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# Assessing antimicrobial consumption in public and private sectors within the Costa Rican health system: current status and future directions

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## Abstract

**Background** Antimicrobial resistance is a significant global health threat. Therefore, robust surveillance systems for antimicrobial consumption (AMC) are essential to develop public health strategies. However, Latin American countries, including Costa Rica, face challenges in regularly reporting AMC data. This study aims to estimate and analyse the overall AMC in Costa Rica for 2019.

**Methods** This study is a national-level, retrospective, observational, and descriptive analysis of AMC in Costa Rica from 1 January to 31 December 2019. The study followed the World Health Organization (WHO) guidelines for the Surveillance of National AMC. The Anatomical Therapeutic Chemical (ATC) / Defined Daily Doses (DDD) system was used to analyse types of antimicrobials and DDD per 1000 inhabitants per day (DID). Antimicrobial dispensation data from the Costa Rican Social Security Fund (CCSS) represented the public sector, while the private sector data was sourced from IQVIA. The analysis included data from both inpatient and outpatient sectors.

**Results** A total AMC of 14.32 DID, of which 12.75 DID was within the public sector and 4.12 DID was within the private sector. Penicillins had the highest consumption nationally and in the public sector, while macrolides and lincosamides predominate in the private sector. According to the WHO-AWaRe (Access-Watch-Reserve) classification, antibiotics predominantly consumed nationally (74.7%) and in the public (83.0%) sectors are categorized under Access, whereas the private (61.0%) sector predominates the Watch category.

**Conclusion** This study illustrates the importance of enhancing AMC surveillance by integrating data from both the public and private sectors. The findings indicate an excessive use of "Watch" antimicrobials in the private sector. To address this issue, all sectors and regulatory authorities must play an active and supportive role, in the development of effective, multisectoral policies. The methodology employed in this study is applicable to other Latin American countries, and therefore should be utilized for future analysis AMC in this region.

**Keywords** Private sector, Public sector, Pharmacoepidemiology, Costa Rica, GLASS, Antimicrobial

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## Background

Antimicrobials have significantly increased human life expectancy [1]. However, the misuse of these drugs has led to a significant public health concern of antimicrobial resistance (AMR), especially in developing countries [2–4].Surveillance systems are essential for identifying and monitoring trend in Antimicrobial Consumption (AMC) and susceptibility. According to the Global Antimicrobial Resistance and Use Surveillance System (GLASS) methodology, AMC is defined as "estimates derived from aggregated data sources such as import or wholesaler data, or aggregated health insurance data, which provide no information on the patients who receive the medicines or why the antimicrobials are being used. These data sources provide a proxy estimate of use of antimicrobials" [5]. These systems are valuable tools for formulating public health strategies and policies, and assessing the impact of their implementation to reduce AMR [6].

Latin America encounters numerous challenges in the regular reporting of AMC data [7]. One significant challenge is the lack of cross-national studies and limited data availability from the public healthcare sector [8]. Such limitations can lead to extrapolation bias, affecting the reliability of cross-country comparisons and hindering comprehensive understanding of AMC patterns [8]. Other contributing factors include financial resources, the absence of specific regulations addressing AMR, inadequate commitment from oversight entities, and an insufficient number of professionals dedicated to these tasks [9].

A study conducted between 1997 and 2007 across eight Latin American countries revealed an increase in total AMC in Peru, Venezuela, Uruguay, and Brazil, while Mexico and Colombia experienced a decrease. Notably, the use of quinolones increased across all studied countries. This highlights the need for relevant data to formulate policies promoting the appropriate use of antibiotics in the region [10].

Recent progress in AMC surveillance was demonstrated in a 2022 study conducted across six Latin American countries, including Costa Rica [7]. The study used the standardized World Health Organization (WHO) methodology for analysis [5]. The results of this study did not account for the entire public and private sectors in any of the countries [7].

In Costa Rica, antimicrobials for systemic use can only be dispensed with a medical prescription and must be registered with the Ministry of Health [11]. In 2018, the National Action Plan against AMR 2018–2025 was published, which coordinates efforts to reduce resistance by promoting good prescribing practices and improving surveillance of antimicrobial use [12–14].

The COVID-19 pandemic has been an obstacle to its implementation, as evidenced by the 2023 Country Self-Assessment Survey (TrACSS) report which monitors the implementation of national action plans on an annual basis. According to the government's responses, Costa Rica is at level B, which means that multisectoral working groups or a coordination mechanism committee on AMR have been established under the leadership of the government. However, levels C through E should be reached [15].

The Costa Rican Social Security Fund (CCSS) serves as the central institution overseeing public healthcare. It provides universal coverage to 91% of the population through three levels of care: primary care, peripheral hospitals, and national and specialized hospitals [16]. In the primary care level, over 1,000 units deliver essential services throughout the country. Secondary care includes approximately 104 specialized clinics offering diagnostic services, while tertiary care is provided by around 29 hospitals [16] .

The CCSS has maintained restrictive measures on the prescription of antibiotics over the past decades, with regulations according to the level of care and medical specialty. There are no specific clinical guidelines for common infections, but there are other regulations such as approval by the infectious diseases departments for prolonged treatment and the requirement to obtain cultures or susceptibility test results before approving the dispensing of antibiotics [17, 18].

In 2019, the total consumption of antimicrobials at the CCSS level in Costa Rica was 12.75 defined daily doses per 1000 inhabitants per day (DDD/1000 inh. /day) of antimicrobials. Of the total, 83.00% corresponded to drugs classified as 'Access', which are first or second choice antimicrobials with the best therapeutic value and minimize potential resistance. Only 0.04% of the AMC registered corresponded to drugs in the 'Reserve' group, which are agents of last resort [7].

The private healthcare sector in Costa Rica has grown significantly in recent years, with an estimated 1,335 pharmacies, 380 beds and 61 operating rooms distributed among various private hospitals. This sector provides comprehensive healthcare coverage, with over half a million people enrolled in prepaid medical plans and private health insurance [19]. Part of the Costa Rican population uses private healthcare services, driven by several key motivations. Notably, the public system often involves lengthy waiting times for certain procedures and treatments, which private facilities are generally able to provide more promptly [20]. Patients also appreciate the option to select their preferred doctors and specialists [20]. Furthermore, some perceive private healthcare as providing a higher quality of care, as private hospitals frequently invest in advanced technology and enhanced facilities, thereby improving both patient experience and treatment outcomes [20].

Given that Costa Rica's private healthcare sector complements the services provided by the CCSS, this study also incorporated AMC data from the private sector to provide a comprehensive overview of antimicrobial usage in the country [21]. This study aims to estimate and analyse the overall AMC in Costa Rica.

## Methods

### Type of study

This study is a national-level, retrospective, observational, and descriptive analysis of AMC in Costa Rica. It was conducted in accordance with WHO Methodology guidelines for the Surveillance of National Antimicrobial Consumption [5, 22].

### Study period

The data cover the period from 1 January to 31 December 2019.

### Variables

The analysis considers the health care sectors, information sources, active ingredients according to the Anatomical Therapeutic Chemical (ATC) classification, types of antimicrobials (ATC groups J01 and P01AB), number of packages, pharmaceutical formulations, antimicrobial concentration in the pharmaceutical presentation, AWaRe (Access-Watch-Reserve) group [23], Defined Daily Dose (DDD), DID (DDD/1000 inhabitants/day), and population under study.

### Health care sectors and levels

Both public (CCSS) and private sector data were collected, analysed, and compared. Furthermore, a national analysis of AMC was conducted, covering consumption in its entirety. The presented data corresponds to total data, not disaggregated by community or hospital level.

### Sources of information

Dispensation data from the CCSS are used to gather information from the public sector, while information from the private sector was obtained through IQVIA (formerly IMS Health Inc.). In Costa Rica, IQVIA's data covers sales of antimicrobials in private community pharmacies and distribution in hospital pharmacies belonging to private sector health institutions, excluding governmental data. To conduct a national analysis of AMC, the data from both sources were integrated. This is possible because the two datasets do not overlap.

### Antimicrobials

The study analysed antimicrobials from the J01 and P01AB subgroups of the ATC classification. J01 constitutes 'systemic antibiotics' and P01AB 'nitroimidazole derivatives'. The study includes 360 commercial presentations, with 305 from the private sector and 55 from the public sector. These presentations encompass a total of 56 single chemical entities and 14 combinations.

### AMC measurement and data analysis

The data analysis was conducted using the ATC/DDD system, which was developed by the WHO Collaborating Centre for Drug Statistics Methodology and the Norwegian Institute of Public Health [24]. The DDD is defined as the average maintenance dose per day of a drug used for its main indication in adults. The AMC was calculated by aggregating the number of DDDs for each antimicrobial according to the following formula:

$$\text{No. of DDD} = \text{Total grams} / \text{DDD value}$$

where the total quantity of drug used (grams) was determined by summing the grams of the active ingredient from various formulations (e.g., different concentrations of tablets, capsules, and syrup formulations), and package sizes. The DDD value corresponds to that assigned to each drug by the WHO Collaborating Centre.

For comparative purposes, these data were adjusted according to the population size under study. The accepted standard metric for national AMC estimates is the DID: DDD per 1000 inhabitants per day.

$$\text{DID} = \text{No. of DDD} \times 1000 / \text{population} \times 365$$

In addition to analysing the total AMC in each sector, patterns of consumption are investigated by therapeutic subgroups according to the ATC classification (third or fourth level of ATC group) and by route of administration. Absolute consumption figures were obtained, expressed in DID, as well as relative measures, expressed as a percentage of total consumption.

Furthermore, the calculation of the Drug Utilization 75% (DU75%) Index was conducted, which encompasses antibiotic substances that constitute 75% of total consumption. This was calculated separately for oral and parenteral formulations. The results were presented as a ranking of consumption, expressed at the fifth ATC group level, in DID and as a percentage of the total consumption [25–27].

### AWaRe classification

The AMC was analysed according to the WHO AWaRe Classification (2023 version) [23]. This tool categorizes antibiotics into three groups: the Access, Watch, and Reserve categories which are based on their clinical importance and the risk of promoting resistance [28].

**Table 1** Sources of information for each analysed sector, population covered by each, and percentage of coverage over the total population of Costa Rica

| Data source sector | Source of information | Covered population | % covered population of total country inhabitants |
|---|---|---|---|
| Public (CCSS) | Dispensation data of the CCSS | 4,608,402 | 91.11 |
| Private | IQVIA | 3,328,168 | 65.8 |
| National consumption | Dispensation data of the CCSS + IQVIA | 5,058,007 | 100 |

**Table 2** Total antimicrobial consumption in each sector, expressed in DID, DDD and percentage (%)

| | National consumption | Public | Private |
|---|---|---|---|
| DID | 14.32 | 12.75 | 4.12 |
| DDD | 26,445,759 (100) | 21,446,746 (81.1) | 4,999,013 (18.9) |

### Study population

The national population data for Costa Rica is obtained from the Population Estimates and Projections report by the National Institute of Statistics and Censuses of Costa Rica (INEC) [29]. The CCSS provides coverage to approximately 91.0% of the population of the country. To determine the user population of the private sector, it is considered that 65.8% of people incur out-of-pocket health expenses, according to the Health Financial Protection Indicators (indicator 3.8.2 SDG) from INEC [21]. In Latin-American countries, it is common that the health sectors are not "pure" since although most of the population has public coverage, people often use the private sector (specially in ambulatory care) to obtain their medicines in private pharmacies. This situation is seen in Table 1 that provides details about the sources of information used for each health sector, the population covered by each of them, and the percentage of coverage in relation to the total national population.

## Results

The national consumption of antibiotics in Costa Rica is 14.32 DID. The public sector accounted for 12.75 DID, while the private sector accounted for 4.12 DID (Table 2).

An analysis of antimicrobial consumption in DDD shows that 81.1% is used in the public sector, while the private sector accounts for 18.9% of total consumption.

Figure 1 presents the relative consumption of antimicrobials, analysed according to the ATC classification. Penicillins are the most consumed group of antimicrobials both nationally (3.54 DID, 24.74%) and in the public sector (3.31 DID, 25.96%). More specifically, amoxicillin is the most used antimicrobial, both nationally (2.99 DID, 20.85%) and in the public sector (3.12 DID, 24.49%) (Table 3). In the private sector, penicillins and their derivatives rank second in terms of consumption (0.80 DID, 19.50%), with the combination of amoxicillin/beta-lactamase inhibitor (clavulanic acid or sulbactam) being the most used antimicrobial within this group (0.56 DID, 13.53%). This combination exceeds amoxicillin consumption (0.22 DID) by 1.5 times in the private sector (Table 3).

Macrolides and lincosamides rank second in terms of national consumption (2.48 DID, 17.32%) (Fig. 1). As shown in Table 3, clarithromycin is the most used antimicrobial within this group, with a consumption of 1.53 DID (10.71%). When comparing the consumption of this group between the public and private sectors, two different scenarios are evident. In the public sector, macrolides are the fifth most consumed antimicrobials (1.67 DID), accounting for 13.11% of total consumption. Clarithromycin is the most widely used (1.56 DID, 12.26%) (Table 3). In contrast, in the private sector, macrolides are the most widely used group, with a consumption of 1.46

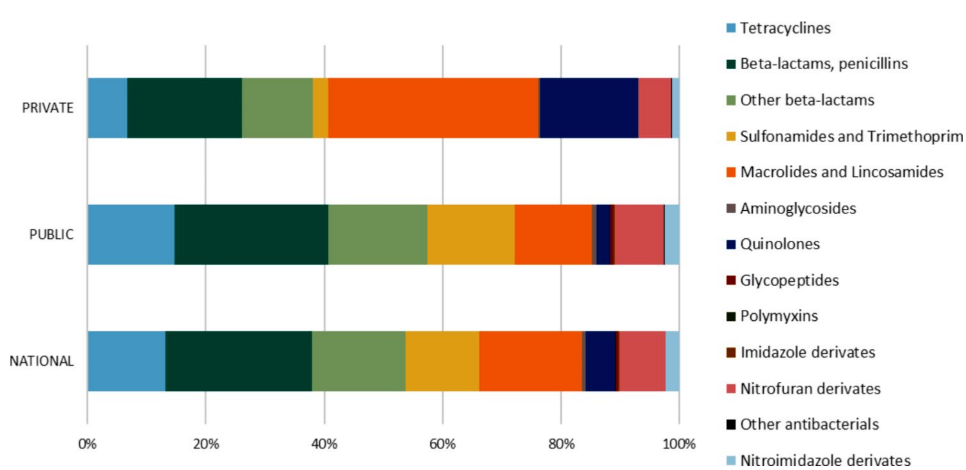


**Fig. 1** Antimicrobial subgroup consumption according to the ATC Classification in each sector, expressed as a percentage (%) of the total consumption

**Table 3** Antimicrobial consumption according to ATC classification in each sector, expressed in DID and as a percentage (%) of the total consumption

| Group | Antibiotic | ATC5 | Route of administration | National | Public | Private |
|---|---|---|---|---|---|---|
| Tetracyclines (J01A) | | | | **1.90 (13.24)** | **1.89 (14.78)** | **0.27 (6.65)** |
| | Doxycycline | J01AA02 | O | 1.88 (13.12) | 1.88 (14.78) | 0.25 (6.02) |
| | Tetracycline | J01AA07 | O | 0.02 (0.12) | - | 0.03 (0.62) |
| | Tigecycline | J01AA12 | P | < 0.01 (0.00) | < 0.01 (0.00) | < 0.01 (0.00) |
| Beta-lactams, penicillins (J01C) | | | | **3.54 (24.74)** | **3.31 (25.96)** | **0.80 (19.50)** |
| | Ampicilin | J01CA01 | O | < 0.01 (0.02) | - | < 0.01 (0.12) |
| | Ampicilin | J01CA01 | P | 0.04 (0.27) | 0.04 (0.33) | < 0.01 (0.01) |
| | Amoxicillin | J01CA04 | O | 2.99 (20.85) | 3.12 (24.49) | 0.22 (5.24) |
| | Benzylpenicillin | J01CE01 | P | 0.07 (0.50) | 0.07 (0.52) | 0.02 (0.40) |
| | Benzathine benzylpenicillin | J01CE08 | P | < 0.01 (0.03) | < 0.01 (0.04) | < 0.01 (0.01) |
| | Oxacillin | J01CF04 | P | 0.06 (0.43) | 0.07 (0.53) | < 0.01 (0.01) |
| | Ampicillin sulbactam | J01CR01 | P | < 0.01 (0.00) | < 0.01 (0.00) | < 0.01 (0.02) |
| | Amoxicillin clavulanic acid/sulbactam | J01CR02 | O | 0.37 (2.57) | < 0.01 (0.01) | 0.56 (13.53) |
| | Amoxicillin/sulbactam | J01CR02 | P | < 0.01 (0.00 | - | < 0.01 (0.00) |
| | Sultamicillin | J01CR04 | O | < 0.01 (0.03) | - | 0.01 (0.15) |
| | Piperacillin/tazobactam | J01CR05 | P | < 0.01 (0.03) | < 0.01 (0.03) | < 0.01 (0.01) |
| Other beta-lactams (J01D) | | | | **2.25 (15.72)** | **2.12 (16.62)** | **0.49 (11.89)** |
| | Cephalexin | J01DB01 | O | 1.68 (11.69) | 1.81 (14.23) | 0.03 (0.82) |
| | Cephalotin | J01DB03 | P | 0.07 (0.47) | 0.07 (0.57) | < 0.01 (0.01) |
| | Cefadroxil | J01DB05 | O | 0.04 (0.29) | - | 0.06 (1.51) |
| | Cefuroxime | J01DC02 | O | 0.03 (0.24) | - | 0.05 (1.29) |
| | Cefotaxime | J01DD01 | P | 0.15 (1.06) | 0.17 (1.30) | < 0.01 (0.02) |
| | Ceftazidime | J01DD02 | P | 0.03 (0.23) | 0.04 (0.28) | < 0.01 (0.02) |
| | Ceftriaxone | J01DD04 | P | 0.11 (0.77) | < 0.01 (0.00) | 0.17 (4.04) |
| | Cefixime | J01DD08 | O | 0.11 (0.76) | - | 0.17 (4.01) |
| | Cefepime | J01DE01 | P | < 0.01 (0.00) | < 0.01 (0.00) | < 0.01 (0.00) |
| | Aztreonam | J01DF01 | P | < 0.01 (0.00) | < 0.01 (0.00) | - |
| | Meropenem | J01DH02 | P | 0.02 (0.15) | 0.02 (0.17) | < 0.01 (0.03) |
| | Ertapenem | J01DH03 | P | 0.01 (0.07) | 0.01 (0.06) | 0.01 (0.12) |
| | Imipenem/cilastatin | J01DH51 | P | < 0.01 (0.00) | < 0.01 (0.00) | < 0.01 (0.00) |
| | Ceftaroline | J01DI02 | P | < 0.01 (0.00) | < 0.01 (0.00) | < 0.01 (0.02) |
| | Ceftolozane/tazobactam | J01DI54 | P | < 0.01 (0.00) | < 0.01 (0.00) | - |
| Sulfonamides and Trimethoprim (J01E) | | | | **1.79 (12.50)** | **1.88 (14.78)** | **0.11 (2.71)** |
| | Sulfadiazine | J01EC02 | O | 0.03 (0.20) | 0.03 (0.24) | - |
| | Sulfamethoxazole/ Trimethoprim | J01EE01 | O | 1.76 (12.30) | 1.85 (14.53) | 0.11 (2.71) |
| | Sulfamethoxazole/ Trimethoprim | J01EE01 | P | < 0.01 (0.00) | < 0.01 (0.00) | - |
| Macrolides and Lincosamides (J01F) | | | | **2.48 (17.32)** | **1.67 (13.11)** | **1.46 (35.40)** |

**Table 3** (continued)

| Group | Antibiotic | ATC5 | Route of administration | National | Public | Private |
|---|---|---|---|---|---|---|
| | Spiramycin | J01FA02 | O | < 0.01 (0.02) | < 0.01 (0.02) | - |
| | Clarithromycin | J01FA09 | O | 1.53 (10.71) | 1.56 (12.26) | 0.17 (4.05) |
| | Azithromycin | J01FA10 | O | 0.83 (5.82) | < 0.01 (0.02) | 1.26 (30.69) |
| | Azithromycin | J01FA10 | P | < 0.01 (0.00) | - | < 0.01 (0.00) |
| | Clindamycin | J01FF01 | O | 0.01 (0.09) | < 0.01 (0.00) | 0.02 (0.48) |
| | Clindamycin | J01FF01 | P | 0.09 (0.65) | 0.10 (0.80) | < 0.01 (0.02) |
| | Lincomycin | J01FF02 | P | < 0.01 (0.03) | - | 0.01 (0.15) |
| Aminoglycosides (J01G) | | | | 0.10 (0.68) | 0.10 (0.75) | 0.02 (0.39) |
| | Gentamicin | J01GB03 | P | 0.07 (0.49) | 0.07 (0.57) | 0.01 (0.18) |
| | Amikacin | J01GB06 | P | 0.03 (0.19) | 0.02 (0.18) | 0.01 (0.21) |
| Quinolones (J01M) | | | | **0.71 (4.95)** | **0.29 (2.25)** | **0.68 (16.56)** |
| | Ofloxacin | J01MA01 | O | 0.02 (0.14) | - | 0.03 (0.76) |
| | Ciprofloxacin | J01MA02 | O | 0.39 (2.69) | 0.27 (2.15) | 0.21 (5.01) |
| | Ciprofloxacin | J01MA02 | P | < 0.01 (0.00) | - | < 0.01 (0.01) |
| | Norfloxacin | J01MA06 | O | < 0.01 (0.00) | - | < 0.01 (0.02) |
| | Levofloxacin | J01MA12 | O | 0.27 (1.91) | < 0.01 (0.03) | 0.41 (9.98) |
| | Levofloxacin | J01MA12 | P | 0.01 (0.06) | 0.01 (0.06) | < 0.01 (0.06) |
| | Moxifloxacin | J01MA14 | O | 0.02 (0.13) | - | 0.03 (0.70) |
| | Moxifloxacin | J01MA14 | P | < 0.01 (0.01) | - | < 0.01 (0.02) |
| Glycopeptides (J01XA) | | | | **0.06 (0.44)** | **0.07 (0.53)** | **< 0.01 (0.04)** |
| | Vancomycin | J01XA01 | P | 0.06 (0.44) | 0.07 (0.53) | < 0.01 (0.04) |
| Polymyxins (J01XB) | | | | **< 0.01 (0.00)** | **< 0.01 (0.00)** | **-** |
| | Colistin | J01XB01 | P | < 0.01 (0.00) | < 0.01 (0.00) | - |
| Imidazole derivates (J01XD) | | | | **0.04 (0.30)** | **0.05 (0.37)** | **< 0.01 (0.00)** |
| | Metronidazole | J01XD01 | P | 0.04 (0.30) | 0.05 (0.37) | < 0.01 (0.00) |
| Nitrofuran derivates (J01XE) | | | | **1.11 (7.76)** | **1.06 (8.28)** | **0.23 (5.53)** |
| | Nitrofurantoin | J01XE01 | O | 1.11 (7.76) | 1.06 (8.28) | 0.23 (5.53) |
| Other antibacterials (J01XX) | | | | **0.01 (0.04)** | **0.01 (0.04)** | **< 0.01 (0.04)** |
| | Linezolid | J01XX08 | O | < 0.01 (0.01) | < 0.01 (0.01) | < 0.01 (0.02) |
| | Linezolid | J01XX08 | P | < 0.01 (0.03) | < 0.01 (0.03) | < 0.01 (0.02) |
| Nitroimidazole derivates (P01AB) | | | | **0.33 (2.30)** | **0.32 (2.54)** | **0.05 (1.30)** |
| | Metronidazole | P01AB01 | O | 0.33 (2.30) | 0.32 (2.54) | 0.05 (1.30) |
| Total | | | | **14.32 (100)** | **12.75 (100)** | **4.12 (100)** |

DID, representing 35.40% of the total. Azithromycin is not only the most used macrolide in this sector but also the most utilized antimicrobial overall (1.26 DID, 30.69%) (Table 3).

Other beta-lactams constitute the third most consumed group nationally (2.25 DID, 15.72%), with cephalexin being the predominant antimicrobial in this group (1.68 DID, 11.69%) (Table 3). In the public sector, this group was the second most used (2.12 DID, 16.62%), with cephalexin also being the most used antimicrobial in the group (1.81 DID, 14.23%). However, in the private sector, ceftriaxone (0.17 DID, 4.04%) and cefixime (0.17 DID, 4.01%) are the primary contributors (Table 3). Within the carbapenems, meropenem is the most consumed antimicrobial in the public sector (0.02 DID, 0.17%), while ertapenem leads in the private sector (0.005 DID, 0.12%) (Table 3).

Tetracyclines rank fourth in national consumption (1.90 DID, 13.24%), third in the public sector (1.88 DID, 14.78%), and fifth in the private sector (0.27 DID, 6.65%), with doxycycline being the primary antimicrobial in both the public (1.88 DID, 14.78%) and private sectors (0.25 DID, 6.02%) (Table 3).

Sulfonamides and trimethoprim constitute the fifth most consumed group nationally (1.79 DID, 12.50%), and the fourth in the public sector (1.88 DID, 14.78%), while in the private sector, they only represent 2.71% of consumption (0.11 DID). Oral sulfamethoxazole/trimethoprim was the predominant antimicrobial in both the public (1.85 DID, 14.53%) and private sectors (0.11 DID, 2.71%) (Table 3).

At the national level, the consumption of nitrofuran derivatives, such as nitrofurantoin, was higher (1.11 DID, 7.76%) than ciprofloxacin (0.39 DID, 2.69%). This trend is consistent in both the public and private sectors (Table 3).

National consumption of quinolones accounted for 4.95% of the total consumption (0.71 DID), while in the public sector, it represented 2.25% (0.29 DID). In both sectors, ciprofloxacin was the most used quinolone (Table 3). However, in the private sector, quinolones were the most consumed group after macrolides and beta-lactams, comprising 16.56% of the total (0.68 DID). Levofloxacin was predominantly used in this sector (0.41 DID) (Table 3).

Regarding the glycopeptides group and other antibacterials, the public sector consumption of vancomycin was higher (0.068 DID, 0.53%) than linezolid consumption (0.005 DID, 0.04%). However, in the private sector, consumption of linezolid (0.002 DID, 0.04%) exceeded vancomycin (0.001 DID, 0.04%) (Table 3).

According to the AWaRe Classification (Fig. 2), the national consumption of antimicrobials was primarily in the Access category, accounting for 74.7% (10.70 DID). This was followed by the Watch category at 25.3% (3.62 DID), and the Reserve category at 0.05% (0.006 DID). A similar trend was observed at the public level, where the Access category accounted for 83.0% (10.59 DID) of consumption. At the private level, consumption in the Access category represented 38.9% (1.60 DID), while the Watch category accounted for 61.0% (2.51 DID).

Upon closer examination of the Reserve category both nationally and in the public and private sectors, linezolid was predominantly consumed (Fig. 3). National consumption was associated with linezolid parenteral (P) at 61.31% (0.004 DID), followed by linezolid oral (O) at 20.07% (0.001 DID) and ceftaroline (8.65%, 0.0006 DID) (Table 3). In the private sector, the consumption of linezolid (O) accounted for 36.84% (0.00091 DID), linezolid (P) consumption was 35.68% (0.00088 DID), and ceftaroline accounted for 26.55% (0.00066 DID) (Table 3). Tigecycline was also used (0.83%, 0.00002 DID). At the public level, the trend was maintained with linezolid (P) (70.47%, 0.004 DID) and linezolid (O) (14.57%, 0.001 DID), however, the consumption of tigecycline (6.04%, 0.0003 DID) was higher than ceftaroline (2.66%, 0.0001 DID) (Table 3). Additionally, colistin (3.43%, 0.0002 DID), aztreonam (1.97%, 0.0001 DID), and ceftolozane/tazobactam (1.01%, 0.0001 DID) were utilized, none of which were employed in the private sector during 2019 (Table 3).

Oral antimicrobial consumption accounted for over 93.0% among all routes of administration in both public and private sectors (Table 4).

When examining the most frequently used oral antimicrobials (DU75%), amoxicillin was the top-ranked nationally (2.99 DID, 22.2%) and in the public sector (3.12

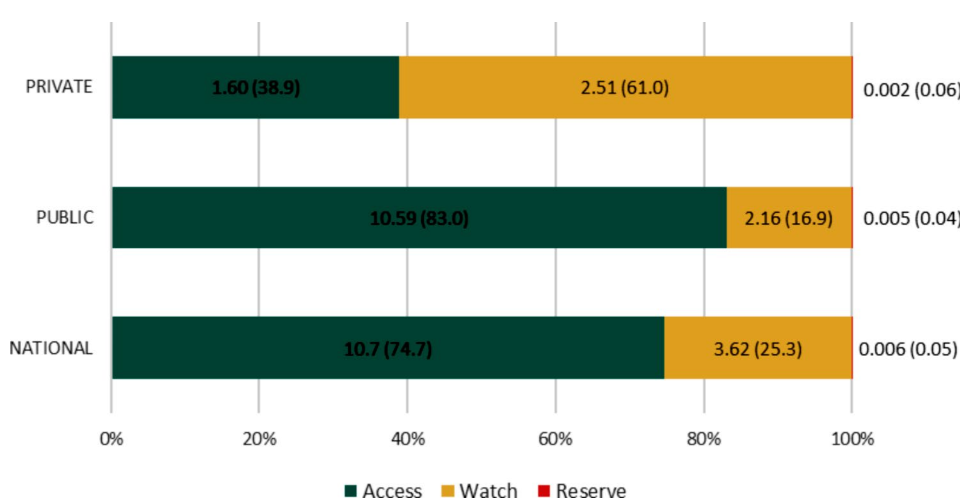


**Fig. 2** Antimicrobial consumption according to the AWaRe Classification in each sector, expressed in DID and as a percentage (%) of the total consumption

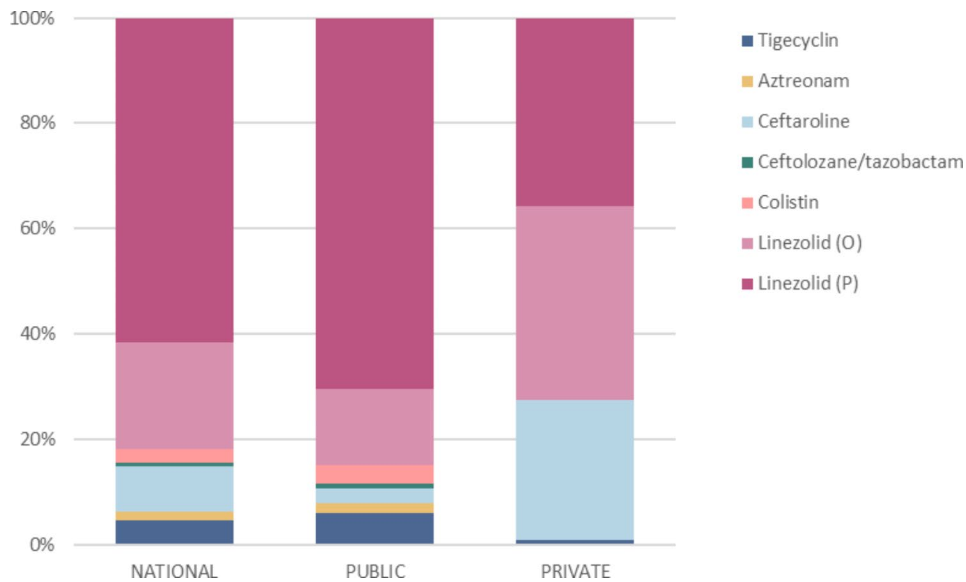


**Fig. 3** Relative consumption of Reserve antimicrobials (AWaRe Classification) in each sector, expressed as a percentage (%)

**Table 4** Antimicrobial consumption by route of administration in each sector, expressed in DID (DDD/1000 inhab/day) and a percentage (%) of the total consumption

| | National | Public | Private |
|---|---|---|---|
| Oral | 13.43 (93.78) | 11.93 (93.61) | 3.89 (94.56) |
| Parenteral | 0.89 (6.22) | 0.82 (6.40) | 0.22 (5.44) |

DID, 26.2%). In the private sector, however, azithromycin was the most used antimicrobial (1.26 DID, 32.5%). Doxycycline, sulfamethoxazole/trimethoprim, cephalexin, and clarithromycin followed in order of frequency both nationally and in the public sector. At the national level, nitrofurantoin ranked sixth in the DU75% and was widely used. In the private sector, the amoxicillin/beta-lactamase inhibitor combination (0.56 DID, 14.3%) occupied second place, followed by levofloxacin (0.41 DID, 10.6%), doxycycline, nitrofurantoin, and amoxicillin. The DU75% includes six antimicrobials nationally and in the private sector, and five in the public sector (Table 5).

The analysis of parenterally administered antimicrobials reveals that cefotaxime was the most used antimicrobial both nationally (0.15 DID, 17.0%) and in the public sector (0.17 DID, 20.3%). Ceftriaxone, clindamycin, benzylpenicillin, gentamicin, cephalothin, vancomycin and oxacillin follow in national consumption. In the public sector, clindamycin was the second most used parenteral antimicrobial, followed by cephalothin, gentamicin, vancomycin, oxacillin and benzylpenicillin. In the private sector, ceftriaxone accounted for 74.2% of consumption (0.17 DID), while benzylpenicillin (0.02 DID, 7.4%) ranked second. At the national level, eight antimicrobials are included in the DU75% ranking, with seven in the public sector and two in the private sector. It is noteworthy that ceftriaxone accounted for most consumption in the private sector (Table 6).

A more detailed analysis was conducted on parenteral antimicrobial consumption in the Watch group.

**Table 5** Ranking of antibacterials at the substance level (5th ATC group level) that compose DU75%, with consumption expressed in DID (DDD/1000 inhabitants/day) and as a percentage (%) of the total oral antimicrobials

| Antimicrobial | ATC5 | National | | Public | | Private | |
|---|---|---|---|---|---|---|---|
| | | Ranking | DID (%) | Ranking | DID (%) | Ranking | DID (%) |
| Amoxicillin | J01CA04 | **1** | 2.99 (22.2) | **1** | 3.12 (26.2) | **6** | 0.22 (5.5) |
| Doxycycline | J01AA02 | **2** | 1.88 (14.0) | **2** | 1.88 (15.8) | **4** | 0.25 (6.4) |
| Sulfamethoxazole/Trimethoprim | J01EE01 | **3** | 1.76 (13.1) | **3** | 1.85 (15.5) | **-** | - |
| Cephalexin | J01DB01 | **4** | 1.68 (12.5) | **4** | 1.81 (15.2) | **-** | - |
| Clarithromycin | J01FA09 | **5** | 1.53 (11.4) | **5** | 1.56 (13.1) | **-** | - |
| Nitrofurantoin | J01XE01 | **6** | 1.11 (8.3) | - | | **5** | 0.23 (5.9) |
| Azithromycin | J01FA10 | - | - | - | - | **1** | 1.26 (32.5) |
| Amoxicillin/ clavulanic acid or sulbactam | J01CR02 | - | - | - | - | **2** | 0.56 (14.3) |
| Levofloxacin | J01MA12 | - | - | - | - | **3** | 0.41 (10.6) |
| **Number of DU75 oral antibiotics** | | *N*=6 | | *N*=5 | | *N*=6 | |

**Table 6** Ranking of antibacterials at the substance level (5th ATC group level) that compose DU75%, with consumption expressed in DID (DDD/1000 inhabitants/day) and as a percentage (%) of the total parenteral antimicrobials

| Antimicrobial | ATC5 | National | | Public | | Private | |
|---|---|---|---|---|---|---|---|
| | | Ranking | DID (%) | Ranking | DID (%) | Ranking | DID (%) |
| Cefotaxime | J01DD01 | 1 | 0.15 (17.0) | 1 | 0.17 (20.3) | - | - |
| Ceftriaxone | J01DD04 | 2 | 0.11 (12.3) | - | - | 1 | 0.17 (74.2) |
| Clindamycin | J01FF01 | 3 | 0.09 (10.5) | 2 | 0.10 (12.5) | - | - |
| Bencylpenicillin | J01CE01 | 4 | 0.07 (8.0) | 7 | 0.07 (8.2) | 2 | 0.02 (7.4) |
| Gentamicin | J01GB03 | 5 | 0.07 (7.9) | 4 | 0.07 (8.9) | - | - |
| Cephalothin | J01DB03 | 6 | 0.07 (7.5) | 3 | 0.07 (8.9) | - | - |
| Vancomycin | J01XA01 | 7 | 0.06 (7.1) | 5 | 0.07 (8.3) | - | - |
| Oxacillin | J01CF04 | 8 | 0.06(6.9) | 6 | 0.07 (8.2) | - | - |
| **Number of DU75 parenteral antibiotics** | | *N*=8 | | *N*=7 | | *N*=2 | |

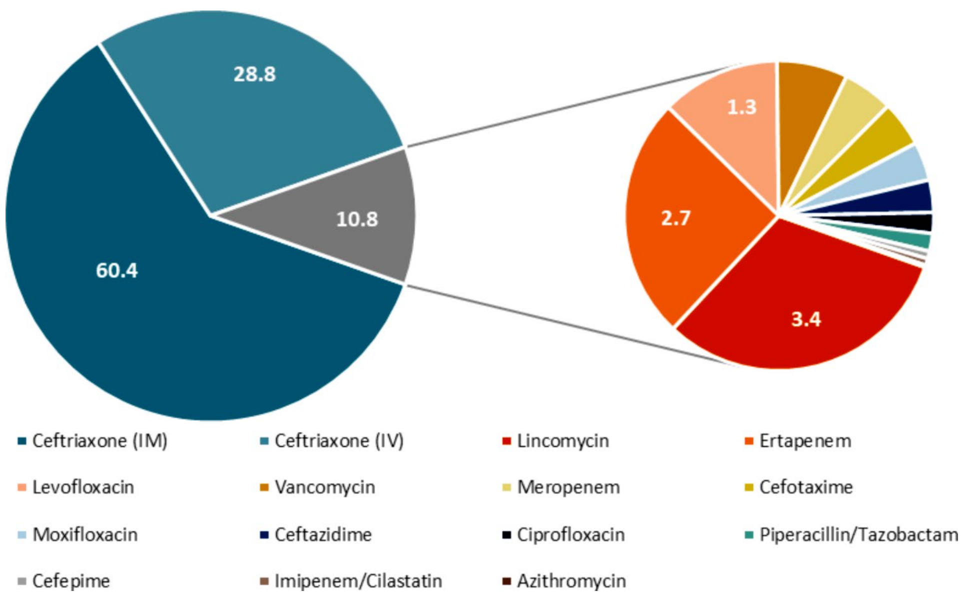


**Fig. 4** Relative consumption of parenteral antimicrobials from the Watch group (AWaRe Classification) in the private sector

Since ceftriaxone represented 74.2% of the total consumption of parenteral antimicrobials in the private sector, and 89.2% if only the Watch group is considered, it was decided to analyse this antibiotic according to its route of administration in this sector (Fig. 4). Most of the available pharmaceutical presentations are for intramuscular (IM) use only. This route represented 60.4% (0.11 DID) of the total consumption of parenteral Watch antimicrobials, while the intravenous (IV) route represented 28.8% (0.05 DID).

A further analysis of the parenteral antimicrobials within the Watch group in the private sector reveals that lincomycin was the most consumed (0.006 DID, 3.4%) after ceftriaxone, followed by ertapenem (0.005 DID, 2.7%), levofloxacin (0.003 DID, 1.3%), vancomycin (0.001 DID, 0.8%), meropenem (0.001 DID, 0.6%) and cefotaxime (0.0010 DID, 0.5%).

On the other hand, in the public sector, cefotaxime was the most consumed parenteral antimicrobial of the Watch group (0.17 DID), representing 53.11%. This was also included in the initial DU75% analysis. This was followed by vancomycin (0.07 DID, 21.81%), ceftazidime (0.04 DID, 11.36%) and meropenem (0.02, 7.06%). There was no consumption of lincomycin. Ertapenem accounted for 2.40% (0.007 DID) and ceftriaxone only 0.15% (0.0005 DID).

## Discussion

Despite the availability of various methodologies [5, 7, 9, 22, 30], middle and low-income countries in Latin America encounter significant challenges in evaluating, surveying, and standardizing the reporting of the AMC. Costa Rica has distinguished itself through its efforts to implement surveillance strategies for resistance and antibiotic usage within its borders [13].

This study reports the first detailed analysis of national consumption in Costa Rica, including both the public and private sectors, based on data from 2019. A previous study, which served as a baseline, limited its analysis exclusively to the public sector [7]. Upon incorporating data from the private sector, it was found that this sector contributes to a 23.3% increase in the amount of DDDs consumed in the country compared to the previous study [7], which shows the extensive use of these medications in this care setting.

Consumption trends in Costa Rica are similar to those reported in other Latin American countries, with a DID range from 6.41 in the public sector of Chile to 36.26 in Argentina, and closer to reports from countries such as Colombia (DID 17.93) and Peru (DID 12.50) [7]. This comparison is also within the ranges observed in European countries, where the DID for 2019 ranges from 9.5 in the Netherlands to 34.1 in Greece [31].

The DID are influenced by both the accessibility of antimicrobials and the nationwide policies governing their use. Therefore, to understand AMC patterns, it is important to consider the differences in prescription policies across various sectors [6].

In the public sector, prescriptions for broad-spectrum antibiotics are subject to restrictions. These restrictions are based on factors such as medical specialties, the level of care, and specific conditions [17]. These measures result in a more regulated consumption pattern, where the predominant consumption of unrestricted antimicrobials, such as amoxicillin, cephalexin, doxycycline, sulfamethoxazole/ trimethoprim, and nitrofurantoin, is observed (Fig. 1; Table 5).

The private sector has greater availability of antimicrobials [32–34]. However, it lacks restrictive measures, allowing prescribers in both outpatient and inpatient settings to prescribe the antibiotics they consider appropriate for their patient. Consequently, there is an increased consumption of antibiotics such as azithromycin and amoxicillin with clavulanic acid. Additionally, there is an increased use of third-generation quinolones and cephalosporins. These are available in the public sector but come with prescription restrictions (Fig. 1). While having a variety of therapeutic options is advantageous, it also carries a higher risk of indiscriminate use and the subsequent development of resistance [35].

The 'Access' group, as proposed by the WHO AWaRe strategy, should account for at least 60% of the total AMC at the national level [23, 36]. This objective has been nationally achieved in Costa Rica, including in the public sector (Fig. 2). According to Tables 5 and Table 6, in the public sector, 72.7% of the most consumed oral antibiotics and 46.7% of the parenteral antibiotics (DU75% index) correspond to the Access category. This could be associated with restrictive measures that prioritize the use of narrower spectrum treatments [17].

Consequently, further research is required within the country to ascertain the veracity of the elevated proportion of Access antibiotic usage. One of the questions that arises from this study is whether these high percentages of Access antibiotic usage can be correlated with the optimal selection of antimicrobial treatment or the timing of the initiation of optimal antimicrobial treatment. The implementation of Antimicrobial Stewardship Programs (AMS) in both outpatient and inpatient settings has the potential to optimize therapies, facilitate feedback interventions, educational interventions, and the development of protocols that allow the prescription of broader-spectrum antibiotics, thereby preventing delays in the initiation of optimal antibiotic treatment [37].

The private sector did not achieve the Access goal, due to the extensive use of Watch antibiotics, both parenteral (74.2%) and oral (43.1%), as indicated by the DU75% index (Fig. 2). In the outpatient setting, azithromycin and levofloxacin were predominant among the oral antibiotics, as per the DU75% index (Tables 5 and 6). The prevalent consumption of azithromycin could be linked to its use in treating upper respiratory tract infections in both adults and children, even though it is considered a second-line treatment for these conditions [38]. Moreover, the typical duration of outpatient treatment is 5 days, leading to significant medication consumption per patient [38].

However, surveillance data from the Costa Rican Institute for Research and Teaching in Nutrition and Health (INCIENSA) reveal that resistance to erythromycin has been detected in microorganisms of interest, such as *Streptococcus pneumoniae*, at rates ranging between 30 and 40%. This could potentially compromise the effectiveness of the treatment [39]. These findings emphasize the necessity for developing national guidelines adapted to antimicrobial sensitivity patterns of the country and supported by available clinical evidence. In this context, evidence supports the use of penicillin and its derivatives as first-line treatment for bacterial infections of the upper respiratory tract [38].

The consumption of quinolones could be related to suboptimal treatment of conditions like cystitis, bronchitis, and sinusitis, which are commonly diagnosed in outpatient settings [40]. The tendency towards overprescribing quinolones, instead of reserving them for situations in which other treatments are not effective, is evident internationally [41]. It is essential to promote restrictive measures through AMSs to reduce the consumption of quinolones in outpatient and inpatient settings. This will not only contribute to decreasing the development of resistance but will also help reduce the risk of *Clostridioides difficile* infections and minimize adverse effects associated with exposure to these medications [40, 41].

Furthermore, while ceftriaxone is the main antibiotic of the parenteral DU75% index, it is predominantly administered IM. This could suggest that its administration primarily occurs in outpatient settings (Fig. 4), as lincomycin, which sees limited use in this setting. Therefore, in the private hospital setting, it is estimated that the use of antibiotics with increased potential for bacterial resistance, such as ceftriaxone, ertapenem, levofloxacin, vancomycin, and meropenem, is particularly notable. The high use of carbapenems is an important aspect to consider, given the low prevalence of Extended-Spectrum Beta-Lactams (ESBLs) reported in private hospitals [32].

Similarly, INCIENSA has reported the presence of beta-lactamases in blood and urine isolates from bacteria such as *Escherichia coli*, *Klebsiella pneumoniae*, and other Enterobacteriaceae. Primarily, AmpC and CTX-M were detected, with percentages ranging from 10.3 to 27.1% in the community [42]. Although carbapenems may be a viable option in these cases, their overuse can accelerate the development of resistance mechanisms, such as the production of carbapenemases. This phenomenon is observed in 10% of *Pseudomonas aeruginosa* isolates nationwide [42].

In terms of the Reserve category, the national consumption of these antibiotics is low. In the private sector, it is observed that both oral and parenteral linezolid are consumed in similar proportions, which suggests a timely transition between inpatient and outpatient treatment (Table 3). The public sector exhibits a tendency towards parenteral administration. This could be attributed to a higher incidence of severe cases, prescription restrictions, limited drug availability, and a lack of national guidelines for transitioning from IV to oral therapy (Fig. 3) [13, 17, 37].

Ceftaroline consumption is prevalent in the private sector, whereas its availability and use in the public sector are restricted, and limited to cases that can be justified [17]. In the public sector, the consumption of tigecycline exceeds that of ceftaroline, a trend that could be linked to its use in treating intra-abdominal and skin infections [43]. According to INCIENSA reports from 2018, a high prevalence of Methicillin-Resistant *S. aureus* (MRSA) was identified in both the community and hospital settings, highlighting the need to use reserve medications due to resistance rates [42].

Several measures could be implemented to control and reduce the consumption of antimicrobials. Among these measures, the creation and promotion of national clinical guidelines are particularly noteworthy. These guidelines would provide clear directives for prescriptions based on the country resistance patterns and the evidence associated with various treatment protocols [13].

It is crucial to offer comprehensive education to professionals who prescribe medications about the implemented restrictive measures. This approach will ensure a better understanding of the purpose of these interventions among these professionals, thereby enhancing their effectiveness [44]. In the public sector, despite the existence of restrictions, some prescribers are unaware of their objective. A significant number of these professionals have received their training in the public sector and concurrently work in the private sector [45]. When these professionals practice in the private sector, they tend to change their prescribing pattern toward broad-spectrum antibiotics [32–34]. This unfamiliarity with the objectives of the restrictions undermines the effectiveness of the restrictive strategy.

Within the "One Health" framework, the inclusion of AMR in the curricula of health-related undergraduate and postgraduate programs can be considered, as well as introducing this topic in primary and secondary school education. In addition, carrying out community outreach and education campaigns, to inform about the dangers of purchasing antimicrobials without a prescription, the importance of medication adherence, and the need to reduce pressure on health professionals to prevent antimicrobial prescription [46].

Implementing electronic prescription systems for systemic antibiotics could greatly enhance the surveillance of these medications, this is part of the national plan of Costa Rica [12, 13]. In Argentina, the promulgation of the "Prevention and Control of Antimicrobial Resistance Law" establishes that all prescriptions for systemic antimicrobials, both in paper and electronic format, must be archived for a minimum of three years, in addition requiring the inclusion of the corresponding diagnosis in each prescription [47]. This regulation not only promotes tighter control over antibiotic prescribing and use but could also be integrated with electronic systems to improve long-term traceability and data analysis.

It is necessary to strengthen monitoring and surveillance systems for consumption, indication and resistance to antimicrobials at the national level. Furthermore, it is important to carry out detailed surveillance at the local or regional level, since consumption and use profiles can vary significantly between different areas, requiring specific measures. The possibility of establishing restrictions on the prescription of antimicrobials in the private sector should also be considered, along with the implementation of measures to develop own sources that allow monitoring consumption in this area [30, 48, 49].

Other specific actions could be considered, such as adapting pharmaceutical presentations according to the recommended dosage and duration of treatment, to promote the rational use of dispensed tablets [47]. Similarly, even though the distribution of antibiotic medical samples in Costa Rica is contingent upon the provision of complete treatments [11], there is a need for improved regulation and supervision.

A limitation of this analysis is that it lacks data regarding the use of antibiotics, rather, it only contains an estimation of consumption data. In addition, the IQVIA database may not include all drugs and brands available on the private market. A major limitation of our study is the inability to differentiate antimicrobial consumption between outpatient and inpatient settings. This challenge is not unique to our study but is prevalent in most other Latin American countries that have evaluated their antimicrobial consumption. Our study inferred consumption in these settings based on the most common use of these antibiotics and the available evidence. Future efforts should focus on enabling this differentiation in the Latin American region to improve the accuracy and utility of antimicrobial consumption data.

## Conclusion

In conclusion, this study demonstrates the efforts of Costa Rica to improve the surveillance of AMC by integrating data from the public and private sectors. The incorporation of the private sector demonstrates that most antimicrobials used in this sector are classified as Watch, indicating irrational use. This issue is associated with the inability to achieve the 60.0% Access indicator established by the WHO. Active participation and strengthening of all sectors and regulatory authorities are essential to reduce irrational use through effective and multisectoral policies. In addition, it is crucial to maintain periodic surveillance of AMC to facilitate the refinement of control measures and strategies at the national level. The methodology used in this study can be replicated in other Latin American countries, allowing for comparisons of antimicrobial consumption by sector and between different countries over time. Furthermore, the findings of this study can be used as a basis for determining differences in antibiotic consumption following the implementation of the digital prescription for systemic antimicrobials, a project by the Costa Rican authorities included in their action plan and set to be implemented soon.

### Author contributions

José Pablo Díaz-Madriz and Gustavo H Marin contributed to the conceptualization and supervision of the project, writing the original draft. Lucia Giangreco designed the methodology and performed data curation, software development, visualization and writing the original draft. Carolina Rojas-Chinchilla performed the formal analysis and writing of the initial draft, as well as reviewing and editing the writing. Esteban Zavaleta-Monestel collaborated in obtaining resources, private data collection and validation. Hugo Marin-Piva and Shing Mi Ching-Fung contributed to public data collection, data curation, writing review and editing, and validation. All authors read and approved the final manuscript.

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### Data availability

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

## Declarations

### Ethics approval and consent to participate

Not applicable.

### Consent for publication

Not applicable.

### Competing interests

The authors declare no competing interests.

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