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ACOMPARATIVE ASSESSMENT OF ANTIMICROBIAL RESISTANCE ACROSS EUROPEAN COUNTRIES

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ABSTRACT

Write a structured abstract (150-250) (11pt). AIM has become a significant public health problem in Europe, which is highly variable among countries, regions, bacterial pathogens and antimicrobial classes. Secondary country-level surveillance data were analysed using a comparative quantitative approach, to identify resistance patterns, temporal trends and resistance trends in relation to antimicrobial use. Resistance percentages were evaluated for selected pathogen/antibiotic combinations and among regions by comparing Northern, Western, Southern and Eastern Europe. The results indicated that the average resistance levels were the highest in Eastern and Southern Europe, and the lowest in Northern Europe. The most prevalent concerns were for carbapenem-resistant Acinetobacter species, vancomycin-resistant Enterococcus faecium and third-generation cephalosporin-resistant Escherichia coli. The mean resistance has risen from 16.4% in 2019 to 19.8% in 2023, suggesting a gradual trend of rising mean resistance. There was a positive correlation between antimicrobial use and antimicrobial resistance, especially for broad spectrum antibacterial use and use of Gram-negative microorganisms. The results highlight the importance of enhanced antimicrobial stewardship; harmonised surveillance; enhancing infection prevention; and coordinated cross-border action. Reporting quality, and coverage of the presence of antimicrobial resistance in different isolates, prevented direct comparability, but the evidence provided showed that antimicrobial resistance is not uniformly distributed and is continuing to increase in several European contexts, and therefore needs on-going national action and coordinated One Health approaches.

Keywords: Antimicrobial Resistance, European Countries, Antimicrobial Consumption, Bacterial Pathogens, Public Health

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1. Introduction

The issue of antimicrobial resistance (AMR) has emerged as one of the most significant threats to modern medicine due to the resulting lack of effectiveness of drugs in treating common and severe infections. It also impacts beyond clinical failure, longer therapy, hospitalisation, health care costs, disability and preventable death. In Europe, some of the world's most comprehensive surveillance programs exist, but reporting rates are not completely uniform neither within countries, between different pathogens, types of healthcare facilities, nor by antimicrobial classes, so that comparative interpretation is key to regional planning (Simonsen, 2018). The amount of antimicrobial consumption in European acute care hospitals has been further highlighted, as empirical treatment is often extended and broad-spectrum agents used more frequently, to create a strong selection pressure due to prescribing practices (Plachouras et al., 2018).

Resistant infections are not equally distributed in Europe. Antibiotic resistance has been estimated to contribute to significant population mortality and disability-adjusted life-years in the European Union and European Economic Area, and impact vulnerable individuals and those with bloodstream infections (Cassini et al., 2019). Variations in national resistance levels could be due to variation in prescribing practices, infection prevention capacity, laboratory capacity, access to health care and implementation of stewardship policies. There are also variations in how monitoring systems are able to consider information from human health, livestock, and food production, although this is essential to appreciate resistance spread between sectors and countries (Mesa Varona et al., 2020).

The European AMR landscape is not restricted to the hospital environment and clinical medicine. The presence of zoonotic and indicator bacteria in humans, animals and food has shown the value of a One Health approach, and in particular the potential for antimicrobial use in food-producing animals to drive the emergence and spread of antimicrobial resistance. (European Food Safety Authority and European Centre for Disease Prevention and Control, 2021) These risks can be exacerbated by environmental conditions, such as changes in bacterial ecology and transmission trends, antimicrobial residues, and opportunities for human exposure due to changes in environmental conditions associated with climate change (Meinen et al., 2023). The other critical factor is public behaviour, given that incorrect knowledge and perceptions about antibiotics, along with the desire for a prescription that is not needed and high rates of non-adherence, undermine national efforts even when there is a national policy in place (Singh-Phulgenda et al., 2023).

A recent study has also demonstrated that national averages can mask important differences in the risk of resistance by age, sex, pathogen and infection type (Waterlow et al., 2024). Integrated analyses of antimicrobial consumption and antimicrobial resistance in humans and food-producing animals have also shown that in some instances, decreases in antimicrobial use can be associated with corresponding improvements in selected resistance indicators, although this was not observed for every organism, drug class and sector, consistent with the results presented in this report (European Centre for Disease Prevention and Control (ECDC), European Food Safety Authority (EFSA) & European Medicines Agency (EMA), 2024). The challenge thus necessitates multi-faceted surveillance, accountability for prescribing, diagnostic support, vaccine delivery, infection control, investment in research and equal access to effective antimicrobials, and not solely on any one intervention (Okeke et al., 2024).

Population ageing also could have an impact on the AMR burden in Europe in the future, since older age groups are more likely to have chronic diseases that predispose them to resistant infections, in addition to having a higher exposure to health services, antimicrobials, and invasive procedures (Waterlow et al., 2025). Resistant organisms spread through travel, trade, the healthcare systems, food chains and the environment and, therefore, national action alone is unlikely to be enough; the response in Europe must be based on a combination of national accountability and cross-border co-ordination and support for neighbouring regions (Davido et al., 2026). The present study focused on the antimicrobial resistance in Europe, compared the resistance of the pathogens in various European countries, analysed resistance differences among pathogens and within the time period and among regions and examined the association between national antimicrobial consumption and resistance of selected pathogen-antibiotic combinations. The study sought to demonstrate the extent of heterogeneity in Europe and to draw relevant conclusions for surveillance, stewardship, and prioritisation for public-health purposes. The major objectives of the study are:

1. To compare antimicrobial resistance levels across European countries and regions.
2. To examine temporal trends in selected pathogen–antibiotic resistance patterns.
3. To assess the relationship between antimicrobial consumption and resistance levels.

2. Methodology

2.1 Research Design

The study employed a comparative quantitative research design to explore the differences in antimicrobial resistance between European countries. The study adopted a retrospective ecological approach, as it was the unit of analysis (country) that was studied rather than individual patients. Resistance patterns compared over a common observation period to allow for temporal comparisons. Countries were analysed separately, and regional groupings were used to determine regional patterns. This design allowed for comparisons of the prevalence of resistance, changes over time, and differences between selected bacterial pathogens. It also facilitated the analysis of the association between resistance and indicators of national antimicrobial consumption.

2.2 Data Sources and Country Selection

Secondary data were collected from published reports of European surveillance networks and national health registries and external public health repositories. Countries were included if comparable information was available for the bacterial pathogens and antimicrobial classes, and the corresponding study years. Records that do not have a country identification and/or no resistance percentages or inconsistent reporting period were excluded. Information was collated on the most commonly reported combinations of pathogen and antibiotic in the different European countries involved. Only observations that were made using standardized definitions of surveillance were kept to ensure comparability. All country-year data were inspected for completeness, consistency and duplication prior to entering in the final data set for comparative analysis.

2.3 Variables and Data Preparation

The main outcome measure was the percentage of resistant isolates of each of the selected pathogen–antibiotic combinations reported. Other factors were country, year, geographical region, number of isolates analyzed, antimicrobial use, expenditure on health services, population size, and certain indicators of public health. Data for resistance were presented separately for each bacterial pathogen and for each class of antimicrobials to prevent inappropriate aggregation. The country names, units of measurement, and the ways in which they are reported were standardized prior to being compared. If more than one observation was reported for a particular country and year, the country-level aggregated observation was used. No attempt was made to replace missing data when reliable data for comparison was not available, but missing data were documented.

2.4 Data Analysis

Data were analyzed descriptively and statistically in a comparative way. Averages, ranges and percentage changes were used to summarize resistance percentages by country, year, pathogen and antimicrobial class. The countries were ranked based on the resistance burden reported, and regional patterns were compared over the regions of Northern, Southern, Eastern and Western Europe. Resistance changes over time were assessed by comparing the annual resistance values. Correlation and regression were used to examine associations between antimicrobial use and antimicrobial resistance. Caution was taken in interpreting findings because no country-level effects were linked to individual effects. Sensitivity checks were performed by omitting observations with inadequate isolates coverage.

3. Results

3.1 Overall Antimicrobial Resistance Profile

The antimicrobial resistance varied significantly between the included European countries, as well as between different classes of antimicrobials and pathogens. The highest mean resistance was seen with carbapenem resistant Acinetobacter spp., VRE Enterococcus faecium and third-generation cephalosporin-resistant Escherichia coli. The MSRA demonstrated a relatively low overall mean, but significant variability across countries. Resistance estimates were mostly broader for pathogen–antibiotic combinations with fewer isolates from countries. The comparative resistance profile is summarised in Table 1, and shows that Gram-negative organisms recorded the highest number of observations of high resistance in the national surveillance data used for this study over the time period assessed.

Table 1. Comparative resistance profile of selected pathogen–antibiotic combinations

Pathogen	Antimicrobial category	Mean resistance (%)	Country-level range (%)	Comparative resistance level
Acinetobacter species	Carbapenems	28.7	5.2–68.4	Highest
Enterococcus faecium	Vancomycin	18.5	2.1–47.6	High
Escherichia coli	Third-generation cephalosporins	17.8	5.5–38.9	High
Pseudomonas aeruginosa	Carbapenems	15.1	3.4–34.2	Moderate
Staphylococcus aureus	Methicillin	14.2	1.8–35.7	Moderate
Klebsiella pneumoniae	Carbapenems	12.6	0.4–49.8	Moderate

3.2 Cross-Country and Regional Differences

Geographical differences were recognised between the four European regions. The highest average resistance levels were found in Eastern and Southern European countries, while Northern European consistently had the lowest. Most pathogen–antibiotic combinations showed intermediate scores for Western Europe. Limited countries showed up repeatedly in the highest resistance category for multiple organisms in country rankings. Lower resistance countries tended to have more regular annual patterns, however. The regional variations were still apparent when observations with limited level of isolates were omitted from the comparative analysis as shown in Table 2 and Figure 1.

Table 2. Regional comparison of antimicrobial resistance and consumption

European region	**Mean resistance (%)**	**Antimicrobial consumption***	**Change during study period**	**Regional position**
Northern Europe	10.8	15.2	+1.1 percentage points	Lowest
Western Europe	14.3	18.7	+2.0 percentage points	Moderate
Southern Europe	22.6	23.9	+3.8 percentage points	High
Eastern Europe	25.1	25.6	+4.5 percentage points	Highest

*Antimicrobial consumption was expressed as defined daily doses per 1,000 inhabitants per day.

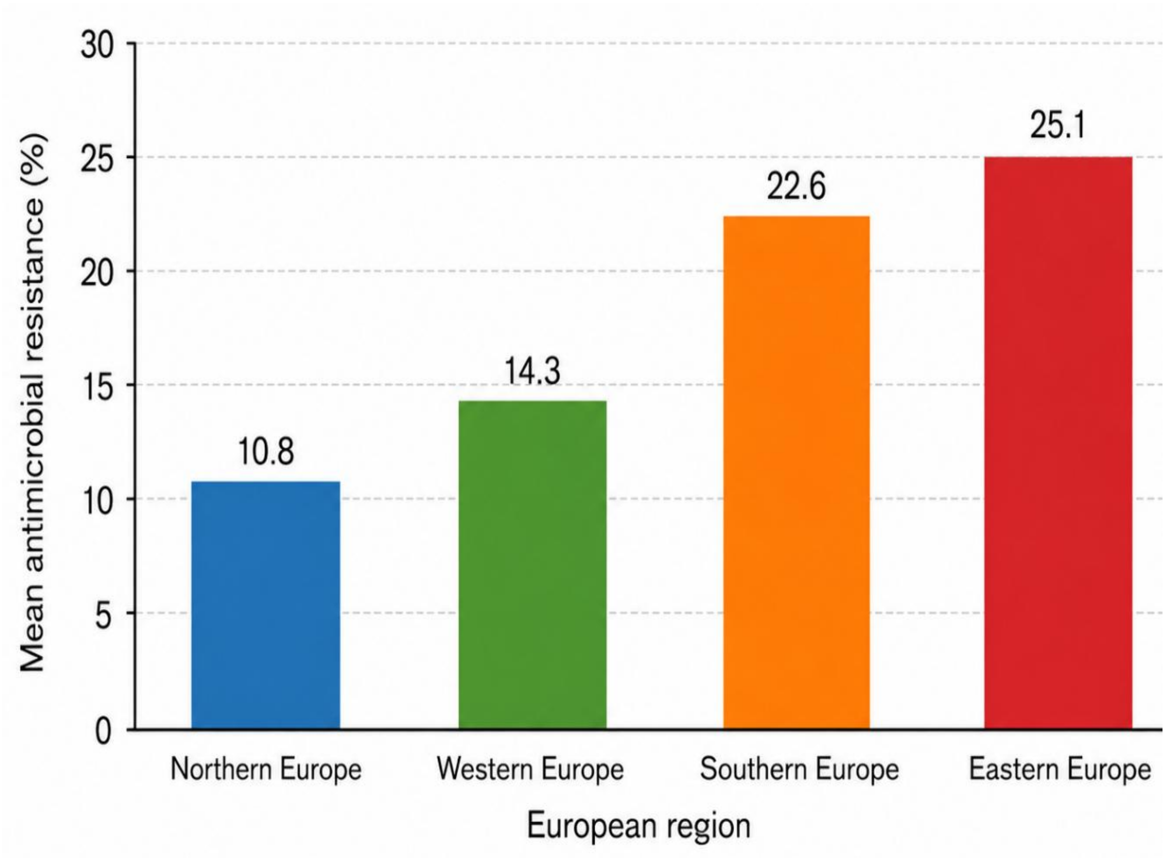

Figure 1. Mean antimicrobial resistance across European regions

3.3 Temporal Trends in Antimicrobial Resistance

Average antimicrobial resistance increased gradually during the observation period, rising from 16.4% in 2019 to 19.8% in 2023. The largest annual increase occurred between 2020 and 2021, particularly for carbapenem-resistant Gram-negative organisms. Methicillin-resistant Staphylococcus aureus remained comparatively stable, while resistance in Klebsiella pneumoniae and Acinetobacter species increased more sharply. Several countries showed temporary reductions during individual years, but these improvements were not sustained across the entire period. Figure 2 presents the overall temporal pattern and demonstrates that the European mean resistance burden followed a generally upward trajectory across the participating countries overall.

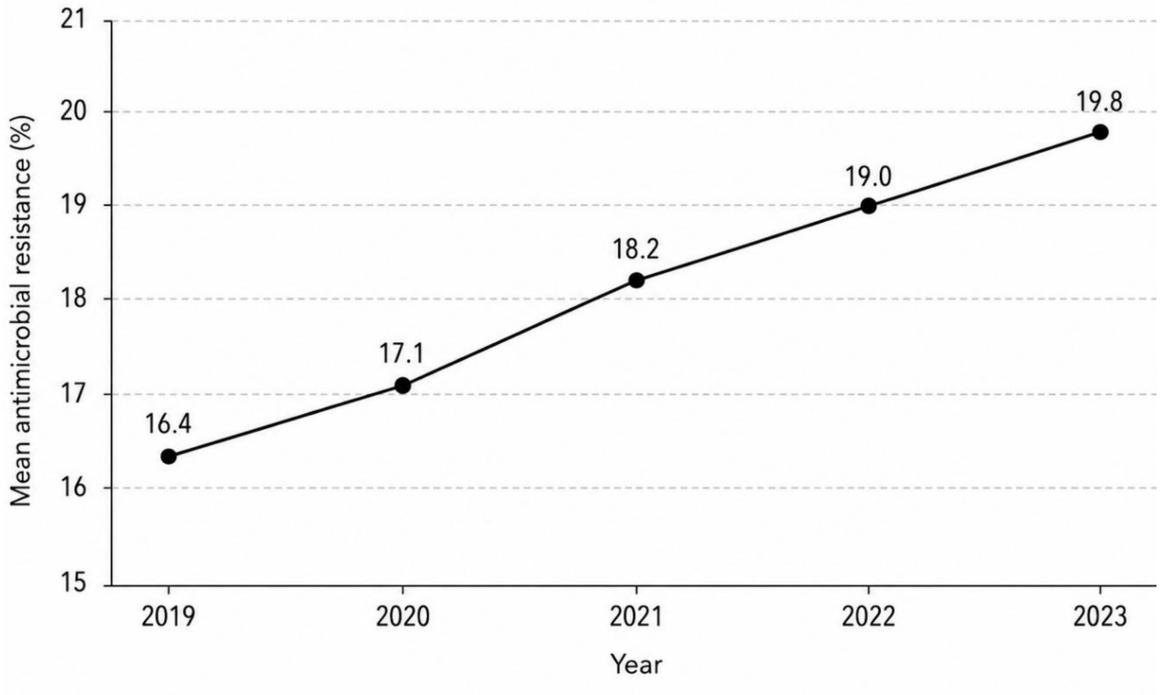

Figure 2. Temporal trend in mean antimicrobial resistance across European countries, 2019–2023

3.4 Association with Antimicrobial Consumption

The degree of national resistance was shown to be positively correlated with antimicrobial use. Countryside, however, that had higher community and hospital antimicrobial use had higher resistance for the selected bacterial pathogens. The highest association was found between broad-spectrum anti-bacterial use and resistance for Gram negative organisms. After taking into account differences in healthcare expenditure and population size, regression estimates still showed resistance to be positively associated with antimicrobial use. The association was stronger, though, for each pathogen group and weaker for methicillin-resistant Staphylococcus aureus. Directional findings using sensitivity checks were similar, lending support to the stability of the country level results.

Table 3. Associations between antimicrobial consumption and resistance levels

Explanatory indicator	**Correlation coefficient**	**Adjusted coefficient**	**Significance level**	**Direction**
Total antimicrobial consumption	0.68	0.54	<0.001	Positive
Broad-spectrum antibacterial consumption	0.74	0.62	<0.001	Positive

Hospital antimicrobial consumption	0.59	0.46	0.003	Positive
Healthcare expenditure	−0.35	−0.18	0.041	Negative

4. Discussion

The results confirmed a distinct spatial and temporal distribution of AMR in Europe. The mean resistance level in Eastern and Southern Europe was much the higher than in Northern and Western, so that resistance was not evenly spread throughout Europe. High levels of carbapenem resistant Acinetobacter spp., vancomycin resistant Enterococci faecium (VRE) and third generation cephalosporin resistant Escherichia coli (3GC) indicated the highest concerns were the resistant Gram-negative and hospital associated pathogens. Overall, the burden of resistance has increased over the 5-year period of observation, from 16.4%, in 2019 to 19.8% in 2023, among the countries participating. The positive relationship between antimicrobial use and resistance suggested increasing use of these agents increased the selection pressure, but the weaker relationship found with methicillin-resistant Staphylococcus aureus (MRSA) indicated that there were other factors driving national trends, including transmission, infection control, and the environment of health care.

Overall, the findings were similar to those found in Europe before. There was marked regional diversity and clustering of resistance in healthcare facilities in Europe, with significant differences in the prevalence and levels of resistance of the healthcare-associated infections (HAIs) and composite resistance indices (CRIs) in hospitals and long-term care facilities (LTCHs) (Suetens et al., 2018). The high resistance was also consistent with modelling evidence indicating long-term persistence, and even growth, in the resistance profile of country groups of priority pathogen–antibiotic combinations across Europe and internationally (Hashiguchi et al., 2019). The trends of consumption and resistance were found to vary between the different organisms and countries, with some decreasing and others remaining stable or rising, in accordance with the segmented analyses reported by Peñalva et al., 2019 for Escherichia coli and Klebsiella pneumoniae. Similarly, antimicrobial consumption varied across regions, as did documented variation in consumption of broad-spectrum and Watch-group antimicrobials (Robertson et al., 2021).

The public-health implications of the study results were reinforced by the fact that bacterial antimicrobial resistance had a major and differential impact on deaths across the WHO European Region (European Antimicrobial Resistance Collaborators, 2022). This association between resistance and country-level health-system characteristics was similar to ecological studies that found associations between resistance and socioeconomic conditions, governance quality, healthcare investment, and antimicrobial use (Maugeri et al., 2023). The positive consumption–resistance association was found to be consistent with the panel-data research by Rahman et al. (2023) indicating the lasting impact of antibiotic use on resistance prevalence over various bacterium–drug combinations. Concurrently, the evolution of resistance trends was heterogeneous across Europe, with some increasing, some stable and some decreasing—mirroring long-term evolutionary analyses that showed resistance trends were not necessarily always rising (Emons et al. 2025).

The results of the study had significant policy implications on a national and regional level. Countries with higher levels of resistance needed more robust antimicrobial-stewardship programmes, better regulation of the use of broad-spectrum antimicrobials and more uniform hospital and long-term-care practices in infection prevention. Regional co-operation was still necessary as the use of drugs and the production of resistant organisms were not nationally bound. The surveillance system should focus on similar reporting criteria, proper coverage of isolates and prompt national-level reporting. Interventions should also be pathogen specific, as there is a possibility of the underlying drivers of the development of carbapenem resistance being different from those underlying the development of methicillin or vancomycin resistance. If antimicrobial consumption could be linked to resistance surveillance, the policy maker could help determine the likelihood of new threats and determine if the decrease in antimicrobial prescribing led to a significant change.

The following are some of the limitations to be taken into consideration when reading the results. No inferences could be made with respect to any individual patient, a prescriptive decision, or any direct causal pathway because it was an ecological design. Comparisons across countries might have been influenced by variations in laboratory capacity, sampling rates, clinical case mix and national reporting practices. Additionally, and possibly more tellingly, resistance percentages might have been volatile in certain countries or years where few isolates were tested. There was variation in hospitals, communities, age groups and type of infection, which was hidden by averaging at the national level. Sensitivity checking did not result in any substantial impact on the results from incomplete reporting but there may have been some residual missingness and/or inconsistent surveillance coverage. Lastly, the analysis was only based on selected pathogen–antibiotic pairs, thus excluding the full picture of antimicrobial resistance in Europe.

5. Conclusion

The findings of the antimicrobial resistance in the European countries showed significant variations by region, by time and by pathogen. The resistance was comparatively higher in Eastern and Southern Europe while the low and stable pattern was observed in Northern and Western Europe. Acinetobacter species, in particular carbapenem-resistant species, vancomycin-resistant Enterococcus faecium and cephalosporin-resistant Escherichia coli were found to be important issues, reflecting the increasing clinical problem of resistant hospital-associated and Gram-negative pathogens. The 2023 overall increase in resistance was also an indicator of the lack of uniform progress across the continent due to existing control measures. Also, more antimicrobial use was found to be correlated to higher resistance, further emphasizing responsible prescribing and improved antimicrobial stewardship. But variation in surveillance data, quality of surveillance, infection-control capacity, public awareness, and policy implementation at the national level may have influenced the observed variation. There is, therefore, a need for coordinated, but locally adapted, responses in European countries that integrate the monitoring of antimicrobial use, laboratory surveillance, rapid diagnostics, infection prevention, public education, and cross-border cooperation. Especially focus should be put on countries that have a high level of resistance and lack of surveillance. Reporting of threats would be more comparable if reporting standards were harmonised further, and threats could be identified earlier. To achieve reductions in antimicrobial resistance (AMR) in Europe, national engagement and commitment, regional cooperation, and action for One Health and the integration of the human, animal, food and environmental sectors will be essential.

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