# Consistency of daily number of reported COVID-19 cases in 191 countries between two major data sources, 2020-2022

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# *Table of Contents*

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## *Abstract*

**Background:** The coronavirus disease 2019 (COVID-19) pandemic is among the greatest global public health challenges of this century.The WHO and the Johns Hopkins University Center for Systems Science and Engineering (JHU CSSE) were two open-access data sources which were widely used in research and decision-making about the COVID-19 epidemic.High-quality data is one key aspect of public health crisis and pandemic preparedness for decision-making, practice, and research about prevention and control. To better respond to pandemics and other health crises in the future, it is necessary to evaluate the quality of pandemic data to improve rapid response to outbreaks.

**Objective:** To evaluate consistency of daily reported Coronavirus disease 2019 (COVID-19) cases in 191 countries from the Johns Hopkins University Center for Systems Science and Engineering (JHU CSSE) and the World Health Organization (WHO) dashboards during 2020-2022.

**Methods:** We retrieved data concerning new daily COVID-19 cases in 191 countries covered by both data sources from January 22, 2020, to December 31, 2022. The ratio of numbers of daily reported cases from the two sources were calculated to measure data consistency. We performed simple linear regression to examine significant changes in the ratio of numbers of daily reported cases during the study period.

**Results:** Of 191 WHO member countries, only 60 displayed excellent data consistency in the number of daily reported COVID-19 cases between the WHO and JHU CSSE dashboards (case number ratio: 0.9-1.1). Data consistency changed greatly across the 191 countries from 2020 to 2022 and differed across four types of countries, defined by income. Data inconsistency between the two data sources generally decreased slightly over time, both for the 191 countries combined and within the four types of income-defined countries. The absolute relative difference between two data sources increased in 84 countries (particularly for Malta, Montenegro, and United States, R2=0.29) but decreased in 40 countries (P<0.05).

**Conclusions:** The inconsistency between the two data sources warrants further research. Construction of public health surveillance and data collection systems for public health emergencies like the COVID-19 pandemic should be strengthened in the future.

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Title

# Consistency of daily number of reported COVID-19 cases in 191 countries between two major data sources, 2020-2022.

Han Liu[1], Huiying Zong[2], Yang Yang[3], David C. Schwebel[4], Bin Xie[1], Peishan Ning[1], Zhenzhen Rao[1], Li Li[1], Guoqing Hu[1, 5, #]

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84 countries (particularly for Malta, Montenegro, and United States, $R^2$=0.29) but decreased in 40 countries ($P$<0.05).

**Conclusions.** The inconsistency between the two data sources warrants further research. Construction of public health surveillance and data collection systems for public health emergencies like the COVID-19 pandemic should be strengthened in the future.

**Key word**: COVID-19, Consistency, WHO

## Introduction

The coronavirus disease 2019 (COVID-19) pandemic is among the greatest global public health challenges of this century. According to WHO statistics, through 31 December 2023, COVID-19 led to over 7 million people deaths globally and 770 million infected cases[1]. Critical flaws in the prevention and control of COVID-19 epidemic have been reported over the past three years[2-5]. To better respond to pandemics and other health crises in the future, it is necessary to examine and summarize important lessons we learned.

One key aspect of public health crisis and pandemic preparedness is the need for high-quality data to guide decision-making, practice, and research about prevention and control. Two open-access data sources were widely used in research and decision-making about the COVID-19 epidemic[6], the COVID-19 Dashboards released by the WHO and the Johns Hopkins University Center for Systems Science and Engineering (JHU CSSE). The two data sources collected data in different ways and have been reported as having somewhat inconsistent data in several countries[7]. However, a comprehensive evaluation of the consistency between the two data sources has not been conducted across multiple countries and over the key time period of the pandemic, from 2020 to 2022.

The present study systematically examined the consistency of number for daily reported COVID-19 cases in 191 countries from two data sources, WHO and JHU CSSE, from 2020 to 2022.

## Methods

### *Database*

We considered the two most cited datasets that offered open-access numbers of daily reported COVID-19 cases during the pandemic, the WHO COVID-19 Dashboard and the JHU CSSE COVID-19 dashboard. The WHO dashboard was created by the WHO. In January 2020, the WHO developed the case definition of COVID-19 infection and requested all member countries to report the number of daily reported cases through the International Health Regulations (IHR) national focal points. It also collected COVID-19 daily cases and death counts from internet-based public sources (public dashboards and social media) as a supplement.[8] The JHU CSSE dashboard was created by Johns Hopkins University in early January 2020. It gathered data from publicly accessible sources referenced in a version-controlled README file on the repository[6].

For this study, we retrieved publicly accessible numbers of daily reported COVID-19 cases in the 191 United Nations member countries from both data sources between January 22, 2020 and December 31, 2022. Data before January 22, 2020 were not included, as the outbreak had just initiated and the JHU CSSE COVID-19 dashboard was not yet established.

*Data analysis*

Two measures were employed to assess the consistency between the two data sources. One measure was the ratio of the daily number of reported cases from the JHU CSSE dashboard to that from the WHO dashboard, aligned by calendar time. To facilitate our description, we refer to the ratio of daily numbers of reported case between the two data sources as “daily ratio” or, simply, “ratio”. Based on the mean ratio of the 191 countries during the study time period, we classified the daily ratios for each country into five categories of consistency: excellent (0.9≤ mean ratio ≤1.1), high (0.8≤ mean ratio <0.9 or 1.1 < mean ratio ≤1.2), moderate (0.7≤ mean ratio <0.8 or 1.2 < mean ratio ≤1.3), low (0.4≤ mean ratio <0.7 or 1.3 < mean ratio ≤1.6), and poor (mean ratio <0.4 or 1.6< mean ratio). In addition, we empirically built the following rules to calculate the daily ratio in certain unusual cases: (1) when the numerator and denominator were both 0, we defined the ratio as 1; (2) when only the numerator was 0 and the denominator was 10 or greater we defined the ratio as 0.5, and when the denominator was less than 10 we used the fourth criterion listed below to define the value of the ratio; (3) when the denominator was 0 and numerator was 10 or greater we defined the ratio as 2.0, and when the numerator was less than 10 we used the fourth criterion below to define the value of the ratio; and (4) when the numerator and denominator were both less than 10 and their differences were less than 3 (explaining 0.1% of all data), between 4 and 6 (explaining 0.3%), or ≥7 (explaining 0.5%), we arbitrarily defined the ratio as 0.9 or 1.1, 0.7 or 1.3, 0.5 or 1.5, respectively, thus avoiding extremely large or small ratios due to small numerators or denominators. We mapped the mean and coefficient of variation (CV) of the daily ratios between the two data sources for each of the 191 countries.

We graphed box plots and performed the Kruskal Wallis rank sum test to display and compare differences in the mean and coefficient of variation of the daily ratios across groups of countries defined by income levels. The 191 countries were classified into four income-based categories according to the World Bank Analytical Classifications of 2023[9]: low-income countries (LICs), lower middle-income countries (LMICs), upper middle-income countries (UMICs), and higher-income countries (HICs). In addition, simple linear regression with the absolute relative difference in daily number used as the dependent variable and year as the independent variable was performed to examine trends in the daily differences during the study period. A significant and positive regression coefficient indicates worsening data consistency over time, while a significant and negative regression coefficient indicates improved data consistency.

SPSS statistics 26, R version 4.3.0, and Excel spreadsheet 2021 were used for data analysis. “*p*

< 0.05” was regarded as statistically significant.

## Results

*Consistency in daily number of reported cases*

For all observed dates combined, the mean ratio between the daily number of reported COVID-19 cases in the two data sources for the 191 countries was 1.26 (*IQR*=0.27), with the lowest mean ratio in Turkey (0.92) and the highest mean ratio in Sudan (2.48) (**Fig. 1A**). The mean ratio did not differ significantly across the four categories of countries organized by income ($P$>0.05). The median CV of ratio between the daily number of reported COVID-19 cases from the two data sources was 1.16 (*IQR*=1.59) for the 191 countries. The four types of countries had significantly different CVs of ratio ($H$= 10.08, $P$ <0.05) (**Fig. 1B**).

**Fig. 2** and **Fig. 3** display the variations in mean and CV of ratio between the daily number of reported COVID-19 cases from the two data sources across the countries. Of the 191 countries, 60 had excellent consistency (mean ratio: 0.9-1.1), while 37 had low consistency (mean ratio: 0.4-0.7 or 1.3-1.6) and 23 had poor consistency (mean ratio: <0.4 or >1.6) (**Fig. 2, Appendix 1**). Most African and European countries had low or poor data consistency and most Asian countries had high or excellent data consistency. Strikingly, the CV of ratio between the number of daily reported COVID-19 cases from the two data sources during the study time period was higher than 100% in 110 countries (57%), and 20% or less in only 8 countries (4%) (**Fig. 3**).

For the 191 countries combined and within all four income-defined types of countries, the absolute relative difference between daily number of reported COVID-19 cases from the two data sources all increased slightly over the study time period, with $R^2$ values of 0.16, 0.08, 0.06, 0.14, and 0.14, respectively (**Table 1**). Country-specific analyses showed that the absolute relative difference increased in 84 countries but decreased in 40 countries ($P$<0.05) (**Table 2**). In particular, the absolute relative difference increased significantly over time in three countries (Malta, $R^2$=0.25; Montenegro, $R^2$=0.30; United States, $R^2$=0.29).

## Discussion

*Main findings*

This study systematically examined the consistency of number of daily reported COVID-19 cases and number-based epidemic cycles in 191 countries from the two most commonly cited data sources between 2020 and 2022. We generated two key findings. First, there was a 14% difference in global number of daily reported COVID-19 cases between the WHO and JHU CSSE data, and data consistency differed between the four categories of income-defined countries and across the 191 countries. Second, data inconsistency between the two data sources generally decreased slightly over time, both for the 191 countries combined and within the four types of income-defined countries, but it changed differently over time across the 191 individual countries.

*Interpretation of findings*

Inconsistencies in the number of daily reported COVID-19 cases between the WHO and JHU CSSE data reflect differences in data collection and data release strategies across the two data sources. The WHO data came primarily from official daily counts reported by WHO member states, territories, and areas[8], while the JHU CSSE data were derived from a combination of more than 400 sources for over 3,500-point locations[6]. Compared to the WHO data, the JHU CSSE data were collected from a higher number of sources, potentially explaining why the number of daily reported COVID-19 cases from the JHU CSSE data was greater than that from the WHO data for the whole world, the four types of income-defined countries, and most individual countries during most dates[11]. The two data sources also adopted different data release strategies. The JHU CSSE COVID-19 dashboard used automated methods to extract data from each source every half hour and therefore updated data hourly[6]. The WHO COVID-19 dashboard, contrarily, relied on official reports from WHO member countries, territories, and areas; those reports were more prone to delay and updates were less frequent[12].

Variations in data inconsistency between the WHO and JHU CSSE data might also be due to diverse data publishing policies and the evolution of data-releasing agencies, particularly at the local level, across the 191 countries. As the epidemic eased, some countries like Sweden reduced the frequency of data-releasing and even stopped publishing epidemic data, particularly at the local level[13]. These practices likely affected the original data collected by the WHO and the JHU CSSE COVID-19 dashboards in different ways. In particular, sources indexed by the JHU CSSE dashboard were more extensive and were more likely to change over time than those covered by the WHO dashboard[14].

*Implications and limitations*

Our findings have two important implications. First, the inconsistencies in the number of COVID-19 cases between the WHO and JHU CSSE dashboards and the large differences in data inconsistency and data inconsistency changes over time underscore the fact that we do not have a full understanding of the extent to which COVID-19 infections and deaths occurred globally in 2020, 2021, and 2022. Policy-makers, researchers, and public health practitioners should recognize that the two data sources generate somewhat different and even occasionally conflicting results when they use the historical COVID-19 data collected by the WHO and JHU CSSE dashboards to summarize pandemic control experiences and lessons, conduct historical trend analyses, and evaluate intervention strategies[14-16]. Because strong and detailed evidence lacks concerning which of the two data sources is more valid for specific periods of time and specific countries, we recommend users consider both, recognizing each may have flaws. It also would be valuable to conduct further research assessing the quality of the data sources; as an example, comparisons of the data sources with known cycles of the COVID-19 epidemic may yield additional information about the validity of each data source[17, 18].

Second, our results highlight the importance of gathering consistent and accurate data to fight against future pandemics or other public health emergencies[19]. Inconsistent data can lead to unwanted results in decision-making, research, and prevention efforts[20, 21]. Development of standardized data collection and release protocols, along with infrastructure- and competency-building to help all countries gather accurate health data, will prepare us not just for current health situations but also for future pandemics and broad public health emergencies[22].

Our research is primarily limited by the unavailability of a gold standard criterion. We assessed the consistency of two data sources and cannot comprehensively assess the reliability or validity of either, or identify which might be more accurate. No alternative or recognized valid measure of COVID-19 infections or fatalities exists worldwide.

## Conclusions

We report a moderate difference in global average daily number of reported COVID-19 cases between 2020 and 2022 in the WHO and JHU CSSE datasets. The COVID-19 data inconsistency changed significantly across the countries studied and across time, both globally and in 123 individual countries. Data users should understand the inconsistency of the two most cited COVID-19 data sources. Further research is recommended to guide data utilization and prepare for valid health-related data collection in response to future pandemics and public health emergencies.

## Conflicts of interest

The authors declare no competing interests.

## Funding

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**References**

1. WHO COVID-19 dashboard, Available from: https://www.who.int/dashboards/covid19 [cited 2023 December 31].
2. Gardner L, Ratcliff J, Dong E, Katz A. A need for open public data standards and sharing in light of COVID-19. Lancet Infectious Diseases. 2020;21(4):E80-E. doi: 10.1016/s1473-3099(20)30635-6.
3. Nageshwaran G, Harris RC, Guerche-Seblain CE. Review of the role of big data and digital technologies in controlling COVID-19 in Asia: Public health interest vs. privacy. Digital Health. 2021;7:20552076211002953. Epub 2021/04/06. doi: 10.1177/20552076211002953.
4. Pollard CA, Morran MP, Nestor-Kalinoski AL. The COVID-19 pandemic: a global health crisis. Physiological genomics. 2020;52(11):549-57. Epub 2020/09/30. doi: 10.1152/physiolgenomics.00089.2020.
5. Lessons learned from COVID-19 pandemic: virtual regional consultation with informal expert group. New Delhi, India: World Health Organization. Regional Office for South-East Asia, 2022.
6. Dong E, Ratcliff J, Goyea TD, Katz A, Lau R, Ng TK, et al. The Johns Hopkins University Center for Systems Science and Engineering COVID-19 Dashboard: data collection process, challenges faced, and lessons learned. Lancet Infectious Diseases. 2022;22(12):E370-E6. doi: 10.1016/s1473-3099(22)00434-0.
7. Alamo T, Reina D, Mammarella M, Abella A. Covid-19: Open-Data Resources for Monitoring, Modeling, and Forecasting the Epidemic. Electronics. 2020;9(5). doi: 10.3390/electronics9050827.
8. Allan M, Lièvre M, Laurenson-Schafer H, de Barros S, Jinnai Y, Andrews S, et al. The World Health Organization COVID-19 surveillance database. International Journal for Equity in Health. 2022;21(S3). doi: 10.1186/s12939-022-01767-5.
9. World Health Organization. Age Standardization of Rates: A new WHO Standard. Available from: https://datahelpdesk.worldbank.org/knowledgebase/articles/906519.
10. Wu Z, Huang NE, Long SR, Peng C-K. On the trend, detrending, and variability of nonlinear and nonstationary time series. Proceedings of the National Academy of Sciences of the United States of America. 2007;104(38):14889-94. doi: 10.1073/pnas.0701020104.
11. Zuo X, Chen Y, Ohno-Machado L, Xu H. How do we share data in COVID-19 research? A systematic review of COVID-19 datasets in PubMed Central Articles. Brief Bioinform. 2021;22(2):800-11. Epub 2021/03/25. doi: 10.1093/bib/bbaa331.
12. Hu T, Guan WW, Zhu X, Shao Y, Liu L, Du J, et al. Building an Open Resources Repository for COVID-19 Research. Data and information management. 2020;4(3):130-47. doi: 10.2478/dim-2020-0012.
13. Lindström M. The COVID-19 pandemic and the timing of government response: A comparison of four Nordic countries March–June 2020. Scandinavian Journal of Public Health. 2023;51(5):754-8. doi: 10.1177/14034948231171201.
14. Badker R, Miller K, Pardee C, Oppenheim B, Stephenson N, Ash B, et al. Challenges in reported COVID-19 data: best practices and recommendations for future epidemics. BMJ Glob Health. 2021;6(5). Epub 2021/05/08. doi: 10.1136/bmjgh-2021-005542.
15. Badr HS, Du H, Marshall M, Dong E, Squire MM, Gardner LM. Association between mobility patterns and COVID-19 transmission in the USA: a mathematical modelling study. Lancet Infectious Diseases. 2020;20(11):1247-54. doi: 10.1016/s1473-3099(20)30553-3.
16. Guerrier C, McDonnell C, Magoc T, Fishe JN, Harle CA. Understanding health care

administrators' data and information needs for decision making during the COVID-19 pandemic: A qualitative study at an academic health system. MDM Policy & Practice. 2022;7(1):23814683221089844. Epub 2022/04/05. doi: 10.1177/23814683221089844.
17. Dowell SF, Ho MS. Seasonality of infectious diseases and severe acute respiratory syndrome - what we don't know can hurt us. Lancet Infectious Diseases. 2004;4(11):704-8. doi: 10.1016/s1473-3099(04)01177-6.
18. Chemaitelly H, Tang P, Hasan MR, AlMukdad S, Yassine HM, Benslimane FM, et al. Waning of BNT162b2 vaccine protection against SARS-CoV-2 infection in Qatar. New England Journal of Medicine. 2021;385(24). doi: 10.1056/NEJMoa2114114.
19. Johnson B. Five discoveries about COVID-19 made since the public health emergency ended. Nature Medicine. 2023;29(12):2974-6. doi: 10.1038/d41591-023-00084-w.
20. Kung S, Doppen M, Black M, Braithwaite I, Kearns C, Weatherall M, et al. Underestimation of COVID-19 mortality during the pandemic. ERJ Open Research. 2021;7(1). doi: 10.1183/23120541.00766-2020.
21. Garcia J TC, Barbieri M, et al. Differences in COVID-19 mortality: Implications of imperfect and diverse data collection systems. Population Health Metrics. 2021;76:35-72. doi: 10.3917/popu.2101.0035.
22. Suthar AB, Schubert S, Garon J, Couture A, Brown AM, Charania S. COVID-19 case definitions, diagnostic testing criteria, and surveillance across the pandemic’s 25 highest burden countries. medRxiv. 2021. doi: 10.1101/2021.05.11.21257047.

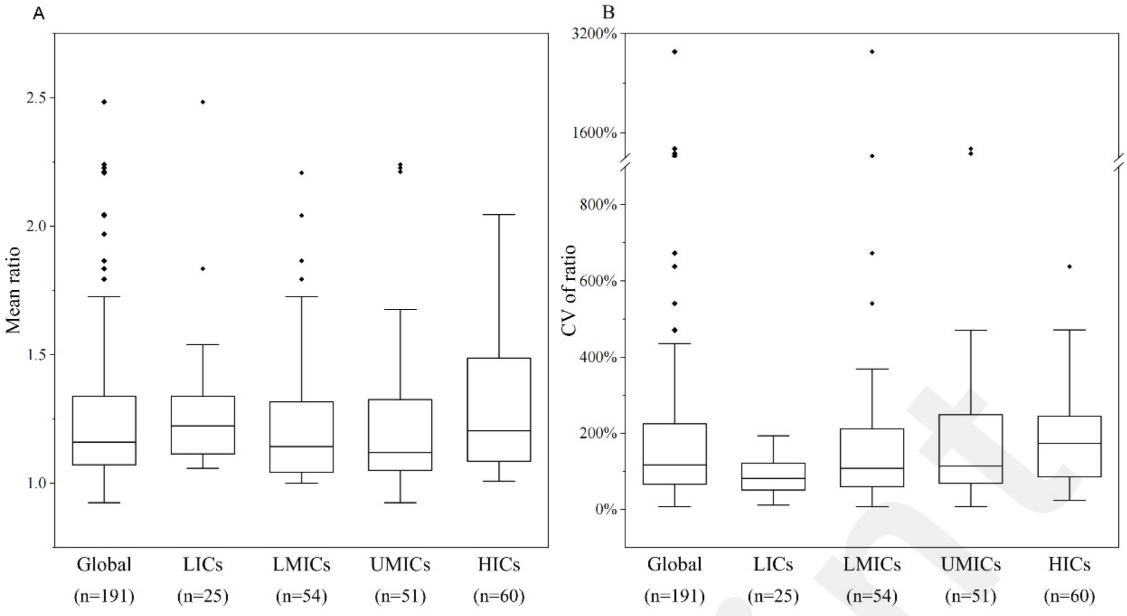


**Fig. 1** Ratio of number of daily new cases from the JHU CSSE COVID-19 dashboard and from the WHO COVID-19 dashboard by country income category, from 01/22/2020 to 12/31/2022

Abbreviations: LICs: low-income countries; LMICs: lower middle-income countries; UMICs: upper middle-income countries; HICs: higher-income countries.

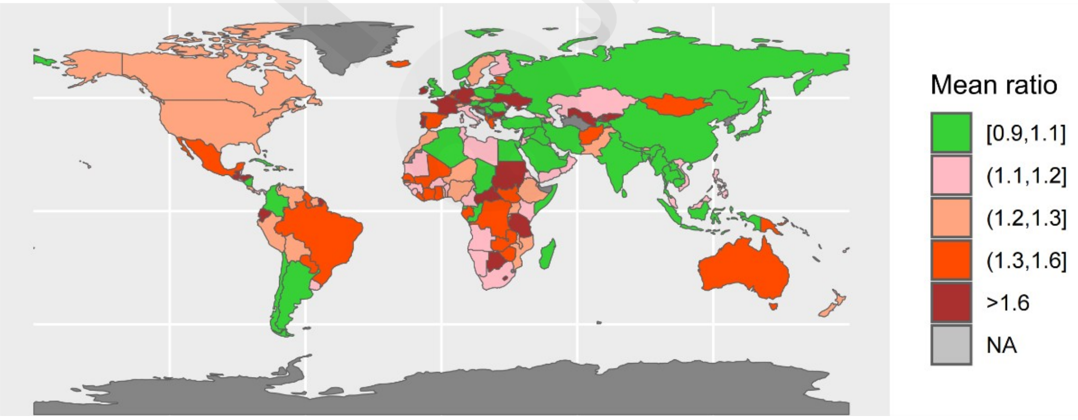


**Fig. 2** Mean ratio of number of daily new cases from the JHU CSSE COVID-19 dashboard and from the WHO COVID-19 dashboard across 191 countries from 01/22/2020 to 12/31/2022

Abbreviations: CV: Coefficient of variation; JHU CSSE: Johns Hopkins University Center for Systems Science and Engineering; WHO: World Health Organization; NA: Not available.

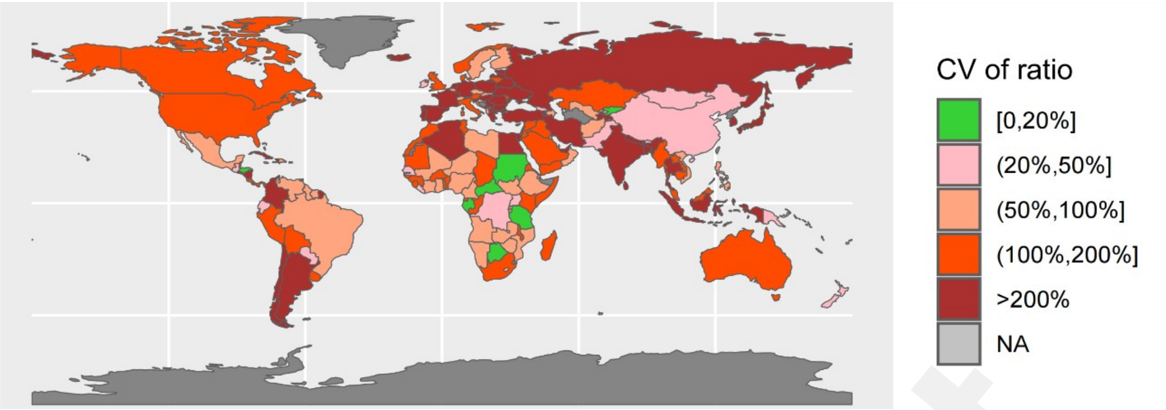


**Fig. 3** CVof ratio of number of daily new cases from the JHU CSSE COVID-19 dashboard and from the WHO COVID-19 dashboard across 191 countries from 01/22/2020 to 12/31/2022

Abbreviations: CV: Coefficient of variation; JHU CSSE: Johns Hopkins University Center for Systems Science and Engineering; WHO: World Health Organization; NA: Not available.

**Table 1.** Linear trends in ratio of number of daily reported cases from the JHU CSSE COVID-19 dashboard and from the WHO COVID-19 dashboard from 01/22/2020 to 12/31/2022, by country income category

| Country income | Linear regression model | Coefficient of determination ($R^2$) | *P* |
|---|---|---|---|
| Global | $\hat{y}$ = -713.80 + 0.00029$x$ | 0.16 | <0.001 |
| LICs | $\hat{y}$ = -1110.18 + 0.00045$x$ | 0.08 | <0.001 |
| LMICs | $\hat{y}$ = -1025.15 + 0.00041$x$ | 0.06 | <0.001 |
| UMICs | $\hat{y}$ = -781.22 + 0.00031$x$ | 0.14 | <0.001 |
| HICs | $\hat{y}$ = -1453.78 + 0.00059$x$ | 0.14 | <0.001 |

Note: Dependent and independent variables of linear regression model were ‘the absolute value of (ratio-1)’ and ‘year’, respectively. Abbreviations: LICs: low-income countries; LMICs: lower middle-income countries; UMICs: upper middle-income countries; HICs: higher-income countries.

**Table 2.** Linear trends in ratio of country-specific number of daily new cases from the JHU CSSE COVID-19 dashboard and from the WHO COVID-19 dashboard from 01/22/2020 to 12/31/2022

| Linear trend | Country |
|---|---|
| **Increased (n=84)** | |
| Substantially (n=3) | Malta ($R^2$=0.25), Montenegro ($R^2$=0.30), United States ($R^2$=0.29) |
| Moderately (n=4) | Australia ($R^2$=0.18), Bulgaria ($R^2$=0.11), Iran ($R^2$=0.13), Slovenia ($R^2$=0.21) |
| Slightly (n=77) | Albania, Algeria, Antigua and Barbuda, Azerbaijan, Bahamas, Bangladesh, Barbados, Belgium, Bhutan, Bolivia, Bosnia and Herzegovina, Brazil, Brunei, Burundi, Cambodia, Canada, Chile, Comoros, Croatia, Cyprus, Czechia, Democratic Republic of Congo, Denmark, Dominica, Dominican Republic, Ecuador, Ethiopia, Fiji, Finland, Georgia, Grenada, Haiti, India, Iraq, Ireland, Italy, Kazakhstan, Kenya, Kiribati, Kuwait, Laos, Latvia, Liechtenstein, Lithuania, Maldives, Marshall Islands, Mauritius, Mexico, Micronesia, Monaco, Mongolia, Morocco, Namibia, Nauru, Norway, Palau, Panama, Papua New Guinea, Peru, Romania, Saint Kitts and Nevis, Samoa, San Marino, Saudi Arabia, Seychelles, Slovakia, Solomon Islands, South Africa, Sweden, Switzerland, Thailand, Timor, Tonga, Ukraine, United Kingdom, Vanuatu, Venezuela |
| **Decreased (n=40)** | |
| Moderately (n=2) | Poland ($R^2$=0.17), Spain ($R^2$=0.11) |
| Slightly (n=38) | Andorra, Argentina, Bahrain, Belarus, Burkina Faso, Cameroon, Chad, Congo, Djibouti, Egypt, El Salvador, Estonia, Germany, Greece, Guinea, Hungary, Japan, Jordan, Madagascar, Malaysia, Mali, Mauritania, Moldova, Myanmar, Netherlands, North Macedonia, Portugal, Russia, Sierra Leone, Somalia, Togo, Tunisia, Turkey, Tuvalu, United Arab Emirates, Uruguay, Yemen, Zambia |
| **No significant change (n=67)** | |
| | Afghanistan, Angola, Armenia, Austria, Belize, Benin, Botswana, Cape Verde, Central African Republic, China, Colombia, Costa Rica, Cote d'Ivoire, Cuba, Equatorial Guinea, Eritrea, Eswatini, France, Gabon, Gambia, Ghana, Guatemala, Guinea-Bissau, Guyana, Honduras, Iceland, Indonesia, Israel, Jamaica, Kyrgyzstan, Lebanon, Lesotho, Liberia, Libya, Luxembourg, Malawi, Mozambique, Nepal, New Zealand, Nicaragua, Niger, Nigeria, Oman, Pakistan, Paraguay, Philippines, Qatar, Republic of Korea, Rwanda, Saint Lucia, Saint Vincent and the Grenadines, Sao Tome and Principe, Senegal, Serbia, Singapore, South Sudan, Sudan, Suriname, Sri Lanka, Syria, Tajikistan, |

| | |
|---|---|
| | Tanzania, Trinidad and Tobago, Uganda, Uzbekistan, Vietnam, Zimbabwe |

Note: Based on coefficient of determination ($R^2$) of linear regression models, we classified linear trends of ratio into three grades: substantially ($R^2 \geq 0.25$), moderately ($0.10 < R^2 < 0.25$), and slightly ($R^2 \leq 0.10$).