Quantifying the effect of inequitable global vaccine coverage on the COVID-19 pandemic

We used a global mathematical model simulating different scenarios to study the effects of increased COVID-19 vaccine equity during 2021. Our results indicate that vaccine nationalism leads to increased infections and mortality worldwide, and by favoring the emergence of new viral variants, in the long term it may adversely affect all countries.

The mission
The severe acute respiratory syndrome coronavirus 2 (SARS-CoV-2) pandemic has generated considerable morbidity and mortality worldwide. Vaccines (and booster doses) protect from or mitigate the worst effects; nevertheless, by the end of 2021, the distribution of vaccine coverage was highly heterogeneous, with some countries achieving over 90% coverage in adults but others reaching less than 2% (https://covid19.who.int/). The most notable factor driving this inequity across 2021 was vaccine availability: there has been a strong correlation between the economic status of a country and the number of vaccine doses acquired (https://data.undp.org/vaccine-equity/). It is of great importance that we understand the effects that this inequity has had on global disease burden, and by doing so better inform future policy decisions that may have a crucial effect on public health.

The discovery
We developed a mathematical model of SARS-CoV-2 transmission and coronavirus disease 2019 (COVID-19) outcomes, which generates, for example, estimates for the number of symptomatic cases and deaths over time. The simulation accounted for 152 different countries, each with its own parameters reflecting demographics and social structure, and ran over the course of 2021, as this year was the key time period for COVID-19 vaccine deployment within the context of a large number of COVID-19-related infections, hospitalizations and deaths worldwide. While keeping the total number of vaccines delivered over time constant, we then tested alternative vaccination coverage scenarios in which available vaccines may have been distributed differently. A further innovation of the model was to correlate the number of global infections with the dominant viral strains present at any time. This correlation enabled us to demonstrate how more equitable vaccination that may limit global infection numbers may be universally beneficial in its potential to delay viral evolution.

We found that increased vaccine sharing, without any associated changes to social behavior, would probably have substantially reduced COVID-19 mortality in low-income countries, although some high-income countries, with reduced vaccination coverage due to increased sharing, would have experienced increased mortality unless additional measures were taken (Fig. 1). Overall, under our modeling assumptions, a fully equitable vaccination scenario may have prevented 1.1–1.5 million deaths worldwide (as a direct result of COVID-19) by the end of 2021, although this figure may be substantially higher if the reduced vaccination in some high-income countries due to increased sharing had been compensated for with prolonged social caution and/or a more gradual easing of non-pharmaceutical interventions, such as mask wearing and social distancing. This global decrease in mortality is due to a combination of increased protection of the most vulnerable individuals (for example, older or immuno-compromised people) and reduced levels of global infections, which would lead to fewer opportunities for new viral variants to arise.

The implications
Although the focus of this work is a retrospective study of the COVID-19 pandemic, there are conclusions to be drawn about national and international policies going forward. Our simulations provide strong analytical evidence to support the message that a vaccine distribution across the globe that is proportional to need, rather than wealth, can have beneficial effects for all. This message is important not only in the response to potential future pandemics, but also in how vaccines may be best directed to tackle existing endemic infections, such as influenza.

The study focuses on supply constraints; however, more recently, with several different vaccines now being produced and the success of the COVAX scheme, which delivered its billionth dose of vaccine by mid-January 2022 (https://www.who.int/initiatives/act-accelerator/covax), limitations surrounding delivery and uptake are becoming increasingly important. Many low-income countries lack the infrastructure needed to rapidly deliver vaccines on the scale required, especially where there are large rural populations. Similarly, although vaccine hesitancy has been a recognized problem in all nations, in countries where public health messaging and education is scant, hesitancy is becoming a severe limiting factor for increased vaccine coverage. Using the developed global infection model, we have the potential to answer questions surrounding the continued deployment of COVID-19 vaccines, including assessing which demographics in different populations around the world may most benefit from further vaccination, especially in the face of new emerging variants that may evade the immunity gained from existing vaccines.

Sam Moore
The Zeeman Institute (SBIDER), University of Warwick, Coventry, UK.
**EXPERT OPINION**

"Although it is widely accepted that a more equitable distribution of vaccines would have led to a better global outcome in terms of deaths, actually quantifying this counterfactual outcome is only possible through mathematical modeling. The results of this and other similar analyses may, therefore, be the basis for future policy decisions regarding vaccine distribution and vaccination strategies". Margarita Pons-Salort, Imperial College London, London, UK.

**FIGURE**

Fig. 1 | The effect of increasing vaccine equity on COVID-19 mortality. Rows represent scenarios with differing amounts of vaccine redistribution during 2021, from a minimal increase in equity (top row) to a fully equitable scenario (bottom row). The left column shows the proportion of the vaccinated population in each country, and the right column shows the estimated change in mortality due to vaccine redistribution compared with no changes being made, and assuming social behavior and control measures to be unaffected by redistribution. © 2022, Moore, S. et al., CC BY 4.0.

**BEHIND THE PAPER**

The team at the University of Warwick behind this study were heavily involved with front-line modeling work that directly contributed to UK policy decisions during the COVID-19 pandemic. Their work underpinned the UK’s highly successful vaccination scheme — from the initial decisions on who should receive it first to the interval between the first and second doses and the need for and effectiveness of booster vaccination. During this time, the focus of the work was necessarily inward looking, and a considerable sense of urgency due to substantial health pressures left little time and appetite for considering a wider global picture. Since the situation within the UK has improved, we were very keen to address this issue and see how the substantial benefits of vaccination within the UK may have been extended more widely if policy decisions had been made on the basis of an international rather than national perspective. S.M.

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**FROM THE EDITOR**

“This paper uses a modeling approach to demonstrate that equitable vaccine distribution in 2021 could have substantially reduced the global burden of SARS-CoV-2 infections and associated mortality. Rather than thinking about what could or should have been, these data will be important for informing future pandemic preparedness policies, driving home an important message: global health equity is beneficial to all, regardless of country-level income status.” Editorial Team, *Nature Medicine*. 