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Nursing-led strategy to combat antimicrobial resistance: multi-method design

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Abstract

Background Antimicrobial resistance is currently a global health threat. Numerous efforts have been made to prevent or mitigate this phenomenon, but all have been insufficient. Although numerous studies have postulated nursing as a potential mediator to address this problem, no research has been conducted to put it into practice. This study aims to contextualize the problem of inappropriate antibiotic use and antimicrobial resistance, as well as to develop and implement a nurse-led educational intervention aimed at mitigating it, emphasizing the role of nurses in health education.

Methods Two different groups of participants were recruited using convenience sampling. Nurses administered a survey to 782 citizens in a population from Spain to assess their knowledge of the correct use of antibiotics and antimicrobial resistance. After completing the survey, nurses explained to the participants how to use antibiotics correctly and the problem of antimicrobial resistance. Furthermore, an educational intervention led by nurses was carried out with 104 adolescents, consisting of an oral presentation to raise awareness about the issue. The effectiveness of this intervention was evaluated through a comparative analysis before and after the activity (pre-test and post-test).

Results Our results indicated that the level of knowledge about the correct use of antibiotics and antimicrobial resistance is not statistically significant related to sex in the general population ($p > 0.05$). However, it is statistically significant related to age ($p < 0.05$), educational level ($p < 0.0001$) and study area ($p < 0.0001$). In addition, the nurse-led educational intervention increased significantly the level of knowledge on the topic among adolescents ($p < 0.0001$).

Conclusions These findings highlight the low level of knowledge in the population about the correct use of antibiotics and antimicrobial resistance. It also demonstrates how nurses, through their role in health education, can actively contribute to addressing the issue, providing a rationale for the inclusion of nursing in the design and implementation of strategies to prevent or mitigate antimicrobial resistance.

Keywords Antimicrobial resistance, Health education, Nursing, Educational intervention, Antibiotics

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Background

Antimicrobial resistance is a major global health concern. In recent decades, a great acceleration in the emergence and spread of antibiotic-resistant bacteria has been observed. This phenomenon is estimated to be responsible for 1.27 million deaths, and 4.95 million related deaths annually [1]. According to the World Health Organization, it is predicted that, if effective solutions are not found, the number of deaths could increase to 10 million by 2050. In addition to the alarming numbers of deaths caused, this problem generates high healthcare costs. It is estimated that infections caused by antibiotic-resistant bacteria account for an annual healthcare expenditure of US$ 55 billion [2, 3].

The excessive and inappropriate use of antibiotics in humans and animals, over-the-counter antibiotics, increased international travel, poor hygienic conditions and the release of unmetabolized antibiotics or their derivatives into the environment are the main causes of the emergence and expansion of antimicrobial resistance [4, 5]. These factors generate a selection pressure on bacteria that favors the acquisition of resistance by different mechanisms. Several mechanisms involved in the development of antimicrobial resistance have been described [3]. These include the modification and/or destruction of antibiotics by bacteria, efflux of the drug component, alteration or elimination of the therapeutic target, changes in the permeability of the bacterial membrane to the antibiotic and the biofilms formation, all of which can be acquired through horizontal gene transfer [3, 6–11].

Numerous efforts have been made to find solutions to this health threat. These strategies include governmental and sanitary actions focused on regulating and controlling the sale and use of antibiotics in humans and animals, strengthening awareness programs, and promoting research in the search for new antibiotics and diagnostic methods [12–16]. Community education has also been proposed as a solution to antimicrobial resistance [17–19], although it has hardly been put into practice [20].

The role of nursing in the prevention and mitigation of antimicrobial resistance is becoming increasingly important [18, 21, 22]. Nurses are the healthcare professionals responsible for providing care from the beginning to the end of a clinical stage [23, 24]. They can contribute significantly to the prevention of infections through nursing-related interventions such as good hand hygiene, cleaning of equipment and isolation measures, among others [22, 24]. Continuing education of nurses is also an important aspect as a measure against antimicrobial resistance, since the more knowledge they have, the better the interventions will be. Another important and less studied aspect of nursing in the face of this health concern is the education of patients, their families and the public on the proper use of antibiotics. They can provide knowledge on how and when to take antibiotics and raise awareness of the need to adhere to treatment guidelines [21].

Various studies have shown a low level of knowledge among the population about the correct use of antibiotics and antimicrobial resistance, which often leads to various forms of incorrect antibiotic use such as self-medication, incomplete courses of treatment, and antibiotic sharing. Furthermore, these studies have linked the level of knowledge on the subject with sociodemographic variables such as gender, age, and educational level [21, 25–28]. For example, the lack of awareness about antimicrobial resistance among adolescents is concerning, as the behaviors and habits acquired during this stage are decisive for their future health behavior. Recent evidence indicates that people under the age of 25 are up to four times more likely to use antibiotics without a prescription than older adults [29–31]. However, most of this research focuses on specific populations, such as healthcare professionals [27, 32, 33]. Some attempts have been made to develop educational programs aimed at the general population to address this public health problem [20, 30]. However, these educational programs tend to focus solely on raising awareness about antimicrobial resistance, without directly addressing its main causes, such as the incorrect use of antibiotics. Furthermore, these interventions are not led by nursing professionals, despite their fundamental role in health education.

This study aims to contextualize the problem of antimicrobial resistance to find sociodemographic characteristics related to this threat and to demonstrate the effectiveness of a potential preventive strategy based on the role of nursing in patient education.

Method

Research design and setting

This work involved two quantitative analyses. The first analysis was based on a survey of the population of Salamanca (Spain) conducted through face-to-face interviews to gather information on the level of knowledge about the correct use of antibiotics and antimicrobial resistance. The second analysis was a pre-test/post-test carried out on pupils of different academic levels (Compulsory Secondary Education, Intermediate Vocational Training Cycle and Baccalaureate) in different educational institutions in Salamanca (Institute Fernando de Rojas and IESO Quercus). These two educational institutions included in the study were selected using convenience sampling, considering their willingness to participate, their accessibility, and their interest in collaborating with the educational intervention developed in this study. Both institutions are public secondary schools located in Salamanca (Spain) and share similar sociodemographic characteristics, which favors comparability between the

groups. The pre-test was carried out just before the intervention, while the post-test was carried out after it. This second analysis aimed to evaluate the effectiveness of the intervention. Both the physically applied survey and the pre-test/post-test were developed for this study (Supplementary file).

Participants

Two different groups of participants were recruited using convenience sampling method. For both groups, the sample size was calculated using Cochran's formula with a confidence level of 95% (Z = 1.96) and a margin of error of 5% (d = 0.05) [34]. 782 citizens of Salamanca participated in the study aimed at contextualising the issue of the correct use of antibiotics and antimicrobial resistance. The target population of the nursing intervention consisted of 104 pupils: 36 pupils in the fourth year of compulsory secondary education, 39 pupils in the intermediate level training cycle in care for people in a dependency situation and 29 pupils in the first year of Baccalaureate. The number of pupils who participated represented the entire population enrolled in each section. All the pupils were enrolled in the 2024–2025 academic year. We selected this target population to implement the educational intervention because educating adolescents about the correct use of antibiotics and antimicrobial resistance is a long-term preventive strategy, as this group is at greater risk of self-medicating. In addition, school-based interventions can extend their impact to the family and community environment.

Data collection

Data were collected from July 2024 to April 2025.

Data collection for the contextualization of the issue

A survey was conducted among the population through face-to-face interviews to contextualize the problem of antimicrobial resistance. To develop this survey, the study aims were first defined, and the existing literature was reviewed to identify relevant topics and previously validated questionnaires [25–28, 35–37]. Based on this, items were developed to assess the population's knowledge, attitudes, and practices. Subsequently, a panel of experts evaluated the validity, clarity, and relevance of each item, calculating the content validity index. The survey was pilot tested with a small group of people ($n = 26$), which allowed for the detection and correction of potential comprehension or formatting issues. The final survey was adjusted in line with the findings of the pilot study and the recommendations of the expert panel. The Cronbach's alpha coefficient was 0.861. To ensure consistency in the administration of the survey, a standardized application protocol was implemented, which included clear and uniform instructions provided in advance to nurses. The language of the survey was clear and simple to ensure its comprehension by the entire study population and its duration of no more than 5 min to ensure participation. The survey consisted of four open-ended questions related to sociodemographic characteristics (age, gender, level of education, and study area), one open-ended question about what an antibiotic is, and four closed-ended (yes/no) questions related to the correct use of antibiotics and antimicrobial resistance. The study level options were low (incomplete or complete primary school), intermediate (complete middle or high school), and high (Bachelor´s Degree or graduate studies). The different areas of study were health sciences, social/legal, services, technical sciences, humanities, art or no studies. The questions design was aimed at finding out possible habits related to the misuse of antibiotics as a cause of antimicrobial resistance. After completing the survey, the nurse in charge of the task explained how to use antibiotics correctly and the need for this habit to prevent antimicrobial resistance. These explanations were aimed at educating the population to raise awareness and prevent the problem under study.

Data collection to determine the effectiveness of the educational intervention in the adolescent sample

To evaluate the effectiveness of the educational intervention, data were collected on the pupils' knowledge of antibiotics, their correct use and different aspects related to antimicrobial resistance through the application of the same questionnaire before and after the intervention (pre-test and post-test). The test consisted of 10 closed questions (multiple choice) related to antibiotics, their correct use, and aspects related to antimicrobial resistance (definition, causes, and consequences). The same strategy described above for the development of the survey applied to the population was followed for the test development. In short, the questionnaire was designed by first defining the study objectives and reviewing the literature to identify relevant topics and previously validated questionnaires [38–44]. This information was used to develop the initial questions. A panel of experts then evaluated the validity, clarity, and relevance of each question, and the content validity index was calculated. Subsequently, a pilot study was conducted with 18 participants, which allowed for the detection and correction of comprehension or formatting issues. Based on the results of the pilot study and the recommendations of the experts, the final version of the questionnaire was obtained. The Cronbach's alpha coefficient was 0.894.

Educational intervention

Before developing the intervention, pupils took a test (pre-test). This test was carried out individually and for a maximum of 8 min. The language used in the test was

clear and simple to facilitate understanding regardless of the student's level of study.

After the pre-test, a 40-minute intervention was carried out in the presence of the tutor responsible for the group. The educational intervention addressed all relevant topics and items identified during the development process of the data collection tools. Before its implementation with the group of adolescents, the intervention was presented to a panel of experts consisting of pharmacology professors, researchers from various disciplines, and primary and secondary school teachers. The purpose of this review was to ensure the message clarity, the content validity, and its appropriate adaptation to the target audience. The oral presentation was standardized to ensure uniformity of intervention across all groups. The intervention consisted of an oral presentation in PowerPoint format where different aspects related to the topic of study were discussed. Firstly, a brief introduction on bacteria and antibiotics was given. This was followed by a brief explanation of how antibiotics work and their correct use. Then, the problem of antimicrobial resistance was presented, discussing its causes, the described resistance mechanisms and their consequences. Finally, the importance that we as citizens must mitigate and curb the health problem of antimicrobial resistance was emphasised. The language of the presentation was adapted to the audience level. During the intervention, pupils were asked different questions and encouraged to participate in the resolution of a clinical case to keep their attention and ensure an effective intervention. The clinical case consisted of a fictitious scenario in which a patient misused antibiotics for a urinary tract infection. The pupils had to identify what mistakes the patient had made, how the patient should have acted and what the consequences of the misuse of antibiotics would be. After the end of the intervention, the pupils were invited to ask questions related to the topic and to solve them. Finally, the pupils took the same test initially applied (post-test) individually and for a maximum of 8 min.

Table 1 Description of the participants of the surveyed population ($n = 782$)

Variable		Participants n (%) ($n = 782$)
Age (years)	Median, IQR (min-max)	27,30.75 (17–90)
	[18–29]	409 (52.30)
	[30–39]	74 (9.46)
	[40–49]	85 (10.87)
	[50–59]	125 (15.98)
	[60–100]	89 (11.38)
Sex	Male	355 (45.40)
	Female	427 (54.60)
Study Level	Low	134 (17.14)
	Intermediate	197 (25.19)
	High	451 (57.67)
Study Area	Health Sciences	172 (21.99)
	Social/legal	150 (19.18)
	Services	138 (17.65)
	Technical Sciences	118 (15.09)
	Humanities	76 (9.72)
	Art	20 (2.56)
	No studies	108 (13.81)

The n represents the number of participants and, in parentheses, the frequency. IQR: interquartile range

Statistical analysis

The data collected were analysed using the statistical programme JMP, version 12 (SAS Institute Inc., Cary, NC, 1989–2023) and GraphPad Prism 9. The data gathered in the surveys were analysed descriptively in terms of sample size and percentages (n, %). The association between different socio-demographic variables and survey responses was analysed using the Chi-square test. The efficacy of the intervention was assessed by comparing the pre-test and post-test results using the non-parametric Mann-Whitney U test. $P < 0.05$ were considered statistically significant.

Ethical considerations

This study was ethically approved by the Research Ethics Committee of the University of Salamanca (serial number: 183) and complied with the ethical standards of the Declaration of Helsinki [45]. Research permissions were provided to the participating organization (University of Salamanca). The director of the educational centers gave us approval to carry out the intervention. Participation in the study was completely voluntary and anonymous. The data were totally protected. The informed consent to participate was obtained from all the participants in the study. Consent was received directly from participants over 16 years of age, while in the case of children (younger than the age of 16), this consent was given by their parents or legal guardians.

Results

Description of the participants of the surveyed population (n = 782)

A total of 782 people completed the survey, of which 355 were male and 427 were female. The median age of the participants was 27 years, with most of the participants ($n = 409$, 52.30%) being between 18 and 29 years of age. The majority of participants had a high level of study ($n = 451$, 57.67%), with the highest number of them belonging to the Health Sciences area ($n = 172$, 21.99%) (Table 1).

General results of the surveyed population

53.07% ($n = 415$) of the participants were unaware of the concept and therapeutic usefulness of antibiotics. 62.28% ($n = 487$) of the respondents claimed to have antibiotics at

home, with some of the reasons provided being the presence of antibiotics left over from previous treatments. Most of the participants ($n = 562$, 71.87%) declared not to have taken antibiotics without prior medical prescription. Furthermore, 59.08% ($n = 462$) of the respondents stated that they had never modified the prescribed regimen. Finally, 69.44% ($n = 543$) of the members were unaware of the concept of antimicrobial resistance (Supplementary table S1).

The level of knowledge about antibiotics, their correct use and antimicrobial resistance is not statistically significant related to sex

To evaluate the influence of sex on the level of knowledge about antibiotics, their correct use and the problem of antimicrobial resistance correlation analyses were performed. Sex did not show a statistically significant association with knowledge of antibiotics, their correct use and antimicrobial resistance (Supplementary table S2).

The level of knowledge about antibiotics, their correct use, and antimicrobial resistance is related to age

To determine the relationship between age and the level of knowledge about antibiotics, their correct use and the problem of antimicrobial resistance, the surveyed population was divided into 5 different age ranges, and a correlation analysis was performed. Age was statistically significant associated with knowledge about antibiotics and their therapeutic usefulness ($p = 0.0282$). Younger participants showed a higher percentage of correct answers regarding the definition of antibiotics compared to older age groups. Likewise, age was statistically significant related to certain incorrect practices in the use of antibiotics, such as keeping leftover antibiotics at home ($p = 0.0053$) and modifying the prescribed regimen ($p = 0.0339$). In both cases, younger people showed a higher proportion of inappropriate behaviors compared to older participants. In contrast, no statistically significant association was found between age and the consumption of antibiotics without a prescription ($p = 0.7699$). Regarding knowledge of the concept of antimicrobial resistance, a statistically significant association with age was also observed ($p = 0.0208$), with younger participants again demonstrating a greater understanding of the term antibiotic resistance. Taken together, these results indicated that, although the younger population had a higher level of knowledge about antibiotics and antimicrobial resistance, it also showed a higher prevalence of incorrect practices related to their use (Table 2).

The level of knowledge about antibiotics, their correct use, and antimicrobial resistance is related to the study level

To assess the relationship between the level of studies and the level of knowledge about antibiotics, their correct use and the problem of antimicrobial resistance, the surveyed population was divided into three levels of studies, and a correlation analysis was carried out. A statistically significant association was observed between the educational level of the participants and their knowledge of antibiotics and therapeutic use ($p < 0.0001$). Study level was also statistically significant associated with incorrect antibiotic use such as possession of antibiotics at home for different reasons ($p = 0.0313$). However, antibiotic consumption without prior medical prescription and modification of the prescribed regimen were not statistically significant related to study level ($p = 0.2105$ and $p = 0.2292$, respectively). Lastly, study level was statistically significant associated with knowledge about the concept of antimicrobial resistance ($p < 0.0001$). Generally, the results indicate that the lower the studies level, the greater the lack of knowledge about the concept and therapeutic usefulness of antibiotics, the greater the possession of antibiotics in the home and the greater the lack of knowledge about the concept of antimicrobial resistance (Table 3).

Table 2 Relationship between age and level of knowledge about antibiotics, their correct use and antimicrobial resistance

		Age n (%)					
		[18–29]	[30–39]	[40–49]	[50–59]	[60–100]	*P*
		(*n* = 409)	(*n* = 74)	(*n* = 85)	(*n* = 125)	(*n* = 89)	
What is an antibiotic?	Correct	202 (49.39)	30 (40.54)	38 (44.71)	67 (53.60)	30 (33.71)	0.0282
	Incorrect	207 (50.61)	44 (59.46)	47 (55.29)	58 (46.40)	59 (66.29)	
Do you have any antibiotics at home?	Yes	280 (68.46)	41 (55.41)	44 (51.76)	72 (57.60)	50 (56.18)	0.0053
	No	129 (31.54)	33 (44.59)	41 (48.24)	53 (42.40)	39 (43.82)	
Have you ever taken antibiotics without a prescription?	Yes	119 (29.10)	22 (29.73)	25 (29.41)	34 (27.20)	20 (22.47)	0.7699
	No	290 (70.90)	52 (70.27)	60 (70.59)	91 (72.80)	69 (77.53)	
Have you changed the timing of taking an antibiotic?	Yes	183 (44.74)	28 (37.84)	32 (37.65)	53 (42.40)	24 (26.97)	0.0339
	No	226 (55.26)	46 (62.16)	53 (62.35)	72 (57.60)	65 (73.03)	
Do you know what the term "antibiotic resistance" refers to?	Correct	131 (32.03)	22 (29.73)	22 (25.88)	48 (38.40)	16 (17.98)	0.0208
	Incorrect	278 (67.97)	52 (70.27)	63 (74.12)	77 (61.60)	73 (82.02)	

The n represents the number of participants and, in parentheses, the frequency. *Chi-square test*

Table 3 Relationship between study level and level of knowledge about antibiotics, their correct use and antimicrobial resistance

		Study Level n (%)			
		High (*n* = 451)	**Intermediate (*n* = 197)**	**Low (*n* = 134)**	***P***
What is an antibiotic?	Correct	256 (56.76)	72 (36.55)	39 (29.10)	< 0.0001
	Incorrect	195 (43.24)	125 (63.45)	95 (70.90)	
Do you have any antibiotics at home?	Yes	271 (60.09)	138 (70.05)	78 (58.21)	0.0313
	No	180 (39.91)	59 (29.95)	56 (41.79)	
Have you ever taken antibiotics without a prescription?	Yes	116 (25.72)	61 (30.96)	43 (32.09)	0.2105
	No	335 (74.28)	136 (69.04)	91 (67.91)	
Have you changed the timing of taking an antibiotic?	Yes	189 (41.91)	71 (36.04)	60 (44.78)	0.2292
	No	262 (58.09)	126 (63.96)	74 (55.22)	
Do you know what the term "antibiotic resistance" refers to?	Correct	178 (39.47)	40 (20.30)	21 (15.67)	< 0.0001
	Incorrect	273 (60.53)	157 (79.70)	113 (84.33)	

The n represents the number of participants and, in parentheses, the frequency. *Chi-square test*

Table 4 Relationship between study area and level of knowledge about antibiotics, their correct use and antimicrobial resistance

		Study Area n (%)							
		HS	**SL**	**S**	**TS**	**H**	**A**	**NS**	***P***
		(*N* = 172)	**(*N* = 150)**	**(*N* = 138)**	**(*N* = 118)**	**(*N* = 76)**	**(*N* = 20)**	**(*N* = 108)**	
What is an antibiotic?	Correct	128 (74.42)	51 (34.00)	50 (36.23)	65 (55.08)	37 (48.68)	7 (35.00)	29 (26.85)	< 0.0001
	Incorrect	44 (25.58)	99 (66.00)	88 (63.77)	53 (44.92)	39 (51.32)	13 (65.00)	79 (73.15)	
Do you have any antibiotics at home?	Yes	116 (67.44)	85 (56.67)	99 (71.74)	75 (63.56)	44 (57.89)	12 (60.00)	56 (51.85)	0.0205
	No	56 (32.56)	65 (43.33)	39 (28.26)	43 (36.44)	32 (42.11)	8 (40.00)	52 (48.15)	
Have you ever taken antibiotics without a prescription?	Yes	53 (30.81)	47 (31.33)	35 (25.36)	30 (25.42)	20 (26.32)	7 (35.00)	28 (25.93)	0.7867
	No	119 (69.19)	103 (68.67)	103 (74.64)	88 (74.58)	56 (73.68)	13 (65.00)	80 (74.07)	
Have you changed the timing of taking an antibiotic?	Yes	61 (35.47)	65 (43.33)	52 (37.68)	49 (41.53)	36 (47.37)	13 (65.00)	44 (40.74)	0.1626
	No	111 (64.53)	85 (56.67)	86 (62.32)	69 (58.47)	40 (52.63)	7 (35.00)	64 (59.26)	
Do you know what the term "antibiotic resistance" refers to?	Correct	113 (65.70)	31 (20.67)	29 (21.01)	30 (25.42)	21 (27.63)	4 (20.00)	11 (10.19)	< 0.0001
	Incorrect	59 (34.30)	119 (79.33)	109 (78.99)	88 (74.58)	55 (72.37)	16 (80.00)	97 (89.81)	

The n represents the number of participants and, in parentheses, the frequency. *HS: health Sciences, SL: Social/Legal, S: Services, TS: technical Sciences, H: Humanities, A: Art and NS: no studies. Chi-square test*

The level of knowledge about antibiotics, their correct use and antimicrobial resistance is related to the study area

To determine the relationship between the study area and the level of knowledge about antibiotics, their correct use and the problem of antimicrobial resistance, the surveyed population was divided into seven different study area and a correlation analysis was performed. A statistically significant association was observed between the study area and the degree of knowledge about antibiotics and their therapeutic use ($p < 0.0001$). Also, a statistically significant relationship was described between the incorrect use of antibiotics and the studies area ($p = 0.0205$). On the other hand, neither the consumption of antibiotics without prior medical prescription nor the modification of the prescribed regimen were statistically significant associated with the studies area ($p = 0.7857$ and $p = 0.1625$, respectively). The level of knowledge of the concept of antimicrobial resistance was statistically significant related to the studies area ($p < 0.0001$). In general, a higher level of knowledge of the concept and therapeutic usefulness of antibiotics, widespread possession of antibiotics in the home and greater knowledge of the concept of antimicrobial resistance were observed in the health sciences area in comparison to services, social-legal, art or no studies areas (Table 4).

Characteristics of the adolescent sample in the educational intervention (n = 104)

104 pupils received the intervention proposed in this study. Of these, 29 were in the first year of Baccalaureate, 39 were in the intermediate level training course in care for dependent persons and 36 were in the fourth year of compulsory secondary education. The pupils median age was 16 years, and this study group consisted of 44 male pupils and 60 female pupils.

The educational intervention increased the level of knowledge about the correct use of antibiotics and antimicrobial resistance in adolescents

The pupils who received the intervention statistically significantly increased their level of knowledge about the correct use of antibiotics and antimicrobial resistance (Fig. 1A). After the intervention, pupils in the first year of Baccalaureate, the intermediate level of training in care for dependent persons and the fourth year of compulsory secondary education increased their level of knowledge about the correct use of antibiotics and antimicrobial resistance in a statistically significant manner (Fig. 1B, C and D, respectively).

Discussion

This study aimed to contextualize the problem of inappropriate antibiotic use and antimicrobial resistance, as well as to develop and implement a nurse-led educational intervention aimed at mitigating it, emphasizing the role of nurses in health education. The use of antibiotics has transformed modern medicine by making it possible to treat previously lethal bacterial infections [46]. However, a set of practices related to the abuse and misuse of antibiotics has led to the emergence of antimicrobial resistance [14]. Antimicrobial resistance has become a global health threat. Numerous efforts have been made to try to mitigate or address this problem, although they have been insufficient [15]. Different studies have described the need to educate and raise awareness about the correct use of antibiotics and antimicrobial resistance [17, 22]. The field of health education is one of the tasks of nursing. Although several studies have evidenced the role of the nurse as a health educator in this context [17, 18, 22, 47], no research has been conducted to implement and evaluate the effectiveness of these interventions.

Our research work demonstrates a low level of general knowledge in the sample analyzed on the correct use of antibiotics and antimicrobial resistance. This result is consistent with multiple studies carried out in different countries [25, 37]. This low level of knowledge observed could be due to a lack of communication between the healthcare professional and the patient, as well as deficiencies in the educational system.

We also report that the degree of knowledge about the correct use of antibiotics and antimicrobial resistance is not statistically significant related to sex. Most studies (developed in Asia) have described that the female population has a higher level of knowledge about the correct use of antibiotics and antimicrobial resistance [26, 48–51], possibly because women tend to seek help and visit health care facilities more regularly than men, as well as women's tendency to obtain information about health care [48]. These investigations are not consistent with our result, although this discrepancy could be due to the difference between Asian and Spanish societies.

In addition, this study reports the relationship between the level of knowledge about the correct use of antibiotics and antimicrobial resistance with age. Our result is consistent with different studies [36, 52, 53]. Thus, it has been observed that the middle-aged population has a lower level of knowledge on the subject than the younger population. This could be explained by the fact that this group, despite having experience with the use of drugs, has not received sufficient health education on the correct use of antibiotics and antimicrobial resistance, retaining erroneous habits acquired in the past such as sharing antibiotics or discontinuing treatment when feeling improvement. Although the level of knowledge on the topic is higher in the younger population than in the middle-aged or elderly, it is still low in both groups. The younger population, due to their access to digital information, may be more exposed to educational content. However, they do not always have the necessary tools to adequately filter such information.

We also found that the level of knowledge on the correct use of antibiotics and antimicrobial resistance was related to the level and study area. This result is consistent with other studies [35, 53, 54]. People with a low level of education have a lower degree of knowledge on the subject since they may be more susceptible to self-medication and myths about antibiotics because of this lack of training. On the contrary, people with higher education may have been exposed to information related to the subject, although it does not always guarantee its correct application in daily life as our results show. In relation to the subject treated, our work reports that the population with studies in health areas presents a higher level of knowledge about the correct use of antibiotics and antimicrobial resistance, explainable by their health training. Surprisingly, even in this subpopulation despite the bad practices in the correct use of antibiotics are still carried out. This result has been previously evidenced in other investigations [18, 22, 27].

Finally, we developed, implemented and evaluated a strategy to raise awareness of the correct use of antibiotics and antimicrobial resistance based on the role of the nurse in health education. Although numerous studies

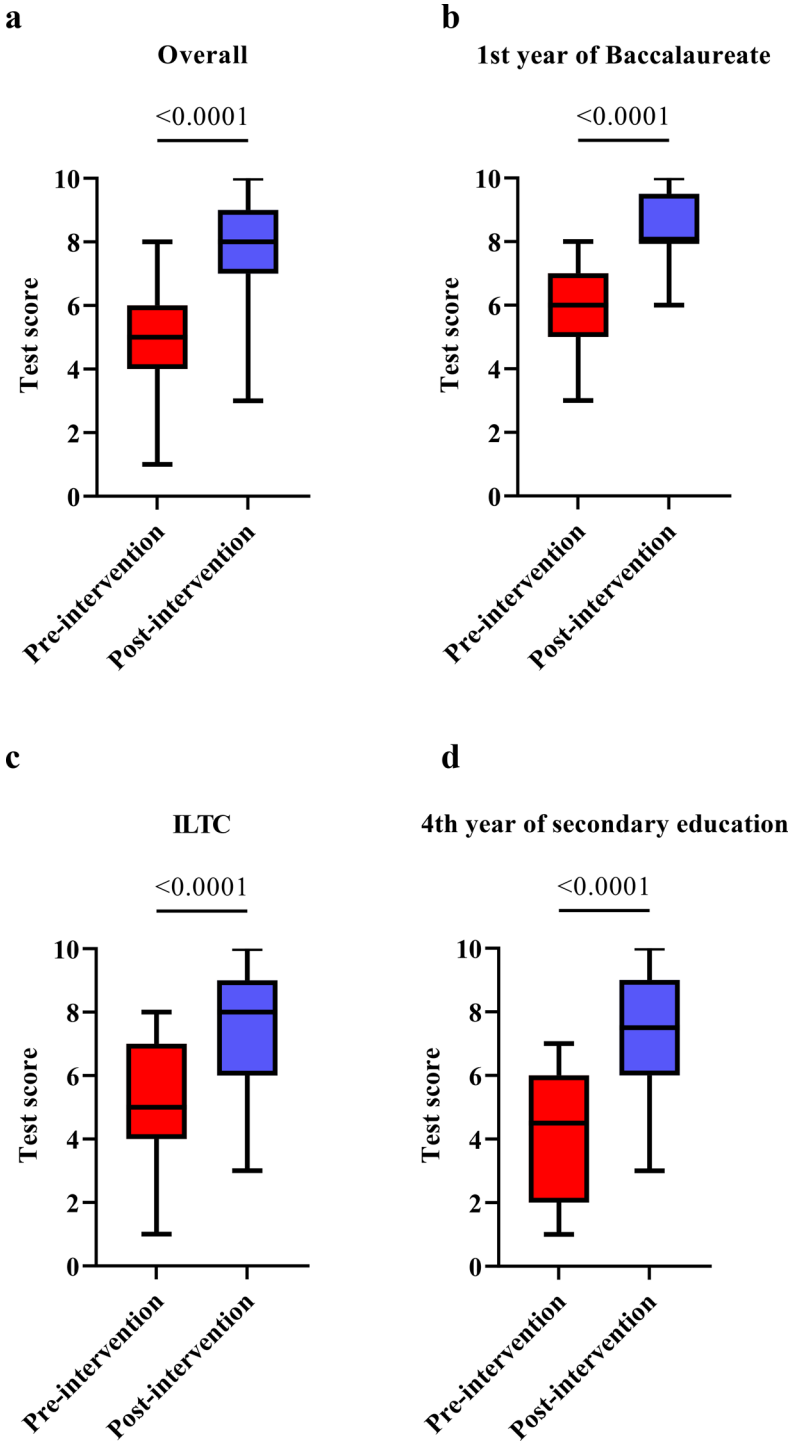

Fig. 1 Evaluation of the effectiveness of the intervention developed in the pupils. Evaluation of the effectiveness of the intervention in all pupils (**a**), 1st year of Baccalaureate (**b**), Intermediate Level Training Cycle (ILTC) in Care for People in a Situation of Dependence (**c**) and 4th year of Compulsory Secondary Education (**d**). The maximum test score was 10. U Mann-Whitney

have reported the need to educate the population on the correct use of antibiotics [17–19], there are no studies that demonstrate how and if this measure is effective. Our work shows that there are statistically significant differences after the educational intervention in the three courses studied. Our research demonstrates how the nurse can significantly increase and raise awareness of correct antibiotic use and antimicrobial resistance effectively. This measure could contribute to prevent or mitigate the current increasing trend of this health problem.

Strengths and limitations

This study describes the level of knowledge from a population in Spain on the correct use of antibiotics and antimicrobial resistance. Likewise, and as a novel contribution, it includes the development, implementation and evaluation of an educational intervention in the adolescent population. However, this research has some limitations. The study was conducted in the population of Salamanca, limiting the generalizability of the findings. On the other hand, the responses of the physically applied survey were self-reported, so these might not be due to the tendency to give a socially accepted answer, or limitations related to memory. In addition, this study evaluates the effectiveness of the educational intervention in adolescents in the short term, being interesting to conduct studies that demonstrate the effectiveness of this type of interventions in the long term.

Conclusions

These findings lead us to conclude that the level of knowledge of the population about the correct use of antibiotics and antimicrobial resistance is insufficient. Furthermore, the study demonstrates the crucial role of nursing in health education to increase the population's knowledge about the correct use of antibiotics and antimicrobial resistance.

However, further studies are needed to validate the long-term effectiveness of these interventions and to develop educational interventions tailored to different types of subpopulations.

Supplementary Information

The online version contains supplementary material available at https://doi.org/10.1186/s12912-025-03822-2.

Supplementary Material 1

Supplementary Material 2

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Author contributions

MJP-B, AT-G: Conceptualization, Methodology, Formal analysis, Investigation, Writing – original draft, Visualization, Writing – review & editing. MH-M: Conceptualization, Methodology, Formal analysis, Visualization, Writing – review & editing, Supervision. All authors read and approved the final manuscript.

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Data availability

The datasets used and analysed during the current study are available from the corresponding author on reasonable request.

Declarations

Ethics approval and consent to participate

This study was ethically approved by the Research Ethics Committee of the University of Salamanca (serial number: 183) and complied with the ethical standards of the Declaration of Helsinki [45]. Research permissions were provided to the participating organization (University of Salamanca). The director of the educational institutions gave us approval to carry out the intervention. Participation in the study was completely voluntary and anonymous. The data were totally protected. The informed consent to participate was obtained from all the participants in the study. Consent was received directly from participants over 16 years of age, while in the case of children (younger than the age of 16), this consent was given by their parents or legal guardians.

Consent for publication

Not applicable.

Competing interests

The authors declare no competing interests.

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