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Evaluating the COVID-19 responses of Belgium, Denmark, Germany, the Netherlands, Sweden, and the United Kingdom, February–June 2020: a counterfactual modeling study

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Abstract

Background Differences in responses to the COVID-19 pandemic among Northwestern European countries have generated extensive discussion. We explore how the impact of the first pandemic wave might have differed, had Belgium, Denmark, Germany, the Netherlands, Sweden, and the UK adopted responses as implemented in the other countries, or had it delayed its own response.

Methods The time-varying reproduction number R_t for each country was estimated using time-series of laboratory-confirmed COVID-19 deaths. Counterfactual assessment of the impact of responses was conducted by interchanging the reduction in reproduction number by calendar date between countries from March 13th to July 1st, 2020. The impact of a delayed response was evaluated by lagging the time-series of the reproduction number with 1 day or 3 days.

Results The cumulative number of COVID-19 deaths for any of the six countries would have differed substantially, had the response of another country been adopted on the respective calendar date. The order, from the lowest to the highest expected mortality rate, was obtained with the responses of the Netherlands, Belgium, Denmark, the UK, Germany, and Sweden, with a seven- to 12-fold difference between the lowest and highest outcome. Delaying its response by 3 days resulted in approximately doubling the cumulative COVID-19 mortality rate.

Conclusions During the fast-growing first COVID-19 wave, small differences in initial epidemiological situations between countries, together with small differences in the timing and effectiveness of adopting COVID-19 response from neighboring countries, result in large variations in mortality rates.

Keywords COVID- 19, SARS-CoV- 2, Effectiveness, Response strategies, Counterfactual, Modeling, Mortality

Background

The first pandemic wave of coronavirus disease 2019 (COVID-19) cases, from February to June 2020, led to varying health impacts across Northwestern European countries. For instance, Belgium and the United Kingdom (UK) experienced approximately eight times more confirmed COVID-19 deaths during this period

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compared to Germany and Denmark [1]. The difference in COVID-19 response between those countries could have played a crucial role in these variations [2, 3]. All Northwestern European countries implemented sets of non-pharmaceutical interventions (NPIs), although with varying timing of introduction and stringency [4]. These NPIs ranged from restrictions on mass gatherings and social contact, along with the closure of schools, bars, and restaurants, to less strict, voluntary measures while keeping schools, bars, and restaurants open with certain restrictions.

For each country, debates emerged on what the outcome would have been, had a different response been used. However, to quantify the impact of diverse responses in a country, one needs to rely on a modeling approach, and one needs to determine alternative, counterfactual strategies. An infinite number of counterfactual strategies are possible involving different combinations of NPIs, varying timings of implementation and relaxation, and diverse levels of compliance. In this context, instead of testing every hypothetical combination, we choose to compare strategies that were actually implemented in a selection of countries of interest. This methodological choice allows for more data-driven assessment of the effectiveness of NPIs, measured as a reduction in reproduction number R_t, as outlined by recent studies [5, 6].

In this study, we explore the impact of counterfactual responses as implemented in Belgium, Denmark, Germany, the Netherlands, the UK, and Sweden on COVID-19 mortality during the first wave of the pandemic. These countries were chosen for their similar socioeconomic characteristics and minor discrepancies in factors such as the timing of SARS-CoV-2 introduction, while showing some variation in the timing of introduction and strictness of the response measures (see Additional file 1: Supplementary Methods for more details on the country selection procedure [1, 7, 8]). The study includes all 30 comparative analyses between all 6 countries; for the sake of presentation, we will first focus on the outcome for the Netherlands and then highlight differences in outcomes for other countries. To distinguish the impact of difference in response timing from differences in selected NPIs, we conduct an additional analysis examining the impact of delaying the implementation of the response.

Methods

Analysis framework

We used the counterfactual modeling framework developed by Mishra et al. [5] for each of the six countries in the period February to June 2020, had it used another country's response. In this framework, the time-varying reproduction number R_t was first estimated using time series of daily laboratory-confirmed COVID-19 deaths by date of death. We chose confirmed deaths as an outcome, as it is available for all selected countries and it is less influenced by differences in testing policies compared to confirmed COVID-19 cases. In the counterfactual analysis, the relative reduction in the reproduction number (R_t with control measures relative to the R_t without control measures) is taken from one country and applied to the other countries. This method is recommended for quantifying the effectiveness of non-pharmaceutical interventions, as it tracks relative changes in person-to-person transmission [6]. Moreover, the approach allows for the transfer of both the timing and the magnitude of reduction of the transmission intensity (i.e., the response effectiveness), while preserving country-specific features upon which R_t without control measures is based, such as population density and international connectivity. Additionally, we conducted a sensitivity analysis using an alternative approach where the absolute values of R_t were exchanged between countries. This means that, instead of transferring the response effectiveness, we transferred the transmission intensity, including country-specific features.

Data

Time series data on deaths by date of death for Belgium, Denmark, Sweden, and the UK up to 1 July 2020, were obtained from a public source [9] or from Mishra et al. [5]. For the Netherlands, such data were extracted from the OSIRIS database, the national registry for laboratory-confirmed COVID-19 cases of the Dutch National Institute for Public Health and the Environment, with deaths with missing date of death omitted. For Germany, data was received from the Robert Koch Institute (personal communication, Matthias an der Heiden, 1 December 2022). Consistent with observed serial interval for SARS-CoV2 transmission in the Netherlands, we used a generation time that followed a gamma distribution with a mean of 4 days and a standard deviation (SD) of 2 days [10]. The mean of the infection-to-death delay distribution was assumed to be the same between countries, using the sum of the infection to onset duration (approximate mean of 5.2 days with SD of 2.2 days [11]) and the onset to death duration as estimated for England (approximate mean of 15.1 days with SD of 12.6 days [5]). Other parameter values that were used in the analysis can be found in [5].

Estimation of the reproduction number

The reproduction number R_t for each country was estimated by fitting a semi-mechanistic transmission model [5] to the time series of deaths (see Additional file 1: Supplementary Methods for details [12]). R_t is defined here as the instantaneous reproduction number [13, 14], calculated as the number of new individuals infected by a single infectious person who is infected at time t. R_t without control measures was estimated by fitting the model to the first week of time-series of deaths after a country had observed a total of 10 cumulative death cases. This ensures that the deaths were not caused by imported infections but also were not affected by control measures, given the delay between infection and death.

Counterfactual assessment

For each country, a growing epidemic was simulated until March 13, 2020, maintaining a value for the reproduction number as observed in the specific country without control measures. This date marks the point at which countries in Northwestern Europe started taking stringent control measures. Subsequently, from March 13 to July 1, 2020, we substituted the relative reduction in the reproduction number of the one country ("recipient" country, e.g., the Netherlands) by that of another country ("donor" country, e.g., Belgium) on the corresponding calendar day. We repeat this approach for each country, and substituted the relative reduction in the reproduction number as observed for other countries, and assessing the consequences in terms of mortality. Same methods were applied in the sensitivity analysis, except for that the absolute R_t was transferred instead of the relative reduction in R_t without control measures.

As an additional analysis, we assessed the impact of a delayed response in each country by shifting the observed time-series of deaths to 1 day later or 3 days later. We computed the corresponding (lagged) reproduction number R_t and interchanged the values of the relative reduction in the reproduction number without control measures, as in the between-country comparison.

Results

Time course of observed COVID- 19 mortality per country

The observed cumulative mortality rate of 1 per million was reached first in the Netherlands, Belgium, and the UK (14 March), and later by Denmark (17 March), Sweden (18 March), and Germany (20 March) (Fig. 1). Whereas the mortality rates for most countries remained close to zero after May 2020, the rate for Sweden was relatively high. This resulted in cumulative mortality rates that were almost constant for most countries after May 2020, and for Sweden a steady increase.

Time-varying reproduction number (R_t) per country

The median reproduction number R_t without control measures for the Netherlands was estimated at 3.7 (see Additional file 1: Fig. S1, R_t before March 13). With a mean generation time of 4 days, this means that the number of infections doubles approximately every 2.1 days. The other countries, in descending order for the reproduction number without control measures, are Belgium (3.7), the UK (3.6), Germany (3.5), Sweden (3.3), and Denmark (3.2).

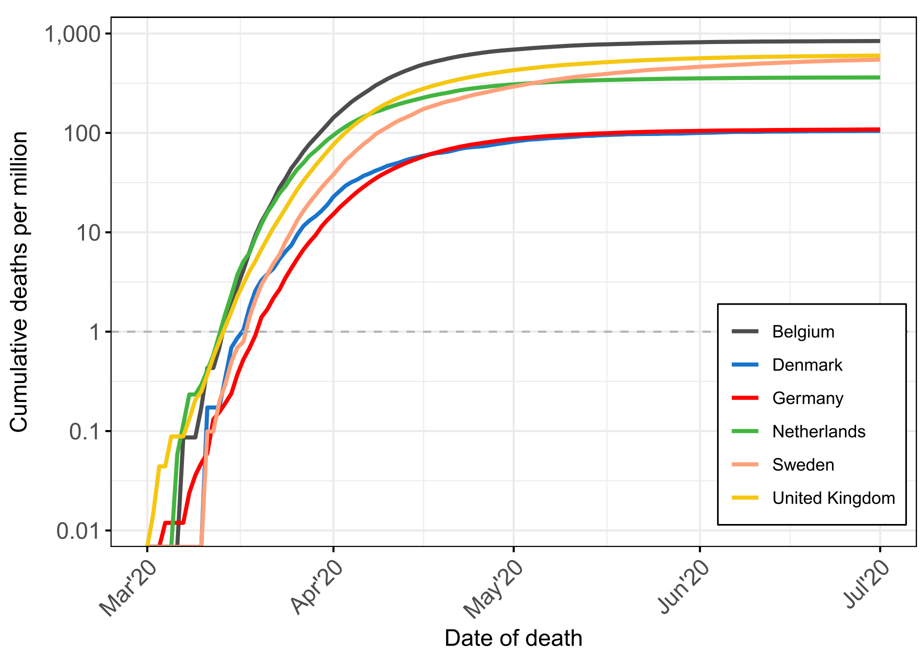

Fig. 1 Cumulative laboratory-confirmed COVID-19 deaths per million by date of death per country, up to 1 July 2020. The gray dotted line represents the level of 1 death per million inhabitants

After the introduction of control measures on March 13, the reproduction number R_t for the Netherlands dropped to 1.8 by the week of 13–19 March, and further to 0.9 by 20–26 March; the critical threshold of 1 was surpassed with an absolute drop of 0.9 per week (from 1.8 to 0.9). Denmark also crossed the threshold in the same week, albeit reaching a higher absolute value of the reproduction number ($R_t \approx 1$) and at a slower rate (absolute weekly drop of 0.8). Belgium, Germany, the UK, and Sweden surpassed the threshold 1 week later, by March 27–April 2, with absolute drops in the range of 0.5 to 0.6 in that week.

The lowest value for the reproduction number R_t for the Netherlands was reached by April 10–16 (R_t of 0.6). The other countries, in increasing order of the lowest values for R_t, were Belgium (0.5), Germany (0.6), Denmark and the UK (0.7), and Sweden (0.8) in the first half of April. The reproduction number R_t increased in all countries in the second half of April; Denmark experienced a relatively smaller rise. By June, Belgium and Germany had a reproduction number R_t around 1, while other countries saw a decline in reproduction number.

Counterfactual assessment of country-specific response strategies

For the Netherlands, the actual decline in reproduction number R_t (Fig. 2, blue lines) was faster from 13 March onwards compared to the decline in the reproduction number R_t corresponding to the counterfactual responses of the other countries in the Netherlands (Fig. 2, red lines). For most of the other countries, the drop in R_t lagged only a few days; the decline in R_t corresponding to the response of Sweden was substantially slower. The responses of Denmark and Sweden corresponded to a drop in the reproduction number R_t that was less far below 1 as compared to the drop in reproduction number corresponding to other countries.

The slight variations in the reproduction number R_t between countries have significant implications for the mortality rate. With strategies as implemented in Denmark, Belgium, Germany, and the UK, the peak mortality

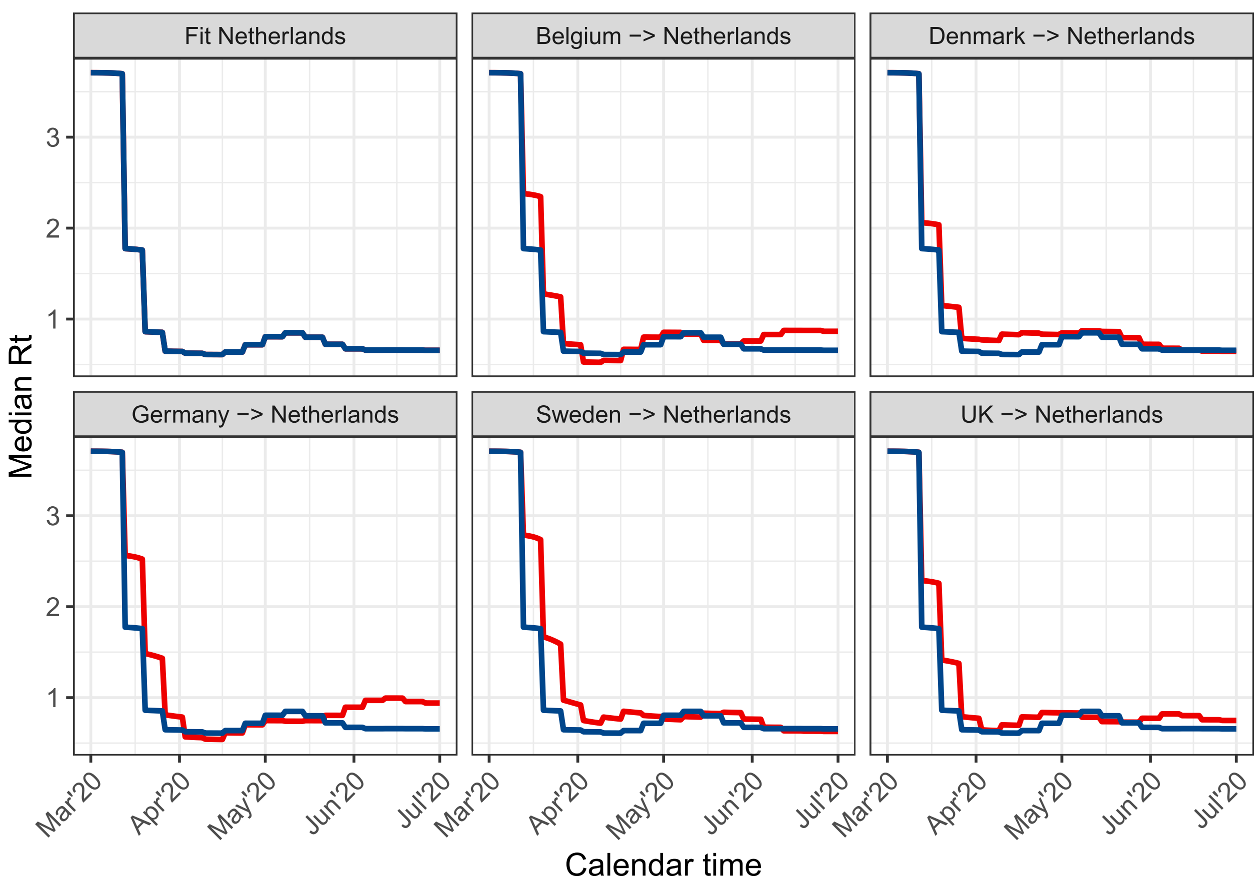

Fig. 2 The estimated median reproduction number R_t for the Netherlands (blue lines) using mortality data, and the R_t for the different counterfactual analyses (red lines), after transferring the relative reduction in reproduction number from Belgium, Denmark, Germany, Sweden, and the UK to the Netherlands between March 13, 2020, and July 1, 2020

rate in the Netherlands during the first wave would have surged from approximately 10 per million population per day to a range of 18 to 35 deaths per million population per day (Fig. 3, based on median estimates). The response as implemented in Sweden increased the peak deaths in the Netherlands to nearly 55 per million population per day. For any of the responses implemented in the five other countries, the counterfactual cumulative deaths per million during the first wave in the Netherlands would have been significantly higher than the actual mortality observed with the actual response (Table 1). The response strategies as implemented in Belgium and Denmark resulted in a two-fold increase in cumulative deaths per million compared to the observed in the Netherlands, while the response strategies as implemented in Germany and UK led to a three-fold increase in cumulative deaths per million. The response as implemented in Sweden was even associated with a seven-fold increase in cumulative deaths per million.

The order of countries' responses with respect to the expected cumulative COVID-19 deaths was consistent when applied to the various countries; the response of the Netherlands yielded the fewest deaths per million, followed by Belgium and Denmark, then the UK and Germany, and finally Sweden (Table 1, counterfactual time series of reproduction numbers R_t and mortality rates for each country are shown in Additional file 1: Figs. S2–S11). In Denmark and Sweden, the response of Denmark resulted in lower mortality rate compared to the response of Belgium; for Belgium, Germany, the Netherlands, and the UK, the response of Belgium resulted in a lower mortality rate compared to the response of Denmark. However, the multiplication factor for cumulative deaths per million depends not only on the response of a donor country but also on the recipient country. Whereas for the Netherlands the ratio between highest and lowest mortality amounted to a seven-fold difference, for the UK this was a ten-fold difference, and for Germany this was a 12-fold difference.

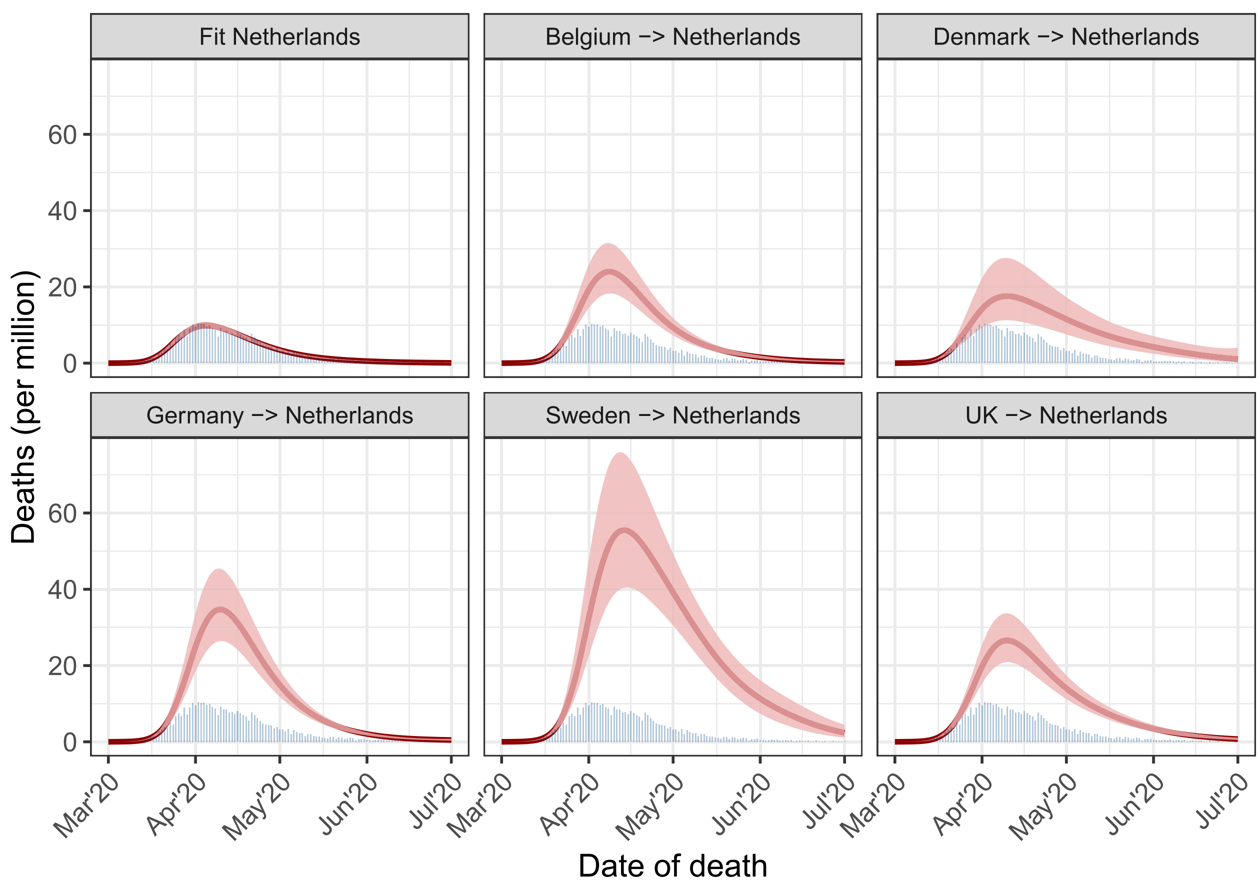

Fig. 3 Estimated median number of deaths per million population per day with 95% credible intervals for the Netherlands, showing the fit to observed data (blue bars) and the counterfactual analyses (red lines), after transferring the relative reduction in reproduction number from Belgium, Denmark, Germany, Sweden, and the UK to the Netherlands between March 13, 2020, and July 1, 2020

Table 1 Cumulative COVID-19-attributed deaths per million inhabitants per country until 1st of July 2020. Diagonal elements show observed mortality and off-diagonal elements show mortality (median with 95% credible intervals) for counterfactual strategies, using the reduction in R_t with control measures relative to the R_t without control measures. In this approach, the relative reduction in the reproduction number R_t from the "donor" country is transposed to the "recipient" country, starting on 13th March 2020. The multiplication factors visually show per column how the mortality of the counterfactual response would have changed relative to observed mortality. A factor above 1 indicates an increase in deaths with the counterfactual response, while a factor below 1 indicates a decrease

Response as implemented in a country (donor country)	Outcome of response when applied to a country (recipient country)											
	Belgium		Denmark		Germany		Netherlands		Sweden		UK	
	Cum. deaths per million	MF[a]	Cum. deaths	MF[a]	Cum. deaths per million	MF[a]	Cum. deaths per million	MF[a]	Cum. deaths per million	MF[a]	Cum. deaths per million	MF[a]
Belgium	840	2.4	117 [75–177]	2.2	72 [53–98]	2.4	850 [661–1091]	2.4	141 [95–204]	2.3	455 [347–595]	2.4
Denmark	878 [607–1255]	2.5	105	1.9	73 [47–115]	2.4	887 [610–1270]	2.5	133 [83–214]	2.1	484 [306–754]	2.6
Germany	1205 [928–1553]	3.4	167 [107–253]	3.1	108	3.6	1221 [956–1558]	3.4	206 [138–300]	3.3	672 [513–876]	3.6
Netherlands	354 [270–462]	1.0	54 [35–81]	1.0	30 [22–40]	1.0	361	1.0	62 [42–88]	1.0	188 [148–239]	1.0
Sweden	2556 [2044–3174]	7.2	378 [241–579]	7.0	363 [246–529]	12.1	2560 [2030–3195]	7.1	546	8.8	1752 [1250–2349]	9.3
UK	1076 [838–1376]	3.0	140 [90–214]	2.6	94 [70–127]	3.1	1088 [874–1348]	3.0	176 [118–258]	2.8	599	3.2

[a] MF is the multiplicative factor in deaths compared to the number of deaths estimated with the response of the Netherlands (= 1). The counterfactual comparisons between Denmark, Sweden, and the UK slightly deviate from the analysis of Mishra et al. [5] due to the use of a different generation time

Sensitivity analysis, counterfactual assessment of country-specific response strategies

We conducted a sensitivity analysis in which the absolute R_t value was transposed (instead of the relative reduction of R_t without control measures). We found that the order of outcome was not affected (Additional file 1: Table S1), although the difference between counterfactual and observed number of deaths per million became smaller for the response of the Netherlands compared to responses from Germany, Denmark, and Sweden. For instance, with the exchange of the absolute R_t, the responses of Denmark and the Netherlands resulted in similar mortality instead of a more than two-fold higher mortality with the response of Denmark using the relative reduction in R_t.

Counterfactual assessment of delaying the response

Delaying the response as implemented in the Netherlands by 1 day or 2 days increased the peak number of deaths in the Netherlands from approximately 10 per million population per day to 12 per million population per day and 23 per million population per day, respectively (Fig. 4, see Additional file 1: Fig. S12 for the reproduction number R_t profiles). The number of deaths throughout the first wave was estimated to increase by a factor 1.2 (95% CrI: 0.9–1.6) for a 1-day delay and by a factor 2.3 (95% CrI: 1.7–3.1) for a 3-day delay (Table 2). Similar multiplication factors were found for other countries when they delayed their responses (range 1.8–2.4 for a 3-day delay). The UK, Denmark, and Sweden showed the smallest differences in R_t between scenarios with the original R_t and those with a delayed response (Additional file 1: Fig. S12), resulting in a relatively lower difference in mortality rates (Table 2 and Additional file 1: Fig. S13).

Table 2 Estimated relative differences in cumulative deaths per million during the first COVID-19 wave, compared to observed number of deaths, if the response of country had been delayed by 1 day or by 3 days. A factor above 1 indicates an increase in deaths with the counterfactual response, while a factor below 1 indicates a decrease

Country	Multiplication factor of cumulative deaths compared to the actual response, median (95% CrI)	
	One-day delay of response	Three-day delay of response
Belgium	1.2 (0.9–1.6)	2.2 (1.7–3.0)
Denmark	1.2 (0.7–2.1)	2.0 (1.1–3.7)
Germany	1.3 (0.9–1.8)	2.4 (1.7–3.6)
Netherlands	1.2 (0.9–1.6)	2.3 (1.7–3.1)
Sweden	1.2 (0.8–1.8)	2.0 (1.3–3.1)
UK	1.1 (0.9–1.4)	1.8 (1.5–2.3)

CrI credibility interval

Discussion

This analysis quantifies the potential impact of different pandemic responses on COVID-19 mortality in six Northwestern European countries during the first pandemic wave in February through June 2020. It highlights that in the rapidly growing first COVID-19 wave—infection rates initially doubled every 2–3 days—small differences in initial epidemiological situations between

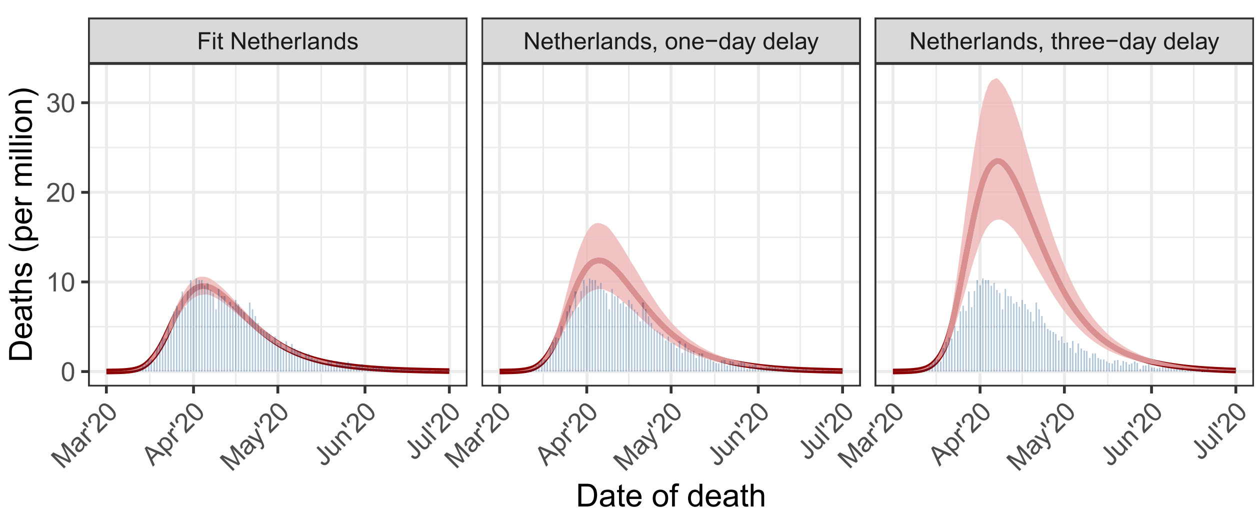

Fig. 4 Estimated median number of deaths per million population per day with 95% credible intervals for the Netherlands, showing the fit to observed data (blue bars) and the counterfactual analyses (red lines), in the period March 13, 2020, to July 1, 2020, if the response measures were taken 1 day later or 3 days later

countries, together with small disparities in the timing and effectiveness of adopting COVID-19 response from neighboring countries, result in large variations in mortality rates. A mere 3-day delay in the response was estimated to result in approximately doubling mortality during a single wave.

For any of the six countries, mortality would have differed substantially, had the response as implemented in another country been adopted. The order of the resulting cumulative COVID-19 deaths per million, from lowest to the highest, was found for the responses of the Netherlands, Belgium, Denmark, the UK, Germany, and Sweden. This order differs from the observed rates of confirmed COVID-19 deaths, where Denmark and Germany reported the fewest deaths per million before the Netherlands, Sweden, Belgium, and the UK. Actual observed per-capita death rates are determined not only by the response but also by underreporting and the epidemiological situation in the early phase of the pandemic wave: for example, the incidence of infection on 13 March 2020 and the reproduction number before this time varied. In early March 2020, COVID-19 mortality trajectories in the Netherlands, UK, and Belgium slightly outpaced those in Germany, Denmark, and Sweden. This implies, for instance, that a marginally lower incidence of infection in Denmark compared to Netherlands allowed for a slower decline in R_t, while still resulting in a lower observed mortality rate. Furthermore, large-scale implementation of response measures may lead to the fastest reduction of the reproduction number R_t in countries with the highest viral transmission, as in countries with low transmission, the virus may emerge in settings where transmission is harder to control.

Another aspect is that the reproduction number R_t without control measures differed between countries, being estimated higher in the Netherlands, Belgium, and the UK compared to Germany, Denmark, and Sweden. A higher reproduction number R_t without control measures requires a more effective response to bring the reproduction number R_t below 1. This explains also the substantial differences between approaches with transferring the relative reduction in R_t without control measures (reduction in transmission intensity) compared to transferring the absolute R_t (transmission intensity). Countries with a lower R_t without control measures tended to perform relatively better when using the transposition of absolute R_t. However, we considered the relative reduction in R_t to be the preferred approach, as it approximates the reduction in contact rates due to NPIs and provides a straightforward mechanistic interpretation. Besides, this approach is regarded as one of the recommended practices for measuring the effectiveness of non-pharmaceutical response measures [6]. Nonetheless, estimation of R_t without control measures could also be influenced by seeding of infections, a factor that diminished after control measures discouraged or even banned international travel.

Our finding that small fluctuations in the reproduction number during a fast-growing epidemic can significantly impact mortality rates aligns with previous studies. For example, a UK study estimated a potential 73% decrease in COVID-19 deaths if lockdown measures were implemented 1 week earlier in spring 2020 [15], while similar analyses for Sweden suggested a 34–40% reduction in deaths by May 2020 with a lockdown similar to Denmark or Norway [16, 17]. Our analysis builds upon the previous study of Mishra et al. [5], incorporating three additional countries: the Netherlands, Belgium, and Germany. This expansion extends the intercountry comparisons from 6 to 30, facilitating the comparison of neighboring countries with similar initial trajectory of COVID-19 mortality in the initial wave (Germany similar to Denmark and Sweden, and Netherlands similar to Belgium and the UK). Our finding that the mortality does not only depend on the response of a donor country but also on the characteristics and epidemiological situation of the recipient country was only possible through this larger-scale intercountry comparison.

Our analysis comes with several limitations. Firstly, we applied the same delay between infection and death across countries. While the median delay time from symptom onset to death in the Netherlands was previously estimated at 11 days [18], consistent with the data from England used in this study, this assumption may not hold across all studied countries. Secondly, we relied on exchanging reproduction numbers derived from time series of confirmed COVID-19 deaths, which can be influenced by reporting quality and case definitions. However, alternative national vital statistics data usually report deaths on a weekly basis, while daily data is needed to accommodate the small differences in timing of interventions between the selected countries. Moreover, the reproduction number is a relative measure, meaning that comparisons between mortality rates remain consistent if the level of underreporting is stable over time. The Netherlands had about 35% underreporting of COVID-19 deaths compared to excess deaths in the first wave [18], while Belgium had no underreporting [19]; nonetheless, the Netherlands also peaked earlier than Belgium in hospitalization rates [1], indicating consistent findings across different outcomes.

Careful distinction between the counterfactual assessments and the actual implementation of a different response in another country is essential. The counterfactual assessments reflect the response as measured by the reduction in the reproduction number

R_t, which is broader than a policy response, as it also encompasses adherence to voluntary recommendations and associated rules. Moreover, implementing a policy response in another country requires the local ability to facilitate measures for discretionary rules and enforce mandatory rules, similar to how it is done in the original country. Therefore, quantifying the implementation of an actual policy response from another country should ideally account for a range of factors, such as variations in healthcare systems, legal systems, culture, public trust in governmental institutions, socioeconomic status, and the nature of the workforce (e.g., possibilities for remote working), which is rather complex. Additionally, time-varying aspects, such as responses in neighboring countries or the potential risk of exceeding healthcare capacities, play a role in public support for control measures.

Our analysis does not account for the active steering of control measures based on the epidemiological situation in each country. Continuous epidemic monitoring will lead to intensified control measures when the current set proves insufficient to curb rising mortality, and to relaxation of measures when mortality is low or control appears overly stringent. However, inherent to delays in monitoring the impact of these measures, from implementation to decreasing rates of hospitalization or mortality due to COVID-19, we believe that adaptive control likely will not alter the presented outcomes.

These findings should also be interpreted considering the limited duration of the study period and available knowledge at the time. For instance, during the first COVID-19 wave, it was unknown that an effective vaccine would become available within a year, that individuals with mild infections could suffer from post-COVID conditions, and that several new, more transmissible variants would emerge within 2 years, each with different illness severity. Moreover, different responses affect the speed of (herd) immunity buildup, potentially leading to varied outcomes when evaluating the same strategies over a longer period.

Our study contributes to discussions about the merits of the different approaches taken in European countries. They demonstrate that the outcome of response is determined not only by the response itself but also to a large extent by small differences in the initial epidemiological situation in each country. Some countries had relatively low mortality rates for any of the six responses evaluated here, and these countries could afford a response that was less stringent; other countries faced relatively high mortality rates for any of the six response evaluated here, and these countries could ill afford a less stringent response. This underscores that a proper response has to be carefully tailored to the epidemiological situation in each country.

Conclusions

This analysis shows that in a fast-growing epidemic, small differences in the timing and effectiveness of measures can result in large variations in mortality. For most countries, adopting a response as implemented in a neighboring European country during the first COVID-19 pandemic wave in 2020 resulted in an outcome that differed greatly from the outcome observed in the neighboring country. The responses from the six countries studied here revealed a seven-fold to twelve-fold difference between the lowest and highest mortality rates. Due to differences in country characteristics and initial epidemiological situations, the outcome of the response in a particular country does not necessarily result in the same mortality as in another country; a response must always be tailor-made. A 3-day delay of the response was estimated to double mortality. These findings provide useful insights in the evaluation of COVID-19 responses and for strategic planning on how to minimize the disease burden of future pandemics.

Abbreviations

COVID- 19	Coronavirus disease 2019
NPI	Non-pharmaceutical intervention
R_t	Time-varying reproduction number
SD	Standard deviation
UK	United Kingdom

Supplementary Information

The online version contains supplementary material available at https://doi.org/10.1186/s12916-025-04071-5.

Additional file 1: Figures S1–S13. Fig. S1: Estimated time-varying reproduction number (R_t) per country in February–June 2020, with their 30%, 60%, and 90% credible intervals. Figs. S2–S6: The estimated median reproduction number R_t for Belgium (Fig. S2), Denmark (Fig. S3), Germany (Fig. S4), Sweden (Fig. S5), and the UK (Fig. S6) using mortality data (blue lines), and the R_t for the different counterfactual analyses (red lines), after applying the relative reduction in reproduction number observed in other included countries between March 13, 2020, and July 1, 2020. Figs. S7–S11: Estimated median number of deaths per day with 95% credible intervals for Belgium (Fig. S7), Denmark (Fig. S8), Germany (Fig. S9), Sweden (Fig. S10), and the UK (Fig. S11), showing the fit to observed data (blue bars) and the counterfactual analyses (red lines), after applying the relative reduction in reproduction number observed in other included countries between March 13, 2020, and July 1, 2020. Fig. S12: Estimated median reproduction number R_t per country using mortality data (blue lines), and the R_t for the different counterfactual analyses (red lines), between March 13, 2020, and July 1, 2020, if the response measures were taken 1 day later or 3 days later. Fig. S13: Estimated median number of deaths per million population per day with 95% credible intervals per country, showing the fit to observed data (blue bars) and the counterfactual analyses (red lines), between March 13, 2020, and July 1, 2020, if the response measures were taken 1 day later or 3 days later. Table S1: Scenario analysis of cumulative COVID-19-attributed deaths per million inhabitants per country until 1st of July 2020, transposing the exact absolute values of the reproduction number R_t between countries from March 13, 2020, instead of using the relative reduction in R_t.

Additional file 2: Time series data of daily laboratory-confirmed COVID-19 deaths by date of death for Belgium, Denmark, the Netherlands, Sweden, and the UK, as used in the analysis. Data for Germany can be obtained from the Robert Koch Institute upon reasonable request.

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Authors' contributions
The project was conceptualized by PTdB, FM, and JW. Data collection was performed by PTdB and GL. PTdB and GL adapted the existing model code for the current analysis, which was critically reviewed by FM. The initial draft of the manuscript was written by PTdB, which was critically revised by FM, GL and JW. All authors read and approved the final manuscript.

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Data availability
Time series data of deaths by date of death are included in the supplementary materials, except for Germany, whose data can be obtained from the Robert Koch Institute upon reasonable request.

Declarations

Ethics approval and consent to participate
Ethical approval was not required for this study as all data used within this work was part of routine surveillance.

Consent for publication
Not applicable.

Competing interests
The authors declare no competing interests.

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