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Determinants of antimicrobial resistance practices in Ethiopia: A One Health mixed-methods study

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ABSTRACT

Background: Antimicrobial resistance (AMR) is a growing One Health challenge in low- and middle-income countries, where inappropriate antimicrobial use across human and animal sectors remains common. In Ethiopia, national AMR strategies and One Health frameworks exist, but evidence remains limited on how knowledge, attitudes, and practices shape antimicrobial-use behaviors across community and animal health settings.

Methods: We conducted a convergent parallel mixed-methods study from June to November 2024 in Addis Ababa, Oromia, and Afar, Ethiopia. Quantitative data were collected using structured knowledge, attitude, and practice surveys among household respondents *(n = 750)* and animal health professionals *(n = 251)*. Knowledge was defined as factual understanding of antimicrobials and AMR; attitude as beliefs, perceived risk, and stewardship orientation; and practice as self-reported antimicrobial-use and stewardship-related behaviors. Composite KAP scores were standardized from 0 to 1, with higher scores indicating better outcomes. Fractional logit regression was used to assess factors associated with AMR-related practice scores. Qualitative data were collected through 24 focus group discussions, 58 key informant interviews, and 34 in-depth interviews, and analyzed thematically to contextualize quantitative findings.

Results: Households had moderate knowledge *(mean = 0.62)* and positive attitudes *(mean = 0.75)* but suboptimal practices *(mean = 0.58)*. Animal health professionals had higher knowledge *(mean = 0.88)* and attitudes *(mean = 0.79)*, but lower practice scores *(mean = 0.49)*. Attitude was the most consistent factor associated with better AMR-related practices among both households *(aOR = 1.26; 95% CI: 1.17–1.36)* and animal health professionals *(aOR = 1.50; 95% CI: 1.28–1.75)*. Knowledge was significantly associated with practice only among animal health professionals. Larger household size was negatively associated with household practice, while professional affiliation was associated with animal health professional practice. Qualitative findings showed that financial constraints, non-prescription antimicrobial access, limited diagnostic capacity, weak enforcement, and client pressure constrained the translation of knowledge and positive attitudes into appropriate practice.

Conclusions: AMR-related practices in Ethiopia are shaped by attitudes, professional and household contexts, and structural constraints, rather than knowledge alone. Interventions should move beyond information provision to address risk perception, social norms, affordability, diagnostic access, regulatory enforcement, and stewardship support. Strengthened One Health coordination across human and animal sectors is essential to translate Ethiopia's AMR policies into effective practice.

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1. Introduction

Antimicrobial resistance (AMR) is an escalating global health crisis that threatens to reverse decades of progress in the prevention and treatment of infectious diseases. It arises when bacteria, viruses, fungi, and parasites no longer respond to antimicrobial agents that were previously effective, leading to higher morbidity, mortality, and health-care costs [1]. AMR is inherently a One Health challenge, driven by interconnected patterns of antimicrobial use and misuse in humans, animals, and the environment. In recognition of this, the World Health Organization (WHO) and partners have called for coordinated multisectoral action, articulated in the Global Action Plan on AMR and supported by tools such as the Global Antimicrobial Resistance and Use Surveillance System (GLASS) and the AWaRe antibiotic classification [2–4].

The global burden of bacterial AMR remains substantial. A landmark analysis estimated that in 2019, 4.95 million deaths were associated with bacterial AMR, including 1.27 million deaths directly attributable to resistant infections [4]. Within the WHO African Region, AMR was responsible for an estimated 1.05 million associated deaths and 250,000 attributable deaths the same year [5]. Ethiopia is among the countries with a particularly high AMR burden, with recent estimates indicating approximately 85,300 deaths associated with bacterial AMR and 21,200 deaths directly attributable to it in 2019—figures exceeding those for maternal and neonatal disorders, cardiovascular diseases, respiratory infections and tuberculosis, enteric infections, and neoplasms [6]. These numbers highlight the urgent need for context-specific, One Health–oriented interventions.

Ethiopia, like many low- and middle-income countries, faces a convergence of AMR risk factors: a high prevalence of infectious diseases, limited diagnostic capacity, widespread unregulated access to antimicrobials, and rapidly expanding livestock production [6,7]. In human and veterinary medicine, antimicrobials are frequently used for empirical treatment, prophylaxis, and even growth promotion in food animals. Practices such as incomplete treatment courses, skipped doses, re-using leftover medications, and prescribing antibiotics for likely viral conditions have been documented and are known to exacerbate the emergence and spread of resistance [7,8]. Resistant bacteria can then spread between animals and humans through direct contact, the food chain, and environmental contamination, underscoring the need for a One Health approach to AMR mitigation.

Environmental pathways further amplify the AMR challenge. The environment serves as both a reservoir and conduit for antibiotic resistance genes (ARGs), with wastewater, river systems, and other contaminated sites enabling horizontal gene transfer and co-selection of resistance traits [9]. In Ethiopia, hospital wastewater and downstream river waters have been shown to harbor high levels of multidrug-resistant bacteria [9,10]. Food-chain studies have detected resistant Salmonella and *Escherichia coli* in retail meat in Addis Ababa and other urban centers, directly linking foodborne exposure to the broader AMR problem [7,8]. These findings illustrate the interconnectedness of human, animal, and environmental health and the need to consider AMR within an integrated One Health framework.

In response, the Ethiopian government has made significant policy and strategic commitments. The 2015 Strategy for the Prevention and Containment of AMR marked the first national framework for coordinated action, followed by the Third One Health Strategic Plan on AMR Prevention and Containment (2021–2025), which formalized multisectoral governance structures across human health, animal health, and environmental sectors [11–13]. The Ethiopian Public Health Institute (EPHI) has led the expansion of national AMR surveillance, publishing annual reports that document resistance patterns among priority pathogens and track trends in key health facilities [14]. Hospital-level studies describe alarming resistance rates in extended-spectrum β-lactamase (ESBL)–producing Enterobacteriaceae causing bloodstream infections, high levels of resistance among Gram-negative pathogens in tertiary hospitals, Gram-negative neonatal sepsis, and outbreaks of Acinetobacter septicemia in vulnerable patient groups [15–18]. Longitudinal antibiograms from multiple hospitals consistently show declining effectiveness of commonly used first- and second-line antimicrobials [19,20].

Despite these advances, translation of AMR policy into routine practice remains uneven in Ethiopia. Antimicrobial stewardship (AMS) and infection prevention and control (IPC) activities are inconsistently implemented across health facilities, and previous assessments have documented gaps in leadership, resources, staff training, laboratory capacity, standardized data systems, and integration of antimicrobial consumption data with resistance surveillance [14,21–24]. Governance challenges, including limited transparency, accountability, regulatory enforcement, and cross-sectoral coordination, further constrain implementation of national AMR action plans [11–13,25]. These system-level limitations are especially important because they may prevent individuals and professionals from translating AMR knowledge into appropriate antimicrobial-use practices.

Knowledge, attitude, and practice (KAP) studies are useful for understanding antimicrobial-use behavior, but the three constructs need to be conceptually distinguished. Knowledge refers to factual understanding of antimicrobials, AMR, appropriate antimicrobial use, consequences of misuse, and transmission pathways. Attitude refers to beliefs, perceived seriousness, perceived responsibility, risk appraisal, and normative orientation toward antimicrobial stewardship. Practice refers to self-reported behaviors related to antimicrobial access, use, adherence, prescribing, dispensing, follow-up, and use of diagnostic information. This distinction is important because knowledge alone may not be sufficient to change behavior when individuals and professionals face barriers such as cost, limited access to formal health and veterinary services, weak enforcement of prescription regulations, limited diagnostic capacity, and social or client pressure [28,29,33,34].

In Ethiopia, existing evidence indicates that inappropriate antimicrobial access, self-medication, incomplete treatment courses, and informal dispensing remain important contributors to AMR risk at community level [33,34]. In animal health settings, antimicrobial use is influenced not only by professional knowledge, but also by veterinary service availability, diagnostic limitations, livestock-owner expectations, drug availability, and the regulatory environment [6,7,23,24]. These factors are strongly aligned with a One Health understanding of AMR, because inappropriate antimicrobial use in humans and animals can contribute to the movement of resistant organisms and resistance genes through direct contact, food-chain pathways, waste, and environmental contamination [7–10,26].

However, limited mixed-methods evidence exists on how knowledge and attitudes are associated with AMR-related practices among both household respondents and animal health professionals in Ethiopia. Many studies focus on either community awareness or professional practice, with less attention to how behavioral factors interact with structural constraints across human and animal health interfaces. Qualitative evidence is therefore important to contextualize quantitative KAP findings and to explain why knowledge and positive attitudes may not always translate into safer antimicrobial-use behaviors.

Therefore, this study aimed to assess knowledge, attitudes, and practices related to antimicrobial use and AMR among household respondents and animal health professionals in Addis Ababa, Oromia, and Afar, Ethiopia. The study further aimed to identify factors associated with AMR-related practice scores and to use qualitative evidence to explain how behavioral, social, professional, and structural conditions shape antimicrobial-use practices. By applying a One Health mixed-methods approach, this study generates evidence to inform community-level behavior change, animal health professional stewardship, diagnostic and regulatory strengthening, and multisectoral AMR action in Ethiopia.

2. Materials and methods

2.1. Study design and setting

A convergent parallel mixed-methods design was used to assess antimicrobial resistance (AMR)-related knowledge, attitudes, and practices among household respondents and animal health professionals in Ethiopia. Quantitative and qualitative data were collected during the same study period, analyzed separately, and integrated during interpretation to provide a comprehensive understanding of behavioral, professional, and structural factors influencing antimicrobial-use practices. This design was selected because it allows statistical associations from survey data to be interpreted alongside qualitative evidence on contextual barriers, social norms, and implementation constraints [27].

The study was conducted between June and November 2024 in three regions of Ethiopia: Addis Ababa, Oromia, and Afar. These regions were selected to capture variation in livelihood systems, antimicrobial access pathways, veterinary service availability, and health-system context. Addis Ababa represented a predominantly urban setting, Oromia represented mixed agrarian and urban settings, and Afar represented pastoralist contexts. The One Health framing was used to interpret antimicrobial use and stewardship across human and animal health interfaces, while recognizing that environmental and governance-related factors were assessed primarily through qualitative evidence.

2.2. Population and sampling strategy

The quantitative component included two study populations: household respondents and animal health professionals. Eligible household respondents were adults aged 18 years or older who were primarily responsible for healthcare decision-making, care-seeking, or antimicrobial-use decisions within their households. A multistage sampling approach was used. Districts were purposively selected to represent the study contexts; kebeles or villages were then selected within districts; and households were selected from available household listings or local sampling frames. One eligible respondent was interviewed from each selected household.

Eligible animal health professionals included veterinary doctors, animal health assistants, animal health technicians, community-based animal health workers, and private practitioners involved in animal treatment, antimicrobial dispensing, or veterinary service delivery. In areas where the number of eligible professionals was limited, complete enumeration was attempted. In areas with larger numbers of eligible professionals, participants were purposively selected based on availability and direct involvement in animal treatment or antimicrobial dispensing.

The final quantitative sample included 1001 respondents: 750 household respondents and 251 animal health professionals. The qualitative component included 24 focus group discussions, 58 key informant interviews, and 34 in-depth interviews across the three study regions. Qualitative participants were purposively selected based on their roles in community health, animal health service delivery, antimicrobial regulation, environmental health, and AMR-related governance.

Community health workers were included only in the qualitative component as focus group discussion or key informant interview participants. They were not part of the quantitative household or animal health professional survey samples. They were included qualitatively because of their role in community-level health education, care-seeking guidance, and communication on antimicrobial use.

Data collection continued until thematic saturation was reached, defined as the point at which three consecutive interviews within a respondent category generated no substantially new themes.

2.3. Data collection tools and procedures

Structured interviewer-administered questionnaires were used for the quantitative survey. Separate tools were developed for household respondents and animal health professionals. The tools were adapted from AMR knowledge, attitude, and practice survey guidance and prior AMR KAP studies, and were reviewed by subject-matter experts to ensure contextual relevance to human and animal health settings [28,29]. Each questionnaire included four sections: sociodemographic characteristics, knowledge of antimicrobials and AMR, attitudes toward antimicrobial use and stewardship, and practices related to antimicrobial access, use, adherence, prescribing, dispensing, follow-up, and safe handling or disposal where applicable.

The tools were pretested among 5–10% of the intended sample size in non-study areas. Feedback from pretesting was used to refine wording, improve cultural appropriateness, correct skip patterns, and improve the flow of the questionnaires. Data collectors received two days of training on study objectives, research ethics, informed consent, confidentiality, interviewing techniques, questionnaire administration, and electronic data collection using KoboToolbox or ODK. Supervisors reviewed submitted forms daily for completeness, internal consistency, and data quality.

Qualitative data were collected using semi-structured guides aligned with the One Health framework and antimicrobial-use pathways. Focus group discussions explored community norms, care-seeking practices, antimicrobial access, adherence, self-medication, storage of leftover medicines, and perceptions of AMR. Key informant interviews and in-depth interviews explored professional practice, prescribing and dispensing behavior, veterinary service delivery, diagnostic capacity, regulation, enforcement, antimicrobial availability, and One Health coordination. Interviews and discussions were conducted in local languages, audio-recorded where consent was provided, transcribed verbatim, and translated into English for analysis.

2.4. Variable definitions and KAP construct composition

The primary outcome variable was AMR-related practice score. Practice was operationalized as a composite score of self-reported behaviors relevant to appropriate antimicrobial use and AMR prevention. Because households and animal health professionals have different roles in antimicrobial use and stewardship, practice was defined separately for the two populations.

For household respondents, practice included behaviors related to appropriate care-seeking, avoidance of non-prescription antimicrobial use, adherence to recommended treatment, avoidance of sharing antimicrobials obtained from relatives or friends, avoidance of keeping unused antimicrobials at home, and awareness of the effect of missed doses. For animal health professionals, practice included stewardship-related behaviors such as awareness and use of veterinary guidelines, use of standardized protocols, counseling on dispensed drugs, communication of withdrawal periods, follow-up of non-responsive infections, use of laboratory diagnostics where available, and avoidance of inappropriate combined antimicrobial therapy.

The main explanatory variables were knowledge and attitude composite scores. Knowledge was defined as factual understanding of antimicrobials, AMR, causes and consequences of resistance, appropriate antimicrobial use, and transmission pathways relevant to human and animal health. Attitude was defined as beliefs, perceived seriousness, perceived responsibility, risk appraisal, and normative orientation toward antimicrobial stewardship. Practice was defined as self-reported antimicrobial-use and stewardship-related behavior.

Covariates included age, sex, education, residence, employment status, household size, and domestic animal ownership for household respondents. For animal health professionals, covariates included age, sex, residence, education, years of practice, profession, and institutional affiliation.

Detailed item composition, scoring logic, reverse coding, and internal consistency estimates for each knowledge, attitude, and practice domain are provided in Supplementary Appendix S1 for household respondents and Supplementary Appendix S2 for animal health professionals.

2.5. Data management and quantitative analysis

Quantitative data were exported from KoboToolbox/ODK and analyzed using Python in Google Colab. Data cleaning, recoding, and analysis were conducted using pandas and NumPy. Descriptive statistics were used to summarize respondent characteristics and composite KAP scores. Continuous variables were summarized using means and standard deviations, while categorical variables were summarized using frequencies and percentages.

Before analysis, variables with more than 50% missing values or zero variance were excluded because they provided limited analytical value. For variables with less than 10% missing data, categorical variables were imputed using the mode and numeric variables using the mean of observed values. Demographic and professional variables were encoded according to their measurement level: binary variables, such as sex, residence, and domestic animal ownership, were coded as 0/1; ordinal variables, such as education level, were encoded to preserve rank order; and multicategorical variables, including employment status, profession, and institutional affiliation, were dummy-coded using predefined reference categories.

Knowledge, attitude, and practice items were scored so that higher values consistently represented better knowledge, more favorable stewardship-related attitudes, or more appropriate antimicrobial-use practices. Likert-type items were coded from 0 to 4 and linearly rescaled to a 0–1 range. Binary items were coded as 1 for correct, desirable, or stewardship-consistent responses and 0 for incorrect, undesirable, unknown, or non-stewardship responses. Negative statements and undesirable behaviors were reverse-coded before score construction to ensure directional consistency.

Composite knowledge, attitude, and practice scores were calculated separately for household respondents and animal health professionals. Items retained after reliability assessment were averaged without weighting to generate domain scores ranging from 0 to 1. For presentation, mean domain scores were also expressed as percentages of the maximum possible score. Higher composite scores indicated better knowledge, more favorable attitudes, or more appropriate reported practices.

Internal consistency was assessed using Cronbach's alpha. An iterative item-retention procedure was applied to remove items that contributed poorly to internal consistency while preserving conceptual coverage of each domain.

Cronbach's alpha was calculated using the following formula:

$$\alpha = \frac{N}{N-1}\left(1 \frac{\sum_{i=1}^{N}\sigma_i^2}{\sigma_T^2}\right)$$

where N is the number of items, σ_i^2 is the variance of each item, and σ_T^2 is the variance of the total score.

Because the practice score was a bounded continuous outcome ranging from 0 to 1, fractional logit regression was used to assess factors associated with AMR-related practice scores [30]. Model diagnostics were assessed using leverage and Cook's Distance [31], and robust standard errors were used to account for potential heteroskedasticity [32].

The model was specified as:

$$\log\left(\frac{P_i}{1-P_i}\right) = \beta_0 + \beta_1 Knowledge_i + \beta_2 Attitude_i + \gamma' Z_i$$

where $P_i = E(Practice_i | Knowledge_i, Attitude_i, Z_i)$, and Z_i represents the vector of sociodemographic or professional covariates.

If no observations exceeded the prespecified influence threshold, the full sample was retained to avoid selection bias and preserve statistical power. Adjusted odds ratios and 95% confidence intervals were reported. For knowledge and attitude scores, adjusted odds ratios represent the association with practice for a one-unit increase in the standardized 0–1 score unless otherwise specified.

Because the study used cross-sectional data, regression estimates were interpreted as associations rather than causal effects.

2.6. Qualitative data analysis and mixed-methods integration

Qualitative data were analyzed using thematic analysis. A preliminary codebook was developed deductively from the study objectives, KAP constructs, and One Health framework. Additional codes were added inductively as new themes emerged from the data. Two qualitative researchers independently coded an initial subset of transcripts and resolved discrepancies through discussion. The agreed codebook was then applied to the remaining transcripts.

Themes were organized around antimicrobial access pathways, self-medication, adherence behavior, medicine sharing and storage, perceptions of AMR risk, professional prescribing and dispensing practices, diagnostic constraints, client pressure, regulation, enforcement, antimicrobial availability, and One Health coordination. Representative quotations were selected to illustrate major themes and to explain quantitative findings.

Quantitative and qualitative findings were integrated during interpretation using a convergent mixed-methods approach. Quantitative results were compared with qualitative themes to identify convergence, complementarity, and explanatory insights. Qualitative findings were used particularly to explain why knowledge and attitudes did or did not translate into appropriate AMR-related practices, and to contextualize structural determinants such as affordability, access to healthcare and veterinary services, diagnostic capacity, antimicrobial availability, regulatory enforcement, and One Health coordination.

2.7. Ethical considerations

Ethical approval was obtained from the Ethiopian Public Health Association Institutional Review Board under approval number EPHA/06/635/24. Written informed consent was obtained from all participants before data collection. Where literacy barriers were anticipated, verbal consent was obtained and documented according to ethics approval procedures. Participation was voluntary, and respondents were informed of their right to decline participation or withdraw at any time without consequence.

Interviews and discussions were audio-recorded only with participant permission. Data were anonymized during collection and analysis. Identifying information was removed from transcripts and datasets. Electronic data were stored on password-protected devices and accessible only to the research team.

3. Results

3.1. Demographic characteristics of study participants

3.1.1. Household respondents

A total of 750 household respondents were included in the quantitative household survey. The mean age of respondents was 38.69 years (SD = 12.38), and the sex distribution was nearly balanced, with 386 males (51%) and 364 females (49%). Most respondents lived in urban areas, 511 (68%), while 239 (32%) lived in rural areas. The mean household size was 5.33 persons (SD = 2.97). Regarding education, 230 respondents (31%) had college or university education, 183 (24%) had secondary education, 145 (19%) had primary education, 170 (23%) had no formal education, and 22 (3%) had vocational training (Table 1).

Household respondents had a mean knowledge score of 0.62 (SD = 0.18), a mean attitude score of 0.75 (SD = 0.16), and a mean practice score of 0.58 (SD = 0.19). These findings indicate moderate AMR-related knowledge and relatively favorable attitudes, but suboptimal self-reported antimicrobial-use practices (Table 1).

Qualitative findings helped contextualize these patterns. Some community participants described AMR as a technical issue known mainly by health workers, while others linked antimicrobial-use decisions to informal advice from neighbors and relatives. For example, one participant described AMR as "something only health workers know about" (Oromia; FGD; community member; male). Another noted that "people who didn't attend school usually use medicines the way neighbors tell them" (Oromia; FGD; community member; female). These findings suggest that formal education and access to reliable information may influence how AMR knowledge is understood and applied.

Urban respondents also described easier access to antimicrobials through pharmacies and private clinics. One community health worker participating in the qualitative component stated, "You can get any antibiotic quickly without waiting" (Addis Ababa; FGD; community health workers; mixed sex). Larger households described medicine sharing and cost-related rationing. One respondent explained, "One person buys medicine for everyone, and we share it when money is short" (Oromia, Bishoftu; FGD; community member; female). Community health workers were qualitative participants only and were not included in the quantitative household or animal health professional survey samples.

3.1.2. Animal health professionals

A total of 251 animal health professionals were included in the quantitative survey. The mean age was 34.92 years (SD = 8.10), and the mean duration of professional practice was 10.10 years (SD = 7.71). Most respondents were male, 191 (76%), and 206 (82%) lived in urban areas. In terms of education, 162 (65%) had a degree, 66 (26%) had a diploma, 18 (7%) had postgraduate education, and 5 (2%) had certificate-level education. By professional category, 122 (49%) were veterinary doctors, 66 (26%) were veterinary assistants, 55 (22%) were animal health technicians, and 8 (3%) were community-based animal health workers. Most respondents, 164 (65%), worked in public practice, while 58 (23%) were employed in private practice and 29 (12%) were self-employed in private practice (Table 2).

Animal health professionals had a high mean knowledge score of 0.88 (SD = 0.20) and a favorable mean attitude score of 0.79 (SD = 0.20). However, their mean practice score was lower, at 0.49 (SD = 0.28), indicating a gap between knowledge, attitudes, and reported stewardship-related practices (Table 2).

Table 1
Socio-demographic characteristics of household respondents (*N* = 750).

Continuous variables	N	Mean (SD)
Age (years)	750	38.69 (12.38)
Household size	750	5.33 (2.97)
Knowledge score	750	0.62 (0.18)
Attitude score	750	0.75 (0.16)
Practice score	750	0.58 (0.19)
Categorical variables	Category	n (%)
Sex	Male	386 (51)
	Female	364 (49)
Residence	Urban	511 (68)
	Rural	239 (32)
Education	College/University	230 (31)
	Secondary	183 (24)
	No formal education	170 (23)
	Primary	145 (19)
	Vocational	22 (3)

Footnote: SD = standard deviation. Knowledge, attitude, and practice scores range from 0 to 1, with higher values indicating better knowledge, more favorable attitudes, and better reported practices.

Table 2
Socio-demographic and professional characteristics of respondents (*N* = 251).

Continuous variables		
Variable	N	Mean (SD)
Age (years)	251	34.92 (8.10)
Years of practice	251	10.10 (7.71)
Knowledge score	251	0.88 (0.20)
Attitude score	251	0.79 (0.20)
Practice score	251	0.49 (0.28)
Categorical variables	Category	n (%)
Sex	Male	191 (76)
	Female	60 (24)
Residence	Urban	206 (82)
	Rural	45 (18)
Education	Degree	162 (65)
	Diploma	66 (26)
	Postgraduate	18 (7)
	Certificate	5 (2)
Profession	Veterinary Doctor	122 (49)
	Veterinary Assistant	66 (26)
	Animal Health Technician	55 (22)
	Community-based animal health worker	8 (3)
Affiliation	Public practice	164 (65)
	Private practice – employed	58 (23)
	Private practice – self-employed	29 (12)

Footnote: SD = standard deviation. Knowledge, attitude, and practice scores range from 0 to 1, with higher values indicating better knowledge, more favorable attitudes, and better reported practices.

Qualitative interviews supported this interpretation. Several professionals reported being aware of AMR and encountering treatment failure in routine practice. One veterinarian stated, "We know AMR very well; we see treatment failure often" (Addis Ababa; KII; DVM; male). However, professionals also described constraints that limited appropriate practice, including limited diagnostic capacity, weak enforcement of guidelines, antimicrobial availability, and pressure from livestock owners. One participant explained, "We know the guidelines, but farmers push for stronger drugs, and without tests, we treat based on experience" (Oromia; KII; DVM; male). These findings suggest that high professional knowledge does not automatically translate into optimal stewardship behavior when system-level constraints remain unresolved.

3.2. Regional and residence-based variation in KAP scores

Knowledge, attitude, and practice scores varied across regions and residence categories. Urban respondents generally had higher KAP scores than rural respondents in both the household and animal health professional datasets. Among households, Addis Ababa had relatively higher knowledge and practice scores, while rural pastoral communities in Afar and rural mixed communities in Oromia showed lower scores across several domains. Among animal health professionals, urban Oromia and Addis Ababa had the highest knowledge scores, while rural pastoral Afar had lower professional KAP scores (Table 3).

Among households, urban respondents had a mean knowledge score of 0.645, compared with 0.564 among rural respondents. Urban household attitude and practice scores were also slightly higher than rural scores. Among animal health professionals, urban respondents had a mean knowledge score of 0.907 compared with 0.751 among rural respondents, and urban practice scores were also higher than rural practice scores (Table 3).

Qualitative findings supported these regional and residence-based patterns. Participants in pastoral and rural areas described lower AMR awareness, informal antimicrobial access, and adherence challenges. One participant from Afar stated that "overall understanding of AMR is very low… most of the community having almost no awareness" (Afar; FGD; community member). In Oromia, a community health worker noted that "patients may not follow the prescribed dosage… stopping

Table 3
Mean knowledge, attitude, and practice scores by region and residence among households (HH) and animal health professionals (AHP).

Region	Residence	HH Knowledge	HH Attitude	HH Practice	AHP Knowledge	AHP Attitude	AHP Practice
Addis Ababa	Urban	0.649	0.783	0.621	0.932	0.835	0.409
Afar	Rural (Pastoral)	0.595	0.634	0.479	0.725	0.629	0.389
Afar	Urban	0.685	0.759	0.518	0.796	0.679	0.444
Oromia	Rural (Mixed)	0.554	0.704	0.568	0.781	0.767	0.524
Oromia	Urban	0.621	0.785	0.588	0.949	0.859	0.622
Total	**Urban**	**0.645**	**0.779**	**0.591**	**0.907**	**0.808**	**0.499**
	Rural	**0.564**	**0.698**	**0.558**	**0.751**	**0.693**	**0.452**

Footnote: HH = household respondents; AHP = animal health professionals; KAP = knowledge, attitude, and practice. Scores range from 0 to 1, with higher values indicating better outcomes.

without taking a full dose is common" (Oromia, Bishoftu; FGD; community health workers). Another participant emphasized the need for coordinated action, stating that "AMR needs multisectoral interventions including healthcare professionals, health promoters, patients, political leaders, and policy makers to ensure accountability at all levels" (Oromia; environmentalist; male).

3.3. Composite KAP scores and internal consistency

Composite KAP scores and internal consistency estimates are summarized in Table 4. Among household respondents, the mean knowledge score was 61.8%, the mean attitude score was 75.2%, and the mean practice score was 58.0%. Among animal health professionals, the mean knowledge score was 86.7%, the mean attitude score was 78.8%, and the mean practice score was 49.1%. These findings show that both groups reported lower practice scores than knowledge and attitude scores, suggesting a knowledge–practice and attitude–practice gap.

Internal consistency was acceptable for household knowledge and attitude domains, with Cronbach's alpha values of 0.78 and 0.76, respectively. Among animal health professionals, Cronbach's alpha was 0.63 for knowledge and 0.71 for attitude. Practice-domain reliability was more modest in both groups, with Cronbach's alpha values of 0.64 for households and 0.66 for animal health professionals (Table 4). This likely reflects the smaller number of practice items and the heterogeneous nature of AMR-related behaviors.

The supplementary appendices provide the detailed item composition and scoring logic for each KAP domain. Supplementary Appendix S1 lists 14 household knowledge items, 12 household attitude items, and 4 household practice items, including reverse-coded practice items related to receiving antimicrobials from relatives or friends, buying antibiotics without prescription, keeping unused antimicrobials at home, and missed doses. Supplementary Appendix S2 lists the animal health professional KAP items, including knowledge items on antimicrobial overuse and AMR transmission, attitude items on professional responsibility and One Health, and practice items on guideline awareness, standardized protocols, counseling, withdrawal-period communication, follow-up, and diagnostic use.

Table 4
Summary of Knowledge, Attitude, and Practice (KAP) domains among Household (HH) respondents and Animal Health Professionals (AHPs).

Domain	No. of items (HH)	Cronbach's α (HH)	Mean score (%) (HH)	No. of items (AHP)	Cronbach's α (AHP)	Mean score (%) (AHP)
Knowledge	14	0.78	61.8	6	0.63	86.7
Attitude	12	0.76	75.2	11	0.71	78.8
Practice	4	0.64	58.0	6	0.66	49.1

Footnote: HH = household respondents; AHP = animal health professionals; KAP = knowledge, attitude, and practice; α = Cronbach's alpha. Mean score (%) was calculated from standardized domain scores. Practice-domain alpha values should be interpreted cautiously because practice items represent heterogeneous stewardship-related behaviors.

Qualitative findings help explain the lower practice scores. Community participants acknowledged the importance of appropriate antimicrobial use but reported inconsistent adherence. One participant stated, "We know we should finish the medicine, but when we feel better, we stop" (Oromia, Bishoftu; FGD; community member; mixed sex). Another explained that "the pharmacy is faster, so people go there even if they know they should see a doctor" (Addis Ababa; FGD; community health workers; mixed sex). Among animal health professionals, respondents described how limited diagnostics, drug shortages, and client expectations affected practice. One veterinarian stated, "We try to prescribe correctly, but without diagnostics, resistance increases" (Oromia; KII; DVM; male), while another noted, "Farmers demand quick treatment, so sometimes we compromise" (Oromia; KII; DVM; male) (Fig. 1).

3.4. Determinants of AMR-related practice scores

3.4.1. Household respondents

In the household fractional logit regression model, attitude score was positively associated with AMR-related practice score. A higher attitude score was associated with better practice (aOR = 1.26; 95% CI: 1.17–1.36; $p < 0.001$). Household size was negatively associated with practice score (aOR = 0.90; 95% CI: 0.84–0.96; $p = 0.002$). Knowledge score, sex, residence, and education level were not statistically significant after adjustment (Table 5).

Qualitative findings supported the role of attitude in shaping practice. Participants described perceived seriousness of AMR as a motivation for more cautious antimicrobial use. One participant stated, "When you know resistance is dangerous, you try to be careful" (Oromia; FGD; community member; female). Another stated, "People who understand the problem don't buy antibiotics anyway" (Addis Ababa; FGD; community health workers; mixed sex).

The negative association between household size and practice was consistent with qualitative accounts of financial pressure, medicine sharing, and partial treatment. One participant explained, "Medicine is expensive; for big families, you buy only what you can afford" (Oromia, Bishoftu; FGD; community member; male). Another noted, "We keep leftover tablets and use them again" (Oromia, Bishoftu; FGD; community member; female). These findings suggest that household economic constraints may limit the translation of knowledge and positive attitudes into appropriate antimicrobial-use behavior.

The lack of a statistically significant association between knowledge and practice among households was also consistent with the qualitative data. Respondents indicated that awareness of antimicrobial-use instructions did not always lead to adherence because of cost, convenience, access, and time constraints. One participant summarized this gap by saying, "People know the instructions, but they don't follow them" (Oromia; FGD; community member).

3.4.2. Animal health professionals

In the animal health professional fractional logit regression model, both attitude and knowledge were positively associated with AMR-related practice scores. Attitude was associated with better practice

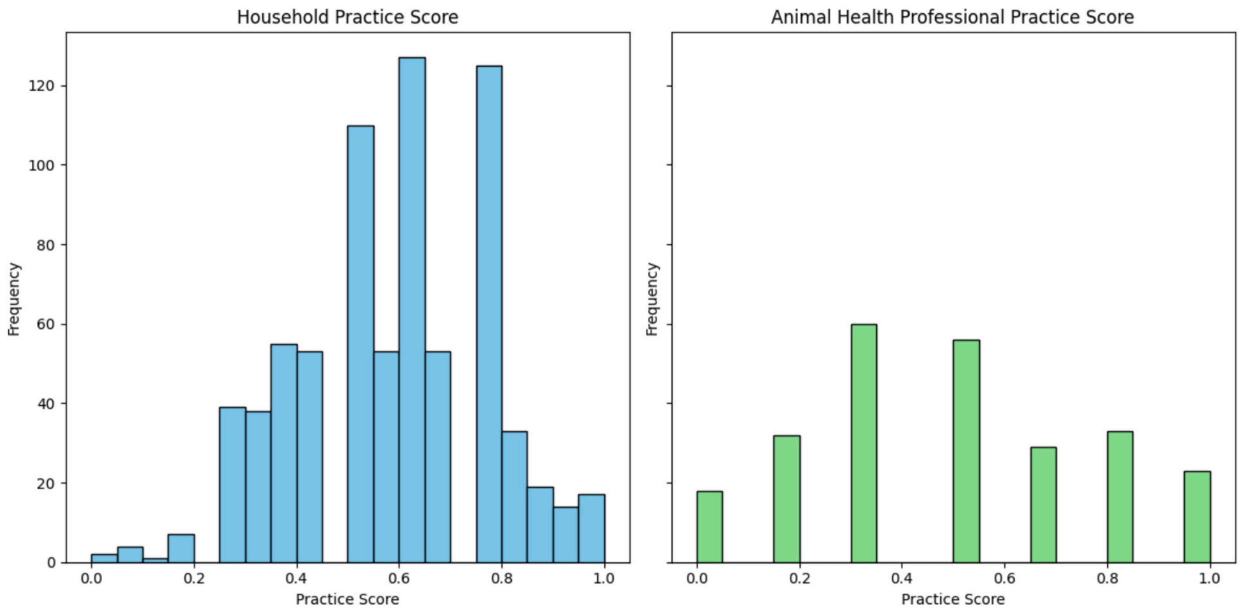

Fig. 1. Distribution of AMR-related practice scores among household respondents and animal health professionals. Practice scores range from 0 to 1, with higher scores indicating better reported antimicrobial-use or stewardship-related practice.

Table 5
Fractional logit regression of AMR-related practice scores among household respondents, $N = 750$.

Predictor	aOR	95% CI	*p*-value
Household size	0.90	0.84–0.96	0.002
Knowledge	1.00	0.93–1.08	0.926
Attitude	1.26	1.17–1.36	<0.001
Sex (Female vs Male)	1.01	0.90–1.13	0.850
Residence (Urban vs Rural)	0.98	0.86–1.12	0.787
Education level	1.01	0.96–1.06	0.725
Employment (Employed vs Unemployed)	1.05	0.92–1.20	0.486
Domestic Animals	0.98	0.87–1.11	0.776

Footnote: aOR = adjusted odds ratio; CI = confidence interval. Reference categories were Male for sex, Rural for residence, no domestic animals, unemployed, and no formal education. Knowledge and attitude scores range from 0 to 1; aORs for these variables represent associations per one-unit increase in the standardized score.

Table 6
Fractional logit regression of AMR-related practice scores among animal health professionals, $N = 251$.

Predictor	aOR	95% CI	p-value
Sex (Female vs Male)	0.75	0.54–1.04	0.086
Residence (Urban vs Rural)	0.96	0.66–1.40	0.820
Education level	1.05	0.76–1.44	0.774
Knowledge score	1.21	1.04–1.41	0.012
Attitude score	1.50	1.28–1.75	<0.001
Profession: Other	0.68	0.35–1.31	0.246
Profession: Veterinary Assistant	0.99	0.69–1.43	0.973
Profession: Veterinary Doctor	0.77	0.51–1.17	0.215
Affiliation: Private practice – self-employed	2.34	1.34–4.07	0.003
Affiliation: Public practice	1.89	1.27–2.79	0.002

Footnote: aOR = adjusted odds ratio; CI = confidence interval. Reference categories were male for sex, rural for residence, certificate-level education for education, community-based animal health worker for profession, and private practice–employed for affiliation. Knowledge and attitude scores range from 0 to 1; aORs for these variables represent associations per one-unit increase in the standardized score.

(aOR = 1.50; 95% CI: 1.28–1.75; $p < 0.001$), and knowledge was also associated with better practice (aOR = 1.21; 95% CI: 1.04–1.41; $p = 0.012$). Institutional affiliation was also associated with practice. Compared with the reference affiliation category, private or self-employed professionals had higher odds of appropriate practice (aOR = 2.34; 95% CI: 1.34–4.07; $p = 0.003$), and those in public practice also had higher odds of appropriate practice (aOR = 1.89; 95% CI: 1.27–2.79; $p = 0.002$). Sex, residence, education level, and most professional categories were not statistically significant after adjustment (Table 6).

Qualitative findings supported the observed association between attitude and practice. Animal health professionals who perceived AMR as serious described being more deliberate in drug selection and prescribing behavior. One veterinarian stated, "If you know the seriousness of AMR, you try your best to avoid misuse" (Oromia; KII; DVM; male). Another professional emphasized the link between technical knowledge and professional responsibility: "We understand the science, and we try to apply it as much as possible" (Addis Ababa; KII; DVM; male).

The association between institutional affiliation and practice was also supported qualitatively. Public-sector workers described the role of guidelines, supervision, and accountability. One participant stated, "In government clinics we follow guidelines strictly" (Oromia; KII; DVM; male). Private practitioners described reputation and client trust as important incentives for appropriate practice. One respondent explained, "In private practice your reputation depends on doing the right thing" (Oromia; KII; DVM; male). However, professionals across both public and private settings reported common structural constraints, including limited laboratory access, pressure from livestock owners, drug availability, and weak enforcement.

Overall, attitude emerged as the most consistent factor associated with AMR-related practice scores in both households and animal health professionals. Knowledge was additionally associated with practice among animal health professionals but not among households. Household size and professional affiliation reflected the influence of social and institutional context on practice, while demographic characteristics showed limited independent association after adjustment.

4. Discussion

This mixed-methods study examined knowledge, attitudes, and practices related to antimicrobial resistance and antimicrobial use among household respondents and animal health professionals in three

Ethiopian regions. The findings show a consistent gap between knowledge, attitudes, and reported practices. Households reported moderate knowledge and relatively favorable attitudes, but lower practice scores. Animal health professionals reported high knowledge and favorable attitudes, yet their practice scores were also suboptimal. These findings suggest that AMR-related practices are shaped not only by factual understanding, but also by attitudes, household constraints, professional environments, service access, diagnostic capacity, antimicrobial availability, and regulatory enforcement.

The most consistent quantitative finding was the positive association between attitude and AMR-related practice scores in both households and animal health professionals. This suggests that perceptions of AMR seriousness, perceived responsibility, and stewardship orientation may be more closely linked to behavior than factual knowledge alone. This finding is consistent with the Theory of Planned Behavior, which proposes that attitudes, perceived norms, and perceived behavioral control are important determinants of behavioral intention and action [35]. In the present study, qualitative findings supported this interpretation. Community members and animal health professionals repeatedly described cautious antimicrobial use as being linked not only to awareness, but also to concern about the consequences of resistance and a sense of responsibility to prevent misuse.

Knowledge had a more context-specific relationship with practice. Among households, knowledge was not significantly associated with AMR-related practice after adjustment. This suggests that awareness of AMR and antimicrobial-use principles may not be sufficient to change behavior when households face financial constraints, convenience pressures, limited access to formal care, and easy access to antimicrobials outside regulated channels. Similar findings have been reported in AMR KAP studies in Ethiopia and other African settings, where community awareness did not always translate into appropriate antimicrobial-use behavior because of self-medication, informal drug access, incomplete treatment, and weak enforcement of prescription requirements [28,29,33,34]. In contrast, knowledge was positively associated with practice among animal health professionals, indicating that technical understanding may be more directly relevant in professional decision-making contexts where respondents have formal training and stewardship responsibilities.

The qualitative findings provide important explanation for the knowledge–practice gap. Household respondents described stopping treatment when symptoms improved, purchasing antimicrobials directly from pharmacies, sharing medicines within families, and keeping leftover medicines for future use. These practices are consistent with prior evidence from Ethiopia showing inappropriate antibiotic access and use at community level [33,34]. Financial constraints were especially important in larger households, where respondents described rationing medicines or sharing purchased drugs among several family members. This helps explain the observed negative association between household size and practice scores. Therefore, interventions that focus only on increasing AMR knowledge are unlikely to be sufficient unless they also address affordability, access to appropriate care, household-level economic constraints, and regulation of non-prescription antimicrobial access.

Among animal health professionals, the findings show that high knowledge and favorable attitudes do not automatically ensure optimal stewardship practice. Professionals reported diagnostic limitations, livestock-owner pressure, drug shortages, weak guideline enforcement, and limited regulatory oversight. These constraints may lead professionals to rely on empirical treatment or client expectations even when they understand AMR risks. This finding is consistent with AMR KAP and stewardship evidence showing that antimicrobial-use behavior is shaped not only by individual knowledge, but also by diagnostic capacity, service availability, institutional norms, supervision, and regulatory context [21–24,28,29,33,34,36–39]. The observed association between professional affiliation and practice may reflect differences in supervision, accountability, access to guidelines, client relationships, and organizational culture across public and private practice settings.

Regional and residence-based differences also illustrate the importance of context. Urban respondents generally had higher KAP scores than rural respondents, especially in Addis Ababa and urban Oromia. However, residence was not independently associated with practice in the adjusted household model. This suggests that the rural–urban difference may operate through other factors, including education, access to services, antimicrobial availability, attitudes, and economic constraints. Qualitative findings from Afar and rural Oromia showed lower AMR awareness, limited access to formal services, and adherence challenges. These findings are consistent with Ethiopia's broader AMR landscape, where limited diagnostic capacity, informal antimicrobial access, uneven implementation of stewardship activities, and regulatory gaps remain key barriers [6,11–14,21–25].

The moderate internal consistency of the practice domains should be interpreted carefully. Practice-domain Cronbach's alpha values were 0.64 among households and 0.66 among animal health professionals. These values were lower than those observed for most knowledge and attitude domains, but they are understandable given the small number of retained practice items and the heterogeneous nature of AMR-related behaviors. Household practice items covered behaviors such as avoiding non-prescription access, not receiving antimicrobials from relatives or friends, avoiding storage of unused antimicrobials, and understanding the effect of missed doses. Animal health professional practice items included guideline awareness, standardized protocol use, counseling, withdrawal-period communication, follow-up, diagnostic use, and avoidance of inappropriate combined antimicrobial therapy. These behaviors are conceptually related to antimicrobial stewardship but may not necessarily co-occur within the same respondent. Therefore, the practice score should be interpreted as a composite behavioral index rather than a strictly unidimensional psychometric scale.

The findings have important programmatic implications. First, AMR interventions should move beyond information dissemination alone. Community-level interventions should address attitudes, perceived risk, social norms, and practical barriers to appropriate antimicrobial use. Messages that only explain what AMR is may be less effective than interventions that also address why inappropriate antimicrobial use matters personally, socially, and economically. Second, interventions targeting households should address affordability and access barriers. Strengthening primary healthcare access, improving counseling at dispensing points, discouraging non-prescription antimicrobial sales, and promoting adherence support may reduce inappropriate use. Third, interventions targeting animal health professionals should combine continuing professional development with practical stewardship enablers, including diagnostic access, treatment guidelines, supportive supervision, client communication tools, and enforcement of veterinary antimicrobial regulations [21–24,36–39].

A One Health approach is essential because AMR risks in Ethiopia span human, animal, food, and environmental pathways. Antimicrobial use in livestock, informal access to antimicrobials, weak regulatory enforcement, and environmental contamination can interact to sustain AMR transmission. Ethiopia has developed national AMR strategies and a One Health strategic plan, but implementation gaps remain in stewardship, surveillance, laboratory capacity, antimicrobial consumption monitoring, accountability, and multisectoral coordination [11–14,21–26]. The present findings support the need to align community behavior-change interventions, veterinary stewardship, diagnostic strengthening, regulatory enforcement, and One Health governance. Without these system-level supports, improvements in knowledge and attitudes may not translate into sustained practice change.

Overall, this study demonstrates that AMR-related behaviors are shaped by attitudes, socio-economic conditions, institutional environments, and governance structures, not by knowledge alone. The integrated quantitative and qualitative findings show that improving antimicrobial-use practices in Ethiopia requires interventions that combine behavioral change, professional stewardship, health and veterinary system strengthening, diagnostic support, and regulatory enforcement within a coordinated One Health framework.

4.1. Limitations

This study has several limitations. The cross-sectional design prevents causal inference, and self-reported practice measures may be affected by recall and social desirability bias. The practice domains showed moderate internal consistency, with Cronbach's alpha values of 0.64 among households and 0.66 among animal health professionals, likely reflecting the small number and behavioral heterogeneity of practice items. Therefore, practice scores should be interpreted as composite behavioral indices rather than strictly unidimensional psychometric scales.

In addition, structural determinants identified qualitatively—including affordability, service access, antimicrobial availability, diagnostic capacity, regulatory enforcement, supply chains, and One Health coordination—were not measured quantitatively in sufficient detail for inclusion in the regression models. Future longitudinal, multilevel, spatial, or implementation-focused studies should quantify these contextual influences. Finally, because the study was conducted in selected regions, findings may not fully represent all Ethiopian settings.

5. Conclusion and recommendations

5.1. Conclusion

This mixed-methods study shows that AMR-related practices among household respondents and animal health professionals in Ethiopia are shaped more consistently by attitudes and contextual constraints than by knowledge alone. Attitude was associated with better practice scores in both groups, while knowledge was associated with practice only among animal health professionals. Household size and professional affiliation further indicate that social, economic, and institutional conditions influence whether knowledge and attitudes translate into appropriate antimicrobial-use behaviors.

The qualitative findings reinforce this interpretation by showing that affordability, informal antimicrobial access, limited diagnostic capacity, client pressure, weak enforcement, and service-access barriers constrain appropriate practice. These findings suggest that improving antimicrobial stewardship in Ethiopia requires more than awareness creation. Effective interventions should combine behavioral change, professional stewardship support, health and veterinary system strengthening, regulatory enforcement, and coordinated One Health action.

5.2. Recommendations

AMR interventions should prioritize attitude and behavior change alongside knowledge improvement. Community-level programs should use participatory and culturally appropriate approaches that address perceived risk, social norms, adherence, self-medication, medicine sharing, and non-prescription antimicrobial use. These efforts should be supported by improved access to affordable and appropriate healthcare services.

For animal health professionals, training should be linked with practical stewardship enablers, including clear treatment guidelines, supportive supervision, diagnostic access, client communication tools, and mechanisms for follow-up of non-responsive infections. Regulatory authorities should strengthen enforcement of antimicrobial dispensing and prescribing requirements across human and animal health sectors.

At the policy level, Ethiopia's One Health AMR response should prioritize stronger coordination between human health, animal health, and environmental sectors, with attention to antimicrobial supply chains, diagnostic capacity, surveillance, and accountability. Future research should use longitudinal, multilevel, spatial, and implementation-focused designs to evaluate whether integrated behavioral and system-level interventions improve antimicrobial-use practices over time.

CRediT authorship contribution statement

Geteneh Moges Assefa: Writing – review & editing, Writing – original draft, Visualization, Validation, Supervision, Methodology, Formal analysis, Conceptualization. **Abenezer Wgebriel:** Writing – review & editing, Validation. **Michael Tarekegn:** Writing – review & editing, Validation. **Getachew Gebreselassie:** Writing – review & editing, Validation. **Salsawit Shifarraw:** Writing – review & editing, Validation. **Alemtsehay Solomon:** Writing – review & editing, Validation. **Mesfin Mihret:** Writing – review & editing, Validation. **Ataklti Hadush Girmay:** Writing – review & editing, Validation. **Gebrie Alebachew Belete:** Writing – review & editing, Validation. **Wendmnew Abrie:** Writing – review & editing, Validation. **Fredrick Majiwa:** Writing – review & editing, Validation. **Kasahun Negash:** Writing – review & editing, Validation.

Informed consent statement

Informed consent was obtained from all subjects involved in the study. Participants were fully informed about the study's purpose, procedures, data handling, and their rights, including voluntary participation and withdrawal at any time. To ensure confidentiality, interviews were conducted in private settings, and data were anonymized during analysis. Data collectors received training on ethical research conduct, including safeguarding participant privacy and managing sensitive topics related to gender and health behaviors.

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Declaration of competing interest

The authors declare that they have no known competing financial interests or personal relationships that could have appeared to influence the work reported in this paper.

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Appendix A. Supplementary data

Supplementary data to this article can be found online at https://doi.org/10.1016/j.onehlt.2026.101461.

Data availability

The data presented in this study are available from the corresponding author upon reasonable request due to privacy and ethical restrictions.

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