

Master of Pharmacy students' knowledge and awareness of antibiotic use, resistance and stewardship

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Abstract

Background. Antibiotic resistance has become a global public health concern. In this study we investigated the knowledge and awareness of antibiotic use, resistance and stewardship, held by the pharmacy students currently studying at the University of Brighton.

Study design. This was a cross-sectional, online survey, and email invitations to participate were sent to all students attending our Master of Pharmacy (MPharm) course (n = 583). Students' knowledge was assessed with 29 items; responses for these were totaled before comparison among students. Comparison of scores between groups of students was performed using the Kruskal-Wallis or the MannWhitney test, as appropriate.

Results. The response rate was 32%. The overall median knowledge score was 7.9. There was a statistically significant difference in knowledge scores between years of study ($p = 0.02$), particularly between year of study 1 (7.6) and 4 (8.3). A statistically significant difference was found between the knowledge scores of male (8.4) and female (7.9) students ($p = 0.03$). Most students believed a strong knowledge of antibiotics, and microbiology and infection control is important for their pharmacy careers and more than 90% agreed that antibiotic resistance will be a greater clinical problem in the future.

Conclusions. Although the MPharm students studied achieved good overall knowledge scores, a significant proportion showed a lack of understanding with regards to some important aspects of antibiotic resistance mechanisms, factors promoting the emergence and spread of antibiotic resistance, and antibiotic stewardship policies.

Keywords: Antibiotics; Antibiotic resistance; Antibiotic stewardship; Pharmacy students

Conflict of interest and financial disclosure statements None

Specific Contribution to Literature Pharmacists are essential in the battle against antibiotic resistance, and in promoting the implementation of effective antibiotic stewardship programs. Educational gaps in pharmacy education on antibiotics have been identified in a few studies from the

USA and other countries but, as far as we are aware, no similar study has, to date, been carried out in Europe. In this study we investigated the knowledge and awareness of antibiotic use, resistance and stewardship, held by the pharmacy students currently studying in a British university, and their perceptions of the education they receive on these topics. This survey may be replicated in other schools in the UK and abroad in order to collect a wider range of standardized data among pharmacy students.

Introduction

Antibiotic resistance has become a global public health concern, causing the deaths of more than 25,000 people every year in Europe and creating a significant and growing economic burden worldwide.¹ As a consequence, and in an attempt to try to contain and mitigate the development of antibiotic resistance, antimicrobial stewardship programs have been developed worldwide.² The concept of antimicrobial stewardship encompasses a wide range of interventions intended to achieve the optimisation of antimicrobial therapies for individual patients and the prevention of overuse and misuse of these drugs. Key areas for action include the optimisation of antibiotic prescribing, the improvement of infection prevention procedures, diagnostics and control practices, the search for new antimicrobial drugs and therapies, and the improvement of professional education and training. It is particularly relevant that the World Health Organization (WHO) emphasizes the relevance of health-related undergraduate training courses in nurturing prudent prescribing and use of antibiotics.¹

Educational inquiry studies relating to students' knowledge base regarding antibiotic use and the development of resistance are a recent 'hot-topic', and have, to date, mostly been carried out among medical students in Europe,³⁻⁶ the USA,^{7,8} and developing countries.^{9,10} A significant proportion of the medical students surveyed in these studies demonstrated marked gaps in their understanding of appropriate antibiotic usage and the processes involved in the development of antibiotic resistance, and in general, wanted more instruction in these subject areas. Educational deficiencies with respect to an appreciation of the antibiotic drug class in general, and their safe use, also seem to be widespread among students in scientific fields such as biology, nursing and other health-related fields.

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Given their vital role in healthcare systems in terms of the information and access to medicines they provide, pharmacists are essential in the battle against antibiotic resistance, and in promoting the implementation of effective antibiotic stewardship programs in order to support the more rational use and control of antimicrobial drugs.¹⁴⁻¹⁸ However, and somewhat surprisingly, almost no information is available about the knowledge-base and perceptions regarding antibiotics among this professional group. Educational gaps in pharmacy education on antibiotics and their use have been identified in studies from India,¹⁹ Trinidad and Tobago,²⁰ Malaysia,^{21,22} and USA,²³ but, as far as we are aware, no similar study has, to date, been carried out in Europe. In these studies, one common misconception found was the belief that antibiotics are an effective way to treat the common cold and other viruses.

Nevertheless, most pharmacy students believed a strong knowledge of antibiotics was important for their careers and requested more education in this area.²³

In this study, we aimed to learn about our Master of Pharmacy (MPharm) students' knowledge and awareness of antibiotic use, drug resistance and stewardship, and their perceptions about the education they receive on the course relating to these topics.

Methods

Study design, population and ethics

This study was a cross-sectional, online survey designed to evaluate MPharm students' knowledge and awareness of antibiotic use, resistance and stewardship. Survey invitations were sent to all MPharm students attending years 1 (n = 172), 2 (n = 137), 3 (n = 136) and 4 (n = 138). Ethical approval was granted by the Centre for Learning and Teaching Research Ethics Committee of the University of Brighton. The purpose of the study was explained to students in the invitation email, together with a participant information sheet. Students were discouraged from using any additional resources such as guidelines or electronic applications when answering the survey. The survey was anonymous, and the students were informed that it was non-compulsory and would have no impact on their grades. There was no monetary incentive to participate. Online submission of the completed survey by student participants was accepted as consent.

Survey instrument and administration

A 51-item questionnaire was developed after a literature review of comparable studies,^{4-6,19-21,23} composed of five sections and validated by a pilot study on 15 MPharm students for readability, relevance of questions and length (see questionnaire in Supplementary Material). The first part of the questionnaire investigated the demographic characteristics of the participants. The second and third parts assessed the general level of knowledge about antibiotics among the participants, and specific knowledge and awareness regarding antibiotic resistance and antibiotic stewardship, respectively. The fourth part of the study addressed students' perceptions about the education they received on antibiotics. Finally, the last part of the questionnaire provided the students with an option to give additional suggestions or opinions about the different topics covered in the study. Both a three points scale ("Disagree", "Not sure" and "Agree"), and yes/no responses were used. The final survey was self-administered using the Bristol Online Services tool (www.onlinesurveys.ac.uk) between the 10th

and 29th of February 2016, after most teaching and learning activities regarding antibiotics had taken place for the first and second years of study. Students received an email inviting them to participate in the survey and reminders were sent out after both one and two weeks.

Statistics

A descriptive analysis of the sample was performed, considering the distribution of gender and year of study, age range, UK residency status, intended practice area, and association with relatives or close friends working in health-related fields. The results regarding knowledge were dichotomized as "Correct" versus "Incorrect" by grouping the three points scale as appropriate.^{5,6,23} For example, for question 9 (aspirin is an antibiotic), the option "Disagree" was considered "Correct", and the options "Agree" and "Not sure" were merged as "Incorrect". The percentages of correct answers were calculated for each question for all student cohorts and subgroups, as appropriate. Additionally, an overall knowledge score was estimated for each respondent by calculating the proportion of correct answers for the 29 knowledge-based questions (questions 8 to 19 and 24 to 40) and representing this on a scale between 0 and 10 (10 shows good knowledge and 0 poor knowledge).^{8,19,20,23} Knowledge scores, reported as median (25%-75% interquartile range) were computed for each year of study, male and female students, and other groups of students as appropriate. Comparison of knowledge scores between groups of students was performed using the Kruskal-Wallis test with pairwise comparisons adjusted by the Bonferroni correction for multiple tests (for comparisons between the four years of study), or the Mann-Whitney test (for comparisons between genders, students with and without antibiotics training prior entering pharmacy, and students with and without relatives working in health-related fields). A 0.05 significance level was used. Statistical analyses were performed using the software SPSS Statistics 24 (IBM, USA).

Results

Characterization of respondents

A total of 583 students attending the first, second, third and fourth years of the MPharm course were invited by email to participate in an anonymous and non-compulsory online survey. The overall response rate was 32% (n = 185), ranging from 24% (n = 42) in year 1 to 43% (n = 58) in year 3

(Table 1). Detailed demographic characteristics of respondent students, per year of study, are shown in Table 1.

Knowledge and awareness of antibiotics' use, resistance and stewardship

Overall, 98% (n = 180) of the students had heard about antibiotic resistance, and 97% (n = 179) had discussed this topic during their MPharm course. Only 64% (n = 119) of the students had heard about antibiotic stewardship, and 58% (n = 108) stated that they had discussed this topic during their course. Nevertheless, awareness of the term 'antibiotic stewardship' improved from 21% (n = 9) for students in their first year of study to 79% (n = 46) and 79% (n = 30), for students in years 3 and 4, respectively.

A summary of the answers to questions about students' knowledge and awareness of antibiotics use, resistance and stewardship is shown in Table 2. Most students (90%; n = 166) responding provided answers to all questions, and 8% (n = 15) responded to 28 questions. The overall median knowledge score was 7.9 (Table 2). There was a statistically significant difference in knowledge scores between years of study ($p = 0.02$). Scores improved from year 1 of study to year 4, with statistically significant differences of knowledge scores between year 1 and 4 ($p = 0.02$) (Figure 1A). A statistically significant difference was found between knowledge scores of male students [median 8.4 (7.2 - 9.1)] and female students [median 7.9 (6.9 - 8.6)] ($p = 0.03$) (Figure 1B). No statistically significant differences were found between students with [7.9 (6.9 - 8.6)] or without [7.9 (6.9 - 8.8)] relatives or close friends working in health-related fields ($p = 0.42$) (Figure 1C), or between students with [8.3 (7.6 - 8.9)] or without [7.9 (6.9 - 8.6)] education or training on antibiotics prior to entering the pharmacy school ($p = 0.07$) (Figure 1D). The Cronbach's alpha for this knowledge test among our students was 0.7.

Perceptions of education about antibiotics

The responses given to questions about students' perceptions of the education received during the MPharm degree course on antibiotics are summarized in Table 3. Most students (95%; n = 176) provided responses to all questions about education perceptions.

Discussion

Response rates and demography

The overall response rate of 32% in our study, although relatively low, is comparable to those seen in other studies which used online surveys to assess medical and pharmacy students' knowledge of antibiotics.^{4,5,7,8,23} These rates ranged from 20% among medical students at a French school,⁴ to approximately 61% among USA medical students,⁸ but were below 40% in most studies.^{5,7,23} About 70% of our student respondents were female and 30% were male, which reflected the gender ratio of the students in the MPharm course (61% female and 39% male).

Knowledge and awareness of antibiotics' use, resistance and stewardship

Students showed a good level of general knowledge when answering the survey questions, with a mean of 23 correct answers out of 29 questions (corresponding to an overall median knowledge score of 7.9). Knowledge scores increased significantly from the first year of study to year 4, after the students had attended several education sessions on antibiotics and their use. Students with prior knowledge or training on antibiotics prior to entering the MPharm course did not have statistically significant better knowledge scores. This result agrees with data from a previous recent survey in the USA, carried out among medical students, where no significant associations were found between knowledge score and research experience or pharmacology education relating to antibiotics prior to entering medical school.⁸ A statistically significant difference was found between knowledge scores of male and female students. Previous comparable antibiotic surveys with medical and health-related students, including pharmacy students, produced inconsistent results regarding the association between higher knowledge scores and gender.²²

Most responding students were aware that antibiotics have a role in the treatment of bacterial infections (97%) but not viral infections (93%), and were aware of the potential adverse side effects of some of these drugs, such as allergic reactions (97%) and the risk of increased occurrence of secondary infections after the elimination of the normal microbiota present in the body (82%). Notwithstanding the overall good knowledge scores, we did however find some significant education gaps among our student cohorts. In particular regarding the mechanisms and factors involved in promoting the development and spread of antibiotic resistance, and an appreciation of antibiotic stewardship policies. Almost all year 3 and 4 students stated that they had discussed antibiotic resistance topics during their MPharm course, and more than 96% knew the meaning of antibiotic resistance (Table 2), however, only 62% and 74% of the year 3 and year 4 students, respectively,

were aware that exposure to antibiotics appears to be the principal risk factor for appearance of antibiotic-resistant bacteria (Table 2). Population-level studies clearly point to higher levels of resistance in countries that have higher rates of antibiotic prescribing,²⁴ and the isolation of antibiotic-resistant bacteria from individual patients seems also to be strongly correlated with both the number and duration of antibiotic therapy courses the patients had in the previous 12 months.²⁵ Whilst other significant risk factors include the inappropriate use of antibiotics (correctly identified as an important factor by most students), only 29% (year 3) and 26% (year 4) of the students were aware that even the correct use of antibiotics can eventually lead to the development of resistance (Table 2). This finding agrees with that from a similar large survey in the USA in which only 46% of the pharmacy students sampled appeared aware that appropriate use of antibiotics can lead to resistance.²³ We also investigated the students' awareness of what behaviors constituted 'inappropriate use'. Most students knew that antibiotics should not be used to reduce any kind of pain and inflammation (> 90%), to treat colds and coughs (> 95%), or be usually employed prophylactically as a preventive measure against future infections (83%). Nevertheless, a significant proportion of students were unaware of other important factors promoting the emergence and spread of antibiotic resistance, such as the excessive prescribing of broad-spectrum antibiotics, stopping treatments when symptoms improved rather than completing the course, and poor infection control practices by healthcare professionals. These factors were overlooked by more than 30% of year 3 and 4 students (Table 2). In comparison, a higher proportion of pharmacy students in the USA seemed to be more aware of some of these risk factors.²³ The excessive use of antibiotics in livestock production and agriculture was also overlooked as an important risk factor for the development of antibiotic resistance by almost 30% of our students. Currently, more than half of all antibiotic use globally is related to animal production activities such as livestock farming and aquaculture,²⁶ and direct links between antimicrobial resistance in livestock and in humans have been well demonstrated.²⁷ As with the majority of pharmacy students surveyed in the USA,²³ most of our students agreed that antibiotics are overused both nationally and internationally in healthcare (Table 2), an issue that has been widely discussed by the scientific and medical community,²⁸ and more recently in considerable detail in the non-scientific media.

A significant proportion of students surveyed did not correctly answer the two questions which specifically addressed mechanisms of antibiotic resistance. Approximately 35% of year 3 and 4

students incorrectly agreed that bacterial beta-lactamase enzymes inactivate aminoglycoside antibiotics, and were unaware of the role of bacterial efflux pumps as an important mechanism of resistance (Table 2).

Given that antibiotic stewardship forms part of the MPharm curriculum in year 2, it was both surprising and concerning that only 80% of the third and fourth year MPharm students had heard about antibiotic stewardship, and only 60% were able to identify the statement "Antibiotic stewardship is a phenomenon by which a bacterium gains resistance to an antibiotic" as incorrect. In a previous comparable study among medical students in the USA, an even lower proportion of students (40%) recognized the term "antimicrobial stewardship".⁸ Nevertheless, most of our students (> 85%) agreed with the statements which described common antibiotic stewardship policies, such as changing the treatment to narrow-spectrum antibiotics as soon as possible, or the improvement of diagnostic technologies for infectious diseases (Table 2). Approximately 82% of our students agreed that improved healthcare hygiene helps to control the emergence and spread of antibiotic resistance. It is remarkable that about one quarter of the medical students in previous comparable studies in Europe believed poor hand hygiene was not important for mitigating the spread of antibiotic resistant pathogens.^{4,5} About half of our students were unaware of the so-called discovery void in the development of new antibiotic drugs,²⁹ and consequently the difficulties we will face meeting the need for new antibiotics in the future. This compares with previous surveys in several USA medical and pharmacy schools, where over 75% of the students were aware of this situation.^{8,23} Nevertheless, more than 90% of the students agreed that antibiotic resistance will be a greater clinical problem later in their future careers, a figure similar to that found in other comparable surveys among European medical students.^{4,5}

Perceptions of education about antibiotics

The students surveyed revealed a variety of different perceptions regarding the education they received in terms of antibiotics-related material. In years 3 and 4 of study, fewer than 50% of the students felt that their education had prepared them adequately to be able to select the most adequate antibiotic and therapeutic regimen for a specific infection. In contrast, more than 77% of the students felt that their education had prepared them to understand the mechanisms of antibiotic resistance. However, it should be noted that a lower proportion of these students answered correctly to the survey questions regarding mechanisms of antibiotic resistance, showing that a self-perception

of sufficient education received may not directly correspond to knowledge. Almost 40% of our students surveyed did not feel adequately prepared to handle a patient demanding antibiotic therapy that is not indicated, a potential education need that was also found among USA pharmacy students.²³

Most students (84%) declared they would like to receive more education on antibiotic use, resistance and stewardship, which is similar to the findings of other comparable studies with medical and pharmacy students in Europe and the USA.^{4,5,7,8,23} A lower proportion of our students (63%) wanted more education on microbiology and infection control, although these items cannot be easily separated from the topic of antibiotics. Nevertheless, most students declared that a strong knowledge of antibiotics (99%) and microbiology and infection control (87%) in general is important for their future pharmacy careers. A strong knowledge of antibiotics was also considered important by the vast majority of pharmacy students surveyed in the USA.²³ Also of note, 85% of the students of another school of pharmacy in the UK recently surveyed, responded that they considered microbiology a discipline relevant to their careers.³⁰ This is particularly important since the perception by students that a specific subject is relevant to their professional careers is likely to make them more motivated to engage in these parts of the curriculum.³⁰

Teaching and learning on antibiotics

As a result of this study we have identified a number of important and relevant education gaps among our current students and need to address these by designing improved educational interventions. These interventions will primarily focus on microbiology, infectious diseases, clinical pharmacology, and antibiotic stewardship, with an emphasis on prudent and appropriate antibiotic use. Education on the management of demanding patients is also relevant. Indeed, a recent survey in England has found that patients were less satisfied in practices with prudent antibiotic prescribing.³¹ An interesting option to deliver these and other relevant contents would be the implementation of a series of hands-on practical workshops and other active learning activities under a Pharmacy School's "Antibiotic Awareness Week". This could be timed to coincide with the "World Antibiotic Awareness Week", an initiative promoted by the World Health Organization.³² Ideally the intervention should take place during the third year of study of the MPharm course since most scholarly antibiotics-related contents are taught during the first and second years of this course at University of Brighton. This should help to consolidate and strengthen the proficiency and skills of our students in

these vital topics. It is worth noting that passive, rather than interactive, teaching formats are predominantly used in European medical schools to teach prudent antibiotic prescribing.³³ In addition, many of the most important principles in these topics, such as the practical use of point-of-care diagnostic tests, the reassessment of antibiotic regimens and communication skills, are usually poorly covered, with wide variations in medical schools both nationally and internationally.³³ A recent survey also found that antimicrobial stewardship principles are taught in most undergraduate healthcare curricula in the UK but the topics covered and the teaching and learning approaches used vary widely with schools.³⁴ These authors state that national and European actions need to be developed urgently in order to better define and standardize the required specific learning outcomes for antibiotics education.^{33,34} We fully subscribe to this conclusion, with a particular emphasis on pharmacy schools.

Limitations of our study

Our study was based on responses from only one UK school of pharmacy and the response rates themselves were relatively low, although comparable to those of most other similar recently published online antibiotics surveys among medical and pharmacy students. When response rates are too low, respondents have a greater chance of being self-selected rather than randomly selected, with a bias towards more confident and motivated students completing the survey. This may explain the lower participation of year 1 students when compared to year 2 and 3 students. Our study was also based on a self-rated questionnaire and, although the survey was anonymous, students may have given answers they thought were required, potentially resulting in social desirability bias. Nevertheless, students were informed that the survey was anonymous, non-compulsory and would have no impact on their marks, minimizing the risk of them feeling coerced or distorting their answers.

We did not ask our students about the resources they used to search information about antibiotics. The use of different resources and guidelines have been found to influence the knowledge scores on antibiotics of pharmacy students.²³

Our new MPharm case-based course was introduced in the academic year 2013/2014, and has progressively phased out our former more 'conventional' discipline-based curriculum. Consequently, in the academic year 2015/2016, all our first, second and third years students were attending the new course and the fourth year students still followed the former curriculum. Students are now taught the various core science components of a pharmacy degree, such as microbiology, in an integrated way,

contextualized into distinct clinical and pharmacy practice scenarios. This may explain why year 4 students seemed less confident in their education than year 3 students, for example, regarding the selection of the best antibiotic therapy, but this deserves further study. Nevertheless, the difference between the knowledge scores of year 3 and year 4 students was not statistically significant. Most antibiotic-related topics are delivered during the first two years of the new course, which also happened with the former curriculum.

Conclusion

Pharmacists play a key role in promoting good practice in antibiotic use and in antibiotic stewardship programs, often being more accessible educators than other healthcare professionals. By assessing what our MPharm students know and think about these issues, we have identified specific education gaps which will allow us to design more effective targeted educational interventions, particularly regarding the mechanisms and factors promoting the emergence and spread of antibiotic resistance, and antibiotic stewardship policies. It is to be hoped that these interventions will make these future professionals better prepared to assume their decisive role in the battle against antibiotic resistance and in promoting antibiotic stewardship programs.

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Figure 1. Box plots of students' knowledge scores on antibiotics by year of study (A), gender (B), existence of relatives or close friends working in health-related fields (C) and existence of education training on antibiotics prior to entering onto the MPharm course (D). Statistically significant differences between groups of students are highlighted by an asterisk. Horizontal lines indicate the medians and boxes the interquartile range.

Table 1. Response rates and description of respondent MPharm students' demographic characteristics by year of study

	Year 1 (n = 172)	Year 2 (n = 137)	Year 3 (n = 136)	Year 4 (n = 138)	All years¹ (n = 583)
Response rate [n (%)]	42 (24%)	46 (34%)	58 (43%)	38 (28%)	185(32%)
Female students [n (%)]	30 (72%)	37 (80%)	38 (66%)	24 (63%)	129 (70%)
Age group (years)²					
< 20 [n (%)]	24 (57%)	12 (27%)	1 (2%)	0 (0%)	37 (20%)
20 - 25 [n (%)]	9 (21%)	26 (58%)	37 (64%)	28 (74%)	100 (54%)
> 25 [n (%)]	9 (21%)	7 (16%)	20 (35%)	10 (26%)	47 (26%)
Time living in the UK (years)					
< 3 [n (%)]	8 (19%)	15 (33%)	6 (10%)	0 (0%)	29 (16%)
3 - 6 [n (%)]	6 (14%)	7 (15%)	15 (26%)	9 (24%)	38 (21%)
> 6 [n (%)]	28 (67%)	24 (52%)	37 (64%)	29 (76%)	118 (64%)
Practice area considered³					
Community pharmacy [n (%)]	25 (60%)	23 (50%)	31 (53%)	24 (63%)	103 (56%)
Hospital pharmacy [n (%)]	29 (69%)	27 (59%)	33 (57%)	20 (53%)	109 (60%)
Primary care [n (%)]	7 (17%)	5 (11%)	6 (10%)	5 (13%)	23 (12%)
Industrial pharmacy [n (%)]	9 (21%)	10 (22%)	12 (21%)	0 (0%)	32 (17%)
Academia [n (%)]	7 (17%)	7 (15%)	8 (14%)	4 (11%)	26 (14%)
Other areas of pharmacy [n (%)]	5 (12%)	4 (9%)	3 (5%)	0 (0%)	12 (7%)
Undecided[n (%)]	1 (2%)	5 (11%)	7 (12%)	2 (5%)	15 (8%)
Students with antibiotics training prior entering pharmacy school[n (%)]⁴	9 (21%)	12 (26%)	14 (24%)	9 (24%)	45 (25%)

Students with relatives working in health related fields [n (%)]	27 (64.3%)	32 (69.6%)	29 (50.0%)	25 (65.8%)	114 (61.6%)
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¹One student did not indicate his year of study so his data only contribute to the 'All years' column; ²One year 2 student did not answer the question about her age group; ³Students were allowed to select one or more options; ⁴One year 4 student did not answer this question

Table 2. Number and percentage of students giving correct answers to specific statements about knowledge and awareness of antibiotics by year of study

Statements	Year 1 (n = 42)	Year 2 (n = 46)	Year 3 (n = 58)	Year 4 (n = 38)	All years² (n = 185)
Amoxicillin is an antibiotic	39 (93%)	46 (100%)	55 (95%)	37 (97%)	178 (96%)
Aspirin is an antibiotic	41 (98%)	46 (100%)	57 (98%)	37 (97%)	182 (98%)
Cefotaxime is a cephalosporin	9 (21%)	25 (54%)	45 (78%)	32 (84%)	111 (60%)
Antibiotics are useful for bacterial infections	40 (95%)	46 (100%)	57 (98%)	36 (95%)	180 (97%)
Antibiotics are useful for viral infections	37 (88%)	45 (98%)	53 (91%)	36 (95%)	172 (93%)
Colds and coughs should always be treated with antibiotics as patients will recover more quickly	42 (100%)	44 (96%)	55 (95%)	38 (100%)	180 (97%)
Antibiotics cannot treat influenza	27 (64%)	30 (65%)	43 (74%)	31 (82%)	131 (71%)
Antibiotics should always be prescribed as preventive measures to fight against future infections	33 (79%)	43 (94%)	48 (83%)	34 (90%)	159 (86%)
Antibiotics are indicated to reduce any kind of pain and inflammation	37 (88%)	38 (83%)	53 (91%)	36 (95%)	164 (89%)
Antibiotics can cause allergic reactions	39 (93%)	45 (98%)	57 (98%)	37 (97%)	179 (97%)
Antibiotics can cause secondary infections after killing good bacteria present in our organism	35 (83%)	41 (89%)	43 (74%)	33 (87%)	152 (82%)
Antibiotic resistance happens when a bacterium loses its sensitivity to an antibiotic	37 (88%)	39 (85%)	56 (97%)	37 (97%)	170 (92%)
Exposure to antibiotics appears to be the principal risk factor for appearance of antibiotic-resistant bacteria	30 (71%)	28 (61%)	36 (62%)	28 (74%)	123 (67%)

Appropriate use of antibiotics can cause antibiotic resistance	13 (31%)	8 (17%)	17 (29%)	10 (26%)	48 (26%)
Inappropriate use of antibiotics causes antibiotic resistance	39 (93%)	45 (98%)	55 (95%)	37 (97%)	177 (96%)
Patients may stop the use of antibiotics as soon as they start feeling better	25 (60%)	34 (74%)	44 (76%)	26 (68%)	129 (70%)
Prescribing broad-spectrum antibiotics increases antibiotics resistance	27 (64%)	35 (76%)	38 (66%)	26 (68%)	127 (69%)
Poor infection control practices by healthcare professionals cause spread of antibiotic resistance	30 (71%)	37 (80%)	48 (83%)	26 (68%)	142 (77%)
Use of antibiotics in livestock production and agriculture contributes to antibiotic resistance	32 (76%)	36 (78%)	43 (74%)	22 (58%)	134 (72%)
Antibiotics are overused nationally and internationally in healthcare	38 (91%)	41 (89%)	47 (81%)	38 (100%)	164 (89%)
Beta-lactamase is an enzyme produced by bacteria that can break down aminoglycosides	7 (17%)	21 (46%)	35 (60%)	24 (63%)	87 (47%)
Bacteria may acquire efflux pumps that extrude the antibiotic from the cell	23 (55%)	28 (61%)	39 (67%)	24 (63%)	114 (62%)
Antibiotic stewardship is a phenomenon for which a bacterium gains resistance to an antibiotic	6 (14%)	19 (41%)	36 (62%)	22 (58%)	83 (45%)
Antibiotic resistance can be minimized by using narrow-spectrum therapy after identification and susceptibility testing of infectious bacteria	34 (81%)	43 (94%)	49 (85%)	36 (95%)	163 (88%)
Improved healthcare hygiene helps to control antibiotic resistance	33 (79%)	40 (87%)	47 (81%)	30 (79%)	151 (82%)
Improving techniques for bacterial diagnostics will allow combating antibiotic resistance	35 (83%)	41 (89%)	51 (88%)	36 (95%)	164 (89%)

Formal teaching on proper usage of antibiotics among healthcare students may minimize the phenomena of antibiotic resistance	38 (91%)	42 (91%)	51 (88%)	38 (100%)	170 (92%)
Today's research will be sufficient to meet the future needs for new antibiotics	24 (57%)	21 (46%)	25 (43%)	25 (66%)	96 (52%)
Antibiotic resistance will be a greater clinical problem later in my pharmacy career than it is today	38(91%)	45 (98%)	48 (83%)	37(97%)	169 (91%)
Overall knowledge score ¹	7.6 (6.2-8.6)	7.9 (6.9-8.6)	7.9 (6.9-9.3)	8.3 (7.6-9.0)	7.9 (6.9-8.6)

¹Reported as median (25%-75% interquartile range); ²One student did not indicate his year of study so his data only contribute to the 'All years' column

Table 3.Number and percentage of students agreeing with specific statements about the education received on antibiotics

	Year 1 (n = 42)	Year 2 (n = 46)	Year 3 (n = 58)	Year 4 (n = 38)	All years¹ (n = 185)
I have had sufficient pharmacy education to:					
Select the best antibiotic for a specific infection	6 (14%)	15 (33%)	29 (50%)	12 (32%)	62 (34%)
Select an appropriate regimen of antibiotic therapy ²	7 (17%)	21 (46%)	33 (57%)	16 (42%)	77 (42%)
Understand the mechanisms of antibiotic resistance ³	20 (49%)	39 (85%)	45 (78%)	30 (81%)	135 (74%)
Handle a patient who demands antibiotics therapy when it is not indicated ²	21 (51%)	30 (65%)	40 (69%)	24 (63%)	116 (63%)
Understand the appropriate use of antibiotics ⁴	28 (67%)	30 (65%)	47 (83%)	25 (66%)	131 (71%)
I would like more education on:					
Antibiotics ⁴	38 (91%)	38 (83%)	43 (74%)	35 (92%)	155 (84%)
Microbiology and infection control ⁴	34 (81%)	20 (44%)	36 (63%)	24 (63%)	115 (63%)
Strong knowledge of the following subjects is important in my pharmacy career:					
Antibiotics ²	41 (100%)	45 (98%)	58 (100%)	37 (97%)	182 (99%)
Microbiology and infection control ⁵	37 (90%)	37 (82%)	53 (93%)	32 (84%)	159 (88%)

¹One student did not indicate his year of study so his data only contribute to the 'All years' column; ²One year 1 student did not answer this question; ³One student of year 1 and 4 did not answer this question; ⁴One year 3 student did not answer this question; ⁵One student of year 1, 2 and 3 did not answer this question

Fig 1

