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# Unexpected patterns in the global COVID-19 pandemic data

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## Abstract

A number of public health interventions, including mobility restrictions and vaccination, were undertaken to limit the global impact of the SARS-CoV-2 pandemic. The burden of the associated disease COVID-19 was also expected to be dependent on demographic and socio-economic determinants such as older age and general wellbeing. In this exploratory study, we examine country-level relationships between a selection of these interventions and pre-existing determinants on one hand, and public health outcomes, including COVID-19 cases, intensive-care patients, deaths, and excess mortality, on the other hand. We outline the expected results and highlight countries, continents, and time periods during 2020-2022, where/when unexpected patterns can be found in the data. For example at a global per-country scale, neither mobility restrictions nor school closures were associated with improved outcomes; no intervention or determinant came with lower intensive-care patient rates; and when using aggregation per year and continent, Europe is the only world region where vaccination and the human development index correlated with better outcomes. Between 78% and 92% of the relationships at different scales of analysis either were not statistically significant or went in the wrong direction altogether. This failure to yield expected public health benefits suggests the need for an unbiased, critical reassessment of the global pandemic response with a view to improving preparedness for future emergencies. The articles concludes with a set of research hypotheses to guide this effort.

**Keywords:** Correlation analysis; COVID-19; Lockdowns; Pandemic response measures; Public health; Vaccination

## 1 Introduction

First called 2019-nCov, later rechristened SARS-CoV-2 [1], a novel coronavirus is spreading globally since late 2019. In February 2020, reports from Wuhan, China; Bergamo, Italy; and then New York City, USA, conjured fears of a devastating public health crisis, which culminated in the declaration of a pandemic by the World Health Organization (WHO) on 8 March 2020 and the implementation of a rapid succession of unprecedented restrictions of people's social gathering and mobility rights [2].

Meanwhile, the epidemiological bulletins of the Italian public health agency showed the distinct vulnerability of frail seniors, as the median age among COVID-19 fatalities in hospitals was 80 and 96.5% had at least one co-morbidity [e.g. 3]. A thorough investigation of the outbreak during carnival gatherings in the German city of Heinsberg yielded an infection-fatality rate ten times lower than the WHO's initial estimates and a secondary infection rate within households of well below 50% [4]. For the deadly first wave in New York, researchers identified long-term air pollution exposure as a significant factor in serious and fatal outcomes [5].

While halting society for "two weeks to flatten the curve" turned into two months and then two years of restrictions [6], and the rapid development of vaccines emerged as the moonshot solution to force the elusive "end of the pandemic" [7]. The novel mRNA technology was still being adjusted for broad application in the human population [8] and tested on a

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greatly compressed timeline, with trial endpoints limited to symptomatic COVID-19 instead of infection, transmission, hospitalizations, or deaths [9].

From February 2020 onward, many researchers and health-care practitioners raised concerns about issues with the data and models used to substantiate the pandemic response measures [10, 11, 12]; the fear-based approach to ensuring compliance with public health measures [13, 14, 15] inconsistent with the ever-declining infection-fatality rates [16, 17]; the lack of cost-benefit analyses taking negative side effects into account [18, 19, 20]; the actual medical treatment protocols being developed in this climate of panic [21]; and the politics and ethics of government restrictions and mandates [22, 23, 24, 25, 26].

Many of these heterodox views were shared on social media and in preprints, but rejected by scholarly journal editors, reviewers, and in published opinion; instead of triggering scientific and public debate, dissenting doctors and scientists experienced different forms of silencing [27, 28]. Meanwhile, government restrictions were maintained for the goals they were “designed” to achieve: gathering limits, business and school closures, masking, and ultimately vaccination were expected to reduce infections, virus transmission, hospitalizations, and deaths.

The basic assumption for this paper is that aggregate data for the three years of the pandemic should reflect the anticipated success of the response measures; in a global dataset, countries with more, stricter, and/or longer interventions should tend to exhibit lesser impacts of the pandemic. In addition, we will also consider the expected impacts of pre-existing demographic and socio-economic determinants. Comparable research has so far focused on examining the relationship between socio-economic determinants and specific outcomes such as early COVID-19 fatalities [29] or participation in interventions such as vaccination [30]; assessing health-care system preparedness against COVID-19 outcomes [31]; and exploring the early pandemic data [32, 33].

## 2 Materials and methods

Multiple government, academic, and private-sector organizations have collected and shared data for metrics relating to COVID-19 [12]. Here, we use open-access data from Mathieu et al.’s [34] Our World In Data (OWID) COVID-19 Data Explorer. The complete dataset was downloaded on 26 March 2023 in Microsoft Excel spreadsheet format. The 45.5 MB-large file includes 67 columns (variables) and 297,113 rows (countries and dates, starting 3 January 2020). To capture three full years for comparability and avoid reporting delays in recent values, analyses and visualizations are restricted to the period from January 2020 to December 2022. For this period, the majority of variables contained in the OWID dataset were originally collected by the European Centre for Disease Prevention and Control and the Center for Systems Science and Engineering at Johns Hopkins University [34] as well as the Oxford COVID-19 Government Response Tracker (OxCGRT) [35].

All variables selected and described below are enumerated at the country level and were obtained in normalized forms, for example as percentages or per-million rates, so that the values account for differences in population sizes between countries. One of two aggregators was used to combine data points by continent or time period, as specified in the following subsections. Generally, *averages* were used to aggregate cyclical and static variables to describe the central tendency or “typical” value, while *maxima* were used to aggregate cumulative variables to highlight extremes or final outcomes.

### 2.1 Public Health Outcomes

Data on public health outcomes include COVID-19 cases, used as an imperfect proxy for infected people; patients in intensive-care units (ICU), representing seriously ill people; deaths “attributed to COVID-19”; and excess mortality as a broader measure of the most severe impact of the pandemic (see Table 1).

The outcome variables were carefully selected in order to capture specific aspects of the pandemic. New COVID-19 cases as well as excess mortality (percent difference) were used rather than cumulative case rates or cumulative excess mortality to represent fluctuations over time. ICU patients are used rather than hospital admissions to capture the onset, duration, and end of this severe impact. Lastly, total deaths were used as a cumulative metric to reflect a country’s final (per time period) public health outcome.

**Table 1** Public health outcome variables included in the analysis

| Variable | Description |
|---|---|
| new_cases_smoothed_per_million | New confirmed cases of COVID-19 (7-day smoothed) per 1,000,000 people. Counts can include probable cases, where reported. |
| icu_patients_per_million | Number of COVID-19 patients in intensive care units (ICUs) on a given day per 1,000,000 people |
| total_deaths_per_million | Total deaths attributed to COVID-19 per 1,000,000 people. Counts can include probable deaths, where reported. |
| excess_mortality | Percentage difference between the reported number of weekly or monthly deaths in 2020–2021 and the projected number of deaths for the same period based on previous years. |

Source: Our World in Data, https://github.com/owid/covid-19-data/tree/master/public/data

Where needed, the cumulative deaths were aggregated using the maximum, while the other three outcome variables were aggregated using the average.

## 2.2 Government interventions

A number of variables are available to represent the pandemic response measures implemented across countries and time periods. The first intervention represented in this analysis reflects the weekly average of tests completed per 1,000 residents (see Table 2).

Additional metrics originate from the OxCGRT [35]. The Stringency Index is a composite of nine indicators on a 0-1 scale, representing school and workplace closures, gathering limits and cancellations, travel restrictions, and public health campaigns. Due to the contentious issue of school closures, this intervention will also be separately analyzed. The controversial mask rules were also analyzed separately rather than using the broader Containment and Health Index.

Lastly, we used people fully vaccinated (percentage) from the main OWID dataset to portray the coverage of this particular intervention in each country and over time, which also reflects the progress of the policy aspects of the global vaccination campaigns.

Where needed, the cumulative vaccination variable was aggregated using the maximum, while the other four interventions were aggregated using averages.

**Table 2** Government intervention variables included in the analysis

| Variable | Description |
|---|---|
| new_tests_smoothed_per_thousand | New tests for COVID-19 (7-day smoothed) per 1,000 people |
| stringency_index | Government Response Stringency Index: composite measure based on 9 response indicators including school closures, workplace closures, and travel bans, rescaled to a value from 0 to 100 (100 = strictest response) |
| school_closures | Stringency of policies regarding school closures, from no measures (0) through recommend closing (1) to require closing at some levels (2) and require closing at all levels (3) |
| facial_coverings | Stringency of policies regarding face coverings, from no policy (0) through recommended (1) to three levels of requirements (2-4) |
| people_fully_vaccinated_per_hundred | Total number of people who received all doses prescribed by the initial vaccination protocol per 100 people in the total population |

Source: Our World in Data, https://github.com/owid/covid-19-data/tree/master/public/data

### 2.3 Socio-economic determinants

It is well established that demographics and social-economic circumstances in which people live greatly affect public health [e.g. 36]. A key vulnerability factor for COVID-19 is older age [37], thus the consideration of the share of a country's elderly population in this research (see Table 3). In terms of social determinants of health, we limit the analysis to two variables included in the OWID data set to ensure comparability, namely gross domestic product (GDP, per capita) and the broader human development index (HDI), which includes an education component in addition to wealth and life expectancy.

**Table 3** Demographic and socio-economic determinant variables included in the analysis

| Variable | Description |
|---|---|
| aged_65_older | Share of the population that is 65 years and older, most recent year available |
| gdp_per_capita | Gross domestic product at purchasing power parity (constant 2011 international dollars), most recent year available |
| human_development_index | A composite index measuring average achievement in three basic dimensions of human development—a long and healthy life, knowledge and a decent standard of living. Values for 2019 |

Source: Our World in Data, https://github.com/owid/covid-19-data/tree/master/public/data

### 2.4 Approach

The selected variables were loaded into a set of interactive visualizations in the public version of the Tableau software at https://public.tableau.com/app/profile/claus.rinner/viz/UnexpectedPatternsintheGlobalCOVID-19Data/Fig_1aInterventions, making them shareable with other researchers and the public. Spatial and non-spatial data exploration has been shown to be a powerful tool for scientific hypothesis generation [e.g. 38]

We established a set of hypotheses with respect to correlations between pairs of selected variables:

- Larger values in any intervention are associated with smaller values in any outcome
- Smaller values in the share of population 65+ are associated with smaller values in any outcome
- Larger values in GDP and HDI are associated with smaller values in any outcome

The primary method for testing these hypotheses is pairwise comparison using scatterplots with linear trendlines, where the data are aggregated by country, continent, and/or time period. The five selected interventions and three determinants were plotted against the four outcomes, resulting in 32 comparisons made for all countries and the entire three-year time frame.

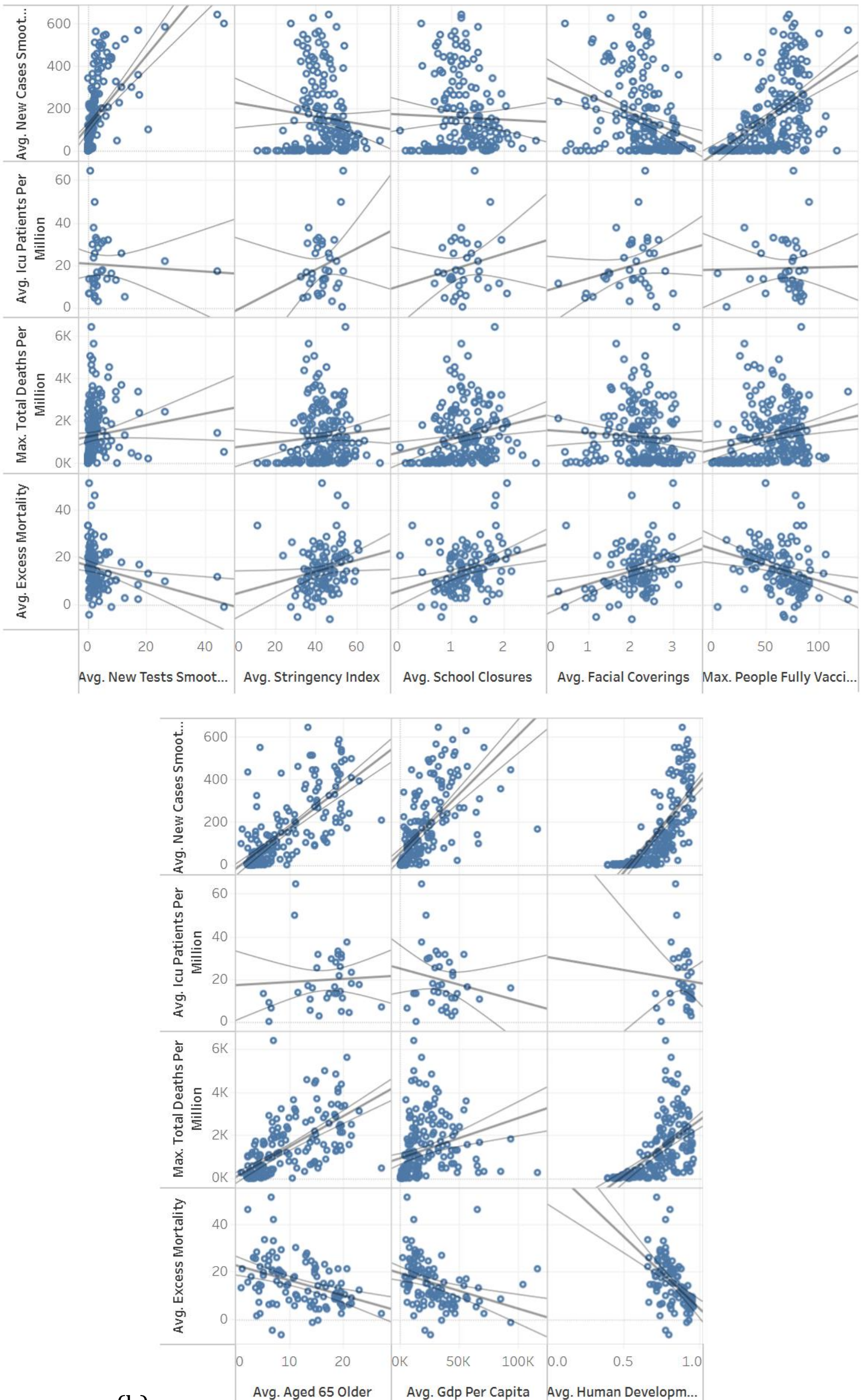
These comparisons were then examined separately by each of the six populated continents, resulting in an additional 192 scatterplots. The 32 comparisons were also inspected separately for each of the years 2020 to 2022, resulting in another 96 scatterplots. Among these additional comparisons by year and continent, only those involving three representative interventions and determinants, i.e. lockdown stringency, vaccination, and HDI, as well as COVID-19 deaths as the most pertinent outcome metric are reported and discussed here.

The above hypotheses were considered as rejected if a linear trendline was sloped in the wrong direction or the corresponding r-squared value was not significant at the 95% level. For statistically significant relationships, we also indicate meaningful magnitudes using a degree of dependence of r-squared = 0.25 or larger, based on Cohen's [39, page 532] "conventional" threshold for "large" effect sizes. Both, inverse relationships as well as non-significant relationships were regarded as unexpected. Based on the resulting patterns, we develop recommendations for future, more detailed investigation.

## 3 Results

### 3.1 Global relationships between interventions, determinants, and outcomes

Figure 1 illustrates the first 32 pairwise comparisons of interventions and determinants against outcomes. Most of the scatterplots present amorphous point clouds. One exception are new tests (first column), where most values are clustered at the low end with few high outliers, while the four outcome variables generate a vertical, almost linear pattern. This observation suggests that many countries implemented similar testing strategies with greatly different (i.e., unrelated) outcomes. The other exceptions are found with the determinants (last three columns), where about one half of the scatterplots present a somewhat linear pattern. This might suggest that the pre-existing, long-term demographic and social determinants of health had a stronger impact on pandemic outcomes than government interventions.




(a)

(b)

Data source: Our World in Data, WHO, and OxCGRT via https://github.com/owid/covid-19-data/tree/master/public/data

**Figure 1** Relationships between (a) five interventions and (b) three determinants on one hand (x-axis), and the four public health outcomes on the other hand (y-axis). Variables and linear trendlines are displayed by country for all three years 2020-2022 combined

Table 4 shows the direction and strength of each global relationship. For example, increased values in testing are associated with higher case rates (r2 = 0.36), as might be expected, since the more you look the more you will find. However, more testing, which would be expected to reduce the impact of the pandemic due to individual awareness, is not associated with fewer hospitalizations or COVID-19 deaths. It does correlate with lower excess mortality, though at a meaningless r-squared of near zero.

Lockdown stringency and school closures are not associated with improvements in any outcome metric; they do indeed correlate with higher deaths/mortality, though again at a meaningless near-zero level. Meanwhile, masking is marginally associated with improved case outcomes but not with the more serious hospitalization and death/mortality outcomes.

Last among the interventions, vaccination is unexpectedly associated with more cases (r2 = 0.25) as well as more hospitalizations (not a statistically significant relationship) and more COVID-19 deaths (significant but near zero), yet lower excess mortality (also significant but near-zero).

**Table 4** Relationships between interventions, determinants, and outcomes with indication of direction, significance, meaningful r-squared values (bolded), and whether expected or unexpected. The grey cells represent 25 unexpected relationships (78%) out of a total of 32.

| | **tests** | **lockdown** | **schools** | **masks** | **vaccination** | | **elderly** | **GDP** | **HDI** |
|---|---|---|---|---|---|---|---|---|---|
| **new_cases_smoothed_per_million** | **/ 0.36** | \ | \ | \ 0.09 | **/ 0.25** | | **/ 0.54** | **/ 0.41** | **/ 0.58** |
| **icu_patients_per_million** | \ | / | / | / | / | | / | \ | \ |
| **total_deaths_per_million** | / | / | / 0.05 | \ | / 0.05 | | **/ 0.43** | / 0.07 | **/ 0.34** |
| **excess_mortality** | \ 0.07 | / 0.04 | / 0.09 | / 0.10 | \ 0.08 | | \ 0.15 | \ 0.11 | **\ 0.26** |

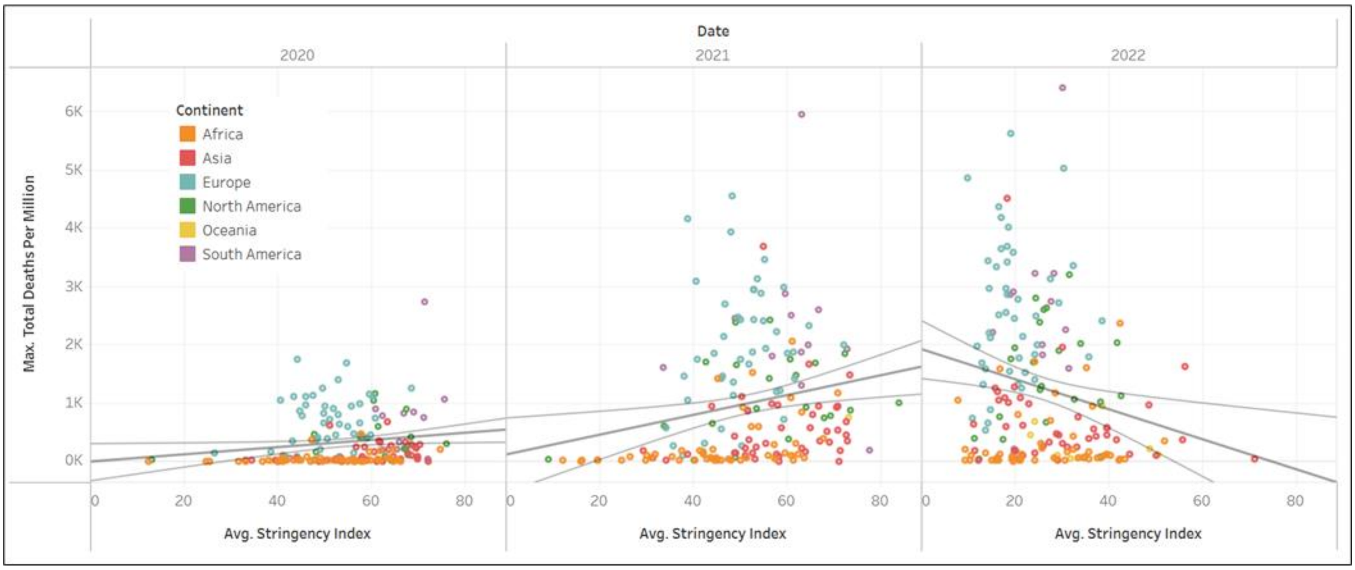
Legend: tests = new_tests_smoothed_per_thousand; lockdown = stringency_index; schools = school_closures; masks = facial_coverings; vaccination = people_fully_vaccinated_per_hundred; elderly = aged_65_older; GDP = gdp_per_capita; HDI = human_development_index; "/" = positive correlation; "\" = negative correlation; r-squared values are provided only for statistically significant relationships ($p < 0.05$)

Among the determinants, older age is strongly associated with higher cases and deaths, but unexpectedly not linked to worse hospitalizations or excess mortality. The other two determinants, GDP and HDI, exhibit similar patterns, which are more pronounced for HDI: a strong, unexpected association with higher cases and deaths, yet a beneficial effect on excess mortality. The two unexpected relationships mean that the better off a country is, the higher its COVID-19 case and death rates tended to be. It must be noted that the life expectancy component of the HDI points in the same direction as the demographic (older age) variable. Nevertheless, it seems that the HDI's education and wealth components could not reverse this trend.

A total of 25 out of 32 (78%) relationships are unexpected in direction and/or strength (grey cells in Table 4).

### 3.2 Relationships between interventions, determinants, and COVID-attributed deaths by continent and year

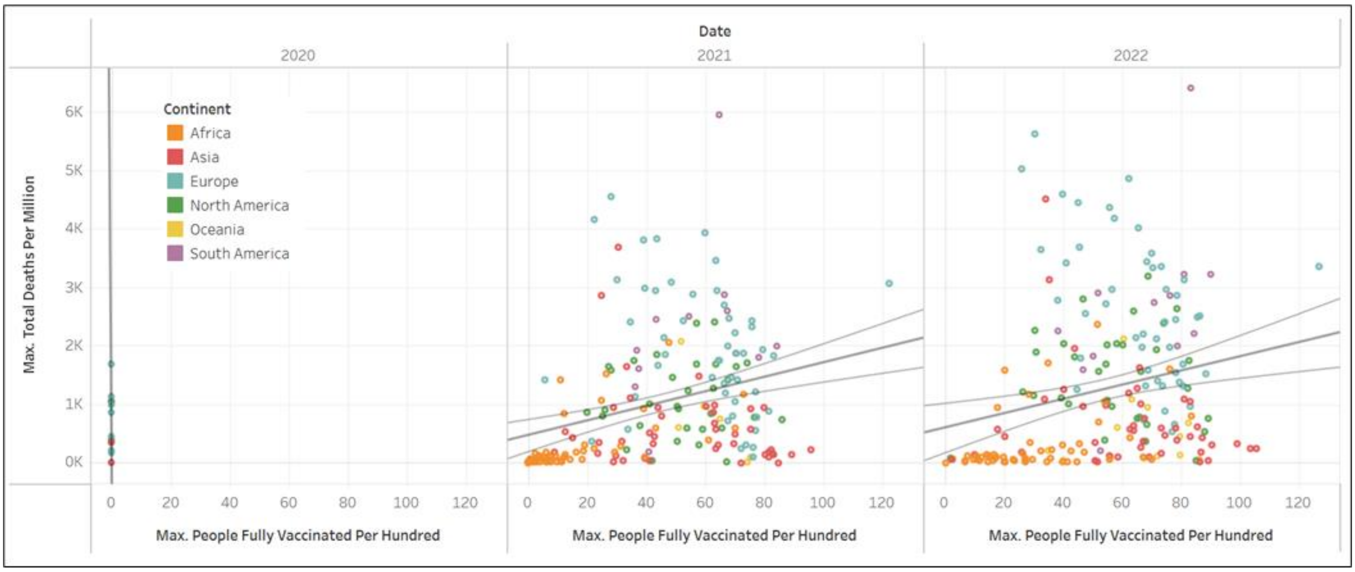
Figure 2 illustrates the impact of average lockdown stringency by country and year, with country data colour-coded to their continent. From a relatively compact range of maximum total deaths per million in 2020, these values spread out in the years 2021 and 2022, while the stringency of government restrictions markedly diminished in 2022. The global relationship indicated by the linear trendline is nearly flat (no effect) in 2020, grows unexpectedly in 2021, and reverses in 2022, meaning that only in that last year, stricter residual lockdowns were indeed associated with improved outcomes.




Data source: Our World in Data, WHO, and OxCGRT via https://github.com/owid/covid-19-data/tree/master/public/data

**Figure 2** Stringency of government restrictions vs. total COVID-19 death rates by continent and year

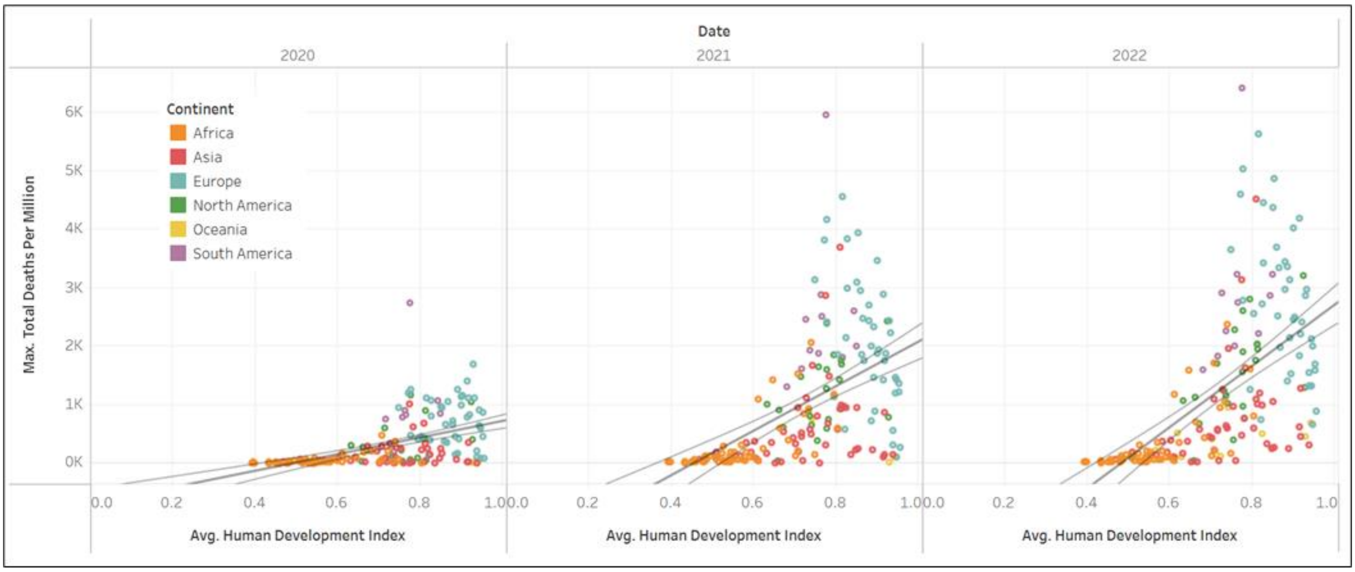
According to Figure 3, higher maximum percentages of fully vaccinated individuals per country and year were associated with higher COVID-19 deaths at a global scale. Generally speaking, African countries (orange dots) are found at the low ends of both axes; Asia (red) tends to have high vaccination and lower death rates; yet Europe (blue) and the Americas (green and purple) have medium to high vaccination rates combined with often unexpectedly high death rates.




Data source: Our World in Data, WHO, and OxCGRT via https://github.com/owid/covid-19-data/tree/master/public/data

**Figure 3** Fully vaccinated % vs. total COVID-19 death rates by continent and year

The HDI determinant is assumed to be constant for the three years. Figure 4 illustrates that many African countries with low HDI keep low deaths throughout the pandemic, while the fatal outcome of most other countries fans out in 2021 and 2022, seemingly unaffected by each country's human development status. In particular, some European countries (blue dots) present among the highest HDI values as well as highest death rates.




Data source: Our World in Data, WHO, and OxCGRT via https://github.com/owid/covid-19-data/tree/master/public/data

**Figure 4** HDI vs. total COVID-19 death rates by continent and year

Tables 5-7 confirm some of these observations numerically. For example, the HDI is consistently associated with higher death rates, irrespective of the year of the pandemic (Table 5). A total of 7 (88%) out of 8 meaningful relationships displayed in Table 5 are unexpected. Only lockdowns met our expectation of an association with lower deaths rates, yet only for the year 2022 and not at a meaningful magnitude (r2 = 0.04).

**Table 5** Relationships between select interventions, determinants, and the COVID-19 death outcome by year of the pandemic, with indication of direction, significance, meaningful r-squared values (bolded), and whether expected or unexpected. The grey cells represent 7 unexpected relationships (88%) out of a total of 8.

| | **lockdown** | **vaccination** | **HDI** |
|---|---|---|---|
| **total_deaths_per_million** | | | |
| 2020 | / 0.03 | n/a | **/ 0.26** |
| 2021 | / 0.04 | / 0.10 | **/ 0.27** |
| 2022 | \ 0.04 | / 0.05 | **/ 0.34** |

Legend: tests = lockdown = stringency_index; vaccination = people_fully_vaccinated_per_hundred; HDI = human_development_index; "/" = positive correlation; "\" = negative correlation; r-squared values are provided only for statistically significant relationships ($p < 0.05$)

Aggregation by continent (Table 6) presents a similar picture, with the HDI associated with worse outcomes in all continents with one exception. In Europe, both vaccination and HDI seem to have a beneficial effect on fatal COVID-19 outcomes. These are the only two relationships where our hypotheses were not rejected. A total of 16 (89%) out of 18 comparisons in Table 6 yield unexpected results.

**Table 6** Relationships between select interventions, determinants, and the COVID-19 death outcome by continent, with indication of direction, significance, meaningful r-squared values (bolded), and whether expected or unexpected. The grey cells represent 16 unexpected relationships (89%) out of a total of 18.

| | **lockdown** | **vaccination** | **HDI** |
|---|---|---|---|
| **total_deaths_per_million** | | | |
| Africa | / | / 0.14 | / 0.46 |
| Asia | / | \ | / 0.10 |

| | | | |
|---|---|---|---|
| Europe | / | \ 0.15 | \ 0.27 |
| North America | / | / | / 0.42 |
| Oceania | / | / | / |
| South America | / | / | / |

Legend: tests = lockdown = stringency_index; vaccination = people_fully_vaccinated_per_hundred; HDI = human_development_index; "/" = positive correlation; "\" = negative correlation; r-squared values are provided only for statistically significant relationships ($p < 0.05$)

Lastly, the view by both continents and years of the pandemic points to Europe, Africa, and North America as cases of interest. Again, Europe is the only continent that has any expected outcomes in Table 7, with vaccination and HDI associated with lower death rates in both, 2021 and 2022. In contrast, Africa has all interventions and determinants associated with worse (unexpected) outcomes, with several statistically significant and meaningful coefficients of determination in the area of 0.3 to 0.46. North America also has worse outcomes for all three interventions/determinants across all years, although only two of them (HDI for 2021 and 2022) are significant. Overall, 44 (92%) out of 48 relationships in Table 7 contradict expectations.

**Table 7** Relationships between select interventions, determinants, and the COVID-19 death outcome by continent, with indication of direction, significance, meaningful r-squared values (bolded), and whether expected or unexpected. The grey cells represent 44 unexpected relationships (92%) out of a total of 48.

| | **lockdown** | | | **vaccination** | | | **HDI** | | |
|---|---|---|---|---|---|---|---|---|---|
| **total_deaths_per_million** | 2020 | 2021 | 2022 | 2020 | 2021 | 2022 | 2020 | 2021 | 2022 |
| Africa | / | / 0.18 | / | n/a | / 0.36 | / 0.14 | / 0.30 | / 0.44 | / 0.46 |
| Asia | / | / | \ | n/a | \ | \ | / | / | / 0.10 |
| Europe | / | / | / | n/a | \ 0.08 | \ 0.22 | \ | \ 0.33 | \ 0.27 |
| North America | / | / | / | n/a | / | / | / | / 0.32 | / 0.42 |
| Oceania | / | / | \ | n/a | / | / | / | \ | / |
| South America | / | \ | / | n/a | / | / | / | / | / |

Legend: tests = lockdown = stringency_index; vaccination = people_fully_vaccinated_per_hundred; HDI = human_development_index; "/" = positive correlation; "\" = negative correlation; r-squared values are provided only for statistically significant relationships ($p < 0.05$)

## 4 Discussion

Our initial hypotheses about the efficacy of the COVID-19 pandemic response measures and the supportive impact of pre-existing population characteristics were mostly rejected. Among the selected variables, no intervention and only one determinant (proportion of those aged 65 and older) was associated at a statistically significant, meaningful level with more than one outcome in the expected direction (cases and deaths – see Table 4). The older a population is, the more cases there were, which might be explained by stricter testing in countries that were more concerned about vulnerable older adults. The elderly are also associated with greater COVID-19 death rates, reflecting the highly age-dependent vulnerability to the virus. At the margins, this finding might support the idea of "focused protection" [40], although the non-significant relationship with ICU patient rates does not underscore this conclusion. Instead, it may reflect the fact that frail elderly patients in many countries remained in nursing homes rather than being treated in hospitals.

From the public health outcome perspective, excess mortality is the only outcome that is associated in an expected fashion with as many as two interventions (tests, vaccination) and two determinants (GDP, HDI). More tests, more vaccinations, a higher GDP, and a higher HDI are all linked to lower excess mortality, although only the r-squared value with the HDI reaches a meaningful level of 0.26 (Table 4). What is confusing is that the two interventions aimed at fighting the pandemic failed with respect to COVID-19 deaths but are associated with reduced excess mortality. This could only be explained if countries with stricter testing and vaccination schemes also tended to over-count COVID-19 deaths [41]. With respect to the two determinants, wealthier and better educated populations are expected to be more healthy to begin with and more resilient in a crisis, assuming that excess mortality is indeed related to the pandemic.

Lastly, Europe presents several expected outcomes, namely higher vaccination rates and a higher HDI came with lower COVID-19 death rates in European countries (Table 6). In the annual aggregate (Table 7), this relationship holds for the years 2021 and 2022. What this could ultimately mean is that interventions such as vaccination and determinants such as the HDI may have been developed and implemented in a Euro-centric way so that they did not work equally on other continents.

Lockdowns and school closures are the two interventions that have the least indication of success, without a single expected relationship with any of the four outcomes considered. The limited evidence for mask and vaccination efficacy is equally concerning. The burden of proof for the implementation of such highly intrusive public health measures rests with the decision-makers. Politicians and medical officers ought to demonstrably justify that measures that interfere with human rights will have an overall positive effect.

Instead, this retrospective analysis suggests the following hypotheses for future research. During the SARS-CoV-2 pandemic:

- Frequent testing did not improve public health outcomes.
- Stringent lockdown did not improve public health outcomes.
- School closures did not improve public health outcomes.
- Community masking did not improve public health outcomes.
- High vaccination rates did not improve public health outcomes.

An important limitation of this analysis is the country-level data aggregation, which may hide important differences within countries. However, this unit of analysis fits with the scope of many pandemic response measures. The disappointing results indicate that a one-size-fits-all approach to public health is not effective. Instead, the local environment in terms of socio-economic, cultural, and population health factors needs to be taken into account and decisions with existential impacts on communities ought to be made decentrally, and quite possibly below the national or even state/provincial level.

Other limitations of this research include the use of linear trendlines; possibly incomplete or inconsistent data; the use of composite variables such as stringency index and HDI; and some choices in the ways in which we looked at each factor, aggregated it, and determined what was considered expected or unexpected. A specific concern and avenue for future research arises from the aggregation of time series data, which could hide time-delayed effects of interventions. Nevertheless, it must be noted that the great number of unexpected relationships suggests that the global COVID-19 pandemic response largely failed.

Pending more detailed research, preliminary recommendations for future crises include to refrain from most lockdowns and school closures; make face coverings and vaccinations optional; and learn from the way in which poorer developing countries responded to this pandemic.

## 5 Conclusion

We used the country-level data from the University of Oxford's Our World In Data global COVID-19 dataset for 2020-2022 to explore statistical relationships between select public health interventions and underlying social determinants along with COVID-19 outcomes. For the most part, and contrary to widely communicated expectations, testing, lockdowns, school closures, face masks, and vaccination could not be shown to have a positive effect on COVID-19 cases, hospitalizations, and deaths. The few exceptions, where our initial hypotheses were not rejected, were concentrated in Europe. The largely unexpected patterns in the global COVID-19 data suggest that the pandemic response was not evidence-based and thus must be considered a policy blunder. Rather than double down on the failed public health measures of 2020-2022, governments and public health agencies should reactivate pre-existing pandemic guidelines and practices focusing on multi-disciplinary perspectives, open scientific and stakeholder dialogue, positive communications, decentralized measures, and voluntary individual participation.

## Compliance with ethical standards

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*Statement of ethical approval*

The present work did not involve any studies performed on animals/humans subjects by any of the authors.

*Statement of informed consent*

No individual participants were included in the study.

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