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Background: Little is known about the effect of the COVID-19 pandemic on antimicrobial consumption worldwide.

Objectives: To describe the impact of the WHO Global Action Plan on Antimicrobial Resistance (GAP-AMR) on antimicrobial consumption pre-pandemic and to evaluate the impact of the COVID-19 pandemic on antimicrobial consumption worldwide.

Methods: A cross-sectional time-series analysis using a dataset of monthly purchases of antimicrobials (antibiotics, antivirals and antifungals) from August 2014 to August 2020. Antimicrobial consumption per 1000 population was assessed pre-pandemic by economic development status using linear regression models. Interventional autoregressive integrated moving average (ARIMA) models tested for significant changes with pandemic declaration (March 2020) and during its first stage from April to August 2020, worldwide and by country development status.

Results: Prior to the pandemic, antimicrobial consumption decreased worldwide, with a greater apparent decrease in developed versus developing countries (−8.4%, P = 0.020 versus −1.2%, P = 0.660). Relative to 2019, antimicrobial consumption increased by 11.2%, P < 0.001 in March 2020. The greatest increase was for antivirals in both developed and developing countries (48.2%, P < 0.001; 110.0%, P < 0.001) followed by antibiotics (6.9%, P < 0.001; 5.9%, P = 0.003). From April to August 2020, antimicrobial consumption decreased worldwide by 18.7% (P < 0.001) compared with the previous year. Specifically, antibiotic consumption significantly decreased in both developed and developing countries (−28.0%, P < 0.001; −16.8%, P < 0.001).

Conclusions: The global decrease in antimicrobial consumption pre-pandemic suggests a positive impact of the WHO GAP-AMR. During the pandemic, an initial increase in antimicrobial consumption was followed by a decrease worldwide. AMR plans should specify measures to ensure full implementation of AMR efforts during health crises such as the COVID-19 pandemic.

Introduction

Antimicrobials including antibiotics, antivirals and antifungals are essential medicines. Antimicrobials are used to prevent and treat infection, improve morbidity and mortality, facilitate modern medicine and serve as the foundation for emerging healthcare systems. However, inappropriate use of these medicines has led to antimicrobial resistance (AMR), which is considered a global threat to humanity by the WHO. Globally, antibiotic consumption has increased by 39% per-capita from 2000 to 2015.1 Although high income countries consume antibiotics at higher rates, low-to-middle income countries (LMICs) are experiencing a rapid growth in antibiotic consumption. However, LMICs continue to face challenges accessing effective antibiotics, while burdened with high rates of infectious disease mortality.2 To balance access and limit excess use of antibiotics, the WHO developed a Global Action Plan on AMR (GAP-AMR) in 2015. The GAP-AMR focuses on infection prevention and antimicrobial stewardship.3,4 As of May 2021, the WHO reports 144 countries have finalized their national action plan in alignment with GAP-AMR objectives.5 However, there is no updated data describing the impact of the GAP-AMR plan on antimicrobial consumption worldwide.

The COVID-19 pandemic occurred during global efforts to combat AMR through the GAP-AMR.6 This unprecedented event
caused disruptions to regular healthcare use and presented new challenges to an already strained drug supply chain. Recommendations for the use of azithromycin early in the pandemic, concerns about secondary bacterial infections among patients hospitalized with COVID-19, and the shift to virtual healthcare may have increased the demand for antibiotics.

Consequently, recent studies have raised concern of possible negative impacts of the pandemic on AMR. While several developed countries, (UK, Netherlands, New Zealand, Canada and the US) reported decreases in antibiotic prescribing during the pandemic, there are no data that describe the effect of the pandemic on antimicrobial consumption worldwide and in developing countries. With the dual challenge of treating infections effectively while continuing efforts to control AMR, it is crucial to understand the impact of the pandemic on antimicrobial drug consumption. Understanding these patterns will aid in developing strategies that ensure adequate treatment of infections and equitable access to antimicrobials without jeopardizing AMR efforts.

The objective of this study was to describe the impact of the WHO GAP-AMR on global antimicrobial consumption from 2015 to 2019 (pre-pandemic) and to evaluate the impact of the COVID-19 pandemic on antimicrobial (antibiotics, antivirals and antifungals) consumption worldwide and stratified by economic development status.

Methods

Data source and setting

A cross-sectional time-series analysis of global monthly purchases of antimicrobials from August 2014 through August 2020.

Data on antimicrobial purchases were obtained from IQVIA’s MIDAS database (Durham, North Carolina, United States). This database contains monthly drug purchases for 66 countries and two geographic regions (Central America (N=6 countries) and French West Africa (N=12 countries)). Drug purchases were reported in standardized units overall and by sector (retail, hospital). On average, MIDAS captures 89.5% of all retail- and hospital-based pharmacy purchases in the areas covered. In 2020, 73.3% of the world’s population resided in a MIDAS region. Standardized units were defined by IQVIA as a single tablet/capsule, vial, or 5 mL oral liquid. Venezuela was excluded from the analysis due to hyperinflation and unstable purchasing rates (data not shown).

Overall purchases of antimicrobials and purchases by WHO level-1 Anatomical Therapeutic Chemical (ATC1) class for antibacterial (referred to as ‘antibiotics’ herein), antifungal and antiviral drugs was examined. Antimicrobials typically used for chronic conditions (such as antibiotics for the treatment of tuberculosis and leprosy and antivirals for the treatment of HIV, hepatitis B and C) and non-systemic antimicrobials were excluded from this analysis. Antivirals were further stratified by viral spectrum of activity (Table S1, available as Supplementary data at JAC Online).

To examine whether changes in antimicrobial consumption trends differed by economic development status, the UN’s 2020 World Economic Situation Prospectus was used to group MIDAS regions into ‘developed’ (N=33) and ‘developing’ (N=35) areas. Economies in transition were included in the developing category. This classification accounts for various aspects of a region’s total human development, including per capita gross national income, life expectancy, and educational attainment.

Thirty-eight countries with a published national AMR plan available on the WHO library of AMR national action plans (WHO GAP-AMR) and WHO level-1 ATC codes were included in the analysis for each year examined (2014–2019). The percentage change in antibiotic consumption rates from April to August 2020 to April to August 2019 was assessed globally and by country development status. Mid-year population sizes were estimated using the United Nations (UN) 2018 Urbanization Prospectus. Linear regression models were utilized to determine the average monthly change in antimicrobial consumption over this period stratified by development status.

Impact of the COVID-19 pandemic on antimicrobial consumption

To describe antimicrobial consumption pre-pandemic and the impact of the WHO GAP-AMR, monthly antimicrobial consumption per 1000 population from January 2015 to December 2019 was assessed globally and by country development status. Mid-year population sizes were estimated using the United Nations (UN) 2018 Urbanization Prospectus. Linear regression models were utilized to determine the average monthly change in antimicrobial consumption per 1000 population stratified by development status.

Impact of WHO GAP-AMR on antimicrobial consumption pre-pandemic

To evaluate the impact of the pandemic, global changes in monthly antibiotic consumption per 1000 population in March 2020 (when COVID-19 was declared a pandemic by WHO), relative to March 2019 were assessed. Monthly new COVID-19 case counts per 1000000 population were reported to visualize the timing of antimicrobial consumption in relation to COVID-19 dissemination. These case counts were sourced from the Johns Hopkins University COVID-19 Data Repository and compiled by the Our World in Data group at the University of Oxford.

Interventional autoregressive integrated moving average (ARIMA) models were used to determine whether antimicrobial consumption trends changed in March 2020, relative to the previous year. A ‘pulse’ intervention in the first month of the pandemic (March 2020) was fitted. Additionally, the impact of the early months of the COVID-19 pandemic was examined by including a ramp intervention function comparing consumption rates from April to August 2020 to April to August 2019. Because drug purchasing trends are often autocorrelated and can demonstrate seasonal patterns, the time series was differentiated by 12 months. This differencing resulted in stationary time series for all examined classes and development categories, as measured by augmented Dickey–Fuller tests. Model fit was optimized by examining residual autocorrelation function (ACF), partial autocorrelation function (PACF) and white noise probability plots to determine the appropriate moving average (q) and autoregressive (p) terms.

Secondary and sensitivity analysis

Because China experienced the pandemic at earlier timepoints, in a secondary analysis, changes in antimicrobial consumption per 1000 population were assessed for China only. As peak COVID-19 infection rates were observed in January 2020 in the data, in this analysis, January 2020 versus January 2019 and February to August 2020 versus February to August 2019 consumption rates were evaluated. As the World Bank (WB) classification is also commonly used in the literature, the analysis on

Ethics approval

Ethical approval was granted by the University of Pittsburgh Institutional Review Board (Ref. STUDY21060160).
the impact of COVID-19 on antimicrobial consumption was assessed classifying MIDAS countries into high income countries (HIC), upper middle income countries (UMIC) and low-to-middle income countries (LMIC).21 Many countries have AMR national action plans, although these are not available in the WHO library. Therefore, a sensitivity analysis was performed evaluating changes in antibiotic consumption per 1000 population for all countries available in MIDAS. In this analysis, antibiotic consumption per 1000 population in 2019 was compared with changes in antibiotic consumption per 1000 population in April to August 2020 versus April to August 2019. Data and statistical analysis were conducted in SAS version 9.4 (Cary, North Carolina, United States).

**Results**

Over the study period, from August 2014 to August 2020, the worldwide monthly antimicrobial purchase rate averaged 1112.9 units per 1000 population. The monthly rate was highest for antibiotics (986.6 units per 1000 population) when compared with antifungals (35.2 units per 1000 population) and antivirals (91.1 units per 1000 population). Overall, antibiotics composed most of the antimicrobial consumption (88.7%) followed by antivirals (8.2%) and antifungals (3.2%).

**Impact of WHO GAP-AMR on antimicrobial consumption pre-pandemic**

Figure 1 displays trends in antimicrobial consumption by development status and antimicrobial spectrum of activity (antibiotic, antiviral, antifungal) pre-pandemic from January 2015 to December 2019. Over the study period, developed countries consistently consumed antimicrobials at higher rates than developing countries (1731.46 per 1000 population versus 776.06 per 1000 population in March 2019, Figure 1a). In developed countries, antibiotic consumption rates decreased steadily from 1634.7 units per 1000 population in January 2015 to 1557.0 units per 1000 population in December 2019 with an average monthly rate of \(-8.4\%\) (\(P = 0.020\)) (Figure 1a). Figure 1(b) shows an apparent decrease in antibiotic consumption in developing countries, however, at a lower non-significant rate (\(-1.2\%\), \(P = 0.6601\)). Antiviral and antifungal consumption rates are displayed in Figure 1(c) for developed countries and Figure 1(d) for developing countries. Although developed countries consumed antivirals at higher rates, in both developed and developing countries antiviral consumption had increased (monthly average rate 1.2%, \(P = 0.0166\) in developed countries).

![Figure 1](https://academic.oup.com/jac/article/77/5/1491/6530407)

**Figure 1.** Consumption per 1000 population of antimicrobials and antibiotics in developed (a) developing countries (b) and of antivirals and antifungals in developed (c) and developing countries (d) from January 2015 to December 2019. Slope and P value derived from linear regression models. This figure appears in colour in the online version of JAC and in black and white in the print version of JAC.
and 0.4%, \( P=0.0281 \) in developing countries) from 2015 through 2019. Antifungal consumption showed a non-significant slight decrease in developed countries (average monthly decrease 0.1%, \( P=0.0677 \)) while antifungal consumption significantly increased in developing countries (average monthly increase 0.4%, \( P<0.001 \)).

**Antibiotic consumption in countries with AMR national action plan before and during the pandemic**

Among countries with an AMR national action plan, all but five countries (Egypt, Korea, Brazil, Pakistan and Australia) experienced a decrease in average monthly antibiotic consumption pre-pandemic from January 2015 to December 2019 (Table S3). Antibiotic consumption during the pandemic showed a decrease in April to August 2020 versus April to August 2019 for all countries except Peru. Figure 2 highlights that regardless of prescribing levels pre-pandemic, most countries did not increase their consumption of antibiotics during the pandemic. However, countries with the lowest decrease or that increased antibiotic consumption pre-pandemic were more likely to experience lower levels of decreases in antibiotic consumption during the pandemic (Peru, Pakistan, Brazil).

**Impact of the COVID-19 pandemic on antimicrobial consumption**

*Changes in March 2020 versus March 2019*

Global antimicrobial consumption increased by 11.2% from 714.0 units per 1000 population in March 2019 to 793.9 units per 1000 population in March 2020 (\( P<0.001 \); Table 1). In developed countries, antimicrobial consumption increased from 1731.5 units per 1000 population in March 2019 to 1918.5 units per 1000 population in March 2020 (10.8% increase, \( P<0.001 \)) (Table 1 and Figure 3a; analysis using WB classification can be found in Table S4). Similarly, in developing countries, antimicrobial consumption increased from 512.1 units per 1000 in March 2019 to 572.0 units per 1000 population in March 2020 (11.7% increase, \( P<0.001 \)) (Table 1 and Figure 3b). Figure 4(a) shows country-specific changes in antimicrobial consumption in March 2020 versus March 2019 among all countries. Countries with the highest increase in antimicrobial purchases (≥50%) were neighbouring countries Ukraine, Belarus, Poland, Bulgaria and Russia. Except for Italy and Japan, countries with greatest decrease in purchasing (between −30% to −10%) were developing countries.

Worldwide, and within development groups, antibiotics made up most of the antimicrobial consumption and significantly increased in March 2020 versus March 2019 (global, 674.1 versus...
Table 1. Changes in purchased units per 1000 population of antimicrobials March 2020 versus March 2019 and April–August 2020 versus 2019, excluding China

<table>
<thead>
<tr>
<th>WHO ATC1 Class</th>
<th>Units per 1000 Pop.</th>
<th>% Change</th>
<th>P&lt;sup&gt;a&lt;/sup&gt;</th>
<th>Units per 1000 Pop.</th>
<th>% Change</th>
<th>P&lt;sup&gt;a&lt;/sup&gt;</th>
<th>Units per 1000 Pop.</th>
<th>% Change</th>
<th>P&lt;sup&gt;a&lt;/sup&gt;</th>
</tr>
</thead>
<tbody>
<tr>
<td>All antimicrobials</td>
<td>Mar-19</td>
<td>714.04</td>
<td></td>
<td>Mar-19</td>
<td>1731.46</td>
<td>11.19</td>
<td>&lt;0.001</td>
<td>Mar-19</td>
<td>512.09</td>
</tr>
<tr>
<td>Antibiotics&lt;sup&gt;b&lt;/sup&gt;</td>
<td>Mar-20</td>
<td>793.92</td>
<td></td>
<td>Mar-20</td>
<td>1918.47</td>
<td>10.80</td>
<td>&lt;0.001</td>
<td>Mar-20</td>
<td>571.97</td>
</tr>
<tr>
<td>Antifungals</td>
<td>Mar-19</td>
<td>24.37</td>
<td></td>
<td>Mar-20</td>
<td>615.6</td>
<td>-4.63</td>
<td>0.1579</td>
<td>Mar-20</td>
<td>16.99</td>
</tr>
<tr>
<td>Antivirals&lt;sup&gt;c&lt;/sup&gt;</td>
<td>Mar-20</td>
<td>54.77</td>
<td></td>
<td>Mar-20</td>
<td>266.14</td>
<td>48.17</td>
<td>&lt;0.001</td>
<td>Mar-20</td>
<td>62.09</td>
</tr>
</tbody>
</table>

The data shown are the authors’ analysis of MIDAS Monthly Sales Data, August 2014 to August 2020. Abbreviations: Pop., population; ATC, anatomical, therapeutic, chemical; P, P-value. Bold denotes P value < 0.05.

<sup>a</sup>Reported P values are for an ARIMA pulse intervention in March 2020 and a ramp intervention in April–August 2020.

<sup>b</sup>Excludes antibiotics for TB and leprosy.

<sup>c</sup>Excludes antivirals for HIV, hepatitis B and hepatitis C.

Global consumption of antimicrobials decreased worldwide by 18.1% (from 2625.5 units per 1000 population in April to August 2019 to 2176.5 units per 1000 population in April to August 2020, P < 0.001). Developed countries had the highest decrease in consumption rates (24.5% decrease, P < 0.001) compared with developing countries (16.8% decrease, P < 0.001) and within development group in March 2020 versus March 2019 (23.4 versus 24.4 units per 1000 population, P = 0.003). Analysis using WB classifications showed a slight increase in consumption rates peaking during this time frame. The decrease in consumption rates during this period was significantly different from the increase in consumption rates during March 2019 versus March 2020 (30.0 units per 1000 population, P < 0.001). Antimicrobial consumption by 10.1% comparing April to August 2020 with April to August 2019 (P = 0.001). The decrease was significantly higher in developed countries (28.6% decrease, P < 0.001) than in developing countries (17.2% decrease, P < 0.001). Antimicrobial consumption by 10.1% comparing April to August 2020 with April to August 2019 (P = 0.001). The decrease was significantly higher in developed countries (28.6% decrease, P < 0.001) than in developing countries (17.2% decrease, P < 0.001). Antimicrobial consumption by 10.1% comparing April to August 2020 with April to August 2019 (P = 0.001). The decrease was significantly higher in developed countries (28.6% decrease, P < 0.001) than in developing countries (17.2% decrease, P < 0.001). Antimicrobial consumption by 10.1% comparing April to August 2020 with April to August 2019 (P = 0.001). The decrease was significantly higher in developed countries (28.6% decrease, P < 0.001) than in developing countries (17.2% decrease, P < 0.001). Antimicrobial consumption by 10.1% comparing April to August 2020 with April to August 2019 (P = 0.001). The decrease was significantly higher in developed countries (28.6% decrease, P < 0.001) than in developing countries (17.2% decrease, P < 0.001). Antimicrobial consumption by 10.1% comparing April to August 2020 with April to August 2019 (P = 0.001). The decrease was significantly higher in developed countries (28.6% decrease, P < 0.001) than in developing countries (17.2% decrease, P < 0.001). Antimicrobial consumption by 10.1% comparing April to August 2020 with April to August 2019 (P = 0.001). The decrease was significantly higher in developed countries (28.6% decrease, P < 0.001) than in developing countries (17.2% decrease, P < 0.001). Antimicrobial consumption by 10.1% comparing April to August 2020 with April to August 2019 (P = 0.001). The decrease was significantly higher in developed countries (28.6% decrease, P < 0.001) than in developing countries (17.2% decrease, P < 0.001). Antimicrobial consumption by 10.1% comparing April to August 2020 with April to August 2019 (P = 0.001). The decrease was significantly higher in developed countries (28.6% decrease, P < 0.001) than in developing countries (17.2% decrease, P < 0.001). Antimicrobial consumption by 10.1% comparing April to August 2020 with April to August 2019 (P = 0.001). The decrease was significantly higher in developed countries (28.6% decrease, P < 0.001) than in developing countries (17.2% decrease, P < 0.001). Antimicrobial consumption by 10.1% comparing April to August 2020 with April to August 2019 (P = 0.001).
to August 2019, antifungal consumption decreased significantly worldwide by 14.4% in April to August 2020 (128.8 units per 1000 population in April to August 2019 versus 110.2 units per 1000 population in April to August 2020, \( P < 0.001 \)). Developed and developing countries observed a significant decrease in antifungal consumption by 15.6% (\( P < 0.001 \)) and 13.6% (\( P < 0.001 \)), respectively (Table 1 and Figure 3c and d.).

**Secondary and sensitivity analysis**

In a secondary analysis, China’s antimicrobial consumption rate per 1000 population was evaluated separately and did not follow trends observed from developing countries in the main analysis. Although China consistently experienced the highest peak in antimicrobial consumption in January pre-pandemic, in January 2020, antimicrobial consumption in China experienced a non-significant decrease of 11.9% compared with January 2019 (Table S5). Antimicrobial consumption significantly decreased in China post January 2020 (4374.0 per 1000 population in February to August 2020 compared with 5808.6 per 1000 population February-August 2019).

A sensitivity analysis was conducted to assess antibiotic consumption among all MIDAS countries, including those with no published AMR plans. Findings were similar to the main analysis. Despite differences in antibiotic consumption pre-pandemic (in 2019), only three countries (Kazakhstan, Belarus and Peru) experienced an increase in antibiotic consumption in April to August 2020 versus April to August 2019 (Figure S1).

**Discussion**

As the WHO aims to tackle AMR globally, this analysis assessed antimicrobial consumption before and during the COVID-19 pandemic, while AMR efforts were already taking place. The results show a promising decrease in antimicrobial consumption worldwide pre-pandemic. Countries with AMR national action plans mostly displayed a decrease in antibiotic consumption, although at various levels. Except for Peru, all countries identified with a national action plan decreased antibiotic consumption in April to August 2020 versus April to August 2019. With the declaration of the pandemic, antimicrobial consumption increased in March 2020 followed by a decrease in April to August 2020. These findings are discussed in the following paragraphs.

The decrease in total antimicrobial consumption pre-pandemic was driven by decreases in antibiotics, which comprise almost 89% of all antimicrobials and is suggestive of a positive impact of commitment to the WHO GAP-AMR. As in other studies, only in this study found developed countries continue to purchase antibiotics at higher rates than developing countries. Higher antibiotic

![Figure 3. Consumption of antimicrobials per 1000 population and new COVID-19 cases per 100 000 population. (a) All antimicrobials and antibiotics in developing countries. (b) All antimicrobials and antibiotics in developed countries. (c) Antivirals and antifungals in developed countries. (d) Antivirals and antifungals in developing countries. This figure appears in colour in the online version of JAC and in black and white in the print version of JAC.](https://academic.oup.com/jac/article/77/5/1491/6530407)
consumption rates in developed countries may explain the greater decrease in antibiotic consumption in developed versus developing countries in the pre-pandemic period. The limited decrease in antibiotic consumption in developing countries may be indicative of inequitable access of certain antibiotics.

Interestingly, although developed countries consumed antivirals at higher rates than developing countries, both groups showed a significant increase in antiviral consumption pre-pandemic. This may reflect advances in antiviral therapies and countries’ abilities to prepare in advance for influenza seasons.

Figure 4. Percentage change in units purchased per 1000 population of antimicrobials by jurisdiction in (a) March 2020 versus March 2019 and (b) April–August 2020 versus April–August 2019. This figure appears in colour in the online version of JAC and in black and white in the print version of JAC.

However, this trend is concerning as antiviral resistance is growing worldwide. While most countries concentrate their efforts on antibiotic stewardship, it is vital to ensure strategies are in place to combat the growth of antiviral resistance. This issue is gaining global attention; in 2020, the WHO expanded the ‘World Antibiotic Awareness Week’ to the ‘World Antimicrobial Awareness Week’ to include all antimicrobials, thus including antivirals.

Among countries with an AMR national action plan, trends in antibiotic consumption varied by country. Although the majority...
saw a decrease, some countries (Egypt, Korea, Brazil, Pakistan and Australia) showed an increase in antibiotic consumption despite having an AMR plan. This requires further attention as countries continue to coordinate efforts on AMR stewardship and the pandemic and may indicate the need for country-specific tailored plans. Following the pandemic, all countries (except Peru) saw a decrease in antibiotic consumption, which is encouraging as it suggests that AMR efforts have not been largely derailed. A recent report from the Tripartite AMR Country Self-Assessment Survey on monitoring global progress on AMR 2019–20 shows that over the past 3 years respondent countries have made gradual progress on key indicators including nationwide AMR awareness campaigns, surveillance on antimicrobial consumption and activities for resistance. Although national action plans have been an important advance in the global fight against AMR, they have not gained their full impact, mainly due to persistent disparities in countries capacities to face AMR. Global coordination is needed to ensure future AMR responses are adequate.

As with many drug classes, there was a global increase of purchasing of antimicrobial drugs in March 2020 compared with March 2019, which suggests drug stockpiling by countries in reaction to the pandemic. Antibiotic consumption showed a significant increase worldwide and in both developed and developing countries. The increase in developing countries may be indicative of improved access to antibiotics. After March 2020 however, antibiotic consumption significantly decreased. This finding could reflect the changing recommendations regarding the use of antibiotics for treatment of COVID-19. At the start of the pandemic, WHO recommended empirical antibiotics for the management of severe acute respiratory infections when COVID-19 was suspected. With emerging evidence of low bacterial superinfection cases, WHO narrowed the recommendation for empirical antibiotics to severe COVID-19 cases. This result reinforces findings from several developed countries that showed decreased antibiotic prescribing rates during the first wave of the pandemic (January to June 2020). It also adds to the literature by providing evidence of similar trends in developing countries, where antibiotic consumption during the pandemic also decreased. Overall, this finding suggests that antibiotic stewardship efforts have largely not been derailed despite realignment of the priorities of infectious disease clinicians towards COVID-19 and disruptions in access to regular healthcare during the pandemic. It also may be a reflection of decreased infection rates in general due to COVID-19 mitigation efforts. Nevertheless, it is equally important to ensure that efforts to improve equitable access to antibiotics are not hindered.

Although the antivirals included in this study were not indicated for COVID-19 treatment, antivirals saw the highest increase in purchases especially in developing countries (110% increase in March 2020 versus March 2019). Increases in antiviral consumption occurred prior to peak COVID-19 infection rates, which could indicate panic purchasing in reaction to the viral nature of the disease. Antiviral consumption decreased in developed countries when peak COVID-19 infection occurred in June to August 2020. In developing countries antiviral consumption was higher in April to August 2020 than previous years, although not significantly. This might be suggestive of countries using acute antiviral drugs for the treatment of COVID-19. Although several antivirals are being tested in clinical trials worldwide for the treatment of COVID-19, during the study period remdesivir was the only antiviral approved by the US Food and Drug Administration for the treatment of COVID-19.

There are several limitations of this study. Drug purchase data may not reflect consumption. However, the data source did reconcile for returns and likely reflects patient use after the drug purchase date. It is important to note that data shows changes in antimicrobial consumption over time but cannot assess responsible consumption. The data do not account for medication supplies accessed from stockpiles, which may include antimicrobials. Additionally, the data do not include medicines that are being used under an emergency use authorization prior to regulatory approval (remdesivir). Therefore, our results for medications needed to treat patients with COVID-19 may be underestimated. In this analysis we are unable to adjust for other confounders that may play a role in the observed changes, such as clinical measures, country-specific COVID-19 mitigation measures, and country-specific antimicrobial stewardship efforts. However, our data covers 5 years pre-COVID-19 and shows trends that are beyond secular changes.

Conclusions
Antimicrobial consumption was decreasing across the globe pre-pandemic, especially for antibiotics, suggesting a positive impact of the WHO GAP-AMR. However, some countries displayed an increasing trend in antibiotic consumption despite having an AMR national action plan. In most countries, AMR efforts have widely focused on antibiotics, however, antiviral consumption has been increasing in both developed and developing countries, which requires attention. AMR plans should include specific measures to ensure continued AMR efforts are fully implemented and continued during health crises such as the COVID-19 pandemic. As we have again seen, infectious diseases do not respect national borders. Thus, to avoid indiscriminate use of antimicrobials and further increasing AMR, global cooperation is needed to preserve the effectiveness of antimicrobials.

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This study was carried out as part of our routine work. All authors had full access to all data (including statistical reports and tables) in the study and take responsibility for the integrity of the data and accuracy of the data analysis.

Transparency declarations
None to declare.

Disclaimer
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Data availability
Data may be obtained from a third party and are not publicly available. Data can be obtained through IQVIA.

Supplementary data
Figure S1 and Tables S1 to S5 are available as Supplementary data at JAC Online.

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