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Original Article

Assessment of perspectives, knowledge and attitude about antibiotic use and resistance in Sudanese population

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Abstract

Introduction: The spread of multidrug-resistant pathogens is a major global health concern. A survey was conducted to evaluate the knowledge and attitudes towards antimicrobial use and resistance in Sudan.

Methodology: A cross-sectional survey with a 39-item questionnaire was distributed via social media platforms to Sudanese residents in Khartoum state. Responses were collected anonymously from April to October 2022 and subjected to statistical analysis to assess associations between variables.

Results: A total of 1,037 participants agreed to participate, with a 94.3% response rate. Two-thirds of participants reported using oral antibiotics in the past 12 months. Only a quarter obtained antibiotics with a prescription. Less than half (45.3%) of the participants underwent diagnostic tests before using antibiotics, and 30.2% adjusted or discontinued the antibiotic dosage. Forty-two percent correctly identified that antibiotics are ineffective against viral infections, but confusion regarding their use persisted. The mean knowledge score was 3.3 ± 1.7, indicating average knowledge levels. Significant variations in knowledge and attitudes were observed based on age, gender, marital status, and education. The mean score of the participants' attitude was 25.5 ± 3.97. Female, younger, and single participants exhibited more positive attitudes towards antibiotics use and resistance.

Conclusions: The participants exhibited average knowledge levels and mixed attitudes towards antibiotic use and resistance. Misconceptions and inadequate indications for antibiotic use were identified. Gender, age, marital status, and education influenced participants' knowledge and attitudes. These findings can inform strategies to promote appropriate practices and combat the spread of antibiotic resistance across health and non-health sectors.

Key words: antimicrobial resistance; knowledge; attitude; public.

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Introduction

The spread of multidrug-resistant and pandrug-resistant pathogens has emerged as a significant global health concern [1]. The misuse and widespread use of antimicrobial agents in animals, humans, and agriculture has contributed to the development of resistance in most microorganisms [2]. These drug-resistant pathogens, along with emerging and re-emerging infectious diseases like COVID-19, pose urgent challenges to population health, social stability, and economic well-being [3]. Antimicrobial resistance is a formidable adversary for antibiotics, including novel agents, in the fight against infectious diseases [4].

The main drivers of antimicrobial resistance are inappropriate use, storage, and prescription of these agents [5]. Insufficient knowledge and awareness about antibiotics contribute to the problem, further exacerbating the global shortage of effective antibiotics [6]. Contributing factors to irrational antimicrobial use and resistance include over-the-counter or internet-based dispensing of antibiotics, reliance on personal experience or advice from acquaintances, use of

leftover antibiotics without proper medical consultation, and gaps in drug discovery and research efforts [7–9]. Antimicrobial resistance is not limited to resource-poor settings; it poses a serious threat to public health worldwide, resulting in over 4 million deaths annually [10,11].

Sudan is not an isolated case, as numerous studies have reported the presence of multidrug-resistant bacteria in clinical and environmental samples [12–14]. Despite the policy in Sudan that restricts the prescription and distribution of antibiotics to licensed healthcare practitioners, survey analyses have revealed that a significant portion of the Sudanese population still practice antibiotic self-medication [15–17]. It is important to note that the Federal Ministry of Health and the Federal Ministry of Animal Resources in Sudan are aligned with the World Health Organization (WHO)'s recommendation to develop and implement national action plans on antimicrobial resistance by adopting a One Health approach. The primary objective of these action plans is to enhance public awareness and understanding of factors contributing to antimicrobial resistance [18,19].

The implementation of antimicrobial stewardship, which involves a coordinated set of actions for the rational use of antimicrobials, is key to successfully combatting antimicrobial resistance [20]. Furthermore, the One Health approach also emphasizes the importance of fostering collaboration among healthcare professionals, environmental and agricultural workers, policymakers, and the general public. This collaborative and transdisciplinary approach is essential for effectively implementing control strategies against antimicrobial resistance [21]. In order to conduct situational analyses, several countries have investigated the public's knowledge and awareness about antimicrobial use and resistance, including the USA [22] and Japan [23]; in addition to the Eurobarometer survey which is regularly carried out by the European Commission [9]. To date, no published reports have been found that assess the knowledge and understanding of antimicrobial resistance among the general population in Sudan. As a result, this study was conducted to evaluate the attitudes, perspectives, and knowledge of the Sudanese general population concerning antibiotics and resistance.

Methodology

Study design and participants

A web-based cross-sectional survey was developed and used to collect participants' opinions anonymously. The Google form was distributed on social media, targeting the Sudanese general population. The front page of the form contained the title, a brief research purpose, and the online informed consent. No identifiable information was collected, and participants had the right to decline or discontinue the survey at any point. Participation in the study was voluntary. Submitted responses belonged to adults aged ≥ 18 years who agreed to participate.

Construction and validation of the survey instrument

The questionnaire was developed to assess the knowledge, attitudes, and perspectives of the Sudanese general population in Khartoum state regarding antibiotic use and resistance. The survey tool was adapted from the Sudan National Action Plan on Antimicrobial Resistance [18], the European Commission's Special Eurobarometer 478 [5], and previous studies [22,23]. The questionnaire consisted of 39 items divided into four sections. The first section collected demographic information through 7 items. The second section, comprising 5 items, focused on participants' antibiotic use in the past 12 months. The third section, containing 20 items, explored participants' knowledge about antibiotic use, resistance, and related information. The fourth section, encompassing 7 items, delved into participants' attitudes towards antibiotic use and resistance. Most of the questions were designed using a closed-ended format, such as Yes/No/Don't Know options, a 5-point Likert scale, and multiple-answer choices. Additionally, participants had the option to provide their own responses using an "other" option when necessary. The questionnaire was initially developed in English and then underwent content validation by independent scientists experienced in similar studies. To ensure the reliability of the survey tool, correlations between study variables were examined using responses from 40 participants, resulting in a confirmed reliability coefficient alpha of 0.83. Subsequently, the questionnaire was translated into Arabic by independent co-authors and then back-translated into English to ensure accuracy. The survey was made available in both English and Arabic languages to cater to participants' language preferences.

Sample size estimation and data collection

To determine the sample size, a Raosoft® calculator [24] was used initially, which resulted in an estimated sample size of 384 participants. This calculation was based on a 5% margin of error, a 95% confidence level, and an assumed response distribution of 50% for a population size of over 100,000. However,

the sample size was adjusted to match the approach taken in similar studies, such as the European Commission's Special Eurobarometer 478 [5], which typically interviewed around 1,000 participants per EU country, including those with population sizes similar to Sudan. A Japanese study also followed a similar approach [23]. The Google form survey was distributed through various social media platforms with a request for assistance in sharing the form with relatives and groups. After four months, the survey was closed once the desired number of participants was reached. The collected data were then downloaded in Microsoft Excel, cleaned, transferred to the Statistical Package for the Social Sciences (SPSS) [25], and assigned numerical codes for analysis.

Data analysis

The collected data were analyzed using SPSS version 25 [25]. Descriptive and inferential statistics were employed. Demographic information and participants' responses to general questions about antibiotic use were summarized using frequencies (N) and percentages (%). For knowledge-related questions, either frequencies (N) and percentages (%), or mean (M) and standard deviation (SD) were used as appropriate. Correct answers were assigned a value of 1, while incorrect or unsure answers were assigned a value of 0. The total knowledge score, ranging from 0 to 6, was dichotomized into high (4 or more) and low (less than 4) using a cutoff point of the mean score of 3.3 ± 1.7. Attitude-related questions, measured on a 5-point Likert scale, were summarized as mean (M) and standard deviation (SD), with the scoring system inverted for negative statements. The total attitude score, ranging from 7 to 35, was dichotomized into high (26 or more) and low (less than 26) using a cutoff point of the mean score of 25.5 ± 3.97. The Chi square test was employed to assess significant associations between demographic variables and knowledge about antimicrobial use and resistance. Continuous data were compared using one-way analysis of variance (ANOVA) or Student's t-test. Further analysis, including Tukey's post-hoc test, was conducted to identify statistically significant mean score differences among specific groups. A significance level of $p \leq 0.05$ was applied to determine statistical significance.

Table 1. Participants' demographics (N = 978).

Variables	Frequency (N)	Percentage (%)
Gender		
Female	531	54.3%
Male	447	45.7%
Age (years)		
18–24	532	54.4%
25–30	120	12.3%
31–40	110	11.2%
41–50	103	10.5%
> 50	113	11.6%
Marital status		
Single	651	66.6%
Married	292	29.9%
Divorced	19	1.9%
Widow	16	1.6%
Monthly income (Sudanese Pound SDG)		
< 50,000	602	61.6%
50–100 thousand	195	19.9%
100–200 thousand	100	10.2%
200–400 thousand	42	4.3%
> 400 thousand	39	4.0%
Education Level		
Intermediate or Elementary	29	3.0%
Secondary	87	8.9%
Graduate	776	79.3%
Postgraduate	86	8.8%
Residence		
Khartoum	692	70.8%
Omdurman	123	12.6%
Bahri	163	16.7%
Working status		
Worker	44	4.5%
Housewife	75	7.7%
Unemployed/retired	45	4.6%
Employee/officer	228	23.3%
Self-employed	77	7.9%
Students	491	50.2%
Manager	18	1.8%
Using oral antibiotics in the last 12 months		
No	194	19.8%
Yes	746	76.3%
Don't Know	38	3.9%

Ethical considerations

Prior to participation, all participants were required to provide informed consent online. This was facilitated by including an informed consent form on the front page of the Google form. Participants had the autonomy to decline or discontinue the survey at any stage, as participation in the study was entirely voluntary. The project received ethical approval from the ethics committee at the College of Pharmacy, International University of Africa.

Results

Out of the total 1,037 participants who agreed to take part, a total of 978 individuals submitted their responses, representing a response rate of 94.3%. The sociodemographic characteristics of the respondents are summarized in Table 1.

Use of oral antibiotics over the last 12 months

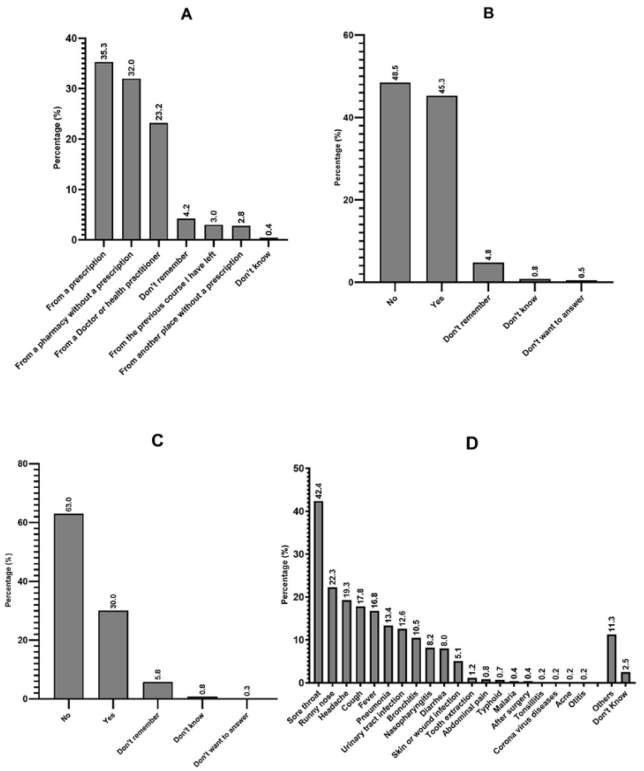
Almost two-thirds of participants (76.3%) used oral antibiotics in the last 12 months (Table 1). Among the participants who reported using antibiotics, 26.9% obtained them through a prescription, 24% obtained

them from a pharmacy without a prescription, and 17.7% obtained them from a doctor or health practitioner. Furthermore, only 45.3% of participants underwent a diagnostic test to determine the cause of their illness before starting antibiotics, while 30.2% adjusted the dosage or number of antibiotics during their treatment course. Additionally, a notable proportion of participants, 38.7%, revealed that they had requested doctors to prescribe antibiotics. These findings are summarized in Figure 1, which provides an overview of the participants' utilization of oral antibiotics over the past 12 months, including information about the acquisition of antibiotics, diagnostic testing behavior, and the reasons underlying their use.

Knowledge regarding antibiotic use and resistance

The average knowledge score was 3.3 ± 1.7 (ranging from 0 to 6). Approximately 46% of participants demonstrated good knowledge (scoring 4 or higher out of 6), while 54% had poor knowledge (scoring less than 4 out of 6). There were notable gender disparities in understanding antibiotics usage for viral or bacterial infections, antibiotics resistance, and antibiotics usage for common colds and side effects. Females exhibited greater knowledge ($p < 0.001$). Only 31% of females and 18.9% of males correctly recognized that antibiotics cannot eradicate viruses, and 42.7% of females and 31.5% of males correctly identified that antibiotics can kill bacteria. However, there was no significant difference in gender regarding knowledge of antibiotic usage for treating COVID-19 ($p = 0.4$). Significant variations in knowledge about the use of antibiotics for virus eradication, treating common cold, or managing COVID-19 were observed across different age groups and marital statuses (p value < 0.001). Conversely, financial situation and residence area had no impact on knowledge ($p > 0.5$). Educational level had a mixed effect on knowledge, with noticeable distinctions seen in understanding antibiotic usage for viruses and antibiotics resistance ($p < 0.05$), but no discernible difference in knowledge regarding antibiotics for bacteria or side effects ($p > 0.05$). Working status had a significant influence on knowledge about antibiotic usage, resistance, and side effects ($p < 0.05$ for all working groups). The differences in participants' knowledge regarding antibiotic use and resistance are presented in Table 2 for reference.

Figure 1. Use of oral antibiotics in the last 12 month: A, how participants got their oral antibiotics in the last 12 months; B, had diagnostic test; C, self-stopping or adjusting dose/number of antibiotics; D, reasons for using antibiotics in the last 12 months.



Antibiotic information

Only a minority (22.6%) of the participants were aware of the World Antimicrobial Awareness Week. Almost half (49%) of the participants recalled receiving information about antibiotics in the past year, particularly concerning the unnecessary use of antibiotics for conditions like colds or other infections. Among those who received information, the internet or social media served as the source for 47.8% of participants, while medical doctors and pharmacists informed 31.5% and 30.5% of participants respectively. Based on the information they obtained, 90.2% claimed that their views on the use of antibiotics have changed. When contemplating future reliance on information, participants indicated that they would trust medical doctors (68.9%) and pharmacists (64.7%) as the most dependable sources. However, a small percentage (1%) of participants expressed disinterest in receiving information about antibiotics. In terms of seeking advice on antibiotic use, a significant majority (72.2%) of participants expressed their intention to consult medical doctors, when necessary, in the future. Additionally, 52.4% stated that they would refrain from using antibiotics without a doctor's prescription, and 44.1% indicated that they would discontinue the

practice of self-medication with antibiotics. Surprisingly, a small proportion (2.3%) of participants confessed that they planned to distribute leftover antibiotics to their relatives or friends when they fell ill. Participants expressed a desire for more information on various aspects of antibiotic usage, such as medical conditions for which antibiotics can be used (57.4%), antibiotic resistance (53.4%), and proper antibiotic usage (43.4%). Interestingly, a minority (2.9%) of participants did not wish to receive further information about antibiotics. Figure 2 provides an overview of the sources of information regarding unnecessary antibiotic usage, participants' plans regarding antibiotic use, the topics they seek more information about, and their preferred sources for future information.

Knowledge regarding antibiotic use for animals

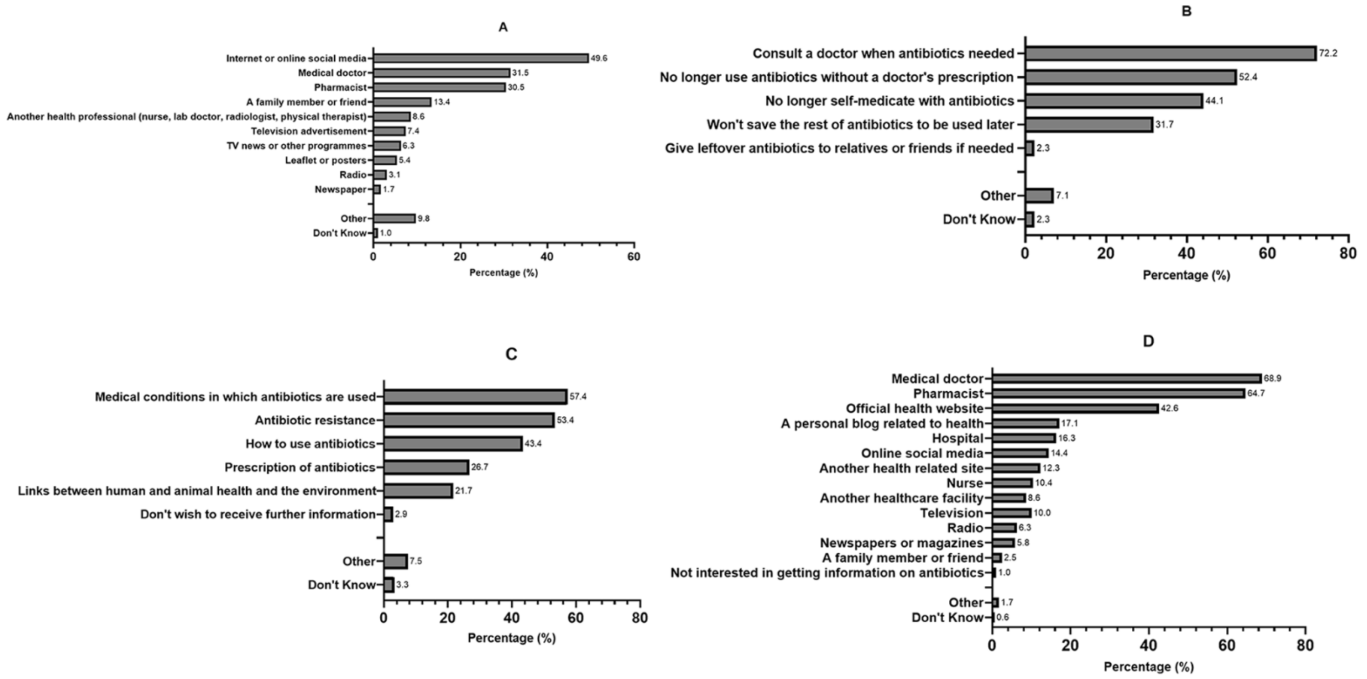
Participants held differing views on the use of antibiotics intended for human consumption in animals, with nearly half (49%) agreeing that antibiotics should be employed if it is deemed the most appropriate treatment. However, a significant majority of participants (72.7% and 66.6%) were unaware that antibiotics are used to promote animal growth in Sudan or that the country has banned the use of antibiotics in animal feed. Furthermore, a notable portion (62.7%) of participants did not have knowledge of the World

Table 2. Participant's knowledge regarding antibiotic use and resistance (N = 978).

	Antibiotics kill viruses			**Antibiotics kill bacteria**			**Antibiotics can be used to treat COVID**			**Antibiotics are effective against common cold**			**Unnecessary use of antibiotics renders them ineffective**			**Antibiotics often causes side effects such as diarrhea**		
	C., N (%)	InC., N (%)	Do.N., N (%)	C., N (%)	InC., N (%)	Do.N., N (%)	C., N (%)	InC., N (%)	Do.N., N (%)	C., N (%)	InC., N (%)	Do.N., N (%)	C., N (%)	InC., N (%)	Do.N., N (%)	C., N (%)	InC., N (%)	Do.N., N (%)
Gender																		
Female	303 (31)	152 (15.5)	76 (7.8)	418 (42.7)	45 (4.6)	68 (7)	234 (23.9)	172 (17.6)	125 (12.8)	238 (24.4)	258 (26.4)	35 (3.6)	453 (46)	36 (3.7)	42 (4.3)	282 (28.8)	75 (7.7)	174 (17.8)
Male	185 (18.9)	177 (18.1)	85 (8.7)	308 (31.5)	39 (4.0)	100 (10.2)	179 (18.3)	150 (15.3)	118 (12.1)	132 (13.5)	269 (27.5)	46 (4.7)	314 (32.1)	56 (5.7)	77 (7.9)	184 (18.8)	129 (13.2)	134 (13.7)
p value		**< 0.001**			**< 0.001**			0.4			**< 0.001**			**< 0.001**			**< 0.001**	
Age (years)																		
18–24	316 (32.3)	135 (13.8)	81 (8.3)	413 (42.2)	44 (4.5)	75 (7.7)	270 (27.6)	137 (14.0)	125 (12.8)	242 (24.7)	236 (24.1)	54 (5.5)	428 (43.8)	43 (4.4)	61 (6.2)	250 (25.6)	99 (10.1)	183 (18.7)
25–30	53 (5.4)	45 (4.6)	22 (2.2)	84 (8.6)	12 (1.2)	24 (2.5)	45 (4.6)	52 (5.3)	23 (2.4)	38 (3.9)	74 (7.6)	8 (0.8)	93 (9.5)	15 (1.5)	12 (1.2)	56 (5.7)	29 (3.0)	35 (3.6)
31–40	47 (4.8)	47 (4.8)	16 (1.6)	84 (8.6)	9 (0.9)	17 (1.7)	41 (4.2)	43 (4.4)	26 (2.7)	38 (3.9)	65 (6.6)	7 (0.7)	78 (8.0)	17 (1.7)	15 (1.5)	53 (5.4)	26 (2.7)	31 (3.2)
41–50	35 (3.6)	51 (5.2)	17 (1.7)	73 (7.5)	8 (0.8)	22 (2.2)	32 (3.3)	38 (3.9)	33 (3.4)	28 (2.9)	71 (7.3)	4 (0.4)	85 (8.7)	8 (0.8)	10 (1.0)	52 (5.3)	27 (2.8)	24 (2.5)
> 50	37 (3.8)	51 (5.2)	25 (2.6)	72 (7.4)	11 (1.1)	30 (3.1)	25 (2.6)	52 (5.3)	36 (3.7)	24 (2.5)	81 (8.3)	8 (0.8)	83 (8.5)	9 (0.9)	21 (2.1)	55 (5.6)	23 (2.4)	35 (3.6)
p value		**< 0.001**			0.08			**< 0.001**			**< 0.001**			0.08			0.4	
Marital status																		
Single	370 (37.8)	177 (18.1)	104 (10.6)	495 (50.6)	54 (5.5)	102 (10.4)	314 (32.1)	188 (19.2)	149 (15.2)	277 (28.3)	312 (31.9)	62 (6.3)	514 (52.6)	58 (5.9)	79 (8.1)	308 (31.5)	133 (13.6)	210 (21.5)
Married	104 (10.6)	138 (14.1)	50 (5.1)	204 (20.9)	26 (2.7)	62 (6.3)	85 (8.7)	121 (12.4)	86 (8.8)	85 (8.7)	189 (19.3)	18 (1.8)	225 (23.0)	29 (3.0)	38 (3.9)	136 (13.9)	66 (6.7)	90 (9.2)
Divorced	7 (0.7)	8 (0.8)	4 (0.4)	15 (1.5)	1 (0.1)	3 (0.3)	9 (0.9)	7 (0.7)	3 (0.3)	3 (0.3)	16 (1.6)	0	17 (1.7)	2 (0.2)	0	11 (1.1)	2 (0.2)	6 (0.6)
Widow	7 (0.7)	6 (0.6)	3 (0.3)	12 (1.2)	3 (0.3)	1 (0.1)	5 (0.5)	6 (0.6)	5 (0.5)	5 (0.5)	10 (1.0)	1 (0.1)	11 (1.1)	3 (0.3)	2 (0.2)	11(1.1)	3 (0.3)	2 (0.2)
p value		**< 0.001**			0.2			**< 0.001**			**< 0.001**			0.3			0.5	
Monthly income (Sudanese Pound SDG) X1000																		
<50	313 (32.0)	194 (19.8)	95 (9.7)	452 (46.2)	55 (5.6)	95 (9.7)	260 (26.6)	190 (19.4)	152 (15.5)	241 (24.6)	314 (32.1)	47 (4.8)	480 (49.1)	57 (5.9)	65 (6.6)	277 (28.3)	123 (12.6)	202 (20.7)
50–100	84 (18.6)	75 (7.6)	36 (3.7)	139 (14.2)	17 (1.7)	39 (4.0)	79 (8.1)	70 (7.2)	46 (4.7)	57 (5.8)	121 (12.4)	17 (1.7)	140 (14.3)	23 (2.4)	32 (3.3)	106 (10.8)	35 (3.6)	54 (5.5)
100–200	50 (5.1)	29 (3.0)	21 (2.1)	74 (7.6)	5 (0.5)	21 (2.1)	37 (3.8)	39 (4.0)	24 (2.5)	35 (3.6)	53 (3.4)	12 (1.2)	81 (8.3)	8 (0.8)	11 (1.1)	43 (4.4)	27 (2.8)	30 (3.1)
200–400	19 (1.9)	16 (1.6)	7 (0.7)	30 (3.1)	4 (0.4)	8 (0.8)	19 (1.9)	12 (1.2)	11 (1.1)	19 (1.9)	20 (2.0)	3 (0.3)	36 (3.7)	0	6 (0.6)	22 (2.2)	7 (0.7)	13 (1.3)
> 400	22 (2.2)	15 (1.5)	2 (0.2)	31 (3.2)	3 (0.3)	5 (0.5)	18 (1.8)	11 (1.1)	10 (1.0)	18 (1.8)	19 (1.9)	2 (0.2)	30 (3.1)	4 (0.4)	5 (0.5)	18 (1.8)	12 (1.2)	9 (0.9)
p value		0.2			0.7			0.9			0.2			0.2			0.2	
Education Level																		
Intermediate/Elementary	6 (0.6)	15 (1.5)	8 (0.8)	18 (1.8)	4 (0.4)	7 (0.7)	9 (0.9)	16 (1.6)	4 (0.4)	6 (0.6)	22 (2.2)	1 (0.1)	16 (1.6)	6 (0.6)	7 (0.7)	17 (1.7)	4 (0.4)	8 (0.8)
Secondary	27 (2.7)	42 (4.3)	18 (1.8)	58 (5.9)	6 (0.6)	23 (2.4)	25 (2.6)	32 (3.3)	30 (3.1)	20 (2.0)	58 (5.9)	9 (0.9)	60 (6.1)	9 (0.9)	18 (1.8)	45 (4.6)	16 (1.6)	26 (2.7)
Graduate	414 (42.3)	240 (24.5)	122 (12.5)	584	68 (8.0)	124 (12.7)	350 (35.8)	236 (24.1)	190 (19.4)	318 (32.5)	393 (40.2)	65 (6.6)	617 (63.1)	70 (7.2)	89 (9.1)	365 (37.3)	167 (17.1)	244 (24.9)
Postgraduate	41 (4.2)	32 (3.3)	13 (1.3)	66 (6.7)	6 (0.6)	14 (1.4)	29 (3.0)	38 (3.9)	19 (1.9)	26 (2.7)	54 (5.5)	6 (0.6)	74 (7.6)	7 (0.7)	5 (0.5)	39 (4.0)	17 (1.7)	30 (3.1)
p value		**< 0.001**			0.2			**0.001**			**0.003**			**0.003**			0.8	
Residence																		
Khartoum	323 (33.0)	245 (25.1)	124 (12.7)	504 (51.5)	62 (6.3)	126 (12.9)	268 (27.4)	245 (25.1)	179 (18.3)	244 (24.9)	386 (39.5)	62 (6.3)	527 (53.9)	73 (7.5)	92 (9.4)	344 (35.2)	140 (14.3)	208 (21.3)
Omdurman	72 (7.4)	38 (3.9)	13 (1.3)	105 (10.7)	6 (0.6)	12 (1.2)	65 (6.6)	30 (3.1)	28 (2.9)	56 (5.7)	61 (6.2)	6 (0.6)	106 (10.8)	8 (0.8)	9 (0.9)	50 (5.1)	32 (3.3)	41 (4.2)
Bahri	93 (9.5)	46 (4.7)	24 (2.5)	117 (12.0)	16 (1.6)	30 (3.1)	80 (8.2)	47 (4.8)	36 (3.7)	70 (7.2)	80 (8.2)	13 (1.3)	134 (13.7)	11 (1.1)	18 (1.8)	72 (7.4)	32 (3.3)	59 (6.0)
p value		**0.03**			0.06			0.012			0.09			0.08			0.2	
Working status																		
Worker	10 (1.0)	24 (2.5)	10 (1.0)	28 (2.9)	1 (0.1)	15 (1.5)	12 (1.2)	18 (1.8)	14 (1.4)	7 (0.7)	29 (3.0)	8 (0.8)	25 (2.6)	6 (0.6)	13 (1.3)	14 (1.4)	13 (1.3)	17 (1.7)
Housewife	23 (2.4)	37 (3.8)	15 (1.5)	53 (5.4)	6 (0.6)	16 (1.6)	20 (2.0)	35 (3.6)	20 (2.0)	18 (1.8)	53 (5.4)	4 (0.4)	57 (5.8)	7 (0.7)	11 (1.1)	45 (4.6)	9 (0.9)	21 (2.1)
Unemployed/Retired	21 (2.1)	16 (1.6)	8 (0.8)	34 (3.5)	3 (0.3)	8 (0.8)	18 (1.8)	14 (1.4)	13 (1.3)	14 (1.4)	28 (2.9)	3 (0.3)	37 (3.8)	2 (0.2)	6 (0.6)	27 (2.8)	6 (0.6)	12 (1.2)
Employee/Officer	87 (8.9)	101 (10.3)	40 (4.1)	160 (16.4)	24 (2.5)	44 (4.5)	70 (7.2)	99 (10.1)	59 (6.1)	65 (6.6)	147 (15.0)	16 (1.6)	174 (17.8)	31 (3.2)	23 (2.4)	103 (10.5)	56 (5.7)	69 (7.1)
Self-employed	32 (3.3)	28 (2.9)	17 (1.7)	53 (5.4)	6 (0.6)	18 (1.8)	31 (3.2)	27 (2.8)	19 (1.9)	23 (2.4)	51 (5.2)	3 (0.3)	61 (6.2)	8 (0.8)	8 (0.8)	40 (0.4)	21 (2.1)	16 (1.6)
Students	304 (31.1)	117 (12.0)	70 (7.2)	384 (39.3)	43 (4.4)	64 (6.5)	255 (26.1)	120 (12.3)	116 (11.9)	234 (23.9)	210 (21.5)	47 (4.8)	397 (40.6)	37 (3.8)	57 (5.8)	230 (23.5)	92 (9.3)	169 (17.3)
Manager	11 (1.1)	6 (0.6)	1 (0.1)	14 (1.4)	1 (0.1)	3 (0.3)	7 (0.7)	9 (0.9)	2 (0.2)	9 (0.9)	9 (0.9)	0	16 (1.6)	1 (0.1)	1 (0.1)	7 (0.7)	7 (0.7)	4 (0.4)
p value		**< 0.001**			**0.04**			**< 0.001**			**< 0.001**			**0.014**			**0.012**	

C., Correct; InC., Incorrect; Do.N., Don't Know.

Figure 2. A, source of information about not taking antibiotics unnecessarily; B, planning about antibiotic use; C, topics on antibiotics that require more information; D, the source of information that will be used in future.



Health Organization's recommendation to abstain from using antibiotics for animal growth promotion and disease prevention. Table 3 offers a comprehensive overview of the participants' perspectives toward the use of antibiotics in animal feed.

Attitude regarding antibiotic use and resistance

Participants were asked to express their agreement, neutrality, or disagreement with various statements related to the use of antibiotics, antibiotic resistance, storage of antibiotics at home, and their disposal. A significant majority (60.5%) of participants agreed that antibiotics are frequently overprescribed or available through doctors and pharmacists. Furthermore, more than two-thirds (84.4%) agreed that if preventive measures are not implemented, the effectiveness of antibiotics will diminish in the future. The majority (70.4%) disagreed with the practice of keeping leftover antibiotics for future use without consulting medical professionals.

However, 39.7% of participants agreed to dispose of leftover antibiotics with regular household waste. The average attitude score was 25.5 ± 3.97 (ranging from 13 to 35), with roughly half of the participants (N = 978) classified as having a positive attitude (scoring 26 or higher out of 35). Female participants exhibited a more positive attitude than males ($p < 0.001$), younger participants (18–24 years) held a more positive attitude than older participants ($p < 0.001$), and single participants showed a more positive attitude than married participants ($p < 0.001$). Participants with higher levels of education (graduates and postgraduates) displayed a more positive attitude compared to those with lower education levels ($p < 0.001$). Additionally, students demonstrated a more positive attitude in comparison to participants in other employment statuses ($p < 0.001$). Table 4 provides a breakdown of attitude scores among different demographic characteristics.

Table 3. Participant's knowledge about the use of antibiotics in animals (N = 978).

Statement	Yes	No	Don't know
Antibiotics are used to stimulate the growth of animals in Sudan	16.2%	11.1%	72.7%
Did you know that Sudan prohibits the use of antibiotics to promote animal growth?	7.4%	26%	66.6%
Did you know that the World Health Organization recommends not to use antibiotics for promoting animal growth or preventing disease?	15.1%	22.2%	62.7%
To what extent do you agree or disagree that the diseases of animals used for daily consumption should be treated with antibiotics if this is the most appropriate treatment?	**Strongly agree/agree**	**Strongly disagree/disagree**	**Don't know**
	49%	14.7%	36.3%

Participants were surveyed regarding their perspectives on discontinuing antibiotic use upon initiating a treatment course. The majority (67.9%) expressed a preference for continuing antibiotic use until completing the entire prescribed course, while 27.7% indicated a preference for stopping once they begin to feel better. Additionally, participants were inquired about their perception of the most effective approach for combating antibiotic resistance, and their responses are depicted in Figure 3.

Discussion

The global One Health program has identified the knowledge and awareness of the general population regarding antimicrobial use and resistance as crucial objectives. This is reflected in national action plans

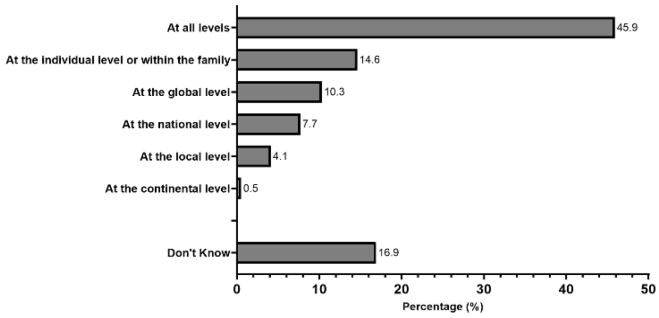
Table 4. Participant's attitude regarding antibiotic use and resistance (N = 978). *p* values in bold (≤ 0.05) show that there is a significant variation.

Variables	Mean	Std. Deviation
Gender		
Female	26.19	3.879
Male	24.67	3.917
p value	**< 0.001**	
Age (years)		
18–24	26.31	3.991
25–30	24.58	3.641
31–40	24.85	4.131
41–50	24.50	3.847
> 50	24.18	3.241
p value	**< 0.001**	
p value with post hoc tests	18 – 24 versus all other age groups < **0.001**	
Marital status		
Single	25.97	4.127
Married	24.54	3.451
Divorced	25.32	3.198
Widow	23.94	3.696
p value	**< 0.001**	
p value with post hoc tests	Single versus married **< 0.001**	
Monthly income (Sudanese Pound SDG)		
< 50,000	25.66	3.862
50–100 thousand	25.04	4.294
100–200 thousand	25.68	3.733
200–400 thousand	24.76	4.230
> 400 thousand	25.59	4.102
p value	0.3	
Education Level		
Intermediate or Elementary	22.76	3.067
Secondary	23.75	3.606
Graduate	25.78	3.967
Postgraduate	25.59	3.836
p value	**< 0.001**	
p value with post hoc tests	Graduate versus Intermediate or Elementary < **0.001** Graduate versus Secondary < **0.001** Postgraduate versus Intermediate or Elementary = **0.004** Postgraduate versus Secondary = **0.01**	
Residence		
Khartoum	25.27	4.037
Omdurman	26.32	3.922
Bahri	25.83	3.607
p value	**0.013**	
p value with post hoc tests	Khartoum versus Omdurman = **0.019**	
Working status		
Worker	23.57	3.719
Housewife	23.72	3.245
Unemployed/retired	24.64	3.856
Employee/officer	24.86	3.908
Self-employed	24.68	3.998
Students	26.42	3.891
Manager	26.28	3.801
p value	**< 0.001**	
p value with post hoc tests	Students versus Worker < **0.001** Students versus Housewife < **0.001** Students versus Employee/Officer < **0.001** Students versus Self-employed = **0.004** Students versus Unemployed/Retired = **0.05**	

designed to combat antimicrobial resistance [19]. The Republic of Sudan has taken proactive measures in response to the World Health Organization's call, having successfully formulated and implemented its National Action Plan (2018-2020) for the One Health Program. This plan addresses antimicrobial resistance at various levels, encompassing human health, animal health, plant health, and environmental considerations [18]. As part of the first goal outlined in the National Action Plans, which emphasizes the promotion of public awareness and education regarding antimicrobial use and resistance, it is essential to assess the existing levels of knowledge, behavior, and perceptions among consumers of antimicrobials. The present study was conducted with this objective in mind.

Examining antibiotic usage within the last year yields valuable information about how individuals acquire antibiotics, if any diagnostic tests were conducted prior to usage, and if individuals modify their dosage or prematurely discontinue treatment. In this study, a significant majority of participants (76.3%) reported having used oral antibiotics within the past 12 months (as demonstrated in Table 1). This percentage is similar to findings from a study conducted in Riyadh, where 69.4% of participants reported using one or more antibiotics within the year prior to the study [26]. In an international context, a notable percentage of Japanese participants (around 50%) reported using oral antibiotics within the last 12 months [23]. This finding contrasts significantly with the Eurobarometer 522 survey conducted concurrently with this study, where only a quarter of Europeans reported using oral antibiotics in the previous year [9]. It is worth noting that a mere quarter of participants acquired antibiotics through a prescription (26.9%), a figure comparable to those who obtained antibiotics without a prescription from a pharmacy (24%) (Figure 1). This trend mirrors observations made in Sudan, where 71.3% of individuals reported resorting to self-medication with antibiotics [17]. Similar practices were also observed in other developing countries such as Ethiopia, where 60.3% obtained antibiotics without a prescription from private pharmacies [27], and Myanmar, where over half of the participants purchased antibiotics without a prescription [6]. Unrestricted access to antibiotics appears to be a contributing factor to the widespread practice of self-medication with antibiotics in certain developing countries. In contrast, Eurobarometer 522 [9] revealed that the majority of European participants (92%) obtained their most recent course of antibiotics from a healthcare professional. This trend is consistent with findings from Japan [23], Thailand [28], and

Figure 3. The levels that need extra work to tackle the antibiotic resistance. Participants were asked to respond to six statements regarding the effectiveness of different approaches to tackling antibiotic resistance, using a multiple-choice format. Descriptive statistics were then used to summarize their responses as percentage.



Singapore [29], where nearly all participants acquired antibiotics from healthcare institutions. Furthermore, this analysis provides evidence that individuals who request antibiotics are likely to receive them, as 38.7% of participants reported specifically requesting doctors to prescribe antibiotics. Moreover, a majority of the participants, for example 53% of Europeans [9], utilized antibiotics without undergoing diagnostic tests to identify the cause of their illness (Figure 1). This survey also disclosed that 30.2% of participants adjusted their antibiotic dosage or prematurely ceased treatment during the prescribed course, as compared to figures of 23.6% in Japan, 59.5% in Saudi Arabia, 52.2% in Ethiopia, 31.9% in Thailand, 7.9% in Singapore, and 13% in European Union [9,23,27–30]. Participants in this study cited various reasons for antibiotic use, including sore throat (42.4%), runny nose (22%), headache (19.3%), cough (17.8%), and other conditions such as pneumonia, urinary tract infections, bronchitis, and fever (Figure 1). The reasons mentioned by the participants for antibiotic usage align with observations from developed and regional countries [9,22,23,30-33].

In this study, it was observed that less than half of the participants (46%) possessed sufficient knowledge (scoring 4 or higher out of 6). While approximately half of the participants displayed confusion regarding the usage of antibiotics for viral infections, a significant majority (three-quarters) were aware that antibiotics can be used to treat bacterial infections. The confusion between the use of antibiotics for bacterial/viral infection is possibly due to the fact that some people have no time to consult the health professionals about the differences between infectious agents, besides the fact that only half of the participants of this study remember that they have received information about the unnecessary use of antibiotics (Figure 2). Such a level

of confusion was also observed in regional or international reports [9,30,31]. Furthermore, 78.1% and 47.6% of participants correctly acknowledged that unnecessary antibiotic use leads to reduced effectiveness and that antibiotic usage often results in side effects such as diarrhoea (Table 2). Females exhibited higher levels of knowledge compared to males regarding the usage of antibiotics for virus or bacterial infections, antibiotic resistance, the use of antibiotics for the common cold, and side effects ($p < 0.001$). Similar findings were observed in a study conducted at a Tertiary Care Center in Riyadh [33]. However, no significant gender disparity was found concerning the accurate understanding of using antibiotics to treat COVID-19 ($p = 0.4$). Additionally, significant differences were observed among various age groups, marital statuses, and educational levels regarding the correct comprehension of using antibiotics to eliminate viruses, treat common cold, or address COVID-19 ($p < 0.001$) (Table 2). The misconception regarding the use of antibiotics for viral infection detected in this study is somewhat similar to that in Ethiopia, European countries, and Japan [9,23,34]. Nonetheless, participants' monthly income or place of residence did not significantly impact their knowledge ($p > 0.05$). Notably, the participants' employment status influenced their understanding of antibiotic use, resistance, and side effects ($p < 0.04$) (Table 2). These outcomes align with those of a local study that identified a significant association between occupational status and knowledge [30].

In this study, it was found that there is a lack of knowledge about the use of antibiotics and antimicrobial resistance. This could be due to a lack of information available to the participants. Less than half (49%) of the participants were able to recall receiving information about the unnecessary use of antibiotics for colds or other infections that do not require antibiotics within the past year. Additionally, only 22.6% of participants knew about the World Antimicrobial Awareness Week. Similar findings have been reported in previous studies, where a quarter of Europeans, four in ten Japanese, two in ten Thai adults, and over half of Myanmar participants reported not receiving information about antibiotics within the past year [6,9,23,28]. The findings of the study show that the majority of participants (90.2%) reported a change in their views about the use of antibiotics based on the information they received. Internet and social media were the most commonly accessed sources of information (47.8%), followed by medical doctors (31.5%), and pharmacists (30.5%); which aligns with the sources of American participants [22]. Furthermore, participants expressed that they consider medical doctors (68.9%) and pharmacists (64.7%) to be the most reliable sources of information for future use. However, it is worth noting that 1% of participants expressed disinterest in obtaining information about antibiotics (Figure 2). Across different regions, health workers have consistently been seen as the most trusted and reliable sources of information, possibly due to their effective communication skills, patient care, or various awareness campaigns conducted by them [9,23,28,35,36]. Fortunately, a significant majority of participants (72.2%) indicated their willingness to use antibiotics only under medical supervision. More than half (52.4%) stated that they would no longer use antibiotics without a doctor's prescription, while 44.1% expressed their intention to avoid self-medication with antibiotics, and 31.7% affirmed that they would not hoard antibiotics for future similar symptoms. Only a small percentage (2.3%) of participants expressed their intention to give leftover antibiotics to relatives or friends when they become ill.

This transition from self-medication to a more rational use of antimicrobial agents aligns with the favorable trends observed in previous studies [17]. It can be seen as a positive step towards the Sudanese government's efforts to raise public awareness and enhance understanding of antimicrobial resistance [18]. Additionally, like the Europeans [9] and the Arabs [37], the majority of participants expressed a strong desire for more information about medical conditions for which antibiotics are appropriate and details about antibiotic resistance. Only a small percentage (2.9%) of participants indicated they did not want to receive further information about antibiotics.

The findings gathered from the data and participants' perspectives in this study make this report significant as a national situational analysis. These findings can serve as a basis for suggesting strategies to address the issue of antimicrobial resistance, particularly in relation to implementing comprehensive behavior change communication, education, and training initiatives across all relevant health and non-health sectors at all levels.

Importantly, the Sudanese government has initiated measures to restrict and gradually eliminate the use of antimicrobials as growth promoters and for disease prevention in animals. This aligns with the actions taken by renowned organizations and countries such as WHO, the United States, the European Union, and China [9,38–40]. However, it is concerning that 62.7% of participants in this study were unaware of WHO's

recommendation against using antibiotics for animal growth promotion or disease prevention (Table 3). Additionally, a significant majority (72.7% and 66.6%) of participants were not aware that antibiotics are used for promoting animal growth in Sudan or that the use of antibiotics in animal feed is prohibited in the country. This lack of knowledge is similar to the majority of Europeans (58%) who are unaware of the ban on using antibiotics to stimulate growth in farm animals within the European Union [9]. In contrast to Europeans, where 64% of participants share the belief that antibiotics can be used for treating animals consumed as daily human food [9], only half of the participants in this study held the same perspective (Table 3). A local survey in Khartoum, Sudan revealed that the majority of farmers engage in the common practice of using antibiotics for prevention, and 5% of participants confirmed the use of antimicrobials for promoting animal growth [41]. Furthermore, reports have indicated the presence of antimicrobial residues in food derived from animals, not just in Sudan but also in several other African countries [42].

Approximately half of the participants in this study exhibited a positive attitude, as determined by a score of 26 or higher out of 35. The majority of participants (84.4%) recognized that failure to implement preventive measures would lead to antibiotic resistance, and seven out of ten (70.4%) participants disagreed with the practice of keeping leftover antibiotics for future use without consulting medical professionals. This positive attitude aligns with findings from similar reports in Saudi Arabia, Europe, Thailand, and Romania [8,9,28,30]. A substantial majority (60.5%) of participants acknowledged that there is an issue with antibiotics being overprescribed or sold by doctors and pharmacists. This observed practice in Sudan is believed to stem from challenges in follow-up visits or uncertainty in diagnoses, which may be influenced by cost constraints or inadequate facilities [43]. The participants' attitude towards antibiotic use, resistance, and disposal had a mean score of 25.5 ± 3.97. Notably, female participants displayed a more positive attitude compared to males ($p < 0.001$), which is consistent with findings from another local study [30]. Significantly, younger participants (aged 18–24 years) demonstrated a more positive attitude compared to their older counterparts ($p < 0.001$). Additionally, single participants displayed a more positive attitude compared to married participants ($p < 0.001$) (Table 3). Likewise, both graduates and postgraduates held a more positive attitude compared to those with intermediate or elementary education levels ($p < 0.001$). Students also exhibited a more positive attitude towards antibiotic use and resistance compared to participants in other employment statuses ($p < 0.001$). This relatively positive attitude among younger individuals, those who are single, or those with higher education levels may be attributed to their increased internet and social media usage, which was the preferred source of information for most participants. It could also be attributed to the opportunities and knowledge they have gained. Interestingly, participants' monthly income did not influence their attitude ($p = 0.3$). Conversely, the behaviour of a significant portion of participants (39.7%) who dispose of leftover antibiotics in their household waste poses a considerable challenge to the health authorities, who are actively striving to implement the One Health approach.

There are several limitations to our study that should be acknowledged. Firstly, as the survey was distributed online through social media platforms, it excludes the perspectives of individuals who do not use social media. Additionally, the data collection method relied on self-administered questionnaires on social media, which introduces the possibility of inaccurate data. Furthermore, there is a potential for recall bias as some questions rely on respondents' recollection of antibiotic use in the past year. The study also did not assess prevailing habits regarding antibiotic usage, highlighting the need for cohort studies that employ an annual face-to-face interview approach with a representative sample. Moreover, it is important to note that the findings from this survey cannot be generalized due to several factors. These factors include sample size limitations, potential selection bias, the majority of respondents being from Khartoum (the capital of Sudan), and the predominance of internet users and students (50.2%) among the study participants. Despite these limitations, this study is the first report to address the opinions of the Sudanese population regarding antimicrobial use and resistance, with its framework based on the National Action Plan for antimicrobial resistance covering various aspects of human health, animal health, and the environment. Thus, these findings can provide valuable insights for developing programs that aim to enhance public awareness and understanding of antimicrobial use and resistance, aligning with the principles of the One Health.

Conclusions

This study reveals a concerning situation regarding antibiotic use and resistance. Most respondents reported taking antibiotics in the past year, with a significant number obtaining them without a prescription.

Diagnostic testing before starting antibiotics was not common practice, and a significant portion of respondents self-adjusted or prematurely discontinued their antibiotic treatment. Knowledge about antibiotic use and resistance was found to be insufficient, with less than half of the participants demonstrating good knowledge. Gender, age, marital status, and education level were factors associated with knowledge, while financial situation and residence area had no impact. Moreover, although some participants had received information about antibiotics in the past year, there was limited awareness about antibiotic use in animals. While female, younger, and single participants displayed a more positive attitude towards antibiotic use and resistance; a negative attitude towards the use of antibiotics in animals and the disposal of antibiotics was still prevalent. Despite positive attitudes observed in certain groups, the inappropriate knowledge and practices identified in this study necessitate immediate and sustained action to tackle the escalating problem of antimicrobial resistance. Addressing this issue calls for the development of targeted educational interventions aimed at improving public awareness and knowledge about appropriate antimicrobial use. Equally important is the provision of continuous professional education for healthcare workers. It is imperative to prioritize efforts to educate and engage the public in responsible antibiotic usage to ensure the effectiveness of these vital medications for future generations.

Authors' contributions

MSM, conceptualization, formal analysis, investigation, methodology, writing—original draft preparation; MK, data curation, formal analysis; MTI, funding acquisition, validation; EME, project administration, all resources including study tool, analysis and approval; TE, Preparation of data, organizing the flow of work and manuscript preparation until submission, supervision; MAM, review and editing, supervision. All authors have read and agreed to the published version of the manuscript.

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