cultural practices or a greater perceived anonymity in urban settings that influences medication-seeking behaviours [8]. This

warrants further investigation to understand the specific drivers of this observed difference.

The findings of this study highlight the critical need for implementing evidence-based stewardship practices as part of AFSPs. Research in AMS has demonstrated that successful interventions require multidisciplinary approaches involving infectious disease specialists, clinical pharmacists, microbiologists, and other HCPs (Cotta et al., 2015; Elshenawy et al., 2023; Mudenda et al., 2023a, 2025; Pauwels et al., 2025). Core stewardship strategies such as prospective audit and feedback mechanisms, formulary restrictions with pre-authorisation protocols, antibiotic review processes, and dose optimisation have shown significant benefits in reducing inappropriate prescribing and resistance development (Johnson et al., 2020). Given the knowledge and practice gaps identified among pharmacy students in our study, establishing comprehensive AFS programs with these evidence-based strategies becomes even more imperative for healthcare institutions in Zambia and similar settings.

While this study achieved its target sample size, the reliance on traditional survey distribution methods may have introduced participation bias and limited the comprehensiveness of data collection. Recent research in AMS studies has demonstrated that innovative hybrid survey distribution methods, combining traditional approaches with digital strategies such as QR code-enabled posters and targeted electronic campaigns, can significantly enhance participation rates and improve research outcomes (Elshenawy et al., 2024). The strategic timing of survey distribution and use of multiple communication channels has proven particularly effective in engaging busy healthcare professionals and students (Elshenawy et al., 2024). Future studies investigating AFR and AFS knowledge could benefit from implementing these evidence-based distribution strategies to potentially increase response rates, reduce sampling bias, and enhance the overall quality of data collection, particularly in resource-limited settings where maximising participation is crucial for generating robust evidence to inform educational and policy interventions. It is against the identified gaps of KAP among future HCPs that AFSPs be instigated in universities, healthcare facilities, and communities, similar to previous recommendations (Albahar et al., 2024; Bienvenu et al., 2022; Chakrabarti et al., 2025; Johnson et al., 2020; Procacci et al., 2024; Ray et al., 2023).

The findings of this study are consistent with previous studies conducted in similar settings, which have reported gaps between knowledge and practice among healthcare students. However, differences observed across studies may be attributed to variations in curriculum design, exposure to clinical training, and access to stewardship programs. These contextual differences highlight the importance of tailoring educational interventions to local healthcare systems and resource availability.

The findings of this study highlight critical gaps in knowledge and practice of AFR and AFS among pharmacy students in Zambia, despite generally positive attitudes. These results underscore the urgent need to strengthen pharmacy curricula by integrating comprehensive AFR and AFS content across all academic years, with emphasis on early and progressive training (Table 4). Regulatory policies must also be reinforced to limit inappropriate access to antifungals, particularly the sales of

TABLE 4 Policy implications and practice of the study findings.

Key finding	Policy implication	Practice implication
Only 18.1% of students had good knowledge of AFR and AFS	Revise and strengthen pharmacy curricula to include comprehensive AFR and AFS modules across all academic years	Integrate case-based learning, simulations, and diagnostic stewardship exercises into training
A total of 67.7% students demonstrated positive attitudes, especially in later years	Leverage positive attitudes to introduce early stewardship training and reinforce responsible antifungal use	Encourage student participation in antifungal stewardship programs, campaigns, and peer education
Only 2.4% demonstrated good practices, with high rates of self-medication and recommending antifungals inappropriately	Develop national guidelines restricting non-prescription access to antifungals and enforce regulatory controls	Promote responsible dispensing practices and patient counselling during training and internships
Overall, 38.9% reported buying antifungals without a prescription	Enforce stronger pharmacy regulation to curb over-the-counter sales of antifungals without prescriptions	Encourage pharmacists-in-training to practice ethical dispensing and report inappropriate access
Overall, 39.9% perceived the current training on AFR as insufficient	The Ministry of Education and Health should collaborate to standardise AFR/AFS teaching across health professions programs	Expand workshops, seminars, and continuous professional development (CPD) opportunities on AFR
Fourth-year students had significantly better attitudes (aOR=5.10)	Introduce structured AFS education earlier (second and third year), not only in the senior years	Scaffold stewardship competencies progressively across the program
Married students showed better practices (aOR=2.75)	Incorporate behavioural and social science insights into AFR education, recognising maturity and responsibility factors	Encourage mentorship and peer-learning models where senior/mature students guide juniors
Urban students were less likely to practice appropriately (aOR=0.11)	Implement public health awareness campaigns targeting urban settings to reduce the self-medication culture	Train pharmacy students in community engagement strategies to promote safe antifungal use
High willingness (91.6%) among students for formal training on antifungal use	Institutionalise antifungal stewardship training as a mandatory part of health professional curricula	Engage students in hospital- and community-based AFR surveillance and stewardship activities
Misuse of antifungals for UTIs and colds indicates poor diagnostic understanding	Strengthen diagnostic stewardship policies within medical and pharmacy education	Train students in differential diagnosis, rational prescribing, and interprofessional collaboration

prescription-only antifungals without prescriptions, which remain a major driver of misuse. Furthermore, targeted capacity-building initiatives such as workshops, simulations, and continuous professional development programs are necessary to translate positive student attitudes into appropriate practice. Collaborative efforts between the Ministry of Health, higher education institutions, and regulatory bodies are essential to standardise stewardship training, enforce dispensing regulations, and foster responsible antifungal use. Ultimately, embedding AFS in HCP education will play a pivotal role in safeguarding the effectiveness of antifungals and combating the growing threat of AFR in Zambia going forward.

The observed gap between positive attitudes and poor knowledge and practice may be explained by several factors. While students may develop favourable perceptions of AFR and AFS through theoretical exposure, insufficient emphasis on practical application, clinical decision-making, and diagnostic stewardship may limit their ability to translate knowledge into practice. Additionally, limited exposure to real-world AMS interventions, inadequate integration of stewardship concepts across academic levels, and prevailing societal practices such as self-medication may further contribute to this disconnect. These findings highlight the need for experiential learning approaches, including case-based training, simulations, and clinical rotations, to reinforce the application of AFS principles.

4.1 Limitations and strengths of the study

This study has several limitations that should be considered when interpreting the findings. First, the cross-sectional design captured the knowledge, attitudes, and practices (KAP) of pharmacy students regarding antifungal resistance (AFR) and antifungal stewardship (AFS) at a single point in time, and therefore does not allow for the establishment of causal relationships or the assessment of temporal changes. Second, the study relied on self-reported responses, which may be subject to social desirability bias and recall bias, potentially resulting in the overestimation of knowledge levels or positive practices. Third, the study was conducted at a single higher education institution, which may limit the generalizability of the findings to pharmacy students in other universities in Zambia or in different educational contexts. Additionally, the use of a structured questionnaire may not fully capture the complexity of students' competencies and practical decision-making related to antifungal stewardship. Future studies should consider longitudinal or mixed-methods approaches, incorporate objective assessments of practice (such as case-based or simulated prescribing scenarios), and include multiple institutions across different regions to enhance the robustness and generalizability of the findings. Nevertheless, despite these limitations, this study provides important baseline evidence on pharmacy students' preparedness

in relation to AFR and AFS, and offers valuable insights that can inform curriculum development, training interventions, and policy initiatives aimed at strengthening antifungal stewardship education.

5 Conclusions

Despite generally positive attitudes towards antifungal resistance and stewardship, pharmacy students demonstrated substantial gaps in knowledge and, most notably, in practice. These findings underscore the urgent need to strengthen pharmacy curricula through comprehensive and practical antifungal stewardship training, with a focus on translating knowledge into appropriate clinical and dispensing practices.

Data availability statement

The original contributions presented in the study are included in the article/[Supplementary Material](#), further inquiries can be directed to the corresponding author.

Ethics statement

The studies involving humans were approved by University of Zambia Health Sciences Research Ethics Committee. The studies were conducted in accordance with the local legislation and institutional requirements. The participants provided their written informed consent to participate in this study.

Author contributions

StM: Project administration, Methodology, Funding acquisition, Validation, Conceptualization, Writing – original draft, Supervision, Formal analysis, Writing – review & editing, Software, Investigation, Data curation, Resources, Visualization. BC: Writing – review & editing, Conceptualization, Writing – original draft, Investigation. MoM: Validation, Writing – review & editing, Formal analysis, Writing – original draft, Software. WM: Data curation, Writing – review & editing, Software, Writing – original draft. VD: Writing – review & editing, Data curation, Writing – original draft. PN: Software, Writing – original draft, Writing – review & editing, Investigation. MK: Validation, Writing – review & editing, Writing – original draft. KK: Validation, Writing – review & editing, Writing – original draft. MaM: Writing – original draft, Writing – review & editing, Validation. JF: Validation, Writing – original draft, Writing – review & editing. AL: Validation, Writing – review & editing, Writing – original draft. NM: Validation, Writing – review & editing, Writing – original draft. MG: Writing – original draft, Data curation, Writing – review & editing. AC: Writing – review & editing, Writing – original draft, Data curation. ShM: Writing – original draft, Writing – review & editing, Validation. JM: Writing – original draft, Data curation,

Writing – review & editing. BM: Writing – original draft, Writing – review & editing, Data curation. MH: Validation, Writing – review & editing, Writing – original draft. TM: Validation, Writing – review & editing, Writing – original draft. TC: Writing – review & editing, Writing – original draft, Validation. MuM: Writing – review & editing, Writing – original draft, Data curation. FM: Writing – original draft, Data curation, Writing – review & editing. RT: Writing – original draft, Data curation, Writing – review & editing. MZ: Data curation, Writing – review & editing, Writing – original draft. JH: Writing – original draft, Data curation, Writing – review & editing. AM: Writing – original draft, Data curation, Writing – review & editing. IS: Writing – review & editing, Writing – original draft, Validation. MS: Writing – review & editing, Data curation, Writing – original draft. RA: Validation, Writing – review & editing, Data curation, Writing – original draft. SJ: Writing – review & editing, Validation, Writing – original draft. JM: Writing – original draft, Validation, Writing – review & editing, Supervision, Data curation. BG: Supervision, Writing – review & editing, Writing – original draft, Validation.

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Conflict of interest

The author(s) declared that this work was conducted in the absence of any commercial or financial relationships that could be construed as a potential conflict of interest.

Generative AI statement

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Supplementary material

The Supplementary Material for this article can be found online at: <https://www.frontiersin.org/articles/10.3389/feduc.2026.1846353/full#supplementary-material>

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