

Incidence, Death, and Vaccination Rates for COVID-19 Across Six Continents

Zahra K Alsairafi, Ph.D* Abdallah Y Naser, Ph.D**, Sara Ibrahim Hemmo, MSc** Hamzeh Mohammad Alrawashdeh, MD*** Hassan Alwafi, Ph.D**** Ahmed M Al Rajeh, Ph.D***** Jaber Alqahtani, Ph.D*****Abdulelah Aldhahir, Ph.D***** Abdullah A. Alqarni, Ph.D***** ,***** Rayan Siraj, Ph.D***** Anan S. Jarab, Ph.D***** ,***** ,***** ,***** ,***** ,***** , Ahmad Taqi, Pharm.D, BCPS*

ABSTRACT

COVID-19 is putting a lot of strain on hospitals in order to stop SARS-CoV-2 from spreading. Stopping the COVID-19 outbreak requires equitable access to effective and safe COVID-19 vaccinations. The aim of this study was to study the global trend of deaths, cases, and vaccinations related to COVID-19. This was an ecological descriptive study that was conducted using publicly available data on deaths, cases, and vaccinations related to COVID-19 for the duration between February 2021 and February 2022 from the Our World in Data portal. A total of 437,091,587 COVID-19 cases were reported in the world until the 28th of February 2022. The prevalence rate of COVID-19 increased by 2.82-fold. The incidence rate of New COVID-19 cases increased by 4.15-fold. The overall COVID-19 mortality rate increased by 1.28-fold. The overall COVID-19 vaccination rate increased by 38.92-fold. The rate of COVID-19 vaccination increased during the study period. This was accompanied by a decrease in the rate of new COVID-19 cases and the rate of COVID-19-related mortality. Vaccination rates varied across continents and according to country income. COVID-19 vaccination must be made more acceptable by public awareness campaigns. This is likely to reduce the disease's incidence and related mortality.

Keywords: Continents; COVID-19; Deaths; Incidence; Income; Vaccination

INTRODUCTION

In December 2019, Wuhan (the capital of Hubei territory in China) has become the epicentre of the 2019 Coronavirus Disease (COVID-19) induced by Severe Acute Respiratory Syndrome Coronavirus 2 (SARS-CoV-2) ^{1,2}. Though it was probable that the spread of COVID-19 began from an event of animal transmission, it quickly grew apparent that effective person-to-person transmission was happening. Then the virus started to spread toward other regions, first to Europe, where it put

tension on all health systems and hit member states violently ³. As of 12 March 2022, there were 452,201,564 confirmed cases of COVID-19 in the world, including 6,029,852 deaths reported to the World Health Organization (WHO) ⁴.

Notwithstanding intense interventions to restrict the spread of SARS-CoV-2, COVID-19 is causing tremendous pressure on hospitals ⁵. In general, the death rate of Covid-19 patients admitted to hospitals was more than 20% ⁶⁻⁹, while it was more than 34% among the intensive

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- * Department of Pharmacy Practice
Faculty of Pharmacy, Kuwait University, Kuwait City, Kuwait.
E-mail: a.taqi@ku.edu.kw
- ** Department of Applied Pharmaceutical Sciences and Clinical Pharmacy
Faculty of Pharmacy, Isra University, Amman, Jordan.
- *** Department of Ophthalmology, National University Hospital, Singapore.
- **** Department of Clinical Pharmacology and Toxicology
Faculty of Medicine, Umm Al-Qura University, Makkah, Saudi Arabia.
- ***** Department of respiratory care, College of Applied Medical Sciences
King Faisal University, 31982 Al-Ahsa, Saudi Arabia.
- ***** Department of Respiratory Care
Prince Sultan Military College of Health Sciences, Dammam, Saudi Arabia.
- ***** Department of Respiratory Care, Faculty of Applied Medical Sciences
Jazan University, Jazan, Saudi Arabia.
- ***** Department of Respiratory Therapy
Faculty of Medical Rehabilitation Sciences, King Abdulaziz University
Jeddah, Saudi Arabia.
- ***** Respiratory Therapy Unit, King Abdulaziz University Hospital
Jeddah, Saudi Arabia.
- ***** College of Pharmacy, Al Ain University, Abu Dhabi P.O. Box 112612, United Arab Emirates.
- ***** AAU Health and Biomedical Research Center, Al Ain University,
Abu Dhabi P.O. Box 112612, United Arab Emirates
- ***** Department of Clinical Pharmacy, Faculty of Pharmacy
Jordan University of Science and Technology, Irbid, 22110, Jordan.

care unit (ICU) admitted patients^{6,10-12}. In addition, the percentage of patients requiring admission into the ICU was between 17-32%^{6,13-15}. Besides, a decrease in the quality of life was seen among 44% of discharged patients^{16,17}. Moreover, re-admission to the hospital was required among 10-30% of discharged patients through the months following their discharge^{16,17}.

Fair access to efficient and safe COVID-19 vaccines is significant to stopping the COVID-19 epidemic¹⁸. Administration and development of COVID-19 vaccines aid protect against infection, this protection results from the development of an immune response against the SARS-CoV-2. That means a lower risk of developing the disease and its complications [19]. Many real-world studies have revealed the high efficacy of available vaccines in preventing asymptomatic and symptomatic infections¹⁹⁻²². COVID-19 vaccines may limit the spread of disease in the community^{23,24}. Moreover, the protection provided by vaccines is especially crucial for people at increased risk for critical conditions from COVID-19 like the elderly, people with other illnesses, and healthcare providers²⁴. A total of 10.86 billion doses of the COVID-19 vaccine had been administered worldwide as of 13 March 2022, where 18.29 million doses are administered daily²⁵. In low-income countries, only 13.7% of the population have received at least one dose of the COVID-19 vaccine, while 63.5% of the inhabitants worldwide have received at least one dose of the vaccine^{23,25}.

To better understand the epidemiology of the COVID-19 pandemic globally, this research aimed to study the global trend of deaths, cases, and vaccinations related to COVID-19.

METHODS

Study Sources and the Population: This was a retrospective ecological descriptive study using online COVID-19 available data from the Our World in Data portal between 1 February 2021 and February 2022 among countries across six continents. The Our World in Data portal is available as a public good and was generated by the Oxford Martin Global Development Program at the University of Oxford. The portal contains detailed data on human rights, the environment, income growth and distribution, health, war, violence, education, and food and nutrition, to give contextual knowledge, explain trends, and present discussion about the sources and quality of data. This portal demonstrates the association between global health matters and the roles they act in changing living circumstances with time²⁶. Oxford University economist Max Roser is the director and founder of Our World in Data²⁷. Regarding COVID-19 data, the portal contains data covering all aspects of COVID-19 in the world that includes the following: mortality risks; policy responses; deaths; COVID-19 data explorer; hospitalization; testing; vaccinations; excess mortality; country profiles; and cases. The portal data is updated daily and is freely available for download and open access²⁸.

Ethical approval and consent to participate: The study protocol was reviewed by the Scientific Research Ethics Committee at the Faculty of Pharmacy at Isra University, Amman, Jordan (SREC/22/09). This study used de-identified data and was considered exempt from human protection oversight by the institutional review board. All methods were carried out following relevant guidelines and regulations.

Statistical analysis: Descriptive statistics were used to present the study findings. The incidence rate with its 95% confidence intervals (CIs) was calculated by dividing the number of new cases by the number of the population during the same time frame. A similar procedure was followed to estimate the death rate and vaccination rate. The change in incidence rate was estimated as the relative change

from the baseline (rate in February 2021). A similar procedure was followed to estimate the change in the death and vaccination rates. All analyses were conducted using SPSS version 27 (IBM Corp, Armonk, NY, USA).

RESULTS

World Epidemiological profile

COVID-19 Cases

A total of 437,091,587 COVID-19 cases were reported in the world until the 28th of February 2022 (figure 1).

The prevalence rate of COVID-19 increased by 2.82-fold [from 14,548.69 (95% CI 14,546.04 – 14,551.33) in February-2021 to 55,503.94 (95% CI 55,498.88 – 55,508.99) in February-2022 per 1,000,000 persons] (figure 2). The incidence rate of New COVID-19 cases increased by 4.15-fold [from 1,429.56 (95% CI 1,428.73 – 1,430.40) in February-2021 to 7,366.33 (95% CI 7,364.45 – 7,368.22) in February-2022 per 1,000,000 persons] (figure 2).

For further details on the incidence rate, death rate, and vaccination rate stratified by country, please refer to the supplementary files.

Deaths: A total of 5,957,345 COVID-19 deaths were reported globally until the 28th of February 2022 (figure 3).

The overall COVID-19 mortality rate increased by 1.28-fold [from 331.42 (95% CI 331.02 – 331.82) in February-2021 to 756.49 (95% CI 755.88 – 757.10) in February-2022 per 1,000,000 persons] (figure 4). The incidence rate of new COVID-19 deaths decreased by 10.5% [from 39.49 (95% CI 39.35 – 39.62) in February-2021 to 35.33 (95% CI 35.20 – 35.46) in February-2022 per 1,000,000 persons] (figure 4).

Vaccinations: A total of 10,716,795,951 COVID-19 vaccinations have been administered globally until the 28th of February 2022 (figure 5).

The overall COVID-19 vaccinations rate increased by 38.92-fold [from 34,093.97 (95% CI 34,089.90 – 34,098.04) in February-2021 to 1,360,868.90 (95% CI 1,360,844.95 – 1,360,892.85) in February-2022 per 1,000,000 persons] (figure 6). The rate of people vaccinated increased by 31.07-fold [from 19,692.89 (95% CI 19,689.82 – 19,695.95) in February-2021 to 631,600.13 (95% CI 631,589.47 – 631,610.78) in February-2022 per 1,000,000 persons] (figure 6). The rate of people fully vaccinated increased by 74.82-fold [from 7,351.43 (95% CI 7,349.54 – 7,353.32) in February-2021 to 557,380.57 (95% CI 557,369.60 – 557,391.55) in February-2022 per 1,000,000 persons] (figure 6). The rate of newly vaccinated people increased by 4.88-fold [from 16,486.53 (95% CI 16,483.72 – 16,489.34) in February-2021 to 96,860.88 (95% CI 96,854.35 – 96,867.42) in February-2022 per 1,000,000 persons] (figure 6).

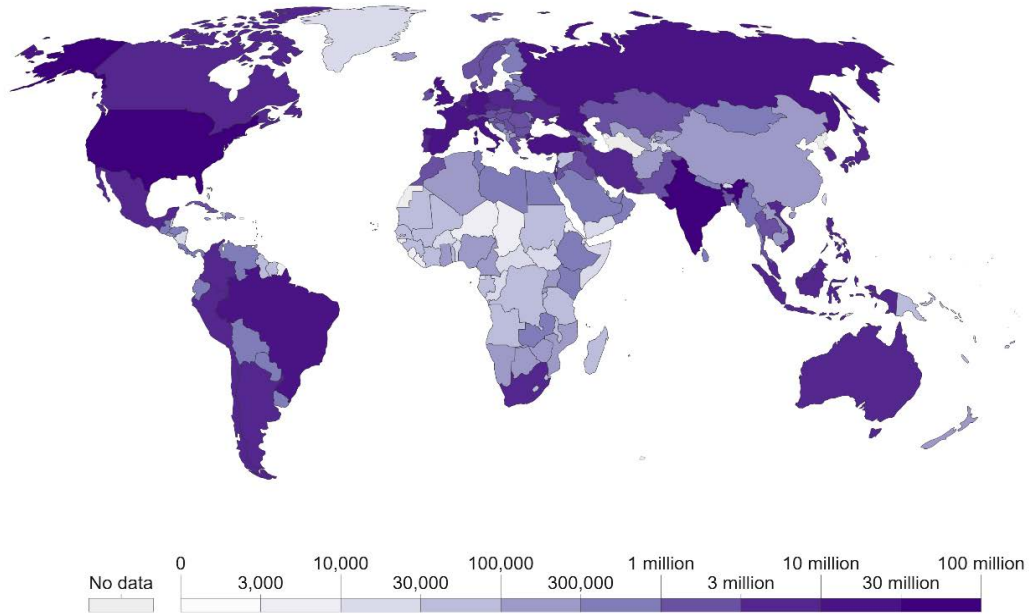
Continent-based Epidemiological profile

Africa: A total of 11,333,186 COVID-19 cases and 248,823 COVID-19 deaths were reported in Africa until the 28th of February 2022. Besides, a total of 411,213,869 COVID-19 vaccinations have been administered in Africa until the 28th of February 2022. From February-2021 to February-2022, a tremendous increase in the rate of people fully vaccinated was noted in Africa by 676.14-fold (Table 1, figure 7).

Asia: A total of 117,210,196 COVID-19 cases and 1,353,846 COVID-19 deaths were reported in Asia until the 28th of February

Cumulative confirmed COVID-19 cases, Feb 28, 2022

Due to limited testing, the number of confirmed cases is lower than the true number of infections.



Source: Johns Hopkins University CSSE COVID-19 Data

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Figure 1. Map visualisation for the epidemiology of COVID-19 cases around the world

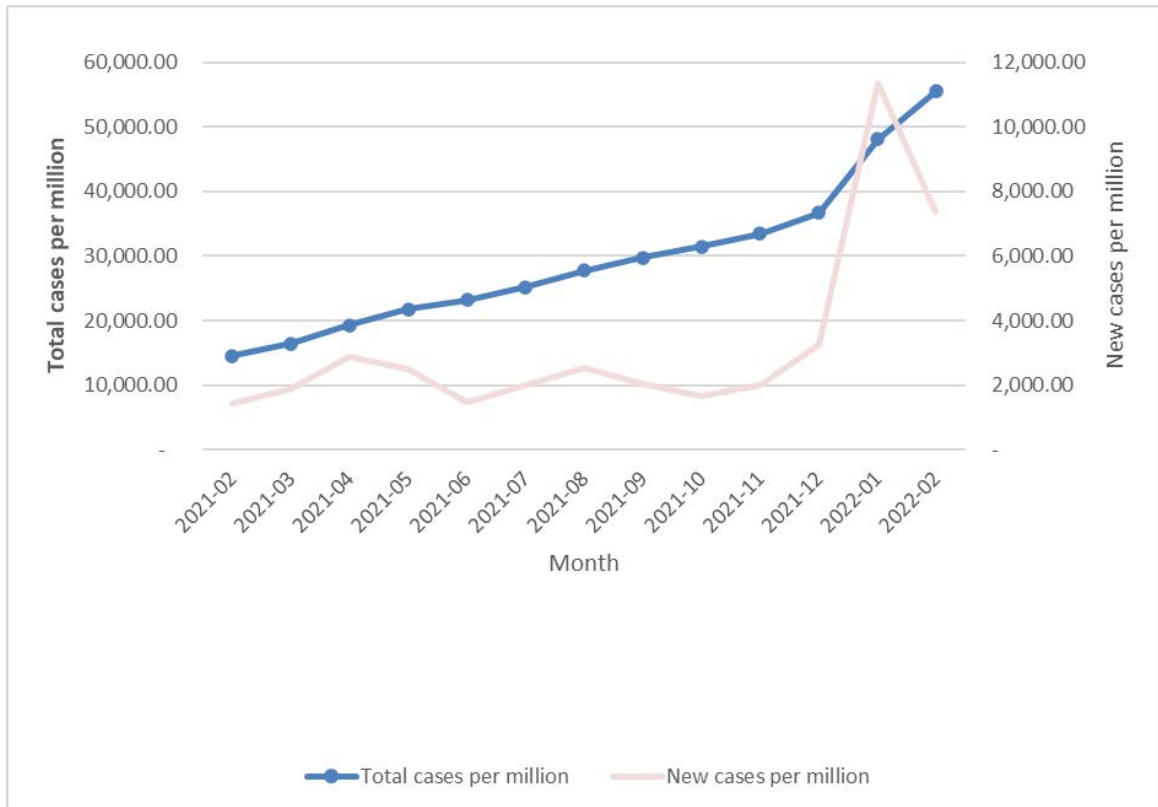
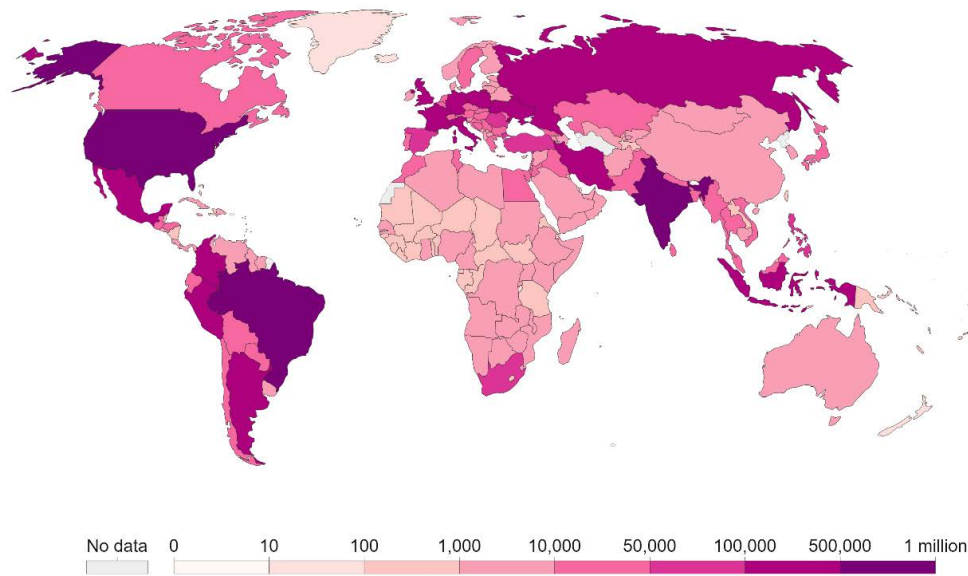


Figure 2. Incidence rate of COVID-19 cases and the total number of cases

Cumulative confirmed COVID-19 deaths, Feb 28, 2022



For some countries the number of confirmed deaths is much lower than the true number of deaths. This is because of limited testing and challenges in the attribution of the cause of death.



Source: Johns Hopkins University CSSE COVID-19 Data

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Figure 3. Map visualisation for the number of COVID-10 deaths around the world

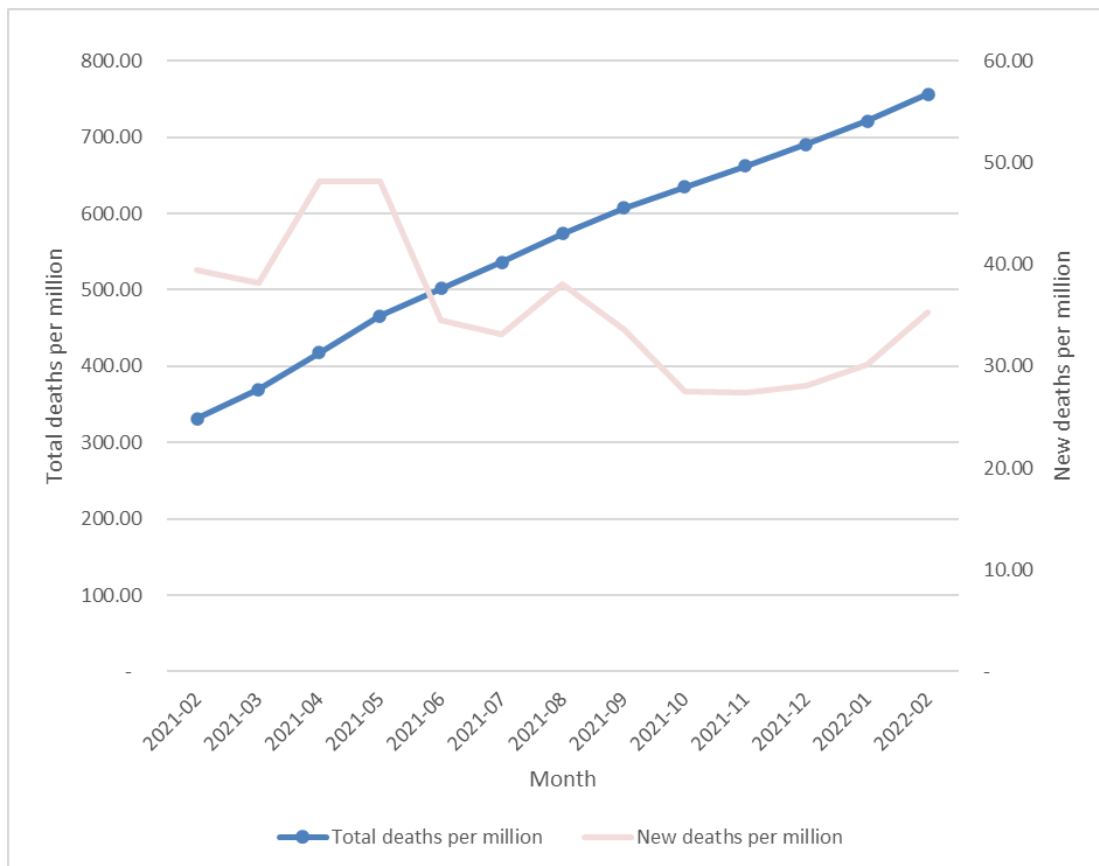
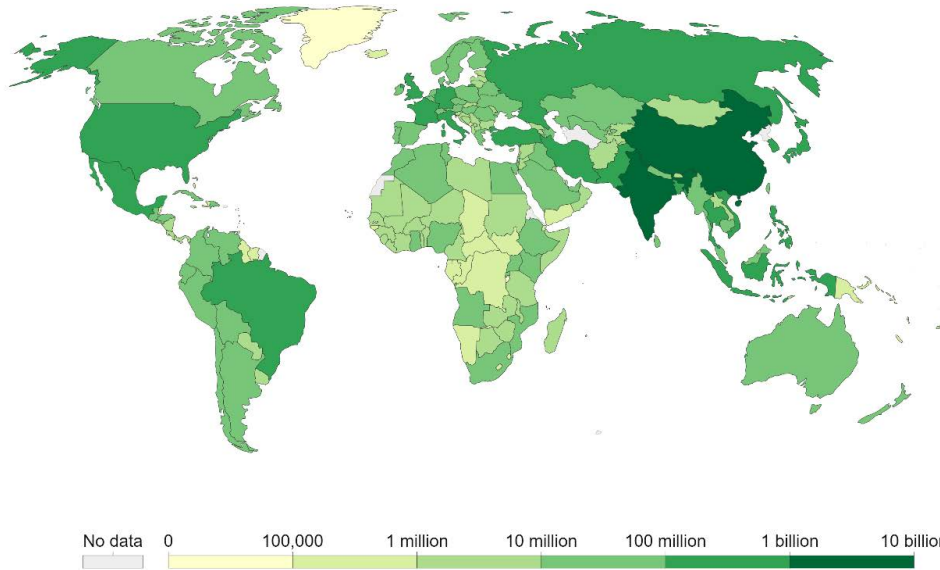


Figure 4. Rate of new deaths related to COVID-19 and the total number of deaths

COVID-19 vaccine doses administered, Feb 28, 2022

Total number of doses administered. All doses, including boosters, are counted individually.



Source: Official data collated by Our World in Data

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Figure 5. Map visualisation for the number of COVID-19 vaccine doses administered around the world

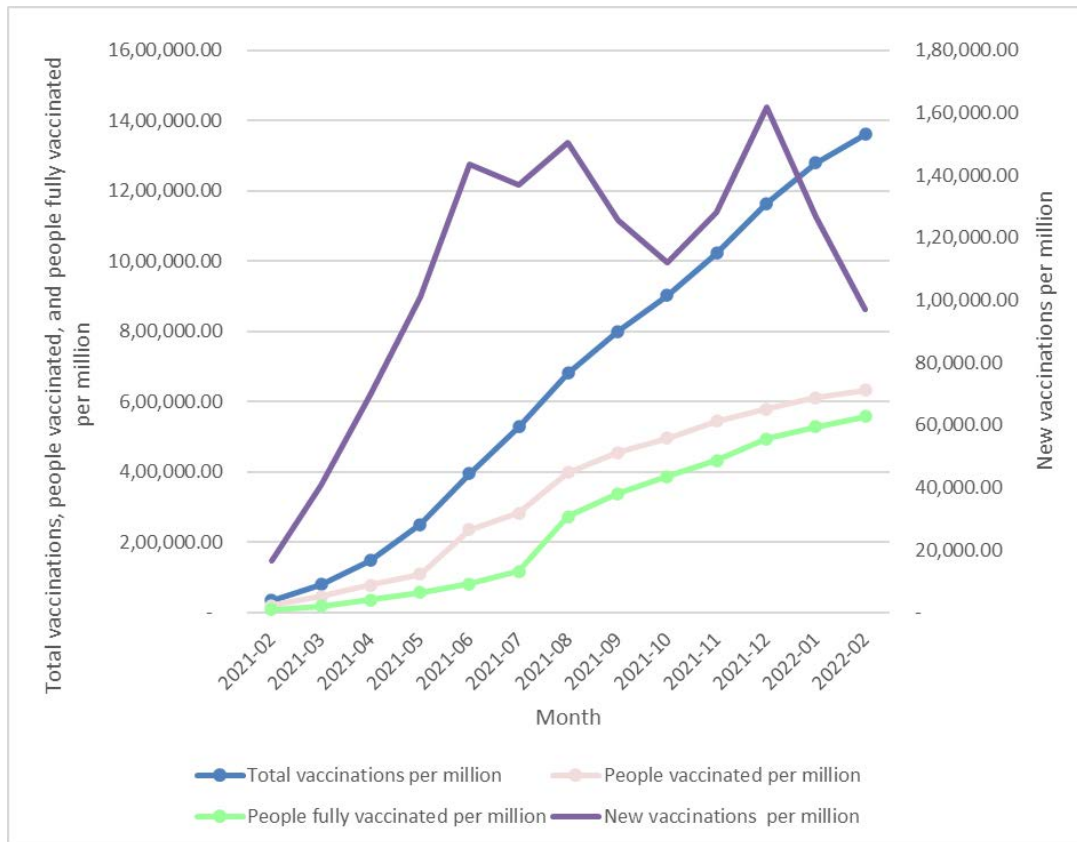


Figure 6. Vaccination rates for COVID-19 around the world

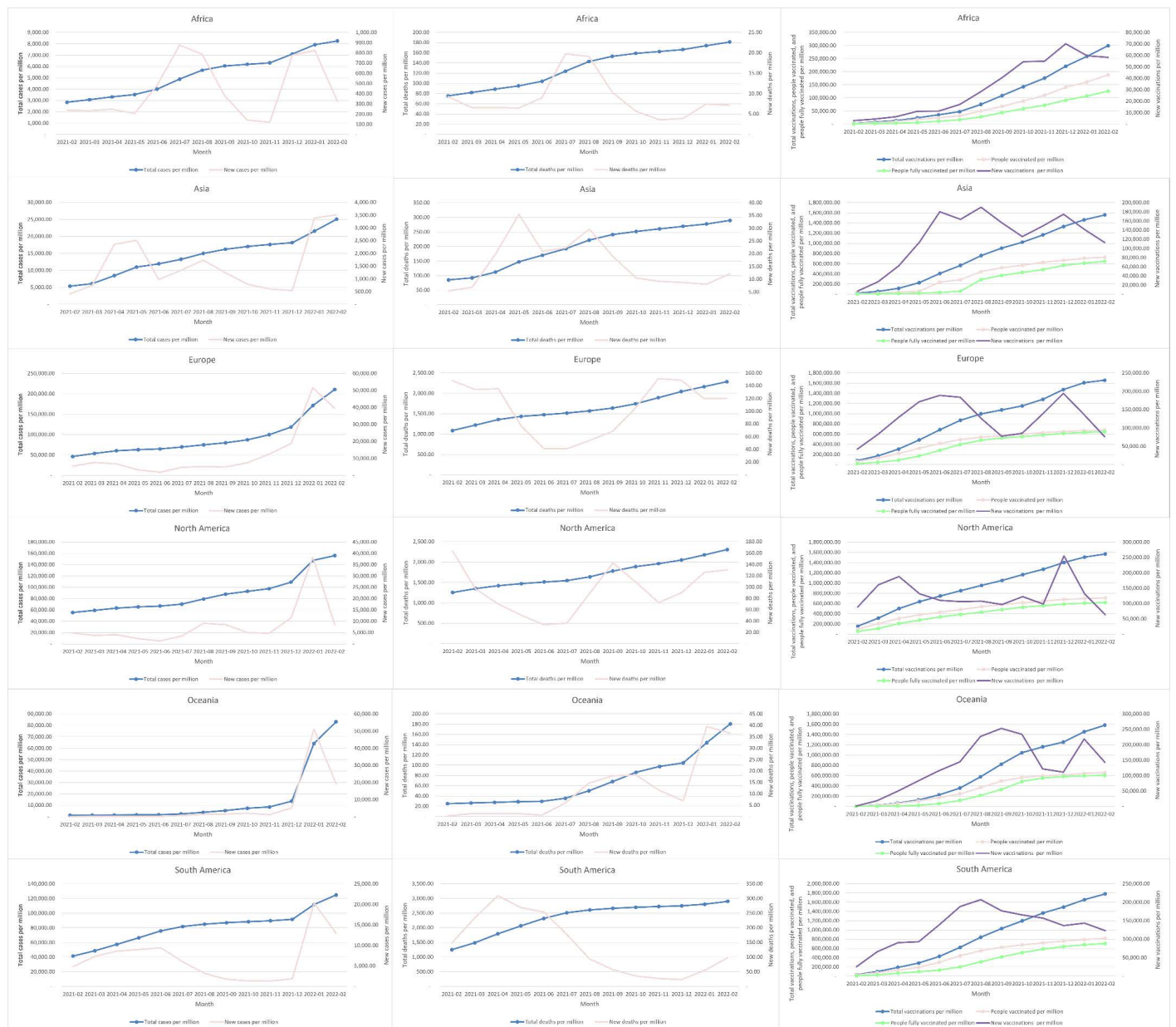


Figure 7. COVID-19 incidence rate, mortality rate and vaccination rate stratified by continent

2022. Besides, a total of 7,287,379,446 COVID-19 vaccinations have been administered in Asia until the 28th of February 2022. From February-2021 to February-2022, a tremendous increase in the rate of people fully vaccinated was noted in Asia by 273.38-fold (Table 1, figure 7).

Europe: A total of 157,685,265 COVID-19 cases and 1,711,461 COVID-19 deaths were reported in Europe until the 28th of February 2022. Besides, a total of 1,241,084,220 COVID-19 vaccinations have been administered in Europe until the 28th of February 2022. From February-2021 to February-2022, a tremendous increase in the rate of people fully vaccinated was noted in Europe by 35.41-fold (Table 1, figure 7).

North America: A total of 93,066,282 COVID-19 cases and 1,377,602 COVID-19 deaths were reported in North America until the 28th of February 2022. Besides, a total of 935,783,187 COVID-19 vaccinations have been administered in North America until the 28th of February

2022. From February-2021 to February-2022, a tremendous increase in the rate of people fully vaccinated was noted in North America by 10.90-fold (Table 1, figure 7).

Oceania: A total of 3,594,539 COVID-19 cases and 7,800 COVID-19 deaths were reported in Oceania until the 28th of February 2022. Besides, a total of 68,377,990 COVID-19 vaccinations have been administered in Oceania until the 28th of February 2022. From February-2021 to February-2022, a tremendous increase in the rate of people fully vaccinated was noted in Oceania by 8,286.78-fold (Table 1, figure 7).

South America: A total of 54,201,398 COVID-19 cases and 1,257,798 COVID-19 deaths were reported in South America until the 28th of February 2022. Besides, a total of 772,957,239 COVID-19 vaccinations have been administered in South America until the 28th of February 2022. From February-2021 to February-2022, a tremendous increase in the rate of people fully vaccinated was noted in South America by 132.71-fold (Table 1, figure 7).

Table 1. Change in the incidence rate, mortality rate and vaccination rate across the study period stratified by continent

		Africa	Asia	Europe	North America	Oceania	South America
Total cases	Rate in 2-2021 per million (95% CI)	2,837.51 (2,834.70 – 2,840.32)	5,348.57 (5,346.48 – 5,350.66)	46,173.51 (46,158.48 – 46,188.54)	55,383.96 (55,365.60 – 55,402.31)	1,183.97 (1,173.71 – 1,194.22)	41,392.13 (41,373.39 – 41,410.86)
	Rate in 2-2022 per million (95% CI)	8,251.40 (8,246.62 – 8,256.18)	25,053.24 (25,048.76 – 25,057.72)	210,538.13 (210,508.93 – 210,567.33)	155,999.33 (155,970.22 – 156,028.45)	83,168.51 (83,086.18 – 83,250.83)	124,813.20 (124,782.12 – 124,844.29)
	% Change	190.8%	368.4%	356.0%	181.7%	6,924.6%	201.5%
New cases	Rate in 2-2021 per million (95% CI)	238.58 (237.76 – 239.39)	408.17 (407.60 – 408.75)	5,431.54 (5,426.28 – 5,436.81)	4,790.87 (4,785.33 – 4,796.41)	23.28 (21.84 – 24.71)	4,820.35 (4,813.83 – 4,826.86)
	Rate in 2-2022 per million (95% CI)	324.79 (323.84 – 325.75)	3,512.52 (3,510.83 – 3,514.22)	39,433.28 (39,419.35 – 39,447.22)	8,626.57 (8,619.15 – 8,633.99)	19,154.44 (19,113.57 – 19,195.30)	12,946.18 (12,935.55 – 12,956.81)
	% Change	36.1%	760.5%	626.0%	80.1%	82,191.7%	168.6%
Total deaths	Rate in 2-2021 per million (95% CI)	75.51 (75.05 – 75.97)	85.28 (85.02 – 85.55)	1,087.69 (1,085.32 – 1,090.05)	1,254.70 (1,251.86 – 1,257.54)	25.17 (23.68 – 26.67)	1,250.27 (1,246.95 – 1,253.60)
	Rate in 2-2022 per million (95% CI)	181.16 (180.45 – 181.87)	289.38 (288.89 – 289.87)	2,285.11 (2,281.69 – 2,288.53)	2,309.16 (2,305.31 – 2,313.01)	180.47 (176.47 – 184.48)	2,896.42 (2,891.36 – 2,901.47)
	% Change	139.9%	239.3%	110.1%	84.0%	616.9%	131.7%
New deaths	Rate in 2-2021 per million (95% CI)	9.27 (9.11 – 9.43)	5.48 (5.42 – 5.55)	147.95 (147.08 – 148.82)	163.54 (162.51 – 164.56)	0.28 (0.12 – 0.43)	147.76 (146.61 – 148.90)
	Rate in 2-2022 per million (95% CI)	7.16 (7.01 – 7.30)	12.14 (12.04 – 12.24)	120.16 (119.37 – 120.94)	130.40 (129.48 – 131.31)	36.51 (34.71 – 38.31)	97.29 (96.36 – 98.21)
	% Change	-22.8%	121.3%	-18.8%	-20.3%	13,050.0%	-34.2%
Total vaccinations	Rate in 2-2021 per million (95% CI)	2,820.74 (2,817.94 – 2,823.55)	21,179.44 (21,175.28 – 21,183.61)	79,789.22 (79,769.07 – 79,809.37)	154,691.99 (154,660.67 – 154,723.31)	1,245.81 (1,235.29 – 1,256.34)	30,922.42 (30,905.91 – 30,938.94)
	Rate in 2-2022 per million (95% CI)	299,394.19 (299,369.97 – 299,418.41)	1,557,649.92 (1,557,617.06 – 1,557,682.78)	1,657,070.17 (1,656,985.96 – 1,657,154.38)	1,568,576.18 (1,568,483.89 – 1,568,668.46)	1,582,093.08 (1,581,749.02 – 1,582,437.13)	1,779,940.58 (1,779,826.81 – 1,780,054.35)
	% Change	10,514.0%	7,254.5%	1,976.8%	914.0%	126,892.8%	5,656.1%
People vaccinated	Rate in 2-2021 per million (95% CI)	2,685.72 (2,682.98 – 2,688.45)	7,354.93 (7,352.48 – 7,357.37)	61,958.00 (61,940.73 – 61,975.26)	99,763.19 (99,739.14 – 99,787.24)	1,172.86 (1,162.66 – 1,183.07)	25,354.86 (25,340.07 – 25,369.64)
	Rate in 2-2022 per million (95% CI)	188,040.46 (188,019.79 – 188,061.12)	727,079.13 (727,066.36 – 727,091.89)	677,276.17 (677,242.69 – 677,309.66)	708,053.76 (708,017.27 – 708,090.24)	655,159.77 (655,018.06 – 655,301.48)	819,730.43 (819,694.27 – 819,766.59)
	% Change	6,901.5%	9,785.6%	993.1%	609.7%	55,760.0%	3,133.0%
People fully vaccinated	Rate in 2-2021 per million (95% CI)	186.37 (185.65 – 187.10)	2,361.64 (2,360.25 – 2,363.03)	17,730.71 (17,721.25 – 17,740.16)	51,992.06 (51,974.25 – 52,009.88)	72.95 (70.41 – 75.50)	5,266.88 (5,260.07 – 5,273.68)
	Rate in 2-2022 per million (95% CI)	126,200.49 (126,182.92 – 126,218.05)	647,980.66 (647,966.98 – 647,994.35)	645,643.83 (645,609.58 – 645,678.09)	618,464.96 (618,425.98 – 618,503.94)	604,613.76 (604,467.99 – 604,759.53)	704,225.47 (704,182.55 – 704,268.40)
	% Change	67,613.6%	27,337.8%	3,541.4%	1,089.5%	828,678.3%	13,270.8%
New vaccinations	Rate in 2-2021 per million (95% CI)	3,025.84 (3,022.94 – 3,028.75)	6,452.57 (6,450.28 – 6,454.87)	42,323.12 (42,308.70 – 42,337.54)	88,403.10 (88,380.32 – 88,425.88)	1081.03 (1,071.23 – 1,090.83)	25,335.25 (25,320.47 – 25,350.03)
	Rate in 2-2022 per million (95% CI)	58,306.03 (58,293.64 – 58,318.43)	112,860.14 (112,851.08 – 112,869.21)	76,502.59 (76,483.55 – 76,521.62)	63,167.18 (63,147.66 – 63,186.70)	142,892.05 (142,787.72 – 142,996.39)	123,257.59 (123,226.67 – 123,288.51)
	% Change	1,826.9%	1,649.1%	80.8%	-28.5%	13,118.2%	386.5%

Table 2. Change in the incidence rate, mortality rate and vaccination rate across the study period stratified by income category

		High income countries	Upper middle income countries	Lower middle income countries	Low income countries
Total cases	Rate in 2-2021 per million (95% CI)	49,278.09 (49,265.92 – 49,290.27)	13,489.21 (13,484.70 – 13,493.72)	6,077.52 (6,074.88 – 6,080.16)	827.38 (825.19 – 829.56)
	Rate in 2-2022 per million (95% CI)	193,001.92 (192,979.73 – 193,024.11)	47,177.87 (47,169.58 – 47,186.16)	24,680.32 (24,675.05 – 24,685.59)	2,711.76 (2,707.81 – 2,715.71)
	% Change	291.7%	249.7%	306.1%	227.8%
New cases	Rate in 2-2021 per million (95% CI)	5,109.38 (5,105.37 – 5,113.39)	1,448.88 (1,447.40 – 1,450.37)	399.74 (399.06 – 400.42)	115.42 (114.60 – 116.23)
	Rate in 2-2022 per million (95% CI)	29,245.18 (29,235.70 – 29,254.65)	6,427.43 (6,424.31 – 6,430.55)	1,887.31 (1,885.84 – 1,888.79)	53.11 (52.56 – 53.67)
	% Change	472.4%	343.6%	372.1%	-54.0%
Total deaths	Rate in 2-2021 per million (95% CI)	1,016.52 (1,014.73 – 1,018.31)	388.54 (387.77 – 389.31)	115.55 (115.18 – 115.91)	20.12 (19.77 – 20.46)
	Rate in 2-2022 per million (95% CI)	1,813.11 (1,810.71 – 1,815.50)	969.29 (968.07 – 970.50)	383.19 (382.53 – 383.86)	62.73 (62.13 – 63.34)
	% Change	78.4%	149.5%	231.6%	211.9%
New deaths	Rate in 2-2021 per million (95% CI)	133.86 (133.21 – 134.52)	48.08 (47.81 – 48.35)	7.79 (7.69 – 7.88)	2.28 (2.16 – 2.39)
	Rate in 2-2022 per million (95% CI)	107.78 (107.20 – 108.37)	39.95 (39.70 – 40.19)	13.66 (13.53 – 13.78)	2.06 (1.95 – 2.17)
	% Change	-19.5%	-16.9%	75.4%	-9.6%
Total vaccinations	Rate in 2-2021 per million (95% CI)	135,525.66 (135,505.10 – 135,546.22)	31,246.87 (31,239.97 – 31,253.77)	7,590.71 (7,587.75 – 7,593.67)	12.33 (12.06 – 12.59)
	Rate in 2-2022 per million (95% CI)	1,899,902.91 (1,899,833.16 – 1,899,972.67)	1,896,618.46 (1,896,569.99 – 1,896,666.92)	1,057,339.92 (1,057,306.89 – 1,057,372.94)	179,461.17 (179,432.01 – 179,490.33)
	% Change	1,301.9%	5,969.8%	13,829.4%	1,455,612.5%
People vaccinated	Rate in 2-2021 per million (95% CI)	93,315.37 (93,299.01 – 93,331.72)	7,974.21 (7,970.73 – 7,977.69)	6,502.15 (6,499.42 – 6,504.88)	12.33 (12.06 – 12.59)
	Rate in 2-2022 per million (95% CI)	786,573.17 (786,550.13 – 786,596.21)	804,654.50 (804,639.00 – 804,670.00)	573,014.65 (572,997.85 – 573,031.45)	130,814.10 (130,788.47 – 130,839.72)
	% Change	742.9%	9,990.7%	8,712.7%	1,061,008.2%
People fully vaccinated	Rate in 2-2021 per million (95% CI)	39,887.75 (39,876.74 – 39,898.75)	2,309.69 (2,307.81 – 2,311.57)	1,088.56 (1,087.44 – 1,089.68)	0 (0.00 – 0.00)
	Rate in 2-2022 per million (95% CI)	732,673.71 (732,648.82 – 732,698.59)	755,828.29 (755,811.50 – 755,845.09)	465,967.12 (465,950.18 – 465,984.06)	71,103.01 (71,083.48 – 71,122.54)
	% Change	1,736.8%	32,624.2%	42,705.8%	-
New vaccinations	Rate in 2-2021 per million (95% CI)	74,923.42 (74,908.62 – 74,938.23)	7,065.93 (7,062.65 – 7,069.20)	6,317.89 (6,315.20 – 6,320.58)	0 (0.00 – 0.00)
	Rate in 2-2022 per million (95% CI)	80,275.52 (80,260.24 – 80,290.80)	100,535.35 (100,523.59 – 100,547.11)	113,035.65 (113,024.90 – 113,046.40)	54,200.68 (54,183.47 – 54,217.88)
	% Change	7.1%	1,322.8%	1,689.1%	-

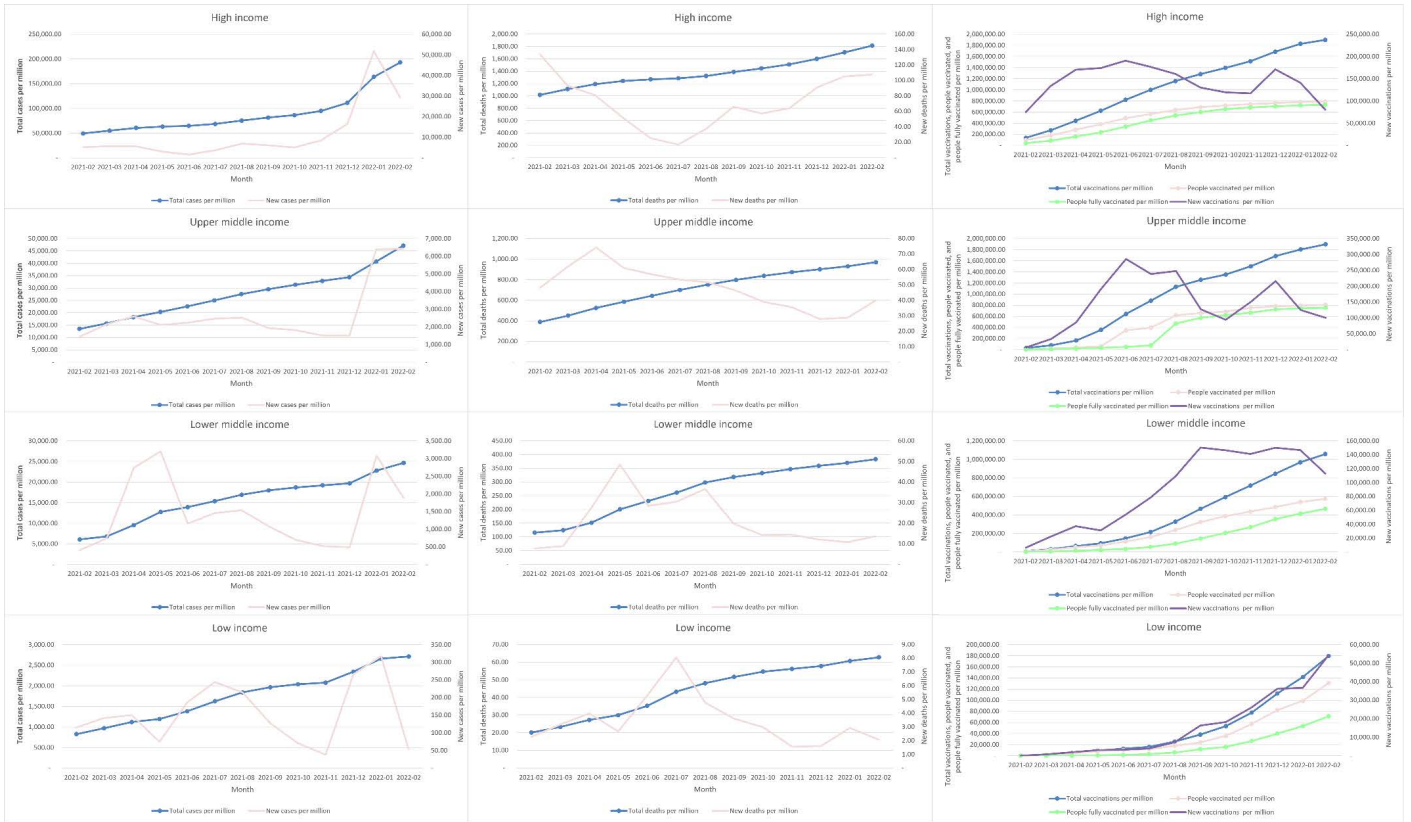


Figure 8. COVID-19 incidence rate, mortality rate and vaccination rate stratified by income category

Income-based Epidemiological profile

High-income countries: A total of 234,483,865 COVID-19 cases and 2,202,797 COVID-19 deaths were reported in high-income countries until the 28th of February 2022. Besides, a total of 2,308,249,484 COVID-19 vaccinations have been administered in high-income countries until the 28th of February 2022. From February-2021 to February-2022, a tremendous increase in the rate of people fully vaccinated was noted in high-income countries by 17.37-fold (Table 2, figure 8).

Upper middle-income countries: A total of 118,589,733 COVID-19 cases and 2,436,468 COVID-19 deaths were reported in upper middle-income countries until the 28th of February 2022. Besides, a total of 4,767,478,212 COVID-19 vaccinations have been administered in upper middle-income countries until the 28th of February 2022. From February-2021 to February-2022, a tremendous increase in the rate of people fully vaccinated was noted in upper middle-income countries by 326.24-fold (Table 2, figure 8).

Lower middle-income countries: A total of 82,201,572 COVID-19 cases and 1,276,288 COVID-19 deaths were reported in lower middle-income countries until the 28th of February 2022. Besides, a total of 3,521,631,885 COVID-19 vaccinations have been administered in lower middle-income countries until the 28th of February 2022. From February-2021 to February-2022, a tremendous increase in the rate of people fully vaccinated was noted in lower middle-income countries by 427.06-fold (Table 2, figure 8).

Low-income countries: A total of 1,803,726 COVID-19 cases and 41,727 COVID-19 deaths were reported in low-income countries until the 28th of February 2022. Besides, a total of 119,368,426 COVID-19 vaccinations have been administered in low-income countries until the 28th of February 2022. From February-2021 to February-2022, a

tremendous increase in the overall COVID-19 vaccinations rate was noted in low-income countries by 14,556.13-fold (Table 2, figure 8).

DISCUSSION

In this study, we found that the prevalence rate of COVID-19 increased by 2.81-fold from 14,549.44 to 55,491.26 per 1,000,000 persons between February-2021 and February-2022. Moreover, the incidence rate of new COVID-19 cases increased by 4.16-fold from 1,429.54 to 7,372.09 per 1,000,000 persons in the same period. These significant results can be attributed to the emersion of the Omicron variant of SARS-CoV-2, also called B.1.1.529, which was reported for the first time on 24 November 2021 in South Africa. It was supposed that Omicron could have been spreading for several months before the first case was reported^{29,30}. By December 2021, Omicron was reported in Africa, North America, South America, Europe, Asia, and Oceania³¹. The currently available data postulate that the fast spread of Omicron is related to the ability of the virus to replicate and its capability to avoid pre-existing responses of the human immune system induced by previous infection or vaccination³². In human bronchi, the Omicron variant can multiply about 70 times faster than the Delta variant³³. It is estimated that Omicron infects about three to six times more people than Delta over the same period. In addition, it can infect individuals who are already immune to other variants³⁴. Compared to other variants of SARS-CoV-2, the risk of reinfection with the Omicron variant is higher³⁵.

The current study found that the incidence rate of new COVID-19 deaths decreased significantly by 10.7%, from 39.49 in February-2021 to 35.27 in February-2022 per 1,000,000 persons. These results can be linked to COVID-19 vaccine administration and lower virulence of Omicron than the other circulating variants. Moghadas et al. (2019) found that vaccination significantly reduced the adverse outcomes in the non-intensive care units (ICU), ICU hospitalizations, and deaths

related to the SARS-CoV-2 infection by 63.5%, 65.6%, and 69.3%, respectively³⁴. Several studies showed the efficacy of vaccination in decreasing the rate of hospitalization and deaths related to COVID-19³⁶⁻³⁸. Moghadas et al. (2019) revealed that in 99 hospitals in the United States, patients hospitalized due to SARS-CoV-2 infection had a lower mean length of stay in hospitals, less need for ICU admission and invasive mechanical ventilation, and a lower rate of death during the Omicron period than during prior periods³⁷.

Several studies demonstrated that COVID-19 vaccines seem to be safe and highly effective³⁹⁻⁴¹. A positive correlation was found between the incidence of adverse reactions and immune response and the dose given to the individuals. The elderly showed a worse immune response to vaccinations than younger subjects, which could explain the higher rate of mortality among the elderly⁴¹. The double-dose vaccination was found to be more effective than the single-dose vaccination by producing a stronger immune response and providing higher levels of protection besides its role in preventing hospitalization and death^{40,41}. Recent evidence support that there is a decrease in protection against SARS-CoV-2 infection over time following vaccination. A study conducted by Lin et al. in North Carolina, USA, between December 2020 and September 2021 to estimate the increase in post-vaccination infection cases found that the reduction in the effectiveness of vaccines was related to the emergence of the Delta variant and declining immunity post-vaccination⁴⁰. Irrespective of the primary course, the third-dose or the booster vaccine dose increased protection against mild and severe COVID-19⁴².

In this study, we noticed a significant increase in the overall COVID-19 vaccinations rate, rate of people vaccinated, rate of people fully vaccinated, and rate of newly vaccinated people by 38.91-fold, 31.06-fold, 74.97-fold, and 4.87-fold between February-2021 and February-2022, respectively. This observation can be correlated to the increasing number of available vaccines worldwide, the improved awareness of people regarding the importance of vaccination in protection against the SARS-CoV-2 infection, and the obligatory regulations led by several governments⁴³. These mandatory policies include mandatory vaccination certificates for employees, officials, and visitors to access governmental, public, private, and educational facilities, mandatory vaccination for all residents aged 18 years and older, especially those over 60 years of age, mandatory vaccination to travel and enter some countries, and mandatory vaccination to all healthcare providers^{43,44}.

The overall increase in COVID-19 vaccination rate, rate of people vaccinated, rate of people fully vaccinated, and rate of newly vaccinated people can explain the noticed significant decrease in the incidence rate of new COVID-19 deaths by 10.7% in our study. A systemic review conducted between January 2020 and December 2021 to assess excess mortality from the COVID-19 pandemic found that the average global rate of mortality was 1200.3 deaths per 1,000,000 (120.3 deaths per 100,000 persons), while our study revealed a significantly lower average rate of mortality at 331.62 deaths per 1,000,000⁴⁵. In the current study, the majority of the analyzed death cases due to COVID-19 were within the era of COVID-19 vaccination. In the other study, the analysis of death cases amid the pandemic started at least one year before the vaccination started. This finding provides clear evidence that COVID-19 vaccines effectively reduce the disease's mortality rate and explain our significantly different results.

Our study revealed a significant difference between the rates of fully vaccinated people by continent. The smallest increase in the rate of people fully vaccinated was noted in North America, followed by Europe with 10.92-fold and 35.41-fold, respectively. The largest

increase in the rate of people fully vaccinated was noted in Oceania, followed by Africa, Asia, and South America with 8,286.82-fold, 675.98-fold, 273.38-fold, and 132.72-fold, respectively. These noticeable differences can be attributed to the large population in Asia and Africa (both present around 77% of the world population), with Asia being the most populous continent with approximately 4.68 billion people (about 59.5% of the global population), followed by Africa with approximately 1.37 billion people (about 17.4% of the global population) in 2021⁴⁶.

In April 2021, around three-quarters of all doses of COVID-19 (1.03 billion doses) have been administered in ten nations only (the United States, China, India, United Kingdom, Brazil, Germany, Turkey, France, and Indonesia), and the rest of the world had to share the remainder (more than 170 nations and territories shared only 268.2 million doses). The United States and China account for almost half of all the administered doses (453.5 million doses), while the entire continent of Africa got only 2% (about 20 million doses)⁴⁷. The early vaccination of the population of those nations and the increasing production of vaccines over time contributed to the rapid coverage of their residents and increased the share of vaccines to other nations in Oceania, Africa, and Asia, which also explained the significantly increased rates of fully vaccinated people in these continents⁴⁸. For instance, in Africa, which has a total population of 1,372,305,269, the reported doses of COVID-9 vaccines were 450,256,372 until 31 March 2022, while in North America, which has a total population of 592,933,271, the reported doses of administered COVID-9 vaccines were 957,794,493 until 31 March 2022. These numbers mean that more people are still in dire need of COVID-9 vaccines in Africa. This need has contributed and will significantly contribute to an increase in the overall rate of COVID-19 vaccinations compared to North America, where the reported doses of COVID-9 vaccines exceeded twice the number of the population there⁴⁹.

We noticed an inverse proportion between the rate of people fully vaccinated and the total number of deaths in each continent. For example, in Europe during the study period, the total number of deaths due to COVID-19 was 1,377,220, which is greater than the total number of deaths in Asia, Africa, and Oceania combined (1,610,351 deaths) despite the smaller population in Europe in contrast to Asia and Africa. Moreover, the total number of deaths in North America (1,377,220 deaths) and South America (1,257,798 deaths) separately is close to the total number of deaths in Asia, Africa, and Oceania combined. In Oceania, where the increase in the rate of people fully vaccinated population was the largest (8,286.82-fold), the total number of deaths due to COVID-19 was the lowest. The elderly are prone to more severe complications of COVID-19 than the younger population⁵⁰. This fact can explain the high number of total deaths in Europe and North America where the percentage of people aged above 65 years was 19% and 17%, respectively, while the percentage of people aged above 65 years in Asia and Africa was 4% and 9%, respectively in 2021⁴⁶. In addition, this study revealed a strong negative correlation between the rate of a fully vaccinated population and the incidence rate of COVID-19. It is worth noting that there is a large overlap between the epidemiological profile and income-based epidemiological profile regarding the total number of COVID-19 cases, the total number of deaths due to COVID-19, and the rate of fully vaccinated people, since most of the high-income and upper-middle-income countries are located in Europe and North America.

Regarding the income-based epidemiological profile, we found that the total number of COVID-19 cases was highest in high-income countries, upper middle-income countries, lower-middle-income countries, and low-income countries by 234,480,824, 118,492,951, 82,201,573, and

1,803,726 deaths, respectively. Furthermore, the total number of deaths due to COVID-19 was highest in the Upper middle-income countries, followed by high-income countries, lower-middle-income countries, and low-income countries by 2,436,350, 2,202,415, 1,276,288, and 41,727 deaths, respectively. Our findings were in the same line as other studies, which showed that developed or high-income countries experienced higher prevalence and death rates related to COVID-19 than developing or low-income countries^{51,52}. These results reflect the highly concentrated mortality in developed countries that present approximately 79% of the death toll due to COVID-19 globally⁵². Bayati et al. (2021) found that the prevalence of COVID-19, the total number of deaths, and the number of critical cases were higher in high-income countries (Y). Our findings can be attributed to the aging or older population⁴⁶, the higher prevalence of cardiovascular disease, diabetes mellitus, and other chronic diseases^{53,54}, the better medical infrastructures that allow for better detection and recording of deaths due to COVID-19^{53,55,56}, the more transparency and accuracy of the disseminated data related to the disease⁵⁷, and the higher flow of air transport in high-income countries than low-income or developing countries. Other factors that may play a role are economic factors, geographical and environmental factors, and socio-demographic factors⁵¹.

CONCLUSION

The rate of COVID-19 vaccination increased during the study period. This was accompanied by a decrease in the rate of new COVID-19 cases and the rate of COVID-19-related mortality. Vaccination rates varied across continents and according to country income. COVID-19 vaccination must be made more acceptable by public awareness campaigns. This is likely to reduce the disease's incidence and related mortality.

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