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Paradoxical increase in global COVID-19 deaths with vaccination coverage: World Health Organization Estimates (2020-2023)

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Abstract

Background: Many reports on the impact of vaccination on COVID-19 pandemic deaths were projections undertaken as the global emergency was unfolding. An increasing number of independent investigators have drawn attention to the subjective nature and inherent biases in mathematical models used for such forecasts that could undermine their accuracy when excess mortality was the metric of choice.

Objective: COVID-19 deaths were compared between the pre-vaccines and vaccination eras to observe how vaccination impacted COVID-19 death trajectory worldwide during the pandemic emergency.

Methods: COVID-19 cases, deaths and vaccination rates in World Health Organization (WHO) database till 07 June 2023, Case fatality rate per 1000 for the pre-vaccines period (CFR1), and that over vaccination era (CFR2) were compared for all WHO regions, while tests of correlation between the percentage change in COVID-19 deaths and variables of interest were examined.

Results: COVID-19 deaths increased with vaccination coverage ranging from 43.3% (Africa) to 1275.0% (Western Pacific). The Western Pacific (1.5%) and Africa (3.8%) regions contributed least to the global cumulative COVID-19 deaths prevaccines, while the Americas (49.9%) and Europe (27.6%) had the highest counts. The Americas (39.8%) and Europe (34.1%) accounted for >70% of global COVID-19 deaths despite high vaccination, and the percentage increase in COVID-19 mortality and the percentage of person's ≥65 years were significantly correlated (0.48) in Africa.

Conclusion: COVID-19 mortality increased in the vaccination era, especially in regions with higher vaccination coverage.

Keywords

COVID-19 deaths, WHO regions, vaccination coverage, paradox

Introduction

Many reports[1–4] on the impact of vaccination on COVID-19 pandemic deaths were projections undertaken as the global emergency was unfolding. An increasing number of independent investigators[5–12] have drawn attention to the subjective nature and inherent

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biases in mathematical models used for such forecasts that could undermine their accuracy when excess mortality was the metric of choice. For these reasons, we segmented the period of COVID-19 emergency into the era before vaccination began and that after vaccination commenced till the crisis was declared over, and compared COVID-19 deaths in the two eras in order to observe the impact of vaccination on the trajectory of COVID-19 deaths during the global health emergency. A preliminary communication of a tiny part of the data at a country-level was made to West African College of Physicians in 2023.13

Materials and methods

Data from the World Health Organization (WHO) database/dashboard14 relating to COVID-19 reported cases, mortality and vaccination were extracted and analyzed for the 236 countries and territories in the six WHO regions, namely, Africa, Americas, Eastern Mediterranean, Europe, South-East Asia, and Western Pacific. The study design entailed the full enumeration, that is, census of all COVID-19 cases and deaths reported from every country and territory in the world and does not involve any sampling procedure as captured in Supplement B. Case fatality rate (CFR) per 1000 for the two periods, namely, before vaccination commenced (CFR1) and after vaccination began up to June 7, 2023 (CFR2) were calculated and compared. The goal here was to assess whether there were differences in the mortality experience of COVID-19 in the two periods: pre-vaccines and that over the vaccination era right up to a month after the emergency was formally declared over on 05 May 2023[15] across the six regions. This almost 1 month interval was chosen as end date as it is generally accepted that the protective effect conferred by vaccination only begin to take effect from about 2 weeks after the last dose. The case fatality rate per 1000 persons for any specified period was computed as

$$\mathrm{CFR} = \frac{\text{Number of deaths from COVID} - 19 \text{ during period}}{\text{Total number of reported cases within the period}} \times 1000 \quad (1)$$

Thus, CFR1 and CFR2 were computed based on equation (1) for the pre-vaccination and vaccination eras, respectively.

There were missing observations in the dataset among the variables considered in the study and this varied between 0% and 22%. No data imputation was performed; hence all missing observations were excluded from the analyses case wise. Forty countries (17%) reported zero COVID-19 deaths/ cases before vaccination commenced or had missing vaccination start

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date. This consisted of 29 countries (12%) with missing vaccination start date and 11 countries (5%) in which vaccination commenced before the first case was reported. The regional distribution of countries with missing data on CFR1 and CFR2 were Africa (3), Americas (11), Eastern Mediterranean (2), Europe (12), South-East Asia (1), and Western Pacific (11). The omission of the missing observations in the analyses do not significantly affect the results and conclusions, as the reasons for omission were due to reporting issues from the various countries and the remaining countries data utilized is representative of the regional and global scenario.

In addition, summary statistics (mean, maximum, and minimum) were computed on a regional basis for the variables of interest; after summing the individual values for each country and dividing by the number of countries and territories in the region to arrive at the mean value for each region. Similarly, the average case fatality rate per 1000 were examined for the two periods, and the paired t-test was computed to determine whether there was a significant decline in the case fatality over time including when vaccination and other interventions were in place. The computation of the CFR was done this way for convenience and it also captures the overall trajectory of the CFR computed for smaller periods of segmentations like daily or weekly.

Further, Pearson correlation analyses were carried out for the regional data, as well as the whole data, and the variables considered in the correlation analyses were: percentage change in the number of deaths during the vaccination era, percentage of the population that is elderly (≥65 years), persons partially vaccinated, persons with complete primary vaccination, persons vaccinated with at least one booster dose per 100, and the case fatality rate per 1000 in the vaccination era up to June 7, 2023. The significant correlation coefficients r (p-value < 0.05 or p-value < 0.01) were asterisked (* and **, respectively), while correlation was considered weak if $0.1<|r|<0.3$, moderate if $0.3 \leq |r| \leq 0.5$, and strong if $|r|>0.5$[16,17].

The IBM Statistical Package for the Social Sciences (SPSS) Version 23 was used to perform the statistical data analysis.

Results

The time between when the first case was documented and vaccination commenced anywhere globally averaged between10 and 12 months (Table 1). Only 27 of the 236 countries across the six regions had lower cumulative deaths in the vaccination era relative to the pre-

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vaccination figures. And countries in this category with less than 100 deaths in the vaccination era were Burundi, Comoros, Chad, South Sudan, Tajikistan, and Nicaragua, while the remainder in the same category but over 100 deaths were Dominican Republic, Saudi Arabia, Sierra Leone, Nigeria, Niger, San Marino, Andorra, Kosovo, Belgium, Central African Republic, Panama, Benin, Liechtenstein, Iraq, Yemen, Mali, Netherlands, Madagascar, Democratic Republic of Congo, Morocco, and Kyrgyzstan.

These 27 countries notwithstanding, the sum of the cumulative COVID-19 deaths in each region after vaccination commenced right up to June 07, 2023 show a general increase relative to pre-vaccination mortality numbers (Table 1/Figure 1). This change in the COVID-19 deaths varied by regions from Africa with the lowest increase of 43.3% to Western Pacific region with the highest change of 1275.0% (Figure 1). Specifically, while the Western Pacific (1.5%) and Africa (3.8%) regions both contributed the least to the global cumulative COVID-19 deaths in the period before vaccination commenced, the Americas (49.9%) and Europe (27.6%) had the highest counts in this regard. And in the vaccination era, Africa (2.1%) and Eastern Mediterranean (4.2%) recorded the lowest numbers of COVID-19 mortality while the Americas (39.8%) and Europe (34.1%) were the biggest contributors to the global total and the hardest-hit regions. Together, the Americas and Europe regions accounted for the bulk (>70%) of COVID-19 deaths globally both before vaccination commenced and over the vaccination era up to June 07, 2023. In terms of the percentage change in cumulative COVID-19 deaths in the vaccination era relative to the pre-vaccines period, Africa (43.3%) and Eastern Mediterranean (54.1%) recorded the lowest increase, while Western Pacific (1275.0%) and Europe (223.9%) were the regions with the highest percentage change as graphically displayed in Figure 1. The multiple bar charts highlight the fact that there were more COVID-19 deaths in the vaccination era compared to the period before vaccination commenced in all six regions. And in terms of vaccination with the complete primary series per 100, Africa had the lowest vaccination rate on average (35.01) while the Western Pacific region had the highest average (79.37). The Eastern Mediterranean region had the lowest average vaccination rates per 100 for persons that had taken at least one booster dose (26.24) while the highest was the Americas (35.57). Overall, most of the regions had average vaccinations per 100 for persons with at least one booster dose ranging between 32 and 33 except in Africa and Eastern Mediterranean where these were below 30.

The region with the lowest average cumulative number of deaths at the start of vaccination was Western Pacific (799.23), followed by Africa (1469.24), while the region with the

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highest average cumulative number of deaths pre-vaccination was South-East Asia (17,418.18), and followed by the Americas (17,047.79). Africa had the lowest average cumulative deaths in the vaccination era (2105.98) and the only region with average cumulative deaths under 5000 among the six regions, while the highest was the Americas (35,722.93). The Eastern Mediterranean region recorded the lowest average percentage change (78.32%) in cumulative deaths after vaccination commenced, while the Western Pacific region had the highest average percentage change (12,385.97%). The region with the lowest cumulative deaths per million as at June 7, 2023 was South-East Asia (340.78) followed by Africa (344.07) while Europe and the Americas had the highest with average cumulative deaths per million of 2359.81 and 1763.69, respectively. The paired t-test analyses showed significant reductions in the case fatality rate per 1000 in the vaccination era in all the regions except in South-East Asia which had a slight increase in the CFR. The average case fatality rate in the vaccination era (CFR2) was between 4.57 (Western Pacific region) and 29.31 (Eastern Mediterranean region). The CFR for the Eastern Mediterranean region was the highest in both the prevaccination and vaccination era, only declining from 34.85 to 29.31. The correlation results for Africa and overall are presented in Tables 2 and 3, respectively, while the results for other regions are conveyed in Supplement A (Tables A.2a–e).

In the Africa region a weak positive correlation was observed between the percentage change in cumulative number of deaths and percentage of persons aged 65 years and older, and persons with incomplete vaccination per 100 persons. A strong positive correlation was observed between the percentage change in deaths and persons with the complete primary vaccination per 100. Additionally, the percentage of persons aged 65 years and above was moderately positively correlated with the person's vaccinated last dose per 100. The results also indicated that there was a weak positive correlation between the percentage of persons vaccinated for the complete dose and the case fatality rate per 1000 in the vaccination era (CFR2). And a strong and almost perfect positive correlation ($r \approx 1$) was evident between the incomplete and complete dose vaccinations per 100 persons. For the Americas region, the significant correlations were the following pairs: persons with incomplete vaccination per 100 versus persons with a complete dose per 100 (strong), percentage aged 65 years and above versus persons with the last dose of vaccination per 100 (mild), and percentage aged 65 years and above versus CFR2. For the Eastern Mediterranean region, the significant correlations were the following pairs: persons with incomplete vaccination per 100 versus

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CFR2 (negative strong), persons with incomplete vaccination per 100 versus persons with the last dose of vaccination per 100 (positive strong), and persons vaccinated with the last dose per 100 versus CFR2 (negative strong). For the European region, the only significant correlation was between the persons vaccinated with the incomplete dose per 100 versus the persons vaccinated with the complete dose per 100 (positive strong). For the South-East Asian region, the significant correlation pairs were: persons vaccinated with the incomplete dose per 100 versus persons vaccinated with the complete dose per 100 (strong positive), persons vaccinated with the incomplete dose per 100 versus persons vaccinated with at least one booster dose per 100 (strong positive), and persons vaccinated with the complete dose per 100 versus persons vaccinated with the booster dose per 100 (strong positive).The only significant correlation in the Western Pacific region was between the persons vaccinated with the incomplete dose per 100 and persons vaccinated with the complete dose per 100 (positive strong). For the entire global data, the significant correlation pairs were: percentage of persons aged 65 years and above versus persons with incomplete vaccination per 100 (positive moderate), percentage of persons aged 65 years and above versus persons with complete vaccination per 100 (positive moderate), percentage of persons aged 65 years and above versus CFR2 (negative weak), persons with incomplete vaccination per 100 versus persons with complete vaccination per 100 (positive strong), persons with incomplete vaccination per 100 versus CFR2 (negative moderate), and persons with complete vaccination per 100 versus CFR2 (negative moderate). All the regional computations showed a strong positive correlation (above 0.9) between persons with incomplete vaccination per 100 and persons with complete primary vaccination per 100.

Discussion

Besides 27 countries scattered across the regions especially in Africa with higher COVID-19 deaths pre-vaccines (see results section and Supplement B), a general increase in COVID-19 deaths over the vaccination era was evident (Table 1). This increased mortality varied by regions and seems higher in regions like the Americas with high vaccination relative to those like Africa with low vaccination (Figure 1).

Against data[1,18–20] indicating decelerating COVID-19 mortality at the time vaccination commenced, the results could suggest that natural trajectory was somehow disrupted and reversed. And despite the low Pearson correlation coefficient values (r) and p-values greater than 0.05, (Tables 2a–2e in Supplement A), a systematic pattern of how COVID-19 deaths

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increased with vaccination in the Africa region emerged (Table 2) as the percentage of elderly persons (≥65 years) rose, with both variables significantly correlated (0.48). The findings were completely unexpected, and counter-intuitive.

Therefore, in interpreting the findings this way, a number of issues need to be addressed going forward. First, the death numbers in this report originate from a complete enumeration and census of every COVID-19 deaths reported to WHO from all countries, territories and regions of the world. This neither involves any sampling procedure nor forecasted deaths from mathematical modeling/excess mortality with all its limitations and biases that could undermine the accuracy of projections so made[5–12]. Even so, COVID-19 deaths as indicator of the human toll of the pandemic is also sometimes criticized as it is said to vary anywhere between 98% and 10% in terms of completeness depending on the reporting country due to issues of infrastructure, resource availability and reporting bias. This has made it seem less of a reliable metric relative to excess mortality according to some experts[21–23]. On the other hand; excess mortality though useful as a metric in times of uncertainty when a deadly epidemic is ongoing, remains a forecast with potential limitations capable of undermining the accuracy of projections made as observed during COVID-19 crisis. For example, the cumulative deaths observed in the US between 2020 and 2023 during the COVID-19 global health emergency was under-estimated by 1,382,480 deaths based on SARIMA model deployed as recently reported[24]. This error in prediction was large and compounded further by a lack of goodness of-fit metrics[24], making it virtually impossible to determine the predictive capacity of the model used to estimate the all-cause deaths at a time when COVID-19 deaths were overwhelmingly the dominant cause of the excess mortality. Such huge difference in mortality values (1,382,480) between observed and predicted/expected mortality was simply the error of the model estimates[12]. Many modeling estimates seem more of an expectation than the reality evident in observed data with an increasing number of experts[5–12] drawing attention to such drawbacks and the subjective nature of excess mortality. Therefore relying on forecasts[1–3,24–27] to determine COVID-19 deaths and assess the impact of policy interventions in the presence of observed data would seem intriguing.

Several previous studies have underscored the fact that COVID-19 mortality may have been highly underreported in many countries. A study by Cabore et al.[2] estimated that 98.6% of infections and 64.7% of deaths were not reported (see Table 1 of the report). This statistic is replicated in all the 47 countries of the WHO Africa region captured in that analysis[2].

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However, it is surprising that Africa was among the least-hit regions at the time the pandemic emergency was declared over, and the fact that Africa's very weak health system did not crumble, coupled with minimal vaccination coverage across the region, calls into question, the validity of the underreporting estimates. If about 99% of infections and 65% of deaths were unreported in Africa, then all-cause mortality in the region would have increased significantly and the effect would have been visible in the already challenged health system in the region. This was clearly not the case, as life expectancies increased throughout the region during COVID-19 pandemic emergency[27–29].

Some have argued[3,10,12] that resorting to modeling without establishing the underlying assumptions is fraught with errors and it's dangerous. Consequently, using forecasted values to determine the human toll of COVID-19 pandemic when observed data are available, which ought to be the basis for any inference drawn particularly when the period of interest—COVID-19 global crisis—has been declared over since May 05, 2023, would be difficult to justify.

Another thing, "data on World Health Organization COVID-19 database are subject to continuous verification based on retrospective updates to accurately reflect trends, changes in country/territory, regions and or reporting processes. And such changes are effected every Friday with respect to the previous fortnight, and significant errors when detected or reported may be corrected at more frequent intervals."[21]

Given the foregoing, the COVID-19 mortality figures in the global public record of WHO utilized in this analysis would be difficult to discount particularly when such deaths were also inputted in models used and remain important in monitoring COVID-19 including the evolution of the SARS-CoV-2 virus which informs global response including vaccine updates and recommendations to member states as global best practice[1,4,18,30].

Coincidentally, the increased COVID-19 deaths over the vaccination era as herein reported (Table 1 and Figure 1) appear to extend recently released US national statistics and other sources[25,26,31] showing COVID-19 deaths continued on an upward trajectory until it stabilized in 2022 before starting to recede when public vaccination had commenced in 2020. Coincidentally, recent data[32] across countries in the Western World showed pandemic deaths as defined by excess mortality remained elevated at comparative levels in 2020, 2021 and 2022 despite expanding COVID-19 vaccination over the period. And more recently published analysis using both modeling estimates and observed values[3] also showed excess mortality

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was consistently elevated at similar levels throughout 2020, 2021, and 2022 across the same European region before falling in 2023 despite rising vaccination including boosters.

In this, the ever-changing genome of SARS-CoV-2, diminishing vaccine effectiveness, dominant vaccine types in different jurisdiction and declining vaccine uptake could have contributed to the mortality figures[18,30,33–35]. The impact of such dynamics in terms of mortality would be expected to be more in places like Africa with lower vaccination including boosters than in areas with higher vaccination/ boosters, but the reverse was observed (Table 1 and Figure 1), thereby, signposting the paradoxical nature of the present findings.

In contrast, the paired t-test results showing declining case fatality rate per 1000 over time could signal the contribution of vaccination to rising population immunity evident even before vaccines became available—with some regions with low vaccination coverage experiencing minimal COVID-19 deaths, while paradoxically, others with high vaccination rates recorded higher mortality[2,36,37] as Figure 1 also captured. Significantly, by the time vaccines became widely available, surveys of SARS-CoV-2 antibodies showed many unvaccinated had been infected and have mostly developed natural immunity seemingly as effective against severe disease as vaccines, if not more so[38–40]. The weak positive correlation

between the percentage of persons vaccinated for complete primary dose and the case fatality rate per 1000 over the vaccination era (CFR2) could reinforce observations suggesting mechanisms besides vaccination might have contributed, in a more powerful way, at least in some regions, to the declining mortality from SARS-CoV-2 infection over time[2,18–20,36,37].

Together, the findings raises the intriguing possibility that at the time mass vaccination began, it probably might have had less impact on the pandemic death toll than widely thought especially as the overwhelming majority of infected people were at minimal/no risk of severe COVID-19,[41–45] with some estimates[34,46–48] suggesting ≥ 90% of lives saved by vaccination were elderly already at high risk of death from morbidities pre-dating COVID-19. For one, while large scale clinical trials show vaccines as highly efficacious/safe in preventing COVID-19 deaths regardless of how the virus is changing further downstream, its impact on lives saved could be exaggerated given the state of natural immunity at the time mass vaccination commenced especially when a subjective metric as excess mortality is used.

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This notwithstanding, it requires restating that this analysis is not about the safety and efficacy of COVID-19 vaccines in preventing severe outcomes including death, which has been well documented in several large-scale clinical trials before marketing authorization. The problem is that a detailed analysis and examination of the global dataset after the pandemic emergency was declared over showed COVID-19 deaths escalated over the vaccination period in virtually all regions of the world. The question arises therefore why this was the case and how did it happen which calls for further investigation. Indeed, a recent population-based study[49] in all four countries of the UK, namely, England, Scotland, Wales, and Northern Ireland, estimated that COVID-19 deaths potentially prevented due to complete vaccination was about 0.0108% of the population, which is negligible. It is also claimed in the study that being fully vaccinated might have prevented about 1.15% of the UK's annual background mortality which represents a marginal and non-significant difference between those fully vaccinated (90%) and partially vaccinated individuals (10%) in the UK[50]. The reports highlight the fact that full vaccination may not be as effective as efficacy data in clinical trials had suggested when it comes to universal vaccination to 70% coverage as a global public health intervention. Further, despite incredible clinical trial results, observations[51–53] in the wider population have emerged suggesting vaccination may not be totally risk-free especially in the young (<60), who are also at minimal or no risk of severe outcomes with SARS-CoV-2 infection that can also induce natural immunity as protective/durable as vaccines.

After all, data available at the start, throughout and after the pandemic consistently show that for the most part, SARSCoV-2 was largely a mild and self-limiting condition for over 90% of the population at little to no risk of severe disease who also tend to acquire natural immunity on first encounter with the new virus widely reported as effective as vaccines even with the virus changing further down-stream.

Finally, this analysis post-pandemic emergency, unlike previous ones[1–4,18,34] on the impact of vaccination on COVID-19 deaths based largely on modeling estimates as the pandemic unfolded, utilized the death counts reported to World Health Organization by member states which informed the global response to the crisis. To be sure deaths/million can define vaccine effectiveness, but COVID-19 death numbers on its own can paint a bigger picture of the human toll specific to the virus regardless of whether a country is small or large when the emergency period is segmented into pre-vaccines and the post-vaccination era as herein undertaken and by others[24]. In this regard, adjusting for population size though critical in

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comparing the mortality experience of two or more populations, a direct comparison of mortality within two periods in the same population can also utilize the actual numbers as the same population is being examined at two different time intervals; hence any adjustment for population size will not vitiate the overall comparison. Consequently, we believe the results, if independently confirmed could mean all narratives based on evidence, no matter how uncomfortable are in the public domain, if all lessons from COVID-19 are to be learned for a better pandemic response in future.

Conclusion

The results show increased COVID-19 mortalities over the vaccination era, and challenge the notion that high vaccination was responsible for saving lives everywhere than would have been the case without.

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Authors' contributions

EOO and NAI are joint first authors, responsible for design, data acquisition, and analysis. All authors contributed to report writing and made inputs consolidated into a final version approved by all for submission.

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Conflicting interests

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Dedication

This independent group started in 2020 in Nigeria and has remained together except for Ayuba O. Giwa, LLB (Hons), BL, LLM, PhD, Associate Professor in Jurisprudence and

International Law, Delta State University, Abraka, Nigeria, who passed on suddenly on May 26, 2024, and to whose memory this work is dedicated.

Supplemental material

Supplemental material for this article is available online.

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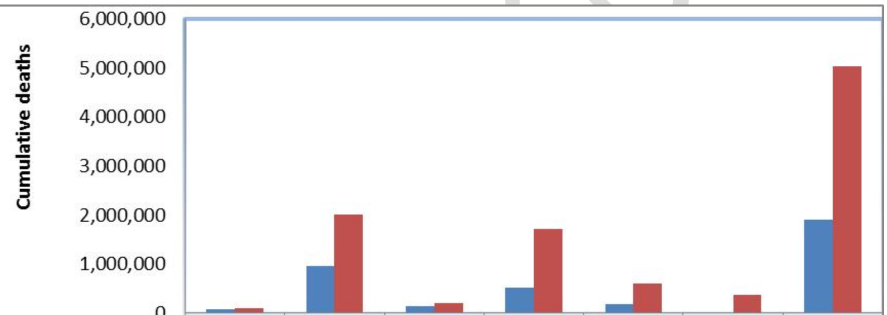

	Africa	Americas	Eastern Mediterranean	Europe	South East Asia	Western Pacific	Overall
Cumulative deaths at vaccination start	71,993	954,673	138,263	528,625	191,600	27,973	1,913,130
Cumulative deaths in the vaccination era	103,193	2,000,484	213,018	1,712,047	614,578	384,632	5,027,952

Figure 1. Bar chart of cumulative COVID-19 deaths before vaccination and in the vaccination era up to June 07, 2023 for the WHO regions.

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Table 1: Some summary statistics (mean, minimum and maximum) of COVID-19 vaccination and cumulative deaths statistics for the WHO regions up to June 7, 2023

WHO Region		Duration of period before vaccination commenced	Cumulative deaths at vaccination start	Cumulative deaths in the vaccination era	% change in cumulative deaths	*Cumulative deaths/10^6 at June 7, 2023 since the pandemic started	Population density as at June 7, 2023	Median age as at June 7, 2023	% of the population aged 65 and above as at June 7, 2023	Persons with incomplete vaccination per 100	Persons vaccinated with a complete primary series per 100	Persons vaccinated with at least one booster or additional dose per 100
Africa	Mean	12.24	1469.24	2105.98	714.11	344.07	116.29	21.22	3.80	41.43	35.01	28.82
	Minimum	10	0	0	-92.86	1.16	3.08	15	2.2	0	0	0
	Maximum	18	48313	54282	17000	3381.57	622.96	41	18.5	90.01	85.56	145.94
Americas	Mean	10.77	17047.79	35722.93	1449.22	1763.69	214.07	32.63	9.40	67.66	61.63	35.57
	Minimum	9	0	0	-59.20	35,26	3.61	23	3.90	4.57	3.07	0.33
	Maximum	12	308161	818991	23600	6498.20	1308.82	46	18.60	101.56	93.97	107.56
Eastern	Mean	11.40	6284.68	9682.64	78.32	674.91	231.69	26.56	3.89	55.07	49.74	26.24
Mediterranean	Minimum	9	0	126	-47.20	64.07	3.62	17	1.10	3.46	2.64	0.68
	Maximum	13	58536	87731	274.07	2381.25	1935.91	34	8.50	101.02	99.01	71.22
Europe	Mean	10.51	8390.87	27175.35	287.24	2359.81	539.85	39.38	15.64	66.25	63.59	32.71
	Minimum	8	0	0	-62.64	12.56	0.14	20	3.50	23.13	20.33	0.43
	Maximum	17	86796	399226	1531.79	5661.05	19347.50	48	23.0	125.18	123.07	77.18
South-East	Mean	11.50	17418.18	55870.73	6360.26	340.78	411.68	26.81	5.37	79.43	71.88	32.79
Asia	Minimum	10	0	0	149.71	12.92	21.19	18	3.1	63.92	50.63	5.17
	Maximum	13	1520.93	379791	40960.24	773.17	1454.43	34	10.1	95.42	87.83	82.25
Western	Mean	10.21	799.23	10989.49	12385.97	560.93	424.65	30.43	8.17	83.74	79.37	33.89
Pacific	Minimum	2	0	0	0	42.85	1.98	21	8.5	4.36	3.68	0
	Maximum	15	12318	116581	106600	2415.84	7915.73	48	27.0	163.19	163.19	77.81
OVERALL	Mean	11.20	8106.48	21304.88	1952.85	1276.39	322.33	30.29	8.64	63.53	58.58	32.15
	Minimum	2	0	0	-92.86	1.16	0.14	15	1.1	0	0	0
	Maximum	18	308161	818991	106600	6498.20	19347.50	48	27.0	163.19	163.19	145.94

Source: World Health Organization, www.ourworldindata.org (reference 14)

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Table 2: Correlation matrix of percentage change in COVID-19 deaths, vaccination rates and case fatality rate per 1,000 persons in vaccination era (Africa region)

	% Change in Deaths	Percentage of persons 65 years and older in the population	Persons vaccinated 1 Plus Dose per 100	Persons vaccinated Last Dose per 100	Persons with Booster Additional Dose per 100	Case Fatality Rate per 1,000 in vaccination era
% Change in Deaths	1	0.486** (moderate)	0.453** (moderate)	0.501** (strong)	-0.049	-0.203
Percentage of persons 65 years and older in the population	0.486** (moderate)	1	0.267	0.335* (moderate)	-0.014	0.020
Persons vaccinated 1 Plus Dose per 100	0.453** (moderate)	0.267	1	0.974** (strong)	-0.067	-0.270
Persons vaccinated Last Dose per 100	0.501** (strong)	0.335* (moderate)	0.974** (strong)	1	-0.060	-0.288* (weak)
Persons with Booster Additional Dose per 100	-0.049	-0.014	-0.067	-0.060	1	-0.182
Case Fatality Rate per 1,000 in vaccination era	-0.203	0.020	-0.270	-0.288*	-0.182	1

Key: **. Correlation is significant at the 0.01 level; *. Correlation is significant at the 0.05 level.

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Table 3: Correlation matrix of percentage change in COVID-19 deaths, vaccination rates and case fatality rate per 1,000 persons in vaccination era (Overall)

	% Change in Deaths	Percentage of persons 65 years and older in the population	Persons vaccinated 1 Plus Dose per 100	Persons vaccinated Last Dose per 100	Persons with Booster Additional Dose per 100	Case Fatality Rate per 1,000 in vaccination era
% Change in Deaths	1	-0.066	0.107	0.113	-0.077	-0.082
Percentage of persons 65 years and older in the population	-0.066	1	0.336** (moderate)	0.396** (moderate)	0.140	-0.248** (weak)
Persons vaccinated 1 Plus Dose per 100	0.107	0.336** (moderate)	1	0.985** (strong)	0.134	-0.374** (moderate)
Persons vaccinated Last Dose per 100	0.113	0.396** (moderate)	0.985** (strong)	1	0.131	-0.388** (moderate)
Persons with Booster Additional Dose per 100	-0.077	0.140	0.134	0.131	1	-0.147
Case Fatality Rate per 1,000 in vaccination era	-0.082	-0.248** (weak)	-0.374** (moderate)	-0.388** (moderate)	-0.147	1

Key: **. Correlation is significant at the 0.01 level; *. Correlation is significant at the 0.05 level.

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