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Research Article

Lives saved, lives lost, and under-reported COVID-19 deaths: Excess and non-excess mortality in relation to cause-specific mortality during the first year of the COVID-19 pandemic in Sweden

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Lives saved, lives lost, and under-reported COVID-19 deaths: Excess and non-excess mortality in relation to cause-specific mortality during the first year of the COVID-19 pandemic in Sweden

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Abstract

BACKGROUND
The number of confirmed COVID-19 deaths differed across countries and across waves of the pandemic. Patterns also differed between groups within a country.

OBJECTIVE
We combine data on excess mortality with data on cause-of-death-specific mortality in the case of Sweden to identify which groups had excess mortality beyond what can be captured by analyses of COVID-19-specific deaths. We also explore the possibility that some groups may have benefited in terms of reduced all-cause mortality, potentially due to home-centered living conditions during the pandemic.

METHODS
We produced and compared three sets of group-specific incidence rates: deaths from (1) any cause in 2020, (2) any cause in 2019, (3) any cause excluding COVID-19 in 2020. We compared rates across different socioeconomic profiles based on combinations of sex, age, marital status, education, and country of birth.

CONTRIBUTION
We show that many of those who died during 2020 would not have done so in the absence of the pandemic. We find some evidence of COVID-19 mortality underestimation, mainly among individuals with a migration background. We also found groups for which mortality decreased during the pandemic, even when including COVID-19 mortality. Progression across the first and second waves of the pandemic shows that more groups

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appeared to become protected over time and that there was less underestimation of COVID-19 mortality in the second part of 2020.

1. Introduction

Since the beginning of the COVID-19 pandemic, there has been a concerted international effort to make available daily counts of cases and deaths associated with COVID-19 (Dong, Du, and Gardner 2020; Karlinsky and Kobak 2021). Thanks to this initiative, most of the empirical evidence produced regarding differences in COVID-19 mortality across space, time, and population subgroups is rooted in deaths directly related to COVID-19. This evidence has informed national public health policies. Nevertheless, assessments of the coverage and quality of national statistics have demonstrated that case numbers and deaths are often extensively under-reported (Biswas, Afiaz, and Huq 2020; Karlinsky and Kobak 2021; Kupek 2021; Lau et al. 2021; Li et al. 2020; Li, Fang, and He 2020; Riffe et al. 2021; Vestergaard et al. 2020). Particularly in the first phase of the pandemic, the under-reporting of COVID-19 mortality was linked to variation in testing strategies and availability (Karanikolos and McKee 2020; Spiegelhalter 2020). This under-reporting was manifested in various ways across countries. Some countries reported only deaths that occurred in hospitals. By contrast, others had limited reporting of deaths following a PCR-confirmed COVID-19 infection. A few countries also counted ‘suspected’ COVID-19 deaths in their reporting (Riffe et al. 2021).

The impact of COVID-19 on death rates can be measured not only through causes of death specifically related to COVID-19 but also through total excess mortality (Islam et al. 2021; Msemburi et al. 2023). Excess mortality can be defined as higher all-cause mortality than would be expected based on recent trends. This excess mortality approach has been used historically to estimate the effects of various pandemics (e.g., the Great Plague of London in 1665 (Boka and Wainer 2020) and the influenza pandemics of 1918, 1957, 1968, and 2009 (Murray et al. 2006; Simonsen et al. 2013; Viboud et al. 2005, 2016)). It has also been used more widely to study environmental disasters, such as Hurricane Maria in Puerto-Rico in 2017 (Milken Institute 2018). During the COVID-19 pandemic, evidence has confirmed the global presence of significant excess mortality (Alicandro, Remuzzi, and La Vecchia 2020; Andersson et al. 2021; Blangiardo et al. 2020; Bradshaw et al. 2021; Ghafari, Kadivar, and Katzourakis 2021; Islam et al. 2021; Karlinsky and Kobak 2021; Kobak 2021; Kolk et al. 2022; Kontis et al. 2020; Modi et al. 2021; Weinberger et al. 2020; Woolf et al. 2020a, 2020b).

Estimates of excess mortality reflect all changes in death counts, including deaths directly related to the pandemic, deaths unrelated to the pandemic (which happened during the pandemic), and deaths that may be related to, but were not caused directly by, the pandemic (Kaczorowski and Del Grande 2021). For example, the overburdening of national health systems may have compromised the efficiency and capacity of such systems to function normally, indirectly leading to an increase in deaths from other causes (Dinmohamed et al. 2020; Folino et al. 2020; Schwarz et al. 2020; Zubiri et al. 2021). Furthermore, the fear of contracting the virus may have led people in need of medical attention to actively avoid seeking care. These people would have remained untreated for longer, affecting the prognosis of the health problem when they eventually received care (Kaczorowski and Del Grande 2021). Consequently, excess mortality includes not only direct fatalities from the pandemic but also deaths that can be regarded as ‘collateral damage.’

An analysis of excess mortality can shed light on important questions that emerged during the course of the pandemic. Given that the pandemic disproportionately affected populations already at high risk of death – referred to as ‘dry tinder’ – its main impact may have been a shift in the timing of deaths, anticipating fatalities that would have been inevitable in the near future (Herby 2020; SCB 2020). This characterization, however, could mask the true toll of the pandemic.

It may also be the case that non-pharmaceutical interventions, such as working from home, served to reduce the risk to certain population subgroups from other causes of death more than the increased mortality risk posed by COVID-19 itself (Kung et al. 2021; Shilling and Waetjen 2020). Studying all-cause mortality may in this case lead to an underestimation of COVID-19 deaths. For example, COVID-19 recommendations or lockdowns are likely to lead to fewer road accidents (especially for men age 15–44) and less spread of influenza (in the elderly). These shifts in long established patterns of cause-specific mortality (Remund, Camarda, and Riffe 2018), which can be called ‘replacement mortality,’ may complicate the estimation of excess mortality during the pandemic. They blur the lines between the pandemic’s wider effects on societal, economic, and behavioral changes, and the direct consequences of COVID-19 infection.

In this study we examine changes in mortality, drawing comparisons between mortality between 2019 (the year immediately before the pandemic) and 2020 (the first year of the pandemic) and considering scenarios with and without COVID-19 deaths. We explore the true cost of the first waves of the pandemic during 2020 by assessing the extent to which established COVID-19 mortality appears to replace other causes of mortality, and how much excess COVID-19 mortality might be underestimated due to ‘collateral damage’ or under-reporting. Additionally, we contrast the first and second pandemic waves in Sweden in 2020, to ascertain whether there is any indication that COVID-19 deaths in the first wave of the pandemic were represented by anticipated deaths during the fall the same year and if the extent of under-reporting decreased as testing expanded. Conversely, we examine the potential benefits for some groups, such as reduced overall mortality possibly stemming from safer home-centered living conditions during the pandemic.

In addition, we examine whether population subgroups with detailed combinations of sociodemographic characteristics (age, sex, education level, marital status, migrant status) displayed unique mortality risks. Being older, male, having a lower education level, not being married, and not being a migrant have long been associated with a higher mortality risk (e.g., Drefahl 2010; Wallace and Kulu 2014). Consequently, during the pandemic, many studies focused upon these characteristics in relation to COVID-19 mortality. A few studies have examined disaggregated trends by sex, age, and time as single dimensions (Blangiardo et al. 2020; Calderón-Larrañaga et al. 2020; Ghislandi et al. 2020; Hollinghurst et al. 2021; Kepp et al. 2022; Modig et al. 2021; Rizzi, Søgaard, and Vaupel 2022; Scortichini et al. 2021). Others have highlighted specific factors such as migrant status, and adjusted for additional variables such as age, sex, education, and marital status to verify any persistent associations with COVID-19 mortality. Consequently, we know that being older, male, lower-educated, and a migrant are associated with a higher mortality risk from COVID-19, 'net' of these other characteristics (e.g. Drefahl et al. 2020; Williamson et al. 2020). However, our understanding is limited regarding the specific risks by potentially vulnerable subpopulations at the intersections of these factors (Varkey, Kandpal, and Neelsen 2022). This becomes particularly important considering the reversal in direction of the association of at least one of these characteristics before and during the pandemic, i.e., that of migrant status. For example, is the additional risk associated with migrant status concentrated among older, low-educated men? Andersson et al. (2021) is one of the few studies that explore how age intersected with gender, education, and country of birth in Swedish mortality rates. In this study we expand these analyses, examining intricate combinations of education, migrant status, marital status, age, and sex.

Sweden provides the possibility of such an analysis due to the high quality of its population registers, which distinguish between mortality from COVID-19 and other causes. Sweden is also a compelling case because it stood out in the European context due to its reliance on recommendations rather than 'stay at home' orders, with the explicit purpose to accommodate living with the virus for a period that was expected to last more than just a few months.

2. Previous studies and our contribution

Prior research that relies on publicly available all-cause mortality data to perform international comparisons of mortality during the pandemic (February 2020 – May 2023[3]) with mortality in previous years has documented excess mortality (Islam et al. 2020; Konstantinoudis et al. 2022; Kontis et al. 2020; Sanmarchi et al. 2021; Wang et al. 2022). Most studies look at general trends and focus on methodological aspects (Nepomuceno et al. 2022; Sanmarchi et al. 2021).

However, several studies have examined excess mortality at the national/regional level and attempt to look at more detailed differences in trends. Among the former, Blangiardo et al. (2020) present a comprehensive analysis of the spatio-temporal differences in excess mortality during the COVID-19 pandemic in Italy. They predict all-cause weekly deaths and mortality rates at the municipal level in 2016–2019 and 2020 based upon the modeled spatio-temporal trends and show that Lombardia had higher mortality rates than expected from the end of February 2020, with 23,946 total excess deaths. At the peak of the pandemic this excess was particularly high for males in the city of Bergamo. Consistent with this, Ghislandi et al. (2020) show a substantial number of excess deaths in the older age groups in Northern Italy, providing empirical evidence that COVID-19 is especially lethal for older individuals. Similar results were also found in Germany (Stang et al. 2020). Several contributions discuss how sex differentials in COVID-19 mortality vary by age (The Lancet 2020). In a systematic review of the Italian case, Rizzi, Strozza, and Zarulli (2022) confirm that males up to 75 years of age experienced more excess deaths than females. There is some indication that area-level measures of socioeconomic deprivation and a higher proportion of young people may be associated with higher excess mortality. Davies et al. (2021) look at a set of community-level variables to estimate excess mortality during March–May 2020 in England. They find excess mortality in communities with a high density of care homes, and where high proportions of residents are on income support, live in overcrowded homes, and/or are of non-white ethnicity. Similarly, Stokes et al. (2021) document how excess mortality in 2020 in the United States differed across sociodemographic and health-related factors. The latter two studies use an ecological approach by focusing on counties/local communities rather than individuals.

Looking at the Swedish case, Modig et al. (2021) document excess mortality among men (75%) and women (50%) above age 60 during weeks 10–16 in 2020, compared to the same weeks in the previous 5-year period. Similarly, Kolk et al. (2022) report that Sweden experienced excess mortality in some age groups but not in others. For example, in 2020, compared to forecasted mortality, males experienced excess mortality at ages 0–19 and 50+, and females at ages 60+. Simultaneously, mortality among men aged 20–49

[3] The time of this paper's submission.

was lower than expected. Over the course of the calendar year, higher mortality than expected could be found from April to June and November to December, consistent with the onset of different waves of COVID-19. Yet, for individuals younger than 65 years, mortality from August to December was lower than expected. Finally, while some regions (in the north and west of Sweden) continued to make gains in life expectancy compared to previous years, others (particularly Stockholm County) experienced considerable (~1-year) losses. Evidence of an association between higher excess mortality and area-level characteristics such as socioeconomic deprivation and age composition has been found in Sweden (Calderón-Larrañaga et al. 2020). Similarly, higher mortality rates are observed among populations residing in care or nursing homes, as reported by Modig et al. (2021). Another factor that had a major impact on the degree of excess mortality was country of birth (Aradhya et al. 2021; Brandén et al. 2020; Drefahl et al. 2020; Rostila et al. 2021).

The main point of this summary, which is not exhaustive, is that most research on excess mortality at the population level has focused on general trends. In some cases, these trends were disaggregated by single dimensions such as sex, age, and localized temporal trends, or age and sex were interacted. In a notable exception, and only in the case of Sweden, Andersson et al. (2021) look at excess mortality combining four broad age ranges with each of the following variables: gender, educational level, and country of birth. We build on elements from this study by presenting measures of excess mortality based on more detailed sociodemographic profiles that combine the five dimensions of age, gender, educational level, marital status, and country of birth. Additionally, we present measures of mortality for different population groups in 2020 with and without including COVID-19-related deaths, and compare these to the previous number of deaths observed in 2019. In this way we are able to identify population groups that (1) would likely have died in 2020 regardless of the COVID-19 pandemic (‘replacement’); (2) suffered from higher underestimation of COVID-19 deaths due to under-reporting OR faced significant indirect negative impacts from the pandemic (‘underestimation’); and (3) gained the most in terms of reduced mortality from protective measures (‘net reduction in overall risk’). By comparing patterns across time (COVID waves 1 and 2), we also evaluate how patterns of underestimation and net reduction in mortality evolved throughout the pandemic and are able to ascertain the validity of the ‘dry tinder’ assumption in Swedish mortality patterns during the first waves of the pandemic.

3. Data and method

We combine information from several Swedish administrative registers linked through personal identity numbers that are unique to each person with legal residence in Sweden.

Data on deaths were retrieved from the Cause of Death Register provided by the National Board of Health and Welfare (*Socialstyrelsen*). Demographic variables (country of birth, sex, civil status) were drawn from the Total Population Register maintained by Statistics Sweden. Information on the highest achieved educational degree comes from the Longitudinal Integrated Database for Health Insurance and Labour Market Studies (LISA). For analyses of mortality in 2019, demographic variables are measured at the end of 2018 and for analyses of 2020 they are measured at the end of 2019. For both analyses, the highest achieved educational degree is measured at the end of 2018, the latest year for which such data are available in our sources.

Our outcome measures for the analyses of 2020 are all deaths from COVID-19 and all deaths from any other cause of death between March 12th, 2020 and Dec 31st, 2020. The starting date was set one day before the first recorded death attributed to COVID-19 on March 13, 2020 in Sweden. Correspondingly, in the analyses for 2019 our outcomes are all deaths from any cause of death between March 12th, 2019 and Dec 31st, 2019. COVID-19 mortality was identified by the Swedish National Board of Health and Welfare, the agency responsible for the cause of death register, using the following ICD codes: U07.1, U07.2, or B342. In total, we observe 9,871 COVID-19 deaths and 66,756 deaths from other causes in the part of 2020 that we cover.

For the analyses of 2020, our study population consists of all individuals aged 21 and older on March 12th, 2020. The starting age corresponds to the earliest recorded age at death from COVID-19 in Sweden in the first year of the pandemic. Similarly, for the analyses of 2019, our study population comprises all individuals aged 21 and older on March 12th, 2019. For each of these years, our study population encompasses about 6 million individuals.

Despite excess mortality being one of the most reliable methods to study the impact of COVID-19 on mortality (Beaney et al. 2020), there is debate regarding the choice of reference period when comparing non-pandemic mortality and excess mortality from COVID-19. Nepomuceno et al. (2022) conclude that the baseline should include an interval of several years to identify a stable and clear mortality trend, but also that the chosen period should be related to the specific country trend. In essence, the selection of the reference period should be long enough to allow for the most accurate possible estimate when answering the question of what mortality would have been like in 2020 had the COVID-19 pandemic not occurred. Swedish life expectancy in the year preceding the pandemic was observed to be 84.72 years for women and 81.33 years for men, marking an exceptionally large increase on previous years. Consequently, in the Swedish context, mortality conditions of 2019 may closely align with the expected levels for 2020. This reasoning is corroborated by Statistics Sweden’s latest forecast for 2020 (SCB 2020b), published at the beginning of that year, just before the potential impact of COVID-19 on mortality could be known. This forecast represents the last and best possible assessment for the expected mortality conditions of 2020 in the absence of the COVID-19 pandemic in Sweden. The forecast projected life expectancies of 84.8 years for women and 81.4 years for men, figures almost identical to those observed in 2019. We therefore argue that 2019 represents the most suitable comparison period for our analyses. Moreover, given the substantial decrease in Swedish mortality rates over the years preceding the pandemic, incorporating a longer data period would compare 2020 to a time when mortality rates were unexpectedly higher, as indicated by Kolk et al. (2022).

We define a set of study populations based on different combinations of characteristics related to age, sex, marital status, educational attainment, and migration status. These study populations are used to calculate exact exposures in person-years for 2019 and 2020 and the number of deaths separately.[4] Three sets of incidence rates are then calculated:

1. Group-specific incidence rates of death from any cause in 2020.
2. Group-specific incidence rates of death from any cause in 2019.
3. Group-specific incidence rates of death from any cause excluding COVID-19 in 2020.

By examining all-cause mortality, both with and without including COVID-19 deaths, we can determine whether any excess mortality in 2020 was solely due to COVID-19, whether COVID-19 effectively replaced other causes of death, and the extent to which Sweden experienced an underestimation of COVID-19-related deaths either from under-reporting or from other indirect effects of the pandemic.

Each set of incidence rates is calculated for all possible combinations of the variables specified below:

- Sex – Female vs. Male
- Age – Retirement ages (65+) vs. Working ages (21–65)
- Marital Status – Married vs. Non-married
- Education – Secondary and higher vs. Primary
- Country of Birth - Immigrant from High-Income Country (HIC) vs. Immigrant from Low-Middle-Income Country (LMIC) vs. Swedish-born

We exclude individuals with missing information on any of the characteristics described above (N = 161,287, mainly missing information on educational attainment) and present results for groups with 10 or more recorded deaths in 2020.[5] This produces

[4] All estimations of incidence rates and their confidence intervals are presented in Appendix Table A-1.
[5] Our total populations consist of 7,634,627 individuals in 2019 and 7,720,515 in 2020.

47 possible combinations of group characteristics. For example, we produced incidence rates in 2019 and 2020 specifically for primary-educated, married women aged 65+ who were born in Sweden.

To explore differences in rates between the first and second waves of the pandemic, we additionally divided the exposure time across 2020 according to the occurrence of the first (March 12th–June 30th) and second (July 1st–December 31st) waves.

4. Results

In three separate figures, we present the percentage change in mortality rates in Sweden in 2020 relative to 2019, distinguishing COVID-19 mortality from other causes of mortality grouped together. Rates are presented by sociodemographic profile. Groups appear in a specific figure on the basis of the following inclusion criteria: Figure 1 shows all groups that did not experience excess mortality in 2020 but experienced a net reduction in overall mortality risk; Figure 2 shows all groups that had excess mortality overall, but reduced mortality when excluding COVID-19 deaths; and Figure 3 shows groups that had excess mortality even when excluding COVID-19 mortality. These selection criteria allow all combinations of groups to appear once, provided they had 10 or more death events in 2020.

As highlighted in the introduction, the advisories to stay at home and adhere to safety measures might have decreased fatalities from other causes. This includes fewer accidents due to decreased traffic and diminished spread of other infectious diseases due to social distancing and improved hygiene practices. In this context, the excess mortality attributed to COVID-19 might appear less severe, being partially balanced by these reductions. Furthermore, it could result in an overall decrease in the risk of mortality. Figure 1 shows those population subgroups that continued to make mortality improvements in 2020[6] compared to 2019. The purple bars represent the observed relative mortality decrease in 2020 as compared to 2019. The orange bars represent the hypothetical relative decrease in mortality if the observed COVID-19 deaths in 2020 were excluded from the relevant calculation. The difference between the orange and purple bars represents the share of deaths in each group directly attributed to COVID-19. If the orange bar is notably longer than the purple one, it suggests that the overall decline in mortality was small when including COVID-19-related deaths. In total, the groups in Figure 1 comprise 2,706 deaths, which is a very small portion of overall mortality (3.5% of all deaths). Overall, higher relative changes tend to be observed for subgroups that have fewer deaths.

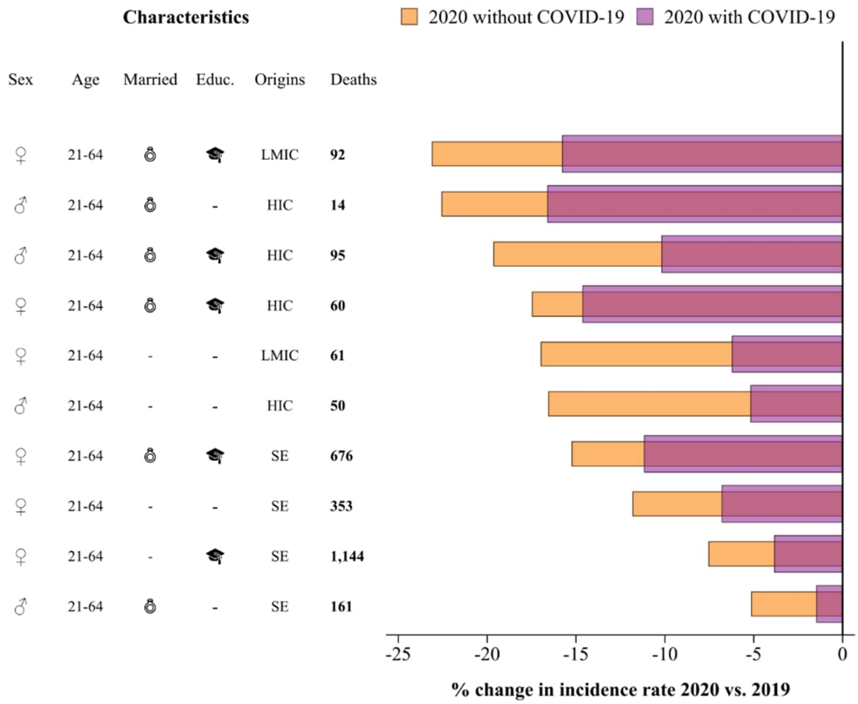
[6] Defined as March 12th, 2020 to Dec 31st, 2020.

These groups share one main characteristic: they are all of working age. The majority are women and the largest relative improvement in mortality occurred among the married. The sociodemographic pattern is otherwise less clear. It is worth noting that individuals from all country-of-birth groups are represented, as well as those of both educational levels. The group that experienced the highest relative decrease in mortality during 2020 (i.e., the most 'protected') consisted of married, working-age women from HIC (not including Sweden) with a high educational level.

If we look at differences across the waves (see Appendix A-1), we see fewer profiles falling into the category of decreased mortality in the first wave of the pandemic than in its second wave. However, the same set of characteristics appears in the first wave as for the full year, suggesting that the overall pattern in 2020 was driven primarily by the profile during the first wave of deaths. The numbers and the diversity in profiles increased dramatically in the second wave. The latter set of profiles also includes more men and individuals aged 65 and above.

Ultimately, we consider this figure to represent those who were able to protect themselves better than others during the pandemic, who had a position in society that offered more protection, or who benefited more from national pandemic recommendations, such as working from home.

Figure 1: Mortality improvement in 2020 compared to 2019 when including COVID-19 mortality (purple bar) and when excluding COVID-19 mortality (orange bar), 2020 all year



Note: - refers to nonmarried / primary education; LMIC = low and middle-income countries, HIC = high-income countries; SE = born in Sweden.

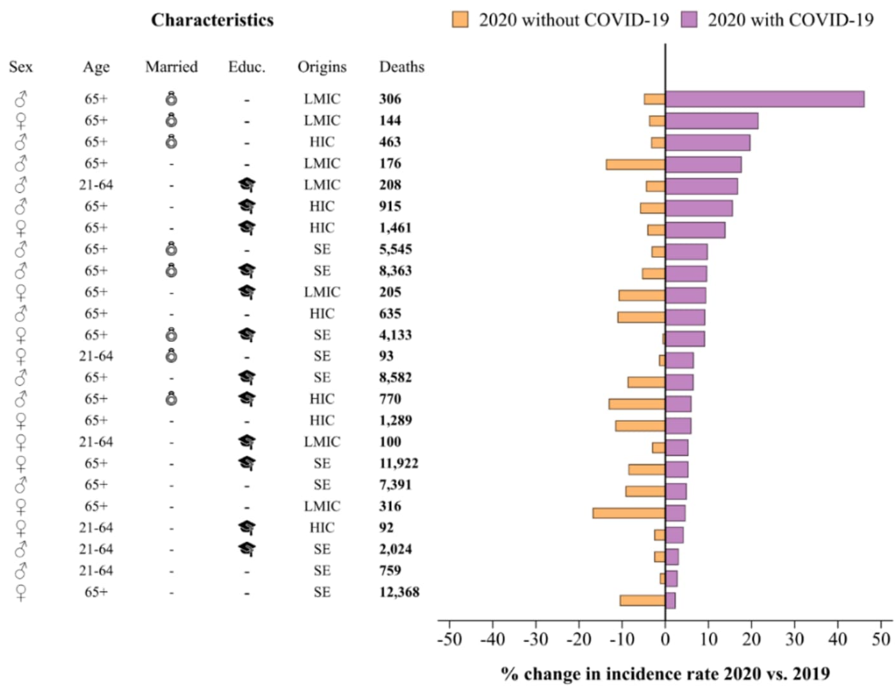
Figure 2 shows groups with excess mortality during 2020, compared to 2019, but for whom mortality due to all other causes of death (i.e., not COVID-19) was lower than in 2019. This was the most common pattern in 2020, comprising 68,260 deaths in total (89.1% of all deaths). The smallest group comprises only 92 deaths, the largest group 12,368 deaths. This pattern is what we might call the default scenario, because we would expect those who were at high risk of mortality in this period to be the most vulnerable to COVID-19. This figure shows the groups for which there may have been some element of replacement mortality in 2020, meaning that some deaths would have also occurred without the pandemic, but due to different causes.

We present a somewhat mirrored image of the declines and increases in mortality in 2020 compared to 2019. The purple bars on the right side represent the group-specific observed relative excess mortality in 2020 relative to 2019, with increases in mortality when COVID-19 deaths are included. The alternative scenario is on the left side of the y-axis (orange bars), with relative decreases in mortality if we were to exclude the observed COVID-19 deaths. If we assume the expected mortality in 2020 to be similar to the 2019 levels, the orange bar can be seen as indicative of mortality replacement, suggesting that this is the share of all deaths that would have taken place without the COVID-19 pandemic.

The dominant characteristic in these profiles is being of pension age. Many of the groups with the largest excess mortality in 2020 are men with an immigrant background. Overall, there also seems to be a tendency towards being non-married and lower-educated, with primary education being the most prevalent educational level among these groups. The profile that had the most excess mortality due to COVID-19, and potentially experienced a small portion of replacement mortality as well, was pension-aged men who were married, had a low educational level, and were born in a LMIC.

We would expect to observe a substantive orange bar with a negligible purple bar where COVID-19 mortality could be considered as having caused the deaths of individuals who would have most likely died in 2020 without the intervention of the pandemic. The profile that comes closest to fitting this scenario is at the bottom of the figure: pension-aged women who were single, had a low educational level, and were Swedish-born.

Figure 2: Excess risk of dying in 2020 as compared to 2019 with COVID-19 mortality (purple bar) and without COVID-19 mortality (orange bar), 2020 all year



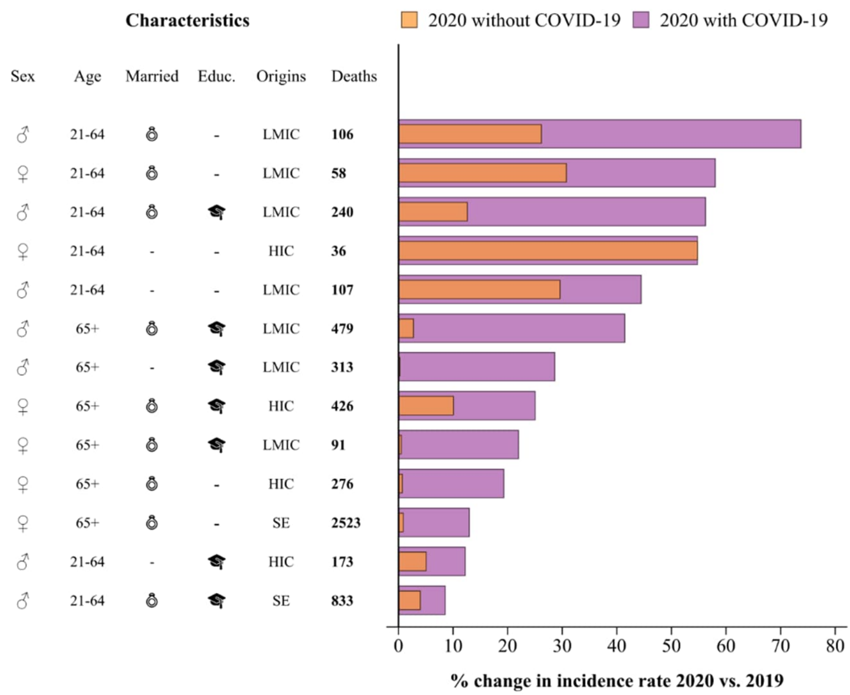
Note: - refers to nonmarried / primary education; LMIC = low and middle-income countries, HIC = high-income countries; SE = born in Sweden.

The general pattern during 2020 is again reflected in the first wave (see Appendix A-2) but not in the second; the excess mortality in the second wave was also driven by elderly male migrants (in particular from HIC). However, instead of seeing an increased diversity in the profiles during the second wave, such as we saw in relation to Figure 1, we rather see a diminished diversity over time. In other words, fewer groups experienced excess mortality with signs of replacement mortality in the second than in the first wave. This is what we would expect if the frailest individuals were most vulnerable to COVID-19, confirming that the ‘dry tinder’ hypothesis can only account for a fraction of Swedish excess mortality in 2020, as argued by Rizzi, Søgaard, and Vaupel (2022).

Figure 3 shows all groups with excess mortality in 2020, with and without COVID-19. The purple bars give the total observed excess mortality in percent. The difference between the purple and the orange bar gives the excess mortality that is due to deaths directly attributed to COVID-19. The orange bar represents the excess mortality due to all other causes of death, meaning that mortality from causes other than COVID-19 was also higher in 2020 than in 2019. The size of the orange bar could be indicative of the amount of under-reporting of COVID-19 deaths, the amount of indirect effects of the COVID-19 pandemic on other causes of death, or a mixture of both. The groups experiencing this pattern are heterogeneous, as are the effect sizes in terms of their observed excess mortality. In total, these groups comprise a minority of 5,661 deaths (7.4% of all deaths), ranging from just 36 deaths to 2,523 deaths in any single group in 2020. The vast majority of groups exhibiting this pattern include foreign-born individuals with relatively few deaths in total. The profile that experienced the largest relative amount of under-reporting or indirect COVID-19 deaths was working-age women who were non-married, low-educated, and born in a LMIC.

Separating the first and second COVID-19 waves in Sweden, we found a more equal coverage of groups according to country of birth that experienced under-reporting or indirect deaths in the first than in the second wave of the pandemic. In the second wave the picture changed dramatically and only foreign-born groups experienced excess mortality with and without including COVID-19 deaths. This indicates a continued under-reporting of COVID-19 deaths or indirect effects of the COVID-19 pandemic on other causes of death for these specific groups, particularly those born in a LMIC. No Sweden-born group continued to experience this pattern in the second half of 2020 (see Appendix Figure A-3).

Figure 3: Excess risk of dying in 2020 as compared to 2019 with COVID-19 mortality (purple bar) and without COVID-19 mortality (orange bar), 2020 all year

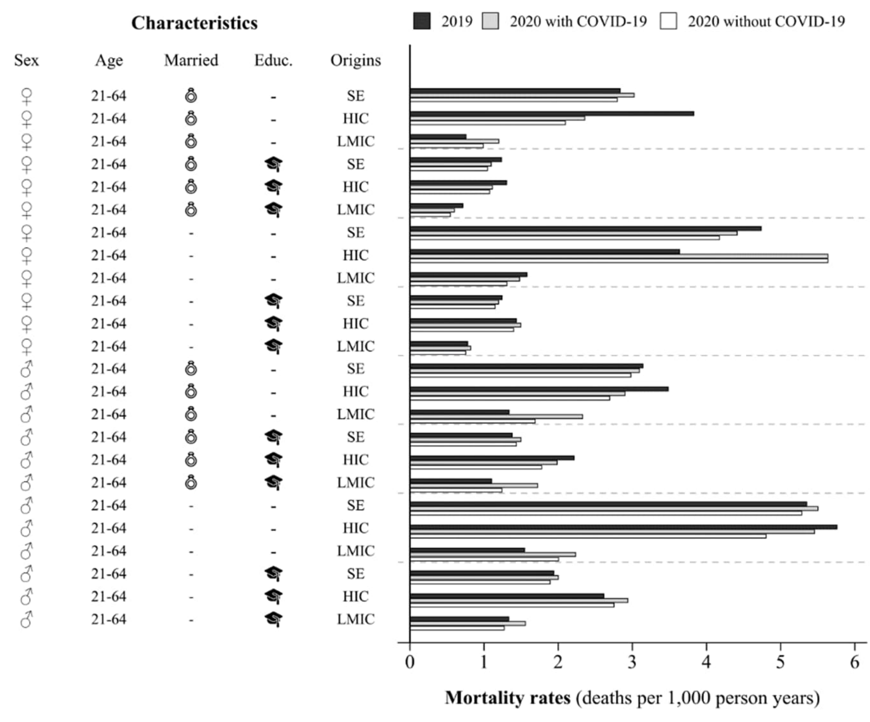


Note: - refers to non-married / primary education; LMIC = low and middle-income countries, HIC = high-income countries; SE = born in Sweden.

Lastly, in Figures 4 and 5 we explore how the relative changes in mortality observed in Figures 1–3 translate into changes in the absolute risk of dying. These figures thus show the magnitude of observed changes, which of the groups were driving overall excess mortality in Sweden in 2020, and whether the observed changes had an impact on sociodemographic inequalities prevailing before the onset of the COVID-19 pandemic. Groups are organized so that all combinations of characteristics are sorted by country of birth. Figure 4 gives the results for the working-age population (ages 21–65) and compares the absolute mortality from all causes of death in 2020 with and without COVID-19, with the mortality observed in 2019. The figure does not reveal a clear pattern of elevated mortality in 2020, with some groups dying less even when COVID-

19 is included and some dying more than in 2019. A main takeaway is that the mortality among Swedes and immigrants from high-income countries was higher than for immigrants from LMICs both before and during the COVID-19 pandemic. However, the gap in mortality between LMIC migrants and natives was reduced in 2020. For example, at the top of the figure, it is apparent that the absolute mortality rates for women from Sweden, HICs, and LMICs were more similar in 2020 than in 2019. Comparing Figures 3 and 4 also demonstrates that large relative mortality changes in 2020 (Figure 3) were happening in the context of low absolute levels of mortality (Figure 4).

Figure 4: Absolute risk of dying in 2019 and 2020 at ages 21–65

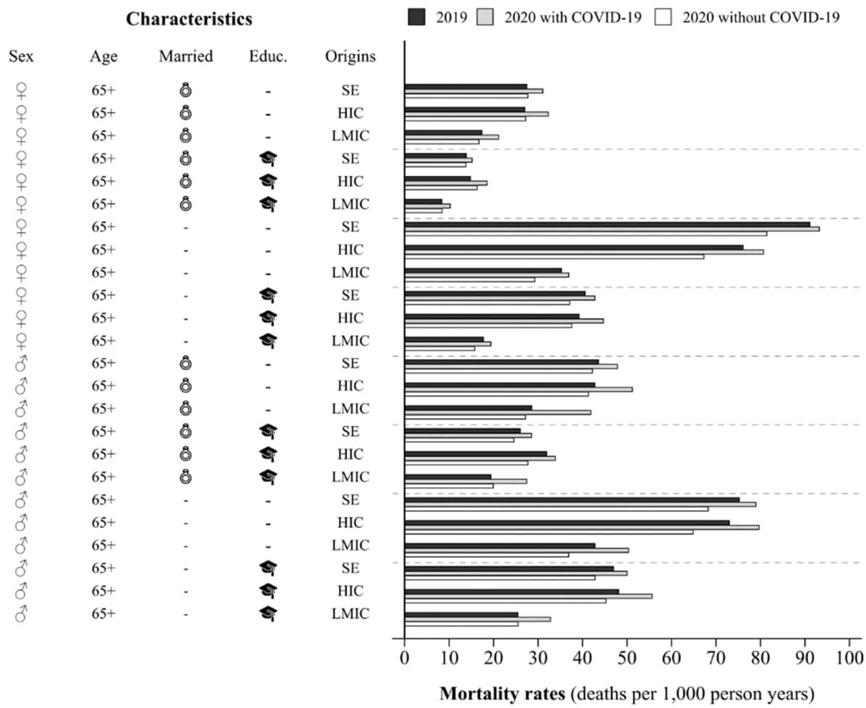


Note: - refers to non-married / primary education; LMIC = low and middle-income countries, HIC = high-income countries; SE = born in Sweden.

Figure 5 shows the same results for the retirement-age population (65+). This figure confirms the elevated mortality in 2020 as compared to 2019 in almost all groups of elderly individuals, when looking at all-cause mortality. However, if we exclude COVID-

19 deaths, mortality was instead lower for most of the groups. Overall, in 2020, we observe stronger relative increases in mortality among groups with migrants than among natives. For most profiles, however, we observe high absolute mortality for individuals from high-income countries as compared to natives. For those from low- and middle-income countries, we continue to observe an overall mortality advantage in 2020, which reflects the usual pattern of healthy-migrant status (Wallace and Wilson 2019).

Figure 5: Absolute risk of dying in 2019 and 2020 at ages 65+



Note: - refers to non-married / primary education; LMIC = low and middle-income countries, HIC = high-income countries; SE = born in Sweden.

5. Discussion

Since the beginning of the pandemic, approximately 6.6 million people globally have died of COVID-19 (WHO 2020, 2023), but this is a figure that might be significantly underestimated. This is true even in contexts that provide continuously updated mortality data. The cumulative excess mortality during the pandemic makes COVID-19-related mortality one of the leading causes of death worldwide during the pandemic (Vos et al. 2020; Wang et al. 2022). Understanding the true mortality impact of the COVID-19 pandemic is thus crucial for public health decision-making (Wang et al. 2022).

To assess the entire burden associated with COVID-19 deaths, excess mortality has been suggested as an important alternative to COVID-19-specific death rates (Karlinsky and Kobak 2021). Previous studies have shown that excess mortality during the pandemic, estimated as the difference between the current mortality trend and that of previous years, was not uniformly distributed within the population (Andersson et al. 2021). However, cause-specific mortality data are still essential to gain a solid understanding of the burden associated with COVID-19 mortality. In our study, we aimed to estimate the excess mortality in Sweden for specific sociodemographic profiles – based on age, sex, country of birth, marital status, and education – comparing mortality rates during the pandemic (2020) with previous mortality rates (2019), with and without officially recorded COVID-19 deaths. More precisely, we analyzed data from Swedish population registers that include causes of death, including COVID-19-related mortality events. We estimated excess mortality rates both with and without COVID-19 deaths and compared all-cause and cause-specific mortality in 2020 with all-cause mortality in 2019. In this way, we should be better able to estimate the true extent to which the COVID-19 epidemic led to increased mortality levels and to assess the amount of underestimation of COVID-19-related deaths in specific groups.

Mortality responses to COVID-19 varied across sociodemographic profiles, and the impact was also obvious among others than those most heavily affected, i.e., the elderly and foreign-born. We observed groups for which the overall effect was a decline in death rates, groups for which COVID-19 outpaced the effect of a decline in other causes of death, and groups for which both COVID-19 mortality and other causes of death increased. Our study supports findings from previous research (e.g., Stokes et al. 2021): Many of those who died in 2020 would not have done so without the impact of the pandemic. Furthermore, we found that the share of deaths that would have occurred in 2020 without the pandemic varied considerably by sociodemographic profile. We found two main patterns: (1) when a substantial portion of deaths was avoided in 2020, this usually coincided with very low COVID-19 mortality, while on the other hand (2) overall excess mortality usually coincided with very little reduction, if any, in other causes of death. Our results indicate an underestimation of COVID-19 mortality mainly among individuals with a migrant background; however, we were not able to distinguish whether this was due to under-reported COVID-19-specific deaths or collateral deaths due to other pandemic conditions. High relative excess mortality for some migrant groups continued into the second wave of the pandemic, when the under-reporting of COVID-19-specific deaths presumably was less prevalent. This lends support to the argument that COVID-19 mortality was not independent of other causes of death during the pandemic (Castro et al. 2023).

Despite the high quality of the Swedish data, our study has some limitations. The sociodemographic information was recorded one or two years before the pandemic, which could lead to reduced precision in the measures for civil status and education, particularly for young individuals who transition between different civil-status and education categories more often than others. However, neither of these characteristics change very frequently, unlike other measures of SES such as income. Additionally, when looking at the absolute mortality levels, we should keep in mind that the age profiles of different immigrant groups are quite different: The HIC category might be dominated by Finnish immigrants (an older migrant group with relatively high mortality) and immigrants from LMICs might be dominated by Syrians with a younger age structure and generally lower mortality. These differences, however, do not influence our findings regarding relative changes in mortality. Third, we consider numerous small subgroups for whom mortality remains an infrequent event. Therefore, we must proceed with caution when interpreting the magnitude of some of the relative changes in mortality between 2019 and 2020. Fourth, we concur with Nepomuceno et al. (2022) regarding the choice of baseline period for mortality comparisons. Generally, the use of an interval spanning several years, as opposed to a single year as in our case, can present a more stable depiction of mortality patterns for population forecasts. It is, however, important to select a baseline period that aligns with the specific mortality trends of the country in question. Remarkably, the life expectancy forecasts from Statistics Sweden for 2020 closely mirrored the actual life expectancy in 2019, supporting the idea that the mortality conditions of 2019 provide the most accurate reference point for our analysis. Given Sweden’s substantial reduction in mortality rates in recent years, comparing the 2020 data with a longer historical period would be to juxtapose 2020 with a timeframe in which mortality rates were anomalously high.

The findings from our study contribute to the literature in multiple ways. First, our results demonstrate a remarkable diversity in how the pandemic influenced death rates across a range of sociodemographic groups. Our study confirms the importance of age in estimating excess COVID-19 mortality, as well as the effects of country of origin, civil status, and educational attainment in COVID-19 mortality (Drefahl et al. 2020; Rostila et al. 2021).

Second, we identified profiles according to combinations of characteristics that were particularly unfavorable in terms of greater mortality losses. Working-age men and women from LMICs that were married and had low levels of education had the greatest relative excess mortality of all groups in 2020. The main group-specific mortality pattern (89% of deaths) in 2020 was related to reduced mortality in other causes of death, but overall excess mortality was driven by COVID-19 deaths. The profile most affected by this pattern was pension-aged, married men that were primary educated and born in a LMIC. Much less common (7% of group-specific deaths) was the pattern that we refer to as representing under-reporting of COVID-19 deaths or the impact of other collateral damage, which was most prevalent for working-age women who were non-married, low-educated, and born in a LMIC. Reduced health-seeking behaviors, an overburdened healthcare system, stress/anxiety due to catching the coronavirus, and a widowhood mortality effect from losing a spouse to COVID-19 are all potential indirect factors that could have inflated other causes of death during the course of the pandemic and may be considered in the total toll of COVID-19.

Third, we showed that there are some groups for which the impact of the pandemic did not lead to excess mortality. In fact, we find what can be called a ‘protection’ effect for some groups, whereby deaths from other causes declined substantially and the effect of adding COVID-19 mortality was negligible. These groups were all of working age, primarily married women, and almost all were born in high-income countries, including Sweden. In particular, the group that benefited the most was highly educated, married women born in a HIC. We consider that these groups may have benefited in several ways. They may have experienced less risk of infection due to the measures put in place to slow the spread of coronavirus, such as working from home, or by taking extra precautions to protect themselves, such as avoiding public spaces. The pandemic may also have brought other changes in daily living that could have decreased these groups’ exposure to risk, such as driving less. However, the measures taken during the pandemic have not always been reported as contributing to fewer deaths from other causes such as road accidents and the spread of influenza, either in the first wave in Sweden (Yasin, Grivna, and Abu-Zidan 2021) or elsewhere (e.g., US National Safety Council 2021).

Our results provide evidence of some excess mortality not completely accounted for by COVID-19 deaths. Looking at patterns during the first wave in particular, in relation to the second wave, we interpret these as evidence of underestimated or under-reported COVID-19-related mortality. There have been some previous indications that the registration of COVID-19-related deaths was insufficient early in the pandemic, leading to the underestimation of deaths associated with COVID-19 (Mungmunpuntipantip and Wiwanitkit 2021; Rozenfeld et al. 2021; Salottolo et al. 2021).

Finally, disaggregated rates across the first two waves of the pandemic provide additional insight into developments across time, when, later, testing became more widespread and the healthcare system had adjusted to the new demands. Over time we found more groups following the 'protected' pattern of mortality rates, reaching a decline in overall mortality during the second wave. As expected, we found less evidence of the 'default' mortality pattern in the second wave than in the first: substantially fewer groups exhibited lower mortality rates from other causes of death while having high enough COVID-19 mortality to generate net excess mortality. Even the small amount of replacement mortality that we found peaked in the first wave of the pandemic but declined in the second. And as expected, we found less evidence of underestimation of COVID-19 mortality in the second wave compared to the first. The improvements in testing capacity during the course of 2020 likely brought great improvements in correctly assigning causes of death. We still found some groups with substantial excess mortality in the second wave that could not be attributed to COVID-19, which points to the possibility of the pandemic indirectly increasing mortality for those groups. Why the mortality for working age, non-married, low-educated men and women born in foreign countries in the second wave was elevated by some 50% is an important public health question that still needs to be addressed. It remains for future research to uncover the mortality differentials and mortality patterns that evolved during the final phases of the pandemic in 2021, as well as the possible short- and long-term effects on all-cause and cause-specific mortality in the immediate aftermath of the pandemic and throughout the post-pandemic period.

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Data availability statement

This study is produced under the Swedish Statistics Act, where privacy concerns restrict the availability of register data for research. Aggregated data can be made available by the authors, conditional on ethical vetting. The authors access the individual-level data through Statistics Sweden's micro-online access system MONA. The authors linked data from the Historical Population Register (HBR), the Register of the Total Population (RTB), the Cause of Death Register, and the Longitudinal integrated database for health insurance and labor market studies (LISA). More information about data availability and data access can be obtained from: https://www.scb.se/en/services/guidance-for-researchers-anduniversities/mona–a-system-for-delivering-microdata/.

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Conflict of interest disclosure

The authors declare no competing interests.

Ethics approval statement

The analyses have been approved by the Swedish Ethical Review Authority, Dnr 2020-02199.

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Appendix

Figure A-1: (Lack of) Excess risk of dying in 2020 as compared to 2019 with COVID-19 mortality (purple bar) and without COVID-19 mortality (orange bar)

A WAVE 1

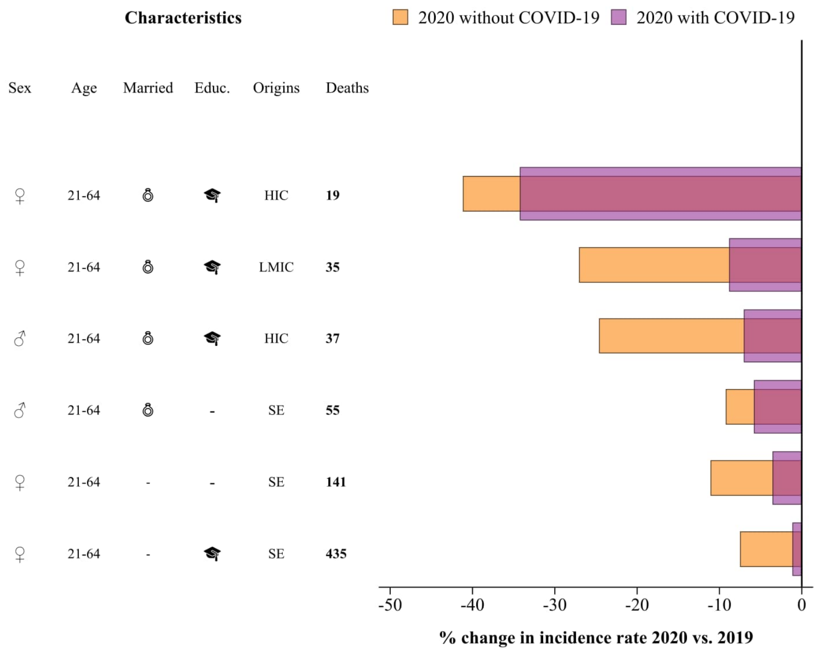
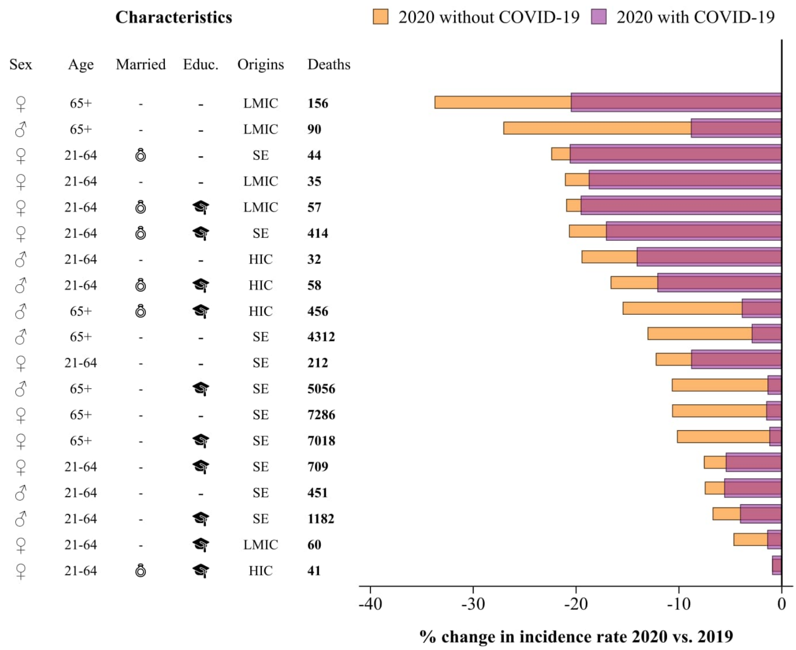


Figure A-1: (Continued)

B WAVE 2



Note: - refers to non-married / primary education; LMIC = low and middle-income countries, HIC = high-income countries; SE = born in Sweden.

Figure A-2: Excess risk of dying in 2020 as compared to 2019 with COVID-19 mortality (purple bar) and without COVID-19 mortality (orange bar)

A WAVE 1

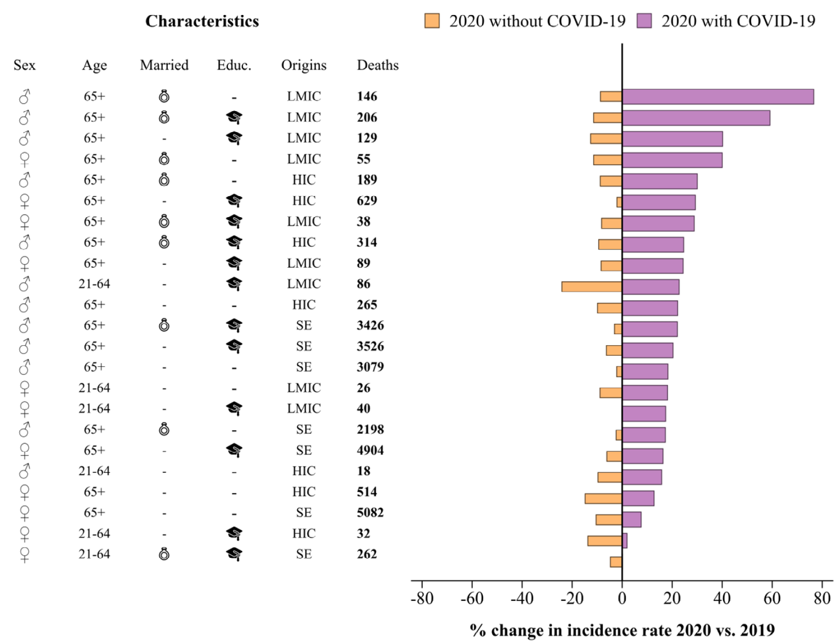
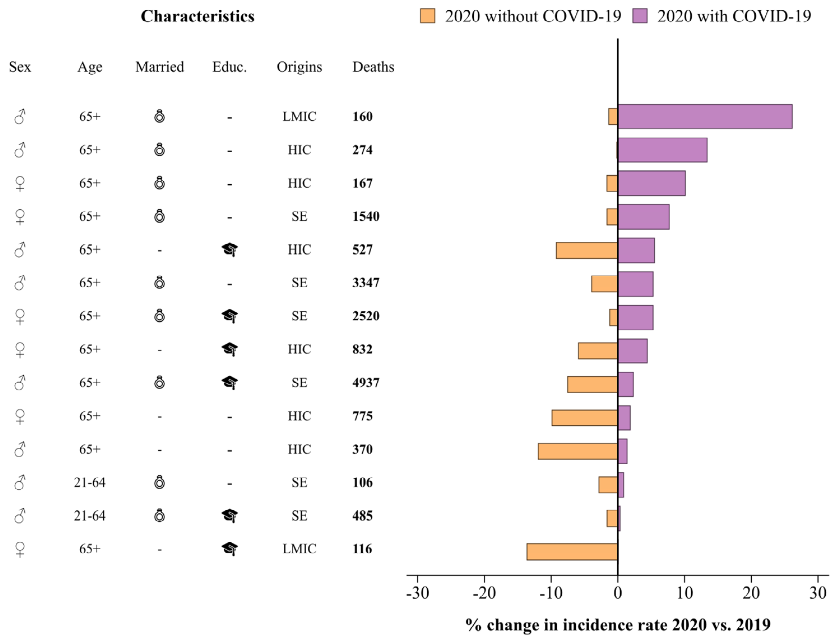


Figure A-2: (Continued)

B WAVE 2



Note: - refers to non-married / primary education; LMIC = low and middle-income countries, HIC = high-income countries; SE = born in Sweden.

Figure A-3: Excess risk of dying in 2020 as compared to 2019 with COVID-19 mortality (purple bar) and without COVID-19 mortality (orange bar)

A WAVE 1

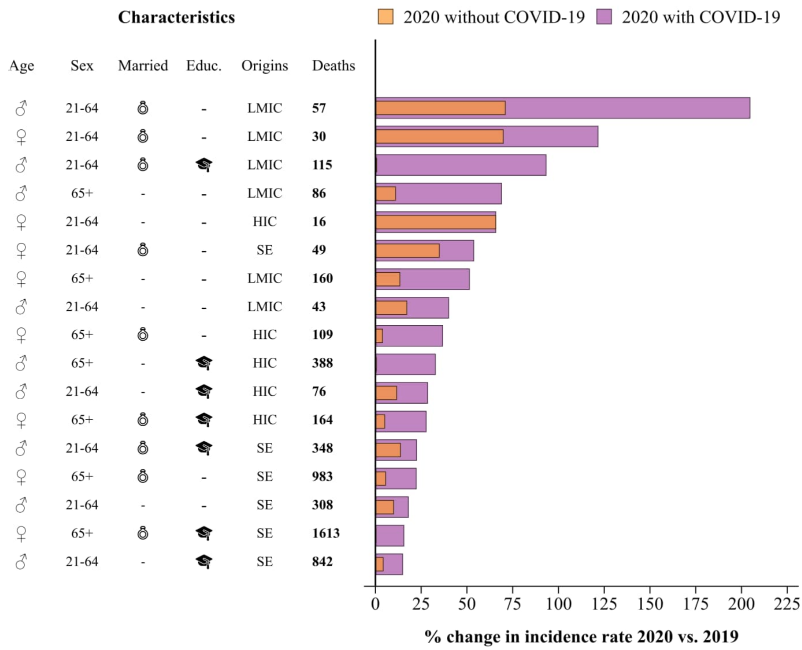
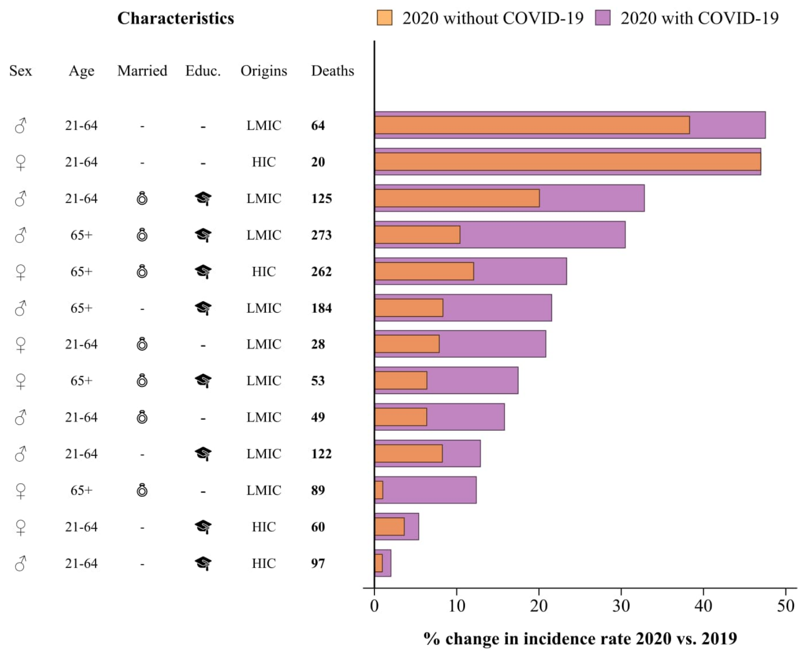


Figure A-3: (Continued)

B WAVE 2



Note: - refers to non-married / primary education; LMIC = low and middle-income countries, HIC = high-income countries; SE = born in Sweden.

Table A-1: Absolute risk of dying in 2019 and 2020 (with and without COVID-19) and their 95% confidence intervals (CI)

Characteristics					Mortality rates		
Sex	Age	Married	Educ.	Origins	2019	2020 with COVID-19	2020 without COVID-19
♂	21–64	-	🎓	LMIC	1.34 (95% CI: 1.16, 1.55)	1.56 (95% CI: 1.42, 1.72)	1.28 (95% CI: 1.15, 1.42)
♂	21–64	-	🎓	HIC	2.62 (95% CI: 2.25, 3.06)	2.95 (95% CI: 2.65, 3.27)	2.76 (95% CI: 2.47, 3.08)
♂	21–64	-	🎓	SE	1.95 (95% CI: 1.86, 2.03)	2.01 (95% CI: 1.95, 2.07)	1.90 (95% CI: 1.84, 1.96)
♂	21–64	-	-	LMIC	1.55 (95% CI: 1.23, 1.96)	2.24 (95% CI: 1.96, 2.56)	2.01 (95% CI: 1.74, 2.32)
♂	21–64	-	-	HIC	5.76 (95% CI: 4.41, 7.52)	5.46 (95% CI: 4.49, 6.65)	4.81 (95% CI: 3.90, 5.93)
♂	21–64	-	-	SE	5.36 (95% CI: 4.98, 5.76)	5.51 (95% CI: 5.24, 5.79)	5.29 (95% CI: 5.02, 5.57)
♂	21–64	💍	🎓	LMIC	1.11 (95% CI: 0.95, 1.30)	1.73 (95% CI: 1.58, 1.89)	1.25 (95% CI: 1.12, 1.39)
♂	21–64	💍	🎓	HIC	2.22 (95% CI: 1.84, 2.68)	1.99 (95% CI: 1.73, 2.30)	1.78 (95% CI: 1.53, 2.07)
♂	21–64	💍	🎓	SE	1.38 (95% CI: 1.29, 1.49)	1.50 (95% CI: 1.43, 1.58)	1.44 (95% CI: 1.37, 1.51)
♂	21–64	💍	-	LMIC	1.34 (95% CI: 1.05, 1.72)	2.34 (95% CI: 2.04, 2.67)	1.70 (95% CI: 1.45, 1.99)
♂	21–64	💍	-	HIC	3.49 (95% CI: 2.20, 5.53)	2.91 (95% CI: 2.01, 4.21)	2.70 (95% CI: 1.84, 3.96)
♂	21–64	💍	-	SE	3.15 (95% CI: 2.71, 3.65)	3.10 (95% CI: 2.78, 3.46)	2.98 (95% CI: 2.67, 3.34)
♀	21–64	-	🎓	LMIC	0.78 (95% CI: 0.64, 0.96)	0.82 (95% CI: 0.72, 0.95)	0.76 (95% CI: 0.66, 0.88)
♀	21–64	-	🎓	HIC	1.44 (95% CI: 1.18, 1.77)	1.50 (95% CI: 1.30, 1.74)	1.40 (95% CI: 1.21, 1.63)
♀	21–64	-	🎓	SE	1.25 (95% CI: 1.18, 1.32)	1.20 (95% CI: 1.15, 1.25)	1.15 (95% CI: 1.11, 1.20)
♀	21–64	-	-	LMIC	1.58 (95% CI: 1.23, 2.03)	1.48 (95% CI: 1.24, 1.77)	1.31 (95% CI: 1.09, 1.59)
♀	21–64	-	-	HIC	3.64 (95% CI: 2.44, 5.44)	5.64 (95% CI: 4.48, 7.11)	5.64 (95% CI: 4.48, 7.11)
♀	21–64	-	-	SE	4.74 (95% CI: 4.28, 5.25)	4.42 (95% CI: 4.10, 4.76)	4.18 (95% CI: 3.88, 4.51)
♀	21–64	💍	🎓	LMIC	0.72 (95% CI: 0.60, 0.87)	0.61 (95% CI: 0.52, 0.70)	0.55 (95% CI: 0.48, 0.64)
♀	21–64	💍	🎓	HIC	1.31 (95% CI: 1.04, 1.65)	1.12 (95% CI: 0.94, 1.34)	1.08 (95% CI: 0.90, 1.30)
♀	21–64	💍	🎓	SE	1.24 (95% CI: 1.16, 1.33)	1.10 (95% CI: 1.04, 1.16)	1.05 (95% CI: 1.00, 1.11)
♀	21–64	💍	-	LMIC	0.76 (95% CI: 0.55, 1.05)	1.20 (95% CI: 1.00, 1.44)	1.00 (95% CI: 0.82, 1.22)
♀	21–64	💍	-	HIC	3.83 (95% CI: 2.35, 6.26)	2.36 (95% CI: 1.49, 3.75)	2.10 (95% CI: 1.29, 3.43)
♀	21–64	💍	-	SE	2.84 (95% CI: 2.32, 3.48)	3.03 (95% CI: 2.62, 3.50)	2.80 (95% CI: 2.41, 3.25)
♂	65+	-	🎓	LMIC	25.56 (95% CI: 22.35, 29.23)	32.89 (95% CI: 30.42, 35.57)	25.64 (95% CI: 23.47, 28.02)
♂	65+	-	🎓	HIC	48.18 (95% CI: 44.81, 51.81)	55.72 (95% CI: 53.22, 58.33)	45.37 (95% CI: 43.12, 47.73)
♂	65+	-	🎓	SE	47.02 (95% CI: 45.96, 48.11)	50.10 (95% CI: 49.36, 50.86)	42.90 (95% CI: 42.21, 43.60)
♂	65+	-	-	LMIC	42.87 (95% CI: 36.15, 50.85)	50.45 (95% CI: 45.45, 56.01)	36.98 (95% CI: 32.73, 41.78)
♂	65+	-	-	HIC	73.06 (95% CI: 67.18, 79.45)	79.80 (95% CI: 75.53, 84.31)	64.97 (95% CI: 61.13, 69.05)
♂	65+	-	-	SE	75.31 (95% CI: 73.52, 77.15)	79.05 (95% CI: 77.79, 80.34)	68.36 (95% CI: 67.18, 69.55)
♂	65+	💍	🎓	LMIC	19.46 (95% CI: 17.39, 21.79)	27.55 (95% CI: 25.86, 29.35)	20.01 (95% CI: 18.58, 21.56)
♂	65+	💍	🎓	HIC	32.02 (95% CI: 29.73, 34.48)	33.95 (95% CI: 32.30, 35.69)	27.82 (95% CI: 26.33, 29.40)
♂	65+	💍	🎓	SE	26.09 (95% CI: 25.50, 26.70)	28.62 (95% CI: 28.19, 29.05)	24.68 (95% CI: 24.28, 25.09)
♂	65+	💍	-	LMIC	28.69 (95% CI: 24.90, 33.07)	41.94 (95% CI: 38.75, 45.40)	27.28 (95% CI: 24.72, 30.09)
♂	65+	💍	-	HIC	42.83 (95% CI: 38.72, 47.36)	51.28 (95% CI: 48.08, 54.69)	41.42 (95% CI: 38.55, 44.50)
♂	65+	💍	-	SE	43.68 (95% CI: 42.48, 44.91)	47.97 (95% CI: 47.08, 48.87)	42.30 (95% CI: 41.47, 43.15)
♀	65+	-	🎓	LMIC	17.79 (95% CI: 15.26, 20.75)	19.48 (95% CI: 17.68, 21.46)	15.87 (95% CI: 14.25, 17.66)
♀	65+	-	🎓	HIC	39.31 (95% CI: 37.14, 41.61)	44.79 (95% CI: 43.19, 46.44)	37.67 (95% CI: 36.21, 39.19)
♀	65+	-	🎓	SE	40.67 (95% CI: 39.90, 41.45)	42.85 (95% CI: 42.31, 43.40)	37.20 (95% CI: 36.70, 37.71)
♀	65+	-	-	LMIC	35.33 (95% CI: 31.37, 39.80)	37.00 (95% CI: 34.22, 40.00)	29.39 (95% CI: 26.92, 32.07)
♀	65+	-	-	HIC	76.18 (95% CI: 71.92, 80.69)	80.77 (95% CI: 77.71, 83.95)	67.36 (95% CI: 64.58, 70.27)
♀	65+	-	-	SE	91.15 (95% CI: 89.50, 92.83)	93.32 (95% CI: 92.16, 94.49)	81.53 (95% CI: 80.45, 82.63)
♀	65+	💍	🎓	LMIC	8.48 (95% CI: 6.67, 10.80)	10.36 (95% CI: 8.96, 11.98)	8.54 (95% CI: 7.27, 10.02)
♀	65+	💍	🎓	HIC	14.89 (95% CI: 13.36, 16.60)	18.63 (95% CI: 17.42, 19.93)	16.40 (95% CI: 15.27, 17.62)
♀	65+	💍	🎓	SE	13.98 (95% CI: 13.53, 14.44)	15.26 (95% CI: 14.94, 15.60)	13.89 (95% CI: 13.58, 14.21)
♀	65+	💍	-	LMIC	17.48 (95% CI: 14.48, 21.09)	21.25 (95% CI: 18.93, 23.85)	16.82 (95% CI: 14.78, 19.16)
♀	65+	💍	-	HIC	27.13 (95% CI: 23.86, 30.84)	32.38 (95% CI: 29.79, 35.20)	27.34 (95% CI: 24.96, 29.93)
♀	65+	💍	-	SE	27.56 (95% CI: 26.45, 28.72)	31.15 (95% CI: 30.31, 32.03)	27.82 (95% CI: 27.02, 28.64)

Note: - refers to non-married / primary education; LMIC = low and middle-income countries, HIC = high-income countries; SE = born in Sweden.