DEMOGRAPHIC RESEARCH
A peer-reviewed, open-access journal of population sciences

DEMOGRAPHIC RESEARCH

VOLUME 45, ARTICLE 45, PAGES 1355–1372
PUBLISHED 22 DECEMBER 2021
https://www.demographic-research.org/Volumes/Vol45/45/
DOI: 10.4054/DemRes.2021.45.45

Descriptive Finding

COVID-19 fatality in Germany: Demographic determinants of variation in case-fatality rates across and within German federal states during the first and second waves

Saskia Morwinsky

Natalie Nitsche

Enrique Acosta

Contents

Demographic Research: Volume 45, Article 45
Descriptive Finding

COVID-19 fatality in Germany: Demographic determinants of variation in case-fatality rates across and within German federal states during the first and second waves

Saskia Morwinsky[1]

Natalie Nitsche[2]

Enrique Acosta[2]

Abstract

BACKGROUND
Germany experienced one of the lowest COVID-19 case-fatality rates (CFRs) in Western Europe in the first pandemic wave, and further CFR decreases in the spring and summer of 2020. However, Germany's CFR increased markedly during the second wave, becoming one of the highest in Western Europe. Furthermore, CFRs varied considerably across German federal states. The drivers of this CFR time trend and the state differences remain unclear.

OBJECTIVE
We aim to identify the contribution to the CFR differences across and within German states of (1) the population age structure, (2) the age structure of confirmed infection rates, and (3) the age-specific fatality.

METHODS
We use data documenting COVID-19 cases and deaths from the COVerAGE-DB, applying demographic decomposition methods proposed by Kitagawa and Horiuchi.

RESULTS
The CFR decrease between spring and autumn 2020 in Germany resulted from a shift toward younger ages in confirmed infection rates and decreasing age-specific fatality. The CFR increase that followed was predominantly driven by a shift toward older ages in the age composition of confirmed infection rates. Although most of the CFR variation across German states resulted from differences in the population age distribution,

[1] University of Rostock and Max Planck Institute for Demographic Research, Rostock, Germany. Interdisciplinary Centre on Population Dynamics, University of Southern Denmark, Odense, Denmark.
Email: morwinsky@demogr.mpg.de.
[2] Max Planck Institute for Demographic Research, Rostock, Germany.

differences in the age structure of detected infection rates contributed substantially to this variation.

CONCLUSIONS
Differences in German CFRs depended mainly on the age structure of the population and the confirmed infection rates. Age-specific fatality played a noteworthy role only in CFR changes over time.

CONTRIBUTION
We provide previously undocumented information for Germany on the factors modulating differences in the COVID-19 fatality across states and over time.

1. Introduction

The COVID-19 pandemic is holding the world in its grip. Despite considerable research, many important questions about COVID-19 remain unanswered. For instance, there is no consensus regarding the risk of dying for those infected with SARS-CoV-2 (Levin et al. 2020; O'Driscoll et al. 2020; Yang et al. 2021). The case-fatality rate (CFR) – defined as the ratio of confirmed deaths to diagnosed infections – is an approximation used to assess the risk of dying from COVID-19. The CFRs of COVID-19 have varied considerably over time and between regions (Fan et al. 2021; Sorci, Faivre, and Morand 2020). Previous research shows that differences in the population age composition or in confirmed infections contribute substantially to CFR variation (Dudel et al. 2020; Green et al. 2020; Sudharsanan et al. 2020), as the risk of dying from COVID-19 increases exponentially with age (Dowd et al. 2020; Goldstein and Lee 2020). COVID-19 CFRs thus depend on a variety of factors: the population age composition, who eventually gets infected, who dies as a consequence, and which infections and deaths are detected. Older populations have more vulnerable individuals, and thus tend to have higher CFRs. Moreover, when infection rates are higher among vulnerable (here, older) people than among others, mortality rises and the CFR increases. Germany is a particularly interesting case for studying this issue. While its first-wave CFR in late March 2020 was the second-lowest among 15 Western European countries, during the second wave Germany's CFR increased to become the third-highest (Morwinsky, Nitsche, and Acosta 2021a). Moreover, as this paper will show, CFRs differed substantially across German states. To date, it remains unclear what factors drove these CFR differences between the German federal states, and over time.

This study aims to identify the potential drivers of the CFR differences between German states and within each state over time. Our first objective, to identify the drivers of differences in the cumulative CFRs between states at the end of the second wave (i.e., February 9, 2021), is achieved by decomposing the contributions of three elements across states: (1) the population age composition, (2) the age composition of confirmed cumulative COVID-19 infection rates (henceforth referred to as confirmed infection rates), and (3) the age-specific COVID-19 fatality. Previous research was limited to analyzing COVID-19 CFR differences by decomposing the CFR into two elements only: the age structure of confirmed infections and the age-specific fatality. The inclusion of the population age structure, which varies considerably across German states, allows us to further decompose the age structure of confirmed cases, thereby disentangling the role of variation in the population age composition and in the age composition of confirmed infection rates across federal states. By enhancing the CFR decomposition process, our study extends the literature not only substantively, but methodologically. Our second objective is to illuminate the drivers of the observed CFR time trend within each German state. As the population age structure was relatively invariant within each state during the observation period, we decompose the CFR variation into the contributions of changes in the age composition of confirmed infection rates and in age-specific fatality over time. We apply the demographic decomposition methods of Kitagawa and Horiuchi. We focus the analyses on the first and second pandemic waves that occurred between March 2020 and March 2021, as thereafter widespread vaccination substantially altered Germany's infection and infection fatality rates. All data and code for reproducing our results are openly available (Morwinsky, Nitsche, and Acosta 2021b).

2. Data and methods

Data on confirmed COVID-19 cases and deaths by age in Germany and federal states was obtained from the COVerAGE-DB (Riffe, Acosta, and the COVerAGE-DB team 2020). This global database provides daily cumulative counts of age-specific confirmed COVID-19 cases and deaths in Germany based on data retrieved from the Robert Koch Institute (RKI) (2020b). All confirmed cases and deaths were diagnosed with a PCR laboratory test. Moreover, for all deaths there was a medical diagnosis suggesting or confirming a relationship between the SARS-CoV-2 infection and the death. Note that deaths from other causes, after recovery from a COVID-19 infection occurred, are not counted as COVID-19 deaths. More detailed definitions are provided in Morwinsky, Nitsche, and Acosta (2021a). Age is measured in categories (0–4, 5–19, 20–34, 35–59, 60–79, 80+), following RKI reporting. Population estimates by age and state in 2020 were obtained from Destatis (2020).

Because the RKI data include information on the vital outcome of each confirmed case (i.e., survived or deceased), we are able to measure the CFR at a given point in time as the proportion of recorded cases that eventually died of COVID-19. This longitudinal approach to estimating the CFR allows us to avoid potential bias resulting from the time lag between infection and death.

Our analytic strategy consists of three steps. First, we examine the development of the pandemic in Germany by analyzing the temporal patterns of daily new confirmed COVID-19 cases and deaths per million inhabitants, the CFRs for each state between February 20, 2020, and April 1, 2021, and differences in the population age structure across states.

Second, we decompose the differences in the cumulative CFR across states on February 9, 2021, when the CFR peaked at the national level at the end of the second wave. Through this decomposition we identify the contributions to the CFR differences of the population age composition, the age structure of confirmed infection rates, and the age-specific fatality.

When interpreting the contributions identified by this decomposition, note that it is the age composition, and not the magnitude, of both the population and the infection rate that affects the overall CFR level. We decompose the CFR differences across states by applying the Horiuchi technique (2008), which allows us to assess the contributions of several components to the differences in a demographic measure. The Horiuchi decomposition is performed using the R package *DemoTools* (Riffe et al. 2019).

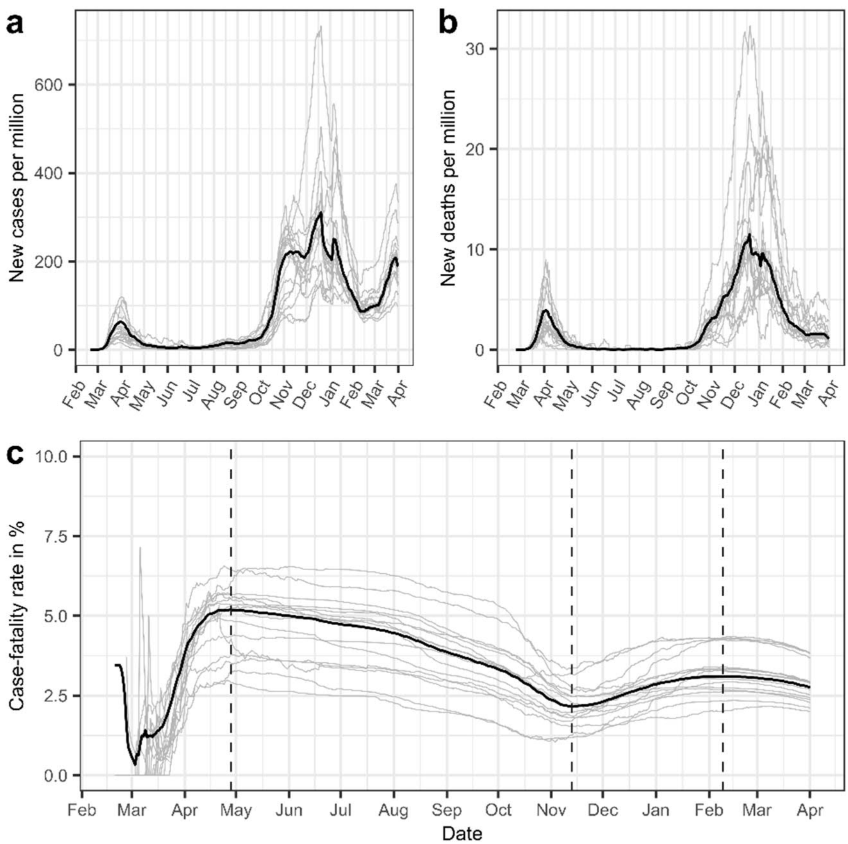
Finally, we identify the contributions of the changes in the age structure of confirmed infection rates and the age-specific fatality components to the CFR variation in each state over time. We focus our analyses on two periods: (1) the period when the state-specific CFR decreased from its peak in spring 2020 (March 13–May 11) and its minimum level in autumn 2020 (October 15–December 2); and (2) the subsequent period when the state-specific CFR increased from its minimum level in autumn 2020 and its peak in winter 2021 (January 4–March 8). Note that as we assume an invariant population during the analyzed periods, the interpretation of the infection component is the same as when decomposing CFR differences across states; i.e., the contribution of the age composition of confirmed infection rates. As proposed previously by Dudel et al. (2020), we break down the CFR changes over time by applying the Kitagawa decomposition technique (1955).

3. Results

3.1 Development of the pandemic

Figure 1 provides an overview of daily new confirmed COVID-19 cases (Panel A) and deaths (Panel B) per million inhabitants and CFRs (Panel C) in Germany. The numbers of confirmed COVID-19 cases and deaths increased sharply during the first wave between mid-March and April 2020. The highest number of confirmed COVID-19 cases reported for one day was 63.5 cases per million at the national level, and at the state level ranged from 16.8 in Mecklenburg-Western Pomerania to 120 in Bavaria. The peak number of daily new confirmed deaths per million was 3.9 at the national level, and at the state level ranged from 1 in Mecklenburg-Western Pomerania to 9 in Saarland.

Figure 1: Daily confirmed COVID-19 cases (Panel a) and deaths (Panel b) per million inhabitants, and cumulative CFRs (Panel c) in Germany (black lines) and the federal states (gray lines) between February 2020 and April 2021



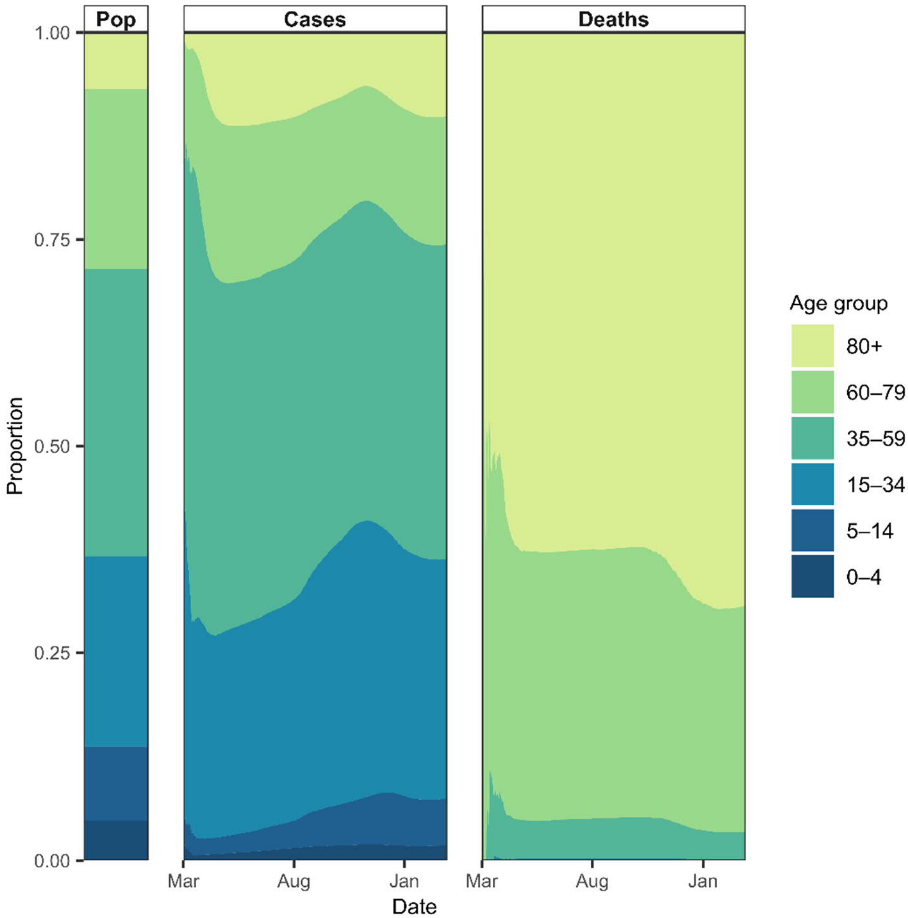
Note: The three vertical dashed lines in Panel (c) indicate, respectively, the dates when the CFR peaked in the first wave (April 28, 2020), reached a minimum between waves (November 13, 2020), and peaked again in the second wave (February 9, 2021), at the national level.
Source: COVerAGE-DB (own analyses and illustration).

Subsequently, daily confirmed cases and deaths decreased until June, marking the end of the first wave, then stayed at very low levels during most of the summer. The second pandemic wave, which was considerably more lethal than the first, took place between August 2020 and February 2021, with cases and deaths rising steeply from early October onward. Daily confirmed cases peaked in each state between November 3, 2020, and January 10, 2021, at values ranging from 156 per million in Schleswig-Holstein to 733 in Saxony, and at 311 at the national level. Daily confirmed deaths peaked in each state between December 14, 2020, and January 19, 2021, at values ranging from 6.3 per million in Bremen to 32.3 in Saxony; and at 11.5 at the national level. Thereafter, new cases and deaths declined sharply. Thus, the second wave ended between mid-February and mid-March. Although Germany faced a third pandemic wave between March and June 2021, with daily cases reaching levels similar to those seen in the second wave, daily deaths remained at relatively low levels, which is consistent with the start of massive vaccination among the most vulnerable segments of the population (RKI 2021a).

The CFR increased in all German states during the first pandemic wave. At the national level the CFR reached a peak at the end of April 2020 (5.19%), declined monotonically until November 2020 (2.15%), and then increased moderately until peaking again during the second wave in February 2021 (3.1%). At the state level, however, the range of CFR variation differed substantially: it fluctuated between 1.13% and 3.28% in Berlin, and between 3.32% and 6.46% in Thuringia.

Before examining the demographic determinants of CFR variation across states and over time, it is important to look at the differences across states and over time in the age composition of the underlying CFR components, namely population, confirmed cases, and deaths (Figure 2 and Figure S4 in Morwinsky, Nitsche, and Acosta 2021a). Although the age composition of confirmed infections varied considerably over time, there is a clear correspondence across states between the population age composition and infections (Figure S4 in Morwinsky, Nitsche, and Acosta 2021a). We distinguish three temporal shifts in the age composition of cumulative diagnosed infections that are observed consistently at both the national and the state level: the infected became older between March and May 2020, then gradually became younger until November 2020, and again became older thereafter. The trend in the age composition of confirmed deaths is considerably different, becoming monotonically older since the beginning of the pandemic, with sudden accelerations during the periods of March–April 2020 and October–January 2021.

Figure 2: Age composition of the German population, and compositional changes in the age structure of confirmed COVID-19 cases and deaths over time at the national level between March 2020 and March 2021



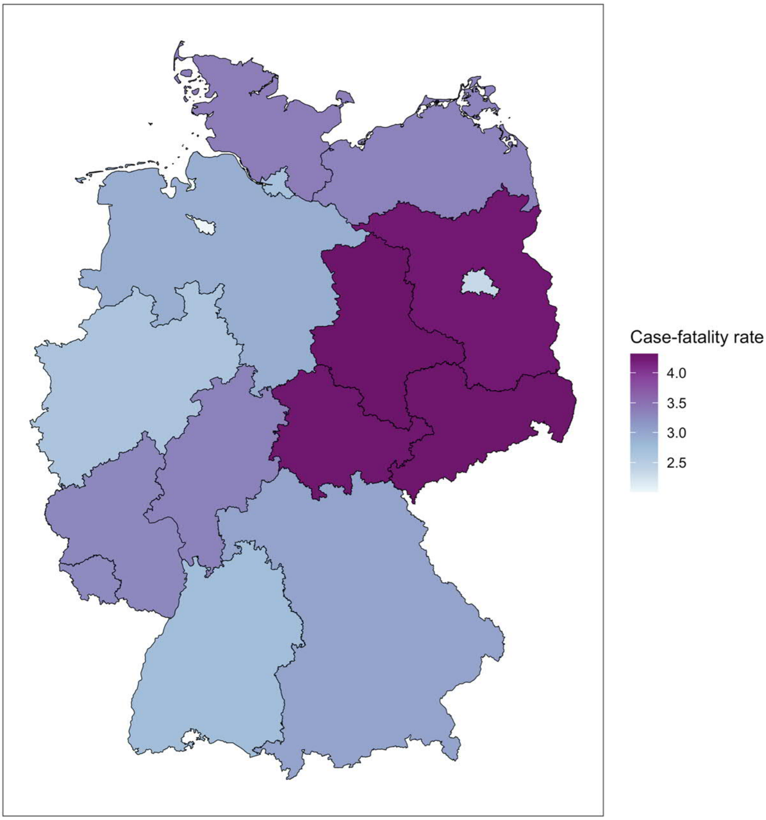
Source: Destatis, COVerAGE-DB (own illustration).

3.2 Demographic decomposition of CFR differences

3.2.1 CFR differences across German federal states

The map in Figure 3 displays the cumulative CFR differences across German states as of February 9, 2021. The eastern states had considerably higher CFRs than the western states. Across the states the CFRs varied from 2.01% in Bremen to 4.31% in Saxony-Anhalt.

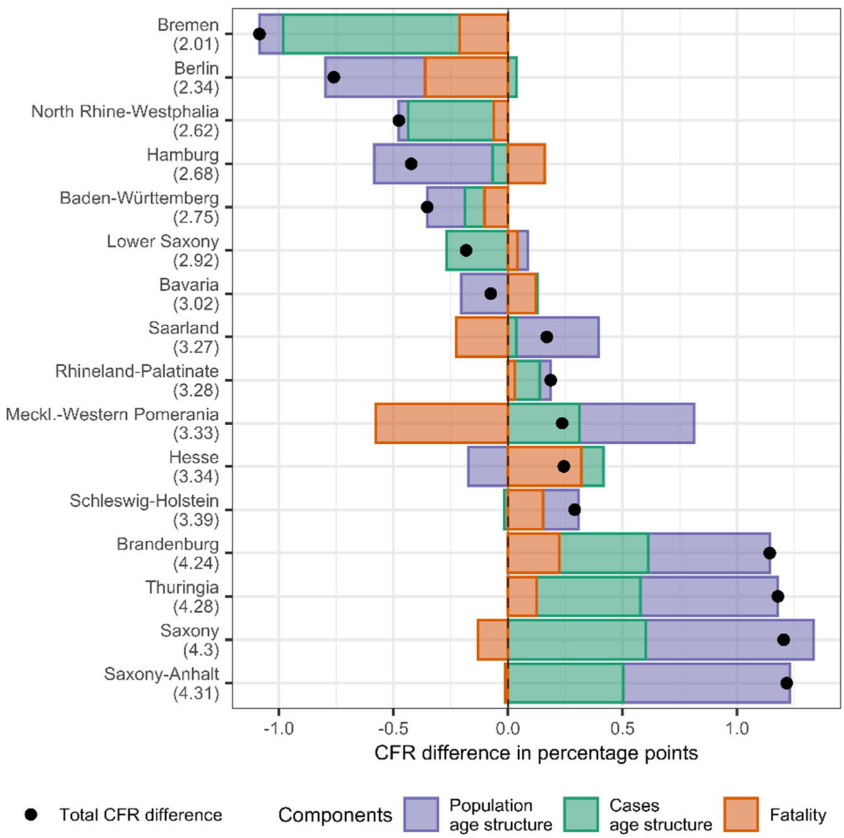
Figure 3: Cumulative case-fatality rates (CFRs) in the German federal states from the beginning of the pandemic until February 9, 2021



Source: COVerAGE-DB (own analyses and illustration).

Figure 4 presents the decomposition of the CFR differences between each state and the national average. It shows that the composition of the CFR differences varied a lot across the states. In 9 of the 16 states the age structure of the population was the main driver of the CFR differences.

Figure 4: Demographic decomposition of CFR differences between the German federal states and the national level into the population age structure, the age structure of confirmed infection rates, and the fatality components; as of February 9, 2021



Note: The dots indicate the total CFR difference between each state and the federal level. The bars indicate the contributions to the total difference of the differences in the population age structure (in purple), the age structure of confirmed infection rates (in green), and the age-specific fatality (in orange). The numbers in parentheses indicate the CFR for each federal state as of February 9, 2021.
Source: COVerAGE-DB (own analyses and illustration).

However, after accounting for the population age distribution, it becomes clear that the age structure of confirmed infection rates also played a substantial role in the CFR differences in several states. This component was the main driver of the differences in the states of Bremen, North Rhine-Westphalia, Lower Saxony, and Rhineland-Palatinate, while it played almost no role in Schleswig-Holstein, Saarland, Hamburg, Berlin, and Bavaria and had only a moderate effect in the remaining states.

Overall, among the three components the age-specific fatality contributed the least in absolute terms to the CFR differences across states. However, in relative terms, the contribution of the fatality component was more than 40% in Berlin, Schleswig-Holstein, Mecklenburg-Western Pomerania, and Hesse.

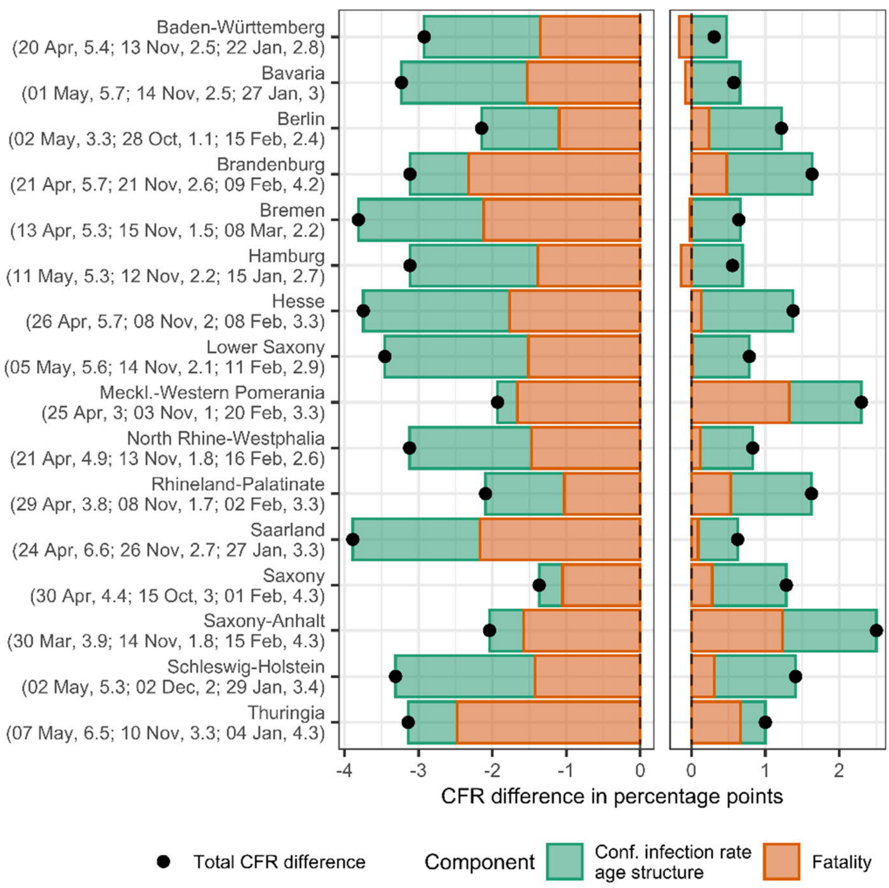
3.2.2 CFR differences within German federal states over time

In every German state the CFRs declined from spring to autumn, with both the age structure of confirmed infection rates and the fatality components contributing to these decreases (Figure 5, Panel A). In other words, during this period the confirmed infection rates shifted to a younger age distribution, and the age-specific fatality decreased in all states. In half of the 16 states the confirmed infection rate structure component was slightly dominant. However, in all eastern German states except Berlin, the relative contribution of the fatality component to the decline in the CFR was higher than 75%.

The CFRs of all German states increased from late autumn to January–March (Figure 5, Panel B). During this period the infection rate shifted to an older age distribution in all states, and was the main determinant of the CFR increases in most states. In 12 states this component accounted for more than 70% of the CFR increases during the observed period. In general, the contribution of the fatality component was marginal, except in Mecklenburg-Western Pomerania, Saxony-Anhalt, and Thuringia, where it accounted for more than half of the total CFR increase.

Two robustness checks were performed on the CFR decomposition over time to test the sensitivity of our results to (1) population changes over time, and (2) the time window differences across states (see Morwinsky, Nitsche, and Acosta 2021a). According to these sensitivity analyses, accounting for population composition changes and using equal time spans led to similar results.

Figure 5: Demographic decompositions of CFR changes within the German federal states over time, depicting (a) the decomposition between the dates when the CFR peaked in the first wave and reached its lowest value between waves; (b) the decomposition between the dates when the CFR attained its lowest value and peaked in the second wave



Note: The dots indicate the total CFR difference. The bars show the contributions of changes in the age structure of confirmed infection rates (in green) and in age-specific fatality (in red) to the total difference. The negative and positive values indicate, respectively, decreasing and increasing CFRs. For instance, the CFR in Saxony decreased during the first wave by 1.4 percentage points due to a decrease in the age-specific death rates, and to a shift toward younger ages in confirmed infection rates. The information in parentheses indicates, respectively, the date and the CFR level (1) at its first wave peak, (2) at its minimum, and (3) at its second wave peak. The whole period under analysis covers the time between April 13, 2020 and March 8, 2021.
Source: COVerAGE-DB (own analyses and illustration).

4. Discussion

Using demographic decomposition methods, we examined the components that contributed to the cumulative CFR differences across German states at the end of the second pandemic wave, and within each state during the first and second waves. We found that most CFR variation across German states could be explained by differences in the age distribution of the population (about 50%). However, after accounting for differences in population age composition, the age structure of confirmed infection rates still contributed substantially to the total CFR differences across states. Overall, age-specific fatality played a smaller role in the CFR differences across states.

These findings are partially consistent with previous literature that analyzed the role of either population or confirmed infection rate age structures in CFR differences (Dudel et al. 2020; Green et al. 2020; Sudharsanan et al. 2020). However, unlike previous analyses, we examined the role of these two factors together, and found that both contributed substantially to the CFR differences.

The decomposition estimates for the eastern states of Brandenburg, Thuringia, Saxony, and Saxony-Anhalt are good examples to elucidate the considerable but still not determinant role of the population age structure in CFR differences. These four states had both the oldest population age structures and the highest CFR levels in Germany. However, even if the contribution of the population age structure was subtracted, the four states would continue to have the highest overall CFRs in Germany.

When monitoring the evolution of CFRs over time within Germany, we found two interesting trends. First, in all states the decrease between spring and autumn resulted from almost equal contributions of both a shift toward younger ages in confirmed infection rates and a decrease in age-specific fatality. Second, the increase in CFRs that followed during the second wave was predominantly driven by another shift in confirmed infection rates, this time toward older ages, in which the risk of dying from COVID-19 was higher. Simultaneously, the age-specific fatality increased, although this time its relative contribution was minor.

We detected a decline in age among the confirmed infection rates, which explains part of the CFR decline from spring to autumn 2020. However, the contribution of the decreasing age-specific fatality was substantial in all states, and was even predominant in several. A plausible explanation for this finding is that an extended testing strategy uncovered milder cases (Dudel et al. 2020; Fan et al. 2020), as the testing documentation indicates (RKI 2020a, 2021c). We performed additional analyses to examine the relationship between increases in overall testing coverage and CFR variation. The results suggest that increases in testing intensity might have played a role in the decrease in the CFR at the end of the first wave and its later increase, but not afterwards (Morwinsky, Nitsche, and Acosta 2021a). Unfortunately, there is no available data on the age structure of testing coverage by state in Germany that would allow us to evaluate the extent to which the testing strategy drove CFR variation across states and over time.

We emphasize that the demographic decomposition methods we applied are descriptive-relational approaches. While they allowed us to identify the components that were attributable to differences between the two rates, they are not suitable for drawing causal inferences (Kitagawa 1955). Thus, our results leave many questions unanswered, and room for speculation about their underlying causes. We cannot examine these issues in detail within the scope of this paper. Nonetheless, we can suggest possible explanations. The considerable regional differences in the age composition of confirmed infection rates might be due to differences in testing strategies, containment measures, or nursing home outbreaks. In addition, the clear east-west gap in CFRs indicates that structural factors might play a substantial role, such as differences in generational mixing, socioeconomic composition, and labor market and working conditions. Regarding the fatality component, a substantial share of the regional differences may be attributable to differences in general population health, and in the capacities and quality of healthcare institutions.

The shift toward more confirmed cases at older ages during the second wave contributed substantially to the rise in CFRs during this period. This shift may have been related to a growing number of outbreaks in nursing homes (RKI 2020c) despite the imposition of stringent lockdown measures, or to changes in the testing regimes. For instance, testing among the younger age groups declined in late 2020, while it remained stable among those aged 80+ (RKI 2021b, 2021c). Future research into the causes of the trends we documented is needed.

Our study has limitations. We used the age group data originally reported by the RKI. The reported age categories were rather wide, which could lead to a skewed representation of the real age distribution of COVID-19 cases and deaths if, for example, the cases were not evenly distributed within age groups. Moreover, both the numerator and denominator of our key measure, the CFR, depended strongly on the testing coverage (Onder, Rezza, and Brusaferro 2020). Reporting and testing errors, and both undetected infections and deaths, were sources of potential bias (Green et al. 2020).

Despite these limitations, this paper provides valuable and previously undocumented information on the factors modulating differences in COVID-19 fatality in Germany across states and over time during the first and second pandemic waves.

5. Author contribution and acknowledgements

Saskia Morwinsky: conceptualization, data curation, formal analysis, methodology, project administration, software, visualization, and writing (original draft, review, & editing). Natalie Nitsche: conceptualization, writing (review and editing), and supervision. Enrique Acosta: conceptualization, data curation, formal analysis, methodology, software, supervision, validation, visualization, and writing (review & editing).

We thank Tim Riffe, Marcus Ebeling, Silvia Loi, and the two anonymous reviewers for their helpful comments and suggestions.

References

Destatis (2020). 12411–0012: Bevölkerung: Bundesländer, Stichtag, Altersjahre.

Dowd, J.B., Andriano, L., Brazel, D.M., Rotondi, V., Block, P., Ding, X., Liu, Y., and Mills, M.C. (2020). Demographic science aids in understanding the spread and fatality rates of COVID-19. *Proceedings of the National Academy of Sciences* 117(18): 9696–9698. doi:10.1073/pnas.2004911117.

Dudel, C., Riffe, T., Acosta, E., van Raalte, A., Strozza, C., and Myrskylä, M. (2020). Monitoring trends and differences in COVID-19 case-fatality rates using decomposition methods: Contributions of age structure and age-specific fatality. *PLOS ONE* 15(9): e0238904. doi:10.1371/journal.pone.0238904.

Fan, G., Yang, Z., Lin, Q., Zhao, S., Yang, L., and He, D. (2021). Decreased case fatality rate of COVID-19 in the second wave: A study in 53 countries or regions. *Transboundary and Emerging Diseases* 68(2): 213–215. doi:10.1111/tbed.13819.

Goldstein, J.R. and Lee, R.D. (2020). Demographic perspectives on the mortality of COVID-19 and other epidemics. *Proceedings of the National Academy of Sciences* 117(36): 22035–22041. doi:10.1073/pnas.2006392117.

Green, M.S., Peer, V., Schwartz, N., and Nitzan, D. (2020). The confounded crude case-fatality rates (CFR) for COVID-19 hide more than they reveal – a comparison of age-specific and age-adjusted CFRs between seven countries. *PLOS ONE* 15(10): e0241031. doi:10.1371/journal.pone.0241031.

Horiuchi, S., Wilmoth, J.R., and Pletcher, S.D. (2008). A decomposition method based on a model of continuous change. *Demography* 45(4): 785–801. doi:10.1353/dem.0.0033.

Kitagawa, E.M. (1955). Components of a difference between two rates. *Journal of the American Statistical Association* 50(272): 1168. doi:10.2307/2281213.

Levin, A.T., Hanage, W.P., Owusu-Boaitey, N., Cochran, K.B., Walsh, S.P., and Meyerowitz-Katz, G. (2020). Assessing the age specificity of infection fatality rates for COVID-19: systematic review, meta-analysis, and public policy implications. *European Journal of Epidemiology* 35(12): 1123–1138. doi:10.1007/s10654-020-00698-1.

Morwinsky, S., Nitsche, N., and Acosta, E. (2021a). Additional information for "COVID-19 fatality in Germany: Demographic determinants of variation in case-fatality rates across and within German Federal States during the first and second waves". 0 ed. Rostock: Max Planck Institute for Demographic Research. doi:10.4054/MPIDR-TR-2021-002.

Morwinsky, S., Nitsche, N., and Acosta, E. (2021b). Reproducible materials for "COVID-19 fatality in Germany: Demographic determinants of case fatality risks variation across and within German Federal States during the first and second waves." https://github.com/saskiamo/COVID-19-CFR_Germany.git.

O'Driscoll, M., Ribeiro Dos Santos, G., Wang, L., Cummings, D.A.T., Azman, A.S., Paireau, J., Fontanet, A., Cauchemez, S., and Salje, H. (2020). Age-specific mortality and immunity patterns of SARS-CoV-2. *Nature* 590(7844): 140–145. doi:10.1038/s41586-020-2918-0.

Onder, G., Rezza, G., and Brusaferro, S. (2020). Case-fatality rate and characteristics of patients dying in relation to COVID-19 in Italy. *JAMA*. doi:10.1001/jama.2020.4683.

Riffe, T., Aburto, J.M., Alexander, M., Fennell, S., Kashnitsky, I., Pascariu, M., and Gerland, P. (2019). *DemoTools: An R package of tools for aggregate demographic analysis*. https://github.com/timriffe/DemoTools/.

Riffe, T., Acosta, E., and COVerAGE-DB project team (2020). Data Resource Profile: COVerAGE-DB: a global demographic database of COVID-19 cases and deaths. *International Journal of Epidemiology* 50(2): 390–390f. doi:10.1093/ije/dyab027.

RKI – Robert Koch Institut (2020a). *Laborbasierte Surveillance von SARS-CoV-2. Wochenbericht Vom 06.05.2020*.

RKI – Robert Koch Institut (2020b). *Tabelle mit den aktuellen Covid-19 Infektionen pro Tag (Zeitreihe)*. https://www.arcgis.com/home/item.html?id=dd4580c810204019a7b8eb3e0b329dd6#overview.

RKI – Robert Koch Institut (2020c). *Täglicher Lagebericht Des RKI Zur Coronavirus-Krankheit-2019 (COVID-19). 29.12.2020 – Aktualisierter Stand Für Deutschland*.

RKI – Robert Koch Institut (2021a). *Digitales Impfquotenmonitoring zur COVID-19-Impfung.* https://www.rki.de/DE/Content/InfAZ/N/Neuartiges_Coronavirus/Daten/Impfquoten-Tab.html;jsessionid=7CD5258893F719D9991A9BAEC2B971F0.internet081.

RKI – Robert Koch Institut (2021b). *Laborbasierte Surveillance von SARS-CoV-2. Wochenbericht Vom 23.02.2021*.

RKI – Robert Koch Institut (2021c). *Laborbasierte Surveillance von SARS-CoV-2. Wochenbericht Vom 26.01.2021*.

Sorci, G., Faivre, B., and Morand, S. (2020). Explaining among-country variation in COVID-19 case fatality rate. *Scientific Reports* 10(1): 18909. doi:10.1038/s41598-020-75848-2.

Sudharsanan, N., Didzun, O., Bärnighausen, T., and Geldsetzer, P. (2020). The contribution of the age distribution of cases to COVID-19 case fatality across countries: A nine-country demographic study. *Annals of Internal Medicine* 173(9): 714–720. doi:10.7326/M20-2973.

Yang, W., Kandula, S., Huynh, M., Greene, S.K., Van Wye, G., Li, W., Chan, H.T., McGibbon, E., Yeung, A., Olson, D., Fine, A., and Shaman, J. (2021). Estimating the infection-fatality risk of SARS-CoV-2 in New York City during the spring 2020 pandemic wave: A model-based analysis. *The Lancet Infectious Diseases* 21(2): 203–212. doi:10.1016/S1473-3099(20)30769-6.