Proceedings of the International Conference on Public Health, Vol. 9, Issue 2, 2024, pp.21-37

ISSN 2424-6735 online
DOI: https://doi.org/10.17501/24246735.2024.9202

ANTIMICROBIAL STEWARDSHIP: KNOWLEDGE, ATTITUDE AND PERCEPTIONS OF AGRICULTURAL SCIENCE STUDENTS, IN A TERTIARY UNIVERSITY IN SOUTH AFRICA

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Abstract: The excessive use of antimicrobials in agriculture significantly contributes to the development of antimicrobial resistance in human and animal health, and impacts food safety, food security, and the economy of the country. In the fight against antimicrobial resistance equipping future professionals and developing a coordinated intervention designed to improve use of antimicrobial agents is essential in the agriculture sector. The aim of this study was to investigate the knowledge, attitudes, and perceptions of final-year students enrolled in plant-related agricultural science programs at the University in South Africa on antimicrobial stewardship. A descriptive cross-sectional study design using a self-administered questionnaire was utilized. The participants were final-year students enrolled in agricultural science programs specializing in plant-related studies. Data was analysed using the IBM SPSS version 28 statistical software. A total of 28 participants which was a 68.29% response rate was attained. The participants demonstrated a solid understanding of antimicrobial stewardship as they all correctly described its role; however, some misconceptions regarding important concepts were observed. The participants demonstrated a positive attitude towards antimicrobial resistance prevention, however, 28.6% felt it is an extra burden. They also recognized the global seriousness of antimicrobial resistance and its threat to them and their families, however, only 32.1% of them felt adequately prepared to contribute to the fight against it. Furthermore, there was moderate, positive association between the participants' overall AMS knowledge and their perception. The association between participants' perceptions and attitudes was found to be moderate and negative. No association was found between their AMS knowledge and their attitude. This study underscores the need to focus on perceptions and attitudes in the preparation of future agricultural science professionals on antimicrobial stewardship.

Keyword: Antimicrobial Stewardship, plant health, agricultural science, antimicrobial resistance

Introduction

In agriculture, the use of antibiotics for plant bacterial diseases control such as fire blight in pears and apples and bacterial spots in peaches is a common practice (Verhaegen et al., 2023). These antimicrobials are usually applied to the plants via spraying, resulting in farmers and farm workers at great risk of exposure to these antimicrobials (Bartlett et al., 2013). This practice has been linked to the transfer of resistant genes to humans as new resistant pathogens and resistance determinants have been transmitted by ingestion of contaminated food or by direct contact with carrier from farms (Verhaegen et al., 2012; Chang et al., 2015; Nelson et al., 2019). Furthermore, antimicrobials which are commonly used therapeutically in plants such as tetracycline, triazoles, and streptomycin are also drugs of choice human health (Velazquez-Meza et al., 2022). However, despite being a major public health risk, antibiotics use in horticulture and plant agriculture is poorly monitored and less studied unlike in medical and veterinary medicines (WHO and FAO, 2018). Antimicrobial extensive use and misuse and

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abuse in agriculture, has been associated with antimicrobial resistance (AMR) development in both humans and animals (Chang et al., 2015; Miller et al., 2022). AMR is a natural phenomenon in which microorganisms evolve and become either partially, or fully resistant to an antimicrobial agent rendering it ineffective (Nelson et al., 2019; Miller et al., 2022). AMR is a global public health threat that negatively impacts clinical patient treatment outcomes by making it difficult to treat common infectious diseases and contributing to long-term healthcare stays leading to increased treatment costs (Economou and Gousia, 2015; WHO, 2020; Uddin et al., 2021). Furthermore, according to WHO, (2020), the clinical pipeline for new antimicrobials is dry despite the rapid global spread of multi- and pan-resistant bacteria. Theuretzbacher et al., (2023) accounted this challenge to the costs, time frames and risks associated with development of new antibiotics chemistry; and the withdrawal from the antibiotics field by many large pharmaceutical companies. In the fight against infectious diseases, a multidisciplinary health workforce is one of the essential key approaches as it can effectively eliminate global barriers that exist due to disciplinary silos (Amuguni et al., 2019). Multi-sectoral, multi-agency approaches that go over national and regional borders are essential to deal with public health threats effectively, and this has been evident in the fight against diseases such as Ebola, Avian Influenza and COVID-19 (Heyman et al., 2015; Chen et al., 2020). In 2003 during the pathogenic Avian Influenza H5N1 spread, the term One Health was first used, and it was defined as "a collaborative, multi-sectoral, and transdisciplinary approach- working at the local, regional, national, and global levels to achieve optimal health outcomes recognising the interconnection between people, animals, plants and their shared environment" (MacKenzie and Jeggo, 2019; CDC, 2020). The One Health approach calls for collaboration between various sectors, professional disciplines, and communities in fostering well-being and tackle threats to health and ecosystems while addressing the collective need for healthy food, energy, air and water; acting on climate change; and contributing to sustainable development (Adisasmito et al., 2022). Implementation of this approach in the fight against AMR is essential as Davies et al., (2015) noted that major behaviour changes across all professional health and other sectors, governments, organisations, patients, and the public are crucial fight against AMR. Antimicrobial Stewardship (AMS) is a coordinated intervention designed to improve and measure the appropriate use of antimicrobial agents by promoting the selection of the optimal antimicrobial drug regimen including dosing, duration of therapy and route of administration (Fishman, 2012). This coordinated intervention helps control AMR by optimizing the use of antimicrobials with an emphasis on their responsible and prudent use in both the animal and agriculture sectors (WHO, 2019). According to Ferreira et al. (2022), AMS support and promotion at global, national and local levels requires strong support pillars. The National Department of Health (NDoH) in South Africa has developed and implemented the National Antimicrobial Resistance Strategy Framework in 2015 which is aimed at addressing the growing problem of AMR in the country. The National AMR Strategy Framework illustrated in Figure 1 consists of four key enablers, which are legislative and policy reform for health systems strengthening, education and workforce development, communication, and research.

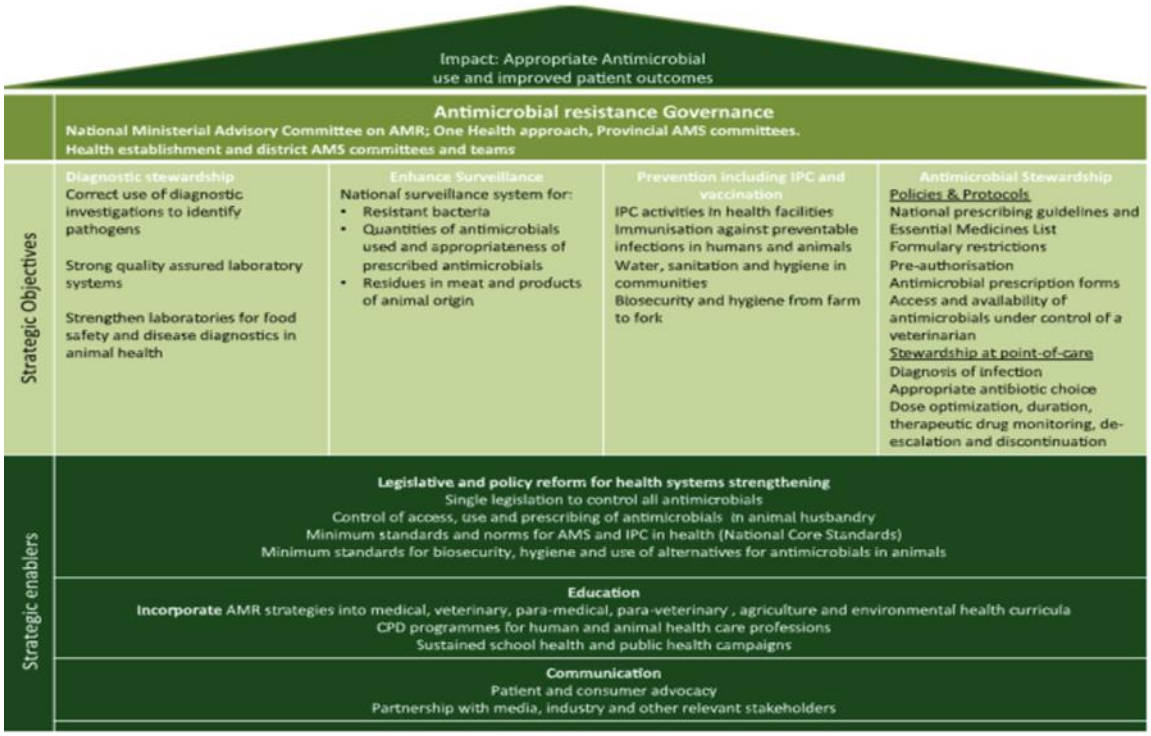

Figure 1: The National AMR Strategy framework with strategic enablers and strategic objectives for antimicrobial resistance governance in South Africa (NDoH, 2018)

In this framework the three pillars identified to be critical in the prevention of AMR were Antimicrobial Stewardship (AMS), Infection Prevention and Control (IPC) and Surveillance enhancement (NDoH, 2017). The education and workforce development strategic enabler of this framework proposes collaborations with training institutions and health professional councils for incorporation of AMR strategies in the undergraduate and postgraduate curriculums (NDoH, 2018). However, the AMR modules incorporation into the curriculum is focusing on medical, nursing, allied health professionals, pharmacy, veterinary and para-veterinary professionals, overlooking plant related agriculture and horticulture. This oversite is concerning as plant agriculture and horticulture have been identified as an emerging area of concern for AMR (WHO and FAO, 2018). AMR infections are estimated to be responsible for 10 million deaths each year globally and an estimated 100 trillion USD accumulative cost to the world's economy by 2050, and if not harmonized this could force approximately 28.3 million people into extreme poverty (O'Neil, 2014). The agriculture sector can play a role in curbing AMR development rate in their field through appropriate use and enforcing compliance with regulatory frameworks for better use and control of antimicrobials (Miller et al., 2022). Moreover, it is important to ensure that future professionals in the field are well informed about AMR and its danger to human health because, according to WHO (2020), even if new antibiotics are produced, if people do not change how they use them, they will also eventually become ineffective. The main objective of this study was to asses knowledge, attitude and perceptions of students enrolled in a plant related agricultural science programme in a Tertiary University in South Africa on Antimicrobial Stewardship.

Materials and Methods

Study site and sample size

The study was conducted amongst final year agricultural science students enrolled for Bachelor of Science: Plant Science, Bachelor of Science Agriculture: Applied Plant and Soil Science and Bachelor of Science Agriculture: Plant Pathology at the University of Pretoria (UP), South Africa. This study site was selected due to the student diversity range and a similar study done at this university on Knowledge, Attitude and Perceptions among veterinary students (Smith et al., 2019). The Faculty of Natural and Agricultural Sciences (FNAS) at the University of Pretoria (UP) is located in the Hatfield campus. The Department of Plant and Soil Science offers the following degrees: Plant Science degree where students can specialize in plant diversity and ecology, plant biotechnology, plant pathology and medicinal plant science; Applied Plant and Soil Sciences degree and students can choose a specialization in agronomy, horticultural science, pasture science and soil science; Plant Pathology and students can choose a specialization in plant biotechnology, microbiology, genetics, plant production, entomology, and plant pathology. The target population were final year students in the Department of Plant and Soil Science registered for BSc: Plant Science, BSc Agriculture: Applied Plant and Soil Sciences degree, and BSc Agriculture: Plant Pathology. This population was targeted as they are enrolled in plant related agriculture and in their final year of study as they have covered majority of the presented curriculum and have already chosen their specialization field. A total of 41 students were enrolled for final year in the in the 2023 academic year, and all these students were set to be included in the study. Only participants who were willing and able to give consent were included, and both male and female students were included.

Study design and data collection

A quantitative cross-sectional study design was applied in this study, and data was collected with the use of a structured questionnaire. The questionnaire was developed and adapted from a quantitative cross-sectional study conducted by Da Silva Carvalho (2021). This questionnaire was found suitable as it successful in determining the knowledge and perception of agriculture students and prehealth biology students on antimicrobial stewardship in the study by Da Silva Carvalho (2021). Self-administered questionnaires were distributed through a Google form link which was loaded on the ClickUP system for participants to access. In the information letter the participants were informed of their right to withdraw from the study and that due to the anonymous nature of the study, withdrawing from participation would not be possible once the questionnaire had been submitted. All individuals who met the inclusion criteria had the same chance of participating in the study.

The questionnaire's face and content validity was confirmed in a pilot study conducted on 5 participant's responses to the questionnaire in the same population of final-year agricultural science students enrolled at the University of Pretoria. The main aim of the pilot study was to determine the consistency and appropriateness of the questions on the questionnaire; therefore, the same criteria for inclusion and exclusion as described for the main study were applied. This exercise led to removal of the question asking participant's race as it was not necessary in the data analysis process and not an important factor in the study. The questionnaire was divided into four parts. The first section collected the participants' demographic characteristics such as level of study, specialization, sex and age. The

second section accessed the participants' knowledge of AMS and one health approach with a combination of two 3-point (yes, no, not sure) and six 5-point (strongly knowledgeable-not knowledgeable; and strongly agree- strongly disagree) Likert type statements. The third section assessed the participants' perceived threat and benefit of AMS with eight 5-point Likert type statements (strongly agree-strongly disagree). The final section assessed the participants' attitude towards AMS, with five 5-point Likert type statements (strongly agree- strongly disagree; highly important-not important; well informed-not at all informed)

Ethical consideration

Approval for this study was obtained from the University of Johannesburg, Faculty of Health Sciences research committee, Department of Environment Ethics Committee, Higher Degrees Committees and Research Ethics Committee (REC-1441-2022). Another approval was obtained from the University of Pretoria Faculty of Agricultural and Natural Sciences Research Committee (NAS 301/2022). The recruitment process was conducted strictly according to the University of Pretoria's information governance policies and rules.

Statistical analysis

Data analysis was conducted using the IBM Statistical Package for the Social Sciences (SPSS) version 28 statistical software. To describe the demographic data of the study population descriptive statistics was performed; summary statistics were performed, and contingency tables were drawn to calculate the frequencies. To determine the strength and direction of association between knowledge and perceptions which are the key theoretical concepts in the study the Spearman's rank of correlation was performed.

Results and interpretation

Demographic characteristics of the participants

A total of 28 (68.3%) of the students responded to the questionnaire, 60.71% of the participants were 21 years of age, and 39.29% were 22 years of age. All the participants were enrolled for their final year of study and most of them were enrolled for Applied Plant and Soil Science, followed by Plant Pathology, and then 10.7% for Plant Science, at 53.6%, 25% and 10.7%, respectively. Unfortunately, 10.7% of the participants did not respond to this question. Lastly, most of the participants were females (60.7%) and 39.3% were males.

Table 1: Frequency table showing the participants 'demographic information from section 1 of the questionnaire

		Frequency	Percentage
Age	21	17	60.7
	22	11	39.3

Sex	Female	17	60.7
	Male	11	39.3
Field of study	Plant Science	3	10.7
	Plant Pathology	7	25
	Applied Plant and Soil Science	15	53.6
	Did not specify	3	10.7

Student's knowledge towards Antimicrobial Stewardship

The study participants (50% strongly agree and 50% agree) accurately described AMS in its role of optimizing antimicrobial use in the animal and agriculture sectors. They all also agreed (28.6% strongly agree and 71.4% agree) that in the fight against AMR communication between human, veterinary medicine, agronomy, ecology, environmental and evolutionary science is essential. Majority of the participants (92.9%) have not attended any webinar, workshop or conference where antimicrobial stewardship (AMS) was discussed. A total of 82.1% (35.7 knowledgeable and 46.4 somewhat knowledgeable) participants felt that they know what AMR and 17.9% were undecided. Furthermore, 82.1% (32.1% strongly agreed and 50% agreed) of the participants agreed that frequent use of antibiotics in the medical and agricultural science field contributed to the antibiotic efficacy, and 17.9% disagreed. When asked if they agreed that there is no connection between antibiotics use and resistance development 64.3% (21.4% disagree and 42.9 strongly disagree) of the participants disagreed and only 35.7% were undecided. However, when asked if antibiotics are used to kill viruses 14.3% of the participants agreed, 71.4% (39.3% disagree and 32.1% strongly disagree) disagreed and 14.3% were undecided. The details of the participant's knowledge as interpreted above is illustrated in table 2.

Table 2: Frequency table for data on participant's knowledge about Antimicrobial Stewardship

		Frequency	Percentage
Antimicrobial stewardship helps to control antimicrobial resistance by optimizing the use of antimicrobials in the animal and agriculture sectors.	1. Strongly Agree	14	50
	2. Agree	14	50
	3. Undecided	0	0
	4. Disagree	0	0
	5. Strongly Disagree	0	0
Have you attended any webinar, workshop, or conference where antimicrobial stewardship was discussed?	1. Yes	2	7.1
	2. No	26	92.9
	3. Not Sure	0	0
Rate your overall level of knowledge of antimicrobial resistance	1. Strongly Knowledgeable	0	0
	2. Knowledgeable	10	35.7
	3. Somewhat Knowledgeable	13	46.4
	4. Undecided	5	17.9
	5. Not Knowledgeable	0	0
Frequent use of antibiotics in medicine and agriculture decreases the efficacy of antibiotics	1. Strongly Agree	9	32.1
	2. Agree	14	50
	3. Undecided	0	0
	4. Disagree	5	17.9
	5. Strongly Disagree	0	0

Antibiotics are powerful medicines to kill viruses	1. Strongly Agree	0	0
	2. Agree	4	14.3
	3. Undecided	4	14.3
	4. Disagree	11	39.3
	5. Strongly Disagree	9	32.1
There is no connection between taking antibiotics and the development of resistant organisms	1. Strongly Agree	0	0
	2. Agree	0	0
	3. Undecided	10	35.7
	4. Disagree	6	21.4
	5. Strongly Disagree	12	42.9
Communication between human medicine, veterinary medicine, agronomy and ecological, environmental and evolutionary science is essential in the fight against antimicrobial resistance.	1. Strongly Agree	8	28.6
	2. Agree	20	71.4
	3. Undecided	0	0
	4. Disagree	0	0
	5. Strongly Disagree	0	0

Assessment of perceived threat and benefit of AMS

Majority of the participants 71.4% (14.3% strongly agree and 57.1% agree) felt that AMR will likely affect their health and that of their family's health and 28.6% strongly disagreed. Overall, 71.4% (21.4% strongly agree and 50% agree) of the participants agree that AMR is a problem globally and in South Africa, while 28.6% were undecided. Only 42.9% (3.6% strongly agree and 39.3% agree) of the participants agree that the use of antibiotics in agriculture is a danger to human health, 46.4% (21.4% strongly disagree and 25 disagree) disagreed and 10.7% were undecided. Majority of the participants 78.6% (28.6% strongly agree and 50% agree) acknowledged that antibiotics misuse will likely lead to resistance in the future and 21.4% disagreed. All the participants (28.51% strongly agree and 71.43% agree) of the participants believe that students in the agricultural science field should receive training on the appropriate use of antibiotics. The details of the participant's AMS perceived threat and benefit is interpreted above also illustrated in table 3.

Table 3: Frequency table for data on participant's perception of Antimicrobial Stewardship

		Frequency	Percentage
Antibiotic resistance will affect your and your family's health	1. Strongly Agree	4	14.3
	2. Agree	16	57.1
	3. Undecided	0	0
	4. Disagree	0	0
	5. Strongly Disagree	8	28.6
Antimicrobial resistance is a major problem in South Africa and globally.	1. Strongly Agree	6	21.4
	2. Agree	14	50.0
	3. Undecided	8	28.6
	4. Disagree	0	0
	5. Strongly Disagree	0	0

The use of antibiotics in farming is a danger to human health	1. Strongly Agree	1	3.6
	2. Agree	11	39.3
	3. Undecided	3	10.7
	4. Disagree	7	25
	5. Strongly Disagree	6	21.4
If misused, antibiotics are less likely to work in the future	1. Strongly Agree	8	28.6
	2. Agree	14	50.0
	3. Undecided	0	0
	4. Disagree	6	21.4
	5. Strongly Disagree	0	0
All agricultural science students should get training on the appropriate use of antibiotics.	1. Strongly Agree	8	28.51
	2. Agree	20	71.43
	3. Undecided	0	0
	4. Disagree	0	0
	5. Strongly Disagree	0	0

Assessment of participant's attitude towards Antimicrobial Stewardship

All the participants (39.3% strongly agree and 60.7% agree) of the participants felt that a positive attitude towards AMS is essential amongst agricultural science students. Majority of the participants 71.4% (39.3% strongly agree and 32.1% agree) agreed that AMS knowledge is essential amongst agricultural science students, 28.6% disagreed. All the participants agreed that being informed about AMR in their career is important (60.7% highly important, 3.6% important and 35.7% somewhat important). However, only 71.4% of the participants felt informed (3.6% well informed, 21.4% informed and 46.4% somewhat informed) concerning the use of antimicrobials in plant health, while 7.1% felt they were not at all informed on the topic, and 21.4% were undecided. Majority of the participants 71.5% (42.9% strongly disagree and 28.6% disagree) felt that antimicrobial use in plant health is not an extra burden of work, while 28.6% agreed that it is an extra burden of work. However, majority of them 92.8% (7.1% strongly agree and 85.7% agree) of the participants agreed that students as the future workforce can contribute to the fight against AMR in the country and only 7.1% disagreed. Most of the participants 85.2% (28.6% strongly agree and 56.6% agree) acknowledged that there is a need to control and monitor antibiotics dispensation without prescription, while 7.4% disagreed and a further 7.4% were undecided. Only 32.1% (10.7% strongly agree and 21.4% agree) of the participants felt they were well prepared to positively contribute to the fight against AMS, while 46.4% (21.4 strongly disagree and 25% disagree) felt unprepared and 21.4% were undecided. Majority of the participants 92.8% (7.1 strongly agree and 85.7 agree) that students as future workforce can contribute to the work being done to control antimicrobial resistance in South Africa, while 7.1% disagreed. The details of the participant's attitude towards AMS is interpreted above also illustrated in table 4.

Table 4: Frequency table for data on participant's attitude towards antimicrobial stewardship.

	Frequency	Percentage

A positive attitude towards antimicrobial stewardship is essential amongst agricultural science students.	1. Strongly Agree	11	39.3
	2. Agree	17	60.7
	3. Undecided	0	0
	4. Disagree	0	0
	5. Strongly Disagree	0	0
Antimicrobial stewardship knowledge is essential amongst agricultural science students.	1. Strongly Agree	11	39.3
	2. Agree	9	32.1
	3. Undecided	0	0
	4. Disagree	8	28.6
	5. Strongly Disagree	0	0
How important do you think it is to be informed about antimicrobial resistance in your career?	1. Highly Important	17	60.7
	2. Important	1	3.6
	3. Somewhat Important	10	35.7
	4. Undecided	0	0
	5. Not Important	0	0
How well-informed do you think you are concerning antimicrobial use in plant health?	1. Well Informed	1	3.6
	2. Informed	6	21.4
	3. Somewhat Informed	13	46.4
	4. Undecided	6	21.4
	5. Not at all informed	2	7.1
In your opinion management of antimicrobial use in plant health is an extra burden of work.	1. Strongly Agree	0	0
	2. Agree	8	28.6
	3. Undecided	0	0
	4. Disagree	8	28.6
	5. Strongly Disagree	12	42.9
Students as future workforce can contribute to the work being done to control antimicrobial resistance in South Africa.	1. Strongly Agree	2	7.1
	2. Agree	24	85.7
	3. Undecided	0	0
	4. Disagree	2	7.1
	5. Strongly Disagree	0	0
Dispensation of antibiotics without prescription should be closely controlled and monitored.	1. Strongly Agree	8	28.6
	2. Agree	16	56.6
	3. Undecided	2	7.4
	4. Disagree	2	7.4
	5. Strongly Disagree	0	0
Do you feel you have been well prepared to contribute to the fight against antimicrobial stewardship positively	1. Strongly Agree	3	10.7
	2. Agree	6	21.4
	3. Undecided	6	21.4
	4. Disagree	7	25
	5. Strongly Disagree	6	21.4

Students as future workforce can contribute to the work being done to control antimicrobial resistance in South Africa.	1. Strongly Agree	2	7.1
	2. Agree	24	85.7
	3. Undecided	0	0
	4. Disagree	2	7.1
	5. Strongly Disagree	0	0

Assessment of findings in the context of the conceptual framework

To determine strength and direction of association amongst the three theoretical concepts knowledge, attitude and perceptions in this study a Spearman's rank order was performed. There was no association between the participant's knowledge and attitude in this study as the Spearman's correlation was not statistically significant. The association strength was moderate and positive between the participant's knowledge and their perception in the current study. The correlation strength between the participant's perceptions and their attitude was moderate and the association in the current study was negative.

Table 5: Spearman's correlation for participant's knowledge, perceptions and attitude variables showing the p-value and the 95% Confidence Intervals.

Variables		Correlation coefficient	p-value	95% Confidence intervals
Knowledge variable	Attitude variable			
Antimicrobial stewardship helps to control antimicrobial resistance by optimizing the use of antimicrobials in the animal and agriculture sectors.	A positive attitude towards antimicrobial stewardship is essential amongst agricultural science students?	-.073	.712	-.444 - .319
Knowledge variable	Perceptions variable			
Antimicrobial stewardship helps to control antimicrobial resistance by optimizing the use of antimicrobials in the animal and agriculture sectors.	Antibiotics resistance will affect you and your family's health	.438	.020	.066 - .703
Perceptions variable	Attitude variable			
Antibiotics resistance will affect you and your family's health	A positive attitude towards antimicrobial stewardship is essential amongst agricultural science students?	-.408	.031	-.684 - -.029

Discussion

The main purpose of this study was to assess knowledge, attitude and perceptions on antimicrobial stewardship (AMS) among final-year students enrolled in plant related agricultural science programme.

This research was conducted within the framework that if the future workforce in any field is adequately equipped on AMS's purpose and aim as reflected in their knowledge, perceptions and attitudes, they will significantly contribute in the fight against it. AMS's main aim is to aid in the control of antimicrobial resistance (AMR) by optimizing the use of antimicrobials with an emphasis on their responsible and prudent use in the animal and agriculture sectors (WHO, 2019). In assessing the level of knowledge on AMS amongst the participants several questions on AMR, the use of antimicrobials, and the purpose of AMS were asked. The participants said they were knowledgeable on AMR (82.1%), and all agreed that AMS helps to control AMR by optimizing the use of antimicrobials in the animal and agriculture sectors. They were then asked on the use of antibiotics and the development of resistance, so to further their knowledge of resistance development. Majority of the participants (82.1%) agreed that frequent use of antibiotics in the medical and agricultural science field contributed to the antibiotic efficacy, but only 64.3% of them knew that there is no connection between antibiotics use and resistance development. Similar to this study, a high knowledge of antimicrobial use was reported in a study by Singh (2016) among health professional students in South Africa (SA) and amongst final-year medical students in Malawi by Kamoto et al. (2020). However, a study by Fasina et al., (2020), amongst pre-final and final-year veterinary students from South Africa, Nigeria and Sudan reported a poor to average knowledge of antimicrobial stewardship. Another study in Zambia by Kalungia et al. (2019), also demonstrated poor AMS knowledge among participants. The number of participants (14.3%) who indicated that antibiotics could be used to treat viruses and the other 14.3% who were undecided are a great concern, as this misinformation according to Ayukekbong et al. (2017), contributes significantly to antibiotic misuse and the development of antimicrobial resistance. To evaluate the knowledge and perceptions of antimicrobial resistance, Smith et al. (2019) conducted a study among final-year veterinary students in South Africa. The study revealed gaps in translating theoretical concepts to clinical practice among the students. This might be a similar problem in the current study as some students said there is no connection between antibiotics use and development of resistance and also said antibiotics are a powerful medicine to kill viruses instead of bacteria.

Chin and Mansori (2019), emphasize that when an individual perceives a health problem as serious, they will engage in behaviours to prevent it from occurring or reduce its severity. Majority of the participants (78.6%) agreed that if antibiotics are misused, they will likely not work in the future, and 42.9% of them acknowledged that antibiotic use in their field is dangerous to human health. Furthermore, 71.4% of them believe that their health and that of their family members can be affected by AMR. When an individual perceive that they are susceptible to a particular health problem, they will likely engage in behaviour to mitigate their risk of developing it (Jones et al., 2015; Ancillotti et al., 2018; Vaillant et al., 2019). Similar to the current study in the study by Kalungia et al. (2019), it was reported that the majority of the participants perceived AMR as a problem. However, a study by Da Silva Carvalho (2021) showed that agricultural science students perceived antibiotic resistance as less threatening in their field of study. In a study by Wasserman et al. (2017) a high perceived threat towards AMR and perceived susceptibility was recorded and this was believed to likely cause the participants to actively engage in behavior to mitigate their risk of developing AMR (Jones et al., 2015; Ancillotti et al., 2018; Vaillant et al., 2019).

All the participants in this study acknowledged that it is essential to have a positive attitude towards AMS, they also felt it was important to be informed about AMR in their career field, and majority (71.4%) of them felt that AMS knowledge is essential in their field. Participants in the current study demonstrated a good overall attitude towards AMS, and according to Singh (2016), attitude can be used to determine a one's acceptance of the AMS and AMR concepts. In a study by Jairoun et al. (2019b) among university students in the United Arab Emirates (UAE) and another conducted by Fetensa et al. (2020), graduating health science students demonstrated a good attitude towards AMR and antibiotics use in general. Several studies identified a positive learning attitude and willingness to participate in the fight against AMS amongst the students (Wasserman et al., 2017; Kalungia et al., 2019; Kamoto et al., 2020). Most participants (71.4%) acknowledged that AMR is a global problem. Murray et al. (2022), emphasizes that in the prevention of AMR's development and spread, determination to improve antimicrobial use governance is essential. In the current study majority (85.2%) of the participants agreed that antibiotic dispensation needs to be controlled and closely monitored. A study by Welsh et al. (2019) suggested that easily available over-the-counter antibiotic usage in the farming sector in most unindustrialized countries influences the level and rate of antibiotic usage in the sector and exacerbates AMR. Moreover, most participants (92.8%) agree that they can contribute to the AMR mitigation as the future workforce in the agricultural science field. Miller et al. (2022) emphasizes that agricultural science structures can play a key role in the fight against AMR by conforming to appropriate use, guidelines, strengthening and enforcing compliance with regulatory frameworks for better use and control of antimicrobials. In a study by Lubwama et al. (2021), even though students knew a lot about antimicrobial resistance, they still preferred that the topic be included in their undergraduate curriculum training. Therefore, identifying focus areas in the incorporation of AMS in the curriculum of plant related programmes at the institutions of higher learning is essential in sensitising the future workforce on the topic of AMR. However, despite all this sound knowledge, high level of perceived threat, and willingness to contribute towards AMR mitigation only a few (32.1%) of the participants felt they were well prepared to contribute to the fight against AMS positively. In a study conducted among medical students, Wasserman et al. (2017) emphasized that when the students feel inadequately prepared to deal with AMR, they may contribute to antibiotic misuse and antibiotic resistance.

To understand the logical order of associated concepts in the current study, the conceptual framework as proposed by Muleme et al., (2017) and Liu et al., (2019) was used. Spearman's Rank correlation coefficient which is a statistical test used to determine the correlation strength between two variables was employed to determine the strength and direction of association between the three key theoretical concepts in this study (Song and Park, 2020). This nonparametric method is employed in small sample sizes (less than 30), as is the case in the current study (Song and Park, 2020). The correlation between the participant's knowledge and perception was found to be significant, positive and moderate. Therefore, the monotonic relationship between them showed that as the participant's knowledge increases their perception on AMS was also increasing. Lippold, Coffman and Greenberg (2014), noted that knowledge and perception variables can be influenced by many confounding variables, which may affect the main relation between them. The relationship between the participant's perceptions and their attitude was found to be significant, negative and moderate. This means that there is a monotonic relationship between them and as participant's perceived threat increases their attitude towards AMS decreases. The relationship between participant's knowledge and their attitude was not statistically

significant and therefore, there is no association between these two concepts in the current study. Amongst the three key theoretical concepts, correlation was found between the participant's knowledge and their perceptions and between their perceptions and their attitude towards antimicrobial resistance.

Conclusion

In this study, knowledge relates to the extent of awareness and the participants' ability to understand antimicrobial use, misuse, and control; attitude related to their awareness and their willingness or readiness to deal with or participate in AMR prevention measures; and perception related to their acknowledgement of the seriousness and the consequences of AMR, as well as their sensitivity towards it. The participants exhibited a good awareness and understanding of AMR. However, some needed to gain more knowledge as they had misinformation, which can contribute to antibiotic misuse and antimicrobial resistance development. The participants showed a willingness and a positive attitude towards participating and playing a role in AMR prevention. Moreover, several felt it was essential to be informed about AMR in their study field. The participants acknowledge the seriousness of AMR and that they and their families might be directly affected by it. However, most participants felt they needed more preparation to contribute to the fight against AMS positively. Lastly, in this study as the participants showed more awareness and understanding of antimicrobial use, misuse, and control they also demonstrated an increased acknowledgement of its seriousness and the consequences of AMR. However, as the participant's showed more sensitivity towards the seriousness of AMR their attitude which encompasses willingness and readiness to deal or participate in AMR prevention measures decreased. It is, therefore, essential to ensure that the future workforce is not only knowledgeable but has a positive attitude and perception towards AMS to avoid antimicrobial misuse.

Acknowledgements

The authors would like to appreciate the support and participation of all the final year students at the University of Pretoria.

Declaration of Interest Statement

The authors declare that they have no conflict of interests.

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