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Abstract

The number of confirmed COVID-19 deaths differed across countries for several reasons, including the timing and pathways of the spread of the virus and societies' responses to it. Patterns also differed between regions and groups within countries. 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. In contrast to the idea that the pandemic primarily hastened inevitable deaths, our results show that many of those who died in 2020 would not have done so in this year without the occurrence of the pandemic. We also find indication of underreporting of COVID-19 mortality, mainly during the first part of 2020 when widespread testing had not yet been implemented. This pattern is most pertinent for individuals with a migrant background. We also found groups for which mortality decreased substantially during the pandemic, even when accounting for COVID-19 mortality. Progression across the first and second waves of the pandemic during 2020 shows that more groups appeared to have become protected over time and that there was less replacement mortality and under-reporting of COVID-19 deaths towards the end of 2020.

Keywords: Sweden, COVID-19, Excess mortality, Underreporting, Demographic profiles

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Introduction

Since the beginning of the COVID-19 pandemic, there has been a concerted international effort to make daily counts of cases and deaths associated with COVID-19 available (Dong, Du, and Gardner 2020; Karlinsky and Kobak 2021). Thanks to this impressive initiative, most of the empirical evidence produced regarding differences in COVID-19 mortality across space, time, and population subgroups has been based upon deaths related specifically to COVID-19. This evidence has directly informed national public health policies. Nevertheless, assessments of the coverage and quality of national statistics have shown that case numbers and deaths are often extensively underreported (Biswas, Afiaz, and Huq 2020; Karlinsky and Kobak 2021; Kupek 2021; Lau et al. 2021; X. Li et al. 2020; Y. Li, Fang, and He 2020; Riffe et al. 2021; Vestergaard et al. 2020). Particularly in the first phase of the pandemic, underreporting was related to strategies for – and the availability of – testing (Karanikolos and McKee 2020; Spiegelhalter 2020). Some countries reported only deaths that occurred in hospitals, some countries only reported deaths following a PCR-confirmed infection with COVID-19; others also included suspected COVID-19 deaths (Riffe et al. 2021).

The impact of COVID-19 on death rates can be measured not only through cause of deaths related to COVID-19 specifically 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 upon recent trends. This excess mortality approach has been used historically to estimate effects of various pandemics (e.g., the Great Plague [epidemic] of London in 1665 (Boka and Wainer 2020) and the influenza pandemics of 1918, 1957, 1968, 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 2016 (Milken Institute 2018). In the current pandemic, mounting evidence has confirmed the presence of excess mortality around the world (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, Chapman, Sabo, Weinberger, and Hill 2020; Woolf, Chapman, Sabo, Weinberger, Hill, et al. 2020).

Excess death rates reflect all changes in death counts, including deaths unrelated to the pandemic and deaths that may be related *to*, but were not caused directly *by*, the virus (Kaczorowski and Del Grande 2021). For example, the over-burdening of national health systems may have affected their efficiency and capacity to function normally, indirectly increasing deaths from other causes (Dinmohamed et al. 2020; Folino et al. 2020; Schwarz et al. 2020; Zubiri et al. 2021). In addition, people in need of medical attention may have actively avoided the health system, and remained untreated, due to fear of catching the virus (Kaczorowski and Del Grande 2021). Excess mortality therefore additionally includes mortality that can be considered "collateral damage" from the pandemic.

Analysis of excess mortality has the potential to address important questions that have arisen during the course of the pandemic. Given that the pandemic affected vulnerable populations already at a high risk of death (i.e., "dry tinder") the most, it may be the case that the main impact was a shift in the timing of deaths that would have been inevitable in the very near future anyway (Herby 2020; Rizzi, Søgaard, and Vaupel 2022; SCB 2020). This somewhat more optimistic scenario could obscure the real cost of the pandemic, if it is unfounded. It may also be the case that non-pharmaceutical interventions such as working from home protected certain population subgroups from hospital admission and mortality more broadly than just due to COVID-19 (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, strict recommendations or lockdowns are likely to lead to fewer road accidents (especially for men age 15-44) and less spread of influenza (among elderly). These changes to long established patterns of cause-specific mortality (Remund, Camarda, and Riffe 2018) will affect the estimation of excess mortality during the pandemic, which confounds the effect of the pandemic on societal, economic, or behavioral changes with the effect of COVID-19 infection.

We examine expected mortality, negative or positive, both with and without COVID-19 deaths and compare all-cause mortality and cause-specific mortality between 2020 and 2019 to establish the extent of underestimated COVID-19 mortality. We argue that this approach also allows us to capture collateral damage from the pandemic.

In addition, we explore whether specific socio-demographic groups display different patterns of excess mortality. We already know that individuals with certain vulnerable characteristics bear a disproportionate burden of the disease (Rizzi, Søgaard, et al. 2022; Varkey, Kandpal, and Neelsen 2022) and that COVID-19 mortality is associated with specific demographic characteristics (Drefahl et al. 2020; Williamson et al. 2020), the prevalence of comorbidities (Williamson et al. 2020), and different environmental factors (Davies et al. 2021; Konstantinoudis et al. 2021; Riou et al. 2021). A few studies *have* looked at disaggregated trends by sex, age, and localized temporal trends 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, et al. 2022; Scortichini et al. 2021). Andersson et al. (2021) explored how age intersected with gender, education, and country of birth in Swedish excess mortality rates. However, studies have yet to assess general trends in excess mortality by detailed socio-demographic profiles. This is important because each individual is a combination of multiple characteristics that may compound health advantages or disadvantages. Our study goes beyond this body of research by exploring the intersection of multiple dimensions that are related to mortality (generally) and COVID-19 mortality (specifically). We document excess mortality in Sweden across population subgroups, using detailed combinations of their educational attainment level, country of birth, marital status and place of residence. Additionally, we compare the first and second pandemic waves in Sweden to ascertain whether there is any indication for COVID-19 deaths in the first wave anticipating potential deaths of spring 2020 or a decrease of underreporting once testing become widely available.

We organize granular population subgroups to identify groups in the population that 1) would have likely died even without the COVID-19 pandemic, 2) had higher under-estimation of COVID-19 mortality than others, and 3) were the most protected in terms of mortality by protective measures or greater health advantage during the pandemic. Our comparative approach across time also allows us to assess whether patterns of under-estimation and protection changed over the course of the pandemic.

Sweden provides the possibility of such an analysis due to the high quality of its population registers, including the distinction between mortality from COVID-19 and other causes. It 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 to live with the virus during a period that was expected to last for more than just a few months.

Previous studies

Prior research that used publicly available all-cause mortality data to perform international comparisons of mortality during the pandemic (February 2020- to today) with mortality in previous years documented some excess mortality (Islam et al. 2020; Konstantinoudis et al. 2022; Kontis et al. 2020; Sanmarchi et al. 2021; Wang et al. 2022). Most studies looked at the general trend and focused more on the minutiae of the methodological aspects (Nepomuceno et al. 2022; Sanmarchi et al. 2021). However, several studies have examined excess mortality at the national/regional level and attempted to look more in detail at the effect of different socio-demographic profiles. Among the first, Blangiardo et al. (2020) presented a comprehensive analysis of the spatio-temporal differences in excess mortality during the COVID-19 pandemic in Italy by sex and adjusting for age, localized temporal trends and the effect of temperature. They predicted all-cause weekly deaths and mortality rates at the municipality level in 2016-2019 and 2020 based upon the modelled spatio-temporal trends. They showed that Lombardia had higher mortality rates than expected from the end of February, with 23,946 (23,013 to 24,786) total excess deaths. This excess was, at the peak of the pandemic, particularly high for males in the city of Bergamo. Consistent with this study, in (North) Italy, Ghislandi et al. (2020) show a substantial number of excess deaths in the older age groups, providing empirical evidence that COVID-19 is especially lethal for older populations. Similar results were also found in Germany (Stang et al. 2020). Similarly, Modig et al. (2021), in Sweden, documented excess mortality among men (75%) and women (50%) above age 60 during weeks 10-16 in 2020 when compared to the same weeks in the previous 5-year period. Several papers discuss how sex differentials in COVID-19 mortality vary markedly by age (The Lancet 2020). In a systematic review of the Italian case, Rizzi et al. (2022), confirmed that males up to 75 years old have been experiencing more excess death compared to females. The results, however, are less clear at older ages. In line with this discussion, Krieger et al. (2020), estimated that, despite the absolute difference in mortality rates being larger for men, old women and men in Massachusetts experienced virtually identical relative increases in mortality from COVID-19 deaths.

Kolk et al. (2022), as well, reported that Sweden has experienced excess mortality in some age groups, but not others. For example, men experienced excess mortality at ages 0-19 and 50+, and women at ages 60+ compared to forecasted mortality for 2020. Simultaneously, mortality among men aged 20-49 was lower than expected. Over the course of the calendar year, higher mortality than expected could be found in April to June and November to December, consistent with the onset of different waves of COVID-19. Yet, for individuals younger than 64-years, mortality from August to December was also lower than expected. Finally, whereas some counties (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.

There is some indication that area-level measures of socioeconomic deprivation and a higher proportion of young people are associated with higher excess mortality in Sweden (Calderón-Larrañaga et al. 2020), as well as the population living in care or nursing homes (Modig et al. 2021). Davies et al. (2021) look at a set of community-level variables at the small-area level to estimate excess mortality during March–May 2020 in England. They found excess mortality in communities with a high density of care homes, and/or a high proportion of residents on income support, living in overcrowded homes and/or with a non-white ethnicity. Similarly, Stokes et al. (2021) have documented how excess mortality in 2020 has differed across socio-demographic or health factors in the United States. These last two studies that add different socio-demographic dimensions in understanding excess mortality used an ecological approach by focusing on counties/local communities and not individuals.

The main point of this summary, which is not exhaustive, is that most of these studies look at general trends. In the best scenarios these trends are disaggregated as a single dimension by sex, age, localized temporal trends, and the effect of temperature, or the interaction of age and sex. In a notable exception in the case of Sweden, Andersson et al. (2021) look at the combination of four broad age ranges in combination with (one by one) the following variables: gender, educational level, and country of birth. They confirm that age is the single most important factor by which excess mortality varied. However, another factor that had a major impact on the degree of excess mortality was country of birth, which is a finding that fits the patterns observed in Swedish COVID-19 mortality research (Aradhya et al. 2021; Brandén et al. 2020; Drefahl et al. 2020; Rostila et al. 2021).

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 stems from the Longitudinal Integrated Database for Health Insurance and Labour Market Studies (LISA). For analyses of 2019, demographic variables are measured at the end of 2018, 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 available in the data.

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 from other causes in 2020.

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. Correspondingly, our study population for the analyses of 2019 consists of all individuals aged 21 and above on March 12th, 2019.

Despite excess mortality being one of the most reliable methods to study the impact of COVID-19 mortality (Beaney et al. 2020), debate has taken place regarding the choice of reference period for mortality when studying excess mortality from COVID-19. Nepomuceno et al. (2022) concludes 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 choice of reference period should be long enough to allow for the best possible estimate for answering the question of what mortality conditions would have been in 2020 if there would not have been the COVID-19 pandemic. Life expectancy in 2019 was observed to be 84.72 years for women and 81.33 years for men. In the beginning of 2020 Statistics Sweden published their forecast for the life expectancy for 2020 and projected 84.8 for women and 81.4 for men. Our interpretation is that the observed values of life expectancy in 2019 are almost identical to what we would have expected to observe for 2020 in the absence of the COVID-19 pandemic in the Swedish case. A similar approach was used by Kolk et al. (2022).

The study populations are used to calculate exact exposures in person-years for 2019 and 2020 separately. Then, three sets of incidence rates are 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

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

- **Sex** – Female **vs.** Male
- **Age** – Retirement ages (65+) **vs.** Working ages (21-65)
- **Marital Status** – Married **vs.** Unmarried
- **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 (N=161,287) and present results only for groups with 10 or more recorded deaths in 2020[1]. This produces forty-seven possible combinations. For example, we produce and compared incidence rates in 2019 and 2020 for primary educated, married women aged 65+ who were born in Sweden.

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

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 socio-demographic profiles. Groups appear in a specific figure on the basis of the following selection criteria: Figure 1 shows groups that did not have excess mortality in 2020; Figure 2 shows groups that had excess mortality overall, but lower mortality when excluding COVID-19 deaths; and Figure 3 shows groups that had excess

[1] Our total population consist in 7,634,627 individuals in 2019 and 7,720,515 in 2020.

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.

Figure 1 shows those population subgroups that continued to make mortality improvements in 2020 (all-year[2]) compared to 2019. The sum of the orange and purple bar represents the relative decrease in mortality in percent if COVID-19 deaths in 2020 were excluded from the relevant calculation. The purple bar alone represents the relative mortality decrease in percent including also all deaths from COVID-19 in 2020. Consequently, the orange bar represents the share of deaths in each group that is due to COVID-19. 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 number of deaths.

Those 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 socio-demographic pattern otherwise is less clear. It is worth noting that individuals from all country of birth groups are represented as well as educational levels. The group that experienced the highest relative decrease in mortality during 2020 (i.e., the most "protected") were married, working-age women from HIC with a higher educational level.

Replacement mortality would be evident, one might argue, by a share of decline in non-Covid mortality that is similar to the share of Covid mortality. Graphically, this scenario would appear with an orange bar that is substantially longer than the purple bar, with stronger replacement showing up with a smaller purple bar and indicating that the overall decline in mortality was small when including Covid mortality. For the most part, those who had lower mortality in 2020 than 2019 experienced low incidence of COVID-19 mortality. In a few groups, however, a substantial portion of offset mortality (purple) was replaced by COVID-19 mortality. In particular, men from HIC and women from LMIC who were primary educated, working age, and unmarried share this pattern. But replacement remained only partial.

If we look at differences across the waves (see Appendix A1), we see fewer profiles fall into the category of decreased mortality in the first wave of the pandemic. But the same set of characteristics appear here, suggesting that the overall pattern in 2020 is driven primarily by the one set during the first wave of deaths. However, the numbers and the diversity in profiles increased dramatically in the second wave. This set of profiles includes more men and individuals over the age of 65. Replacement mortality appeared as a possibility for men and women from HIC, including Sweden, that were pension age.

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 in general, or who benefited more from national pandemic recommendations, such as working from home. We additionally interpret some groups as showing signs of replacement mortality, whereby some deaths did not occur that usually would have and they died from COVID-19 instead. The size of the orange bar could be said to indicate the death of individuals who would have most likely died in 2020 without the pandemic occurring.

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

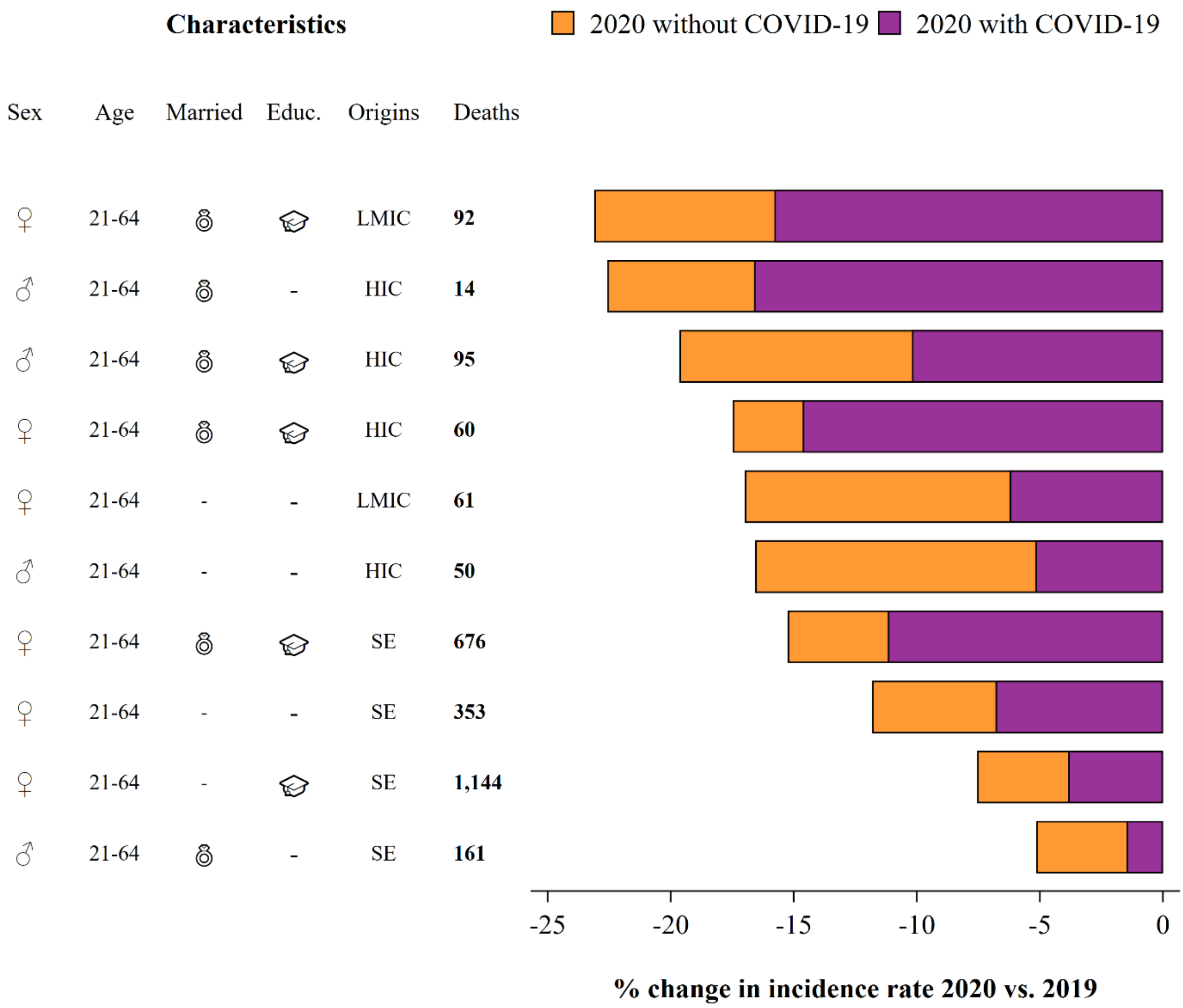

Figure 1: Mortality improvement in 2020 compared to 2019 when includingCOVID-19 mortality (purple bar) and when excluding COVID-19 mortality (orange bar)- 2020 all year
Note: Sec. - refers to primary education; LMIC = low and middle-income countries, HIC = high-income countries; SE = born in Sweden.

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. The most common pattern in 2020 is represented here, comprising 68,260 deaths in total (89.1% of all deaths). The smallest group only includes 92 deaths, the largest group 12,368 deaths. This pattern is what we might call the default scenario, because we would expect that those who are at risk of mortality in this period to be most vulnerable to COVID-19. As in Figure 1, this figure also shows the groups for which there may be some element of replacement mortality in 2020, meaning some deaths here would have occurred without the pandemic but due to different causes.

We present a mirrored image of decline and increase in 2020 mortality compared to 2019. On the left side of the x-axis (orange bar) is the relative decrease in mortality in percent if we exclude COVID-19 mortality. On the right side (purple) is the percent increase in mortality if we do not exclude COVID-19 mortality. The purple bar represents excess mortality in 2020 in percent as compared to 2019. The sum of the purple and orange bar represents the total impact of COVID-19 deaths on the group-specific mortality. If we assume expected mortality in 2020 to be similar to the levels of 2019, the orange bar can be indicative of mortality replacement, suggesting that this is the share of all deaths that would have been taken place even without the COVID-19 pandemic but that were recorded as COVID-19 deaths.

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 unmarried 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 age men who were married, had a low education level and were born in LMIC.

We would expect to see a substantive orange bar with a negligible purple bar if COVID-19 mortality could be said to have caused the death of individuals who would have most likely died in 2020 without the pandemic occurring. The profile that comes closest to fitting this scenario is at the bottom of the figure: pension age women that are single, have a low educational level and were Swedish-born.

The general pattern is again reflected in the first wave (See Appendix A2) but not in the second; the excess mortality in the second wave was driven as well by elderly male migrants (in particular from HIC). Instead of seeing increased diversity in the profiles sharing the pattern in the second wave, such as we saw in relation to Figure 1, we instead see a lessening of diversity here. In other words, fewer groups in the second wave experienced excess mortality with some sign of replacement than in the first wave. This is what we would expect to see if the frailest individuals were most vulnerable to COVID-19.

Characteristics

Sex	Age	Married	Educ.	Origins	Deaths
♂	65+	💍	-	LMIC	**306**
♀	65+	💍	-	LMIC	**144**
♂	65+	💍	-	HIC	**463**
♂	65+	-	-	LMIC	**176**
♂	21-64	-	🎓	LMIC	**208**
♂	65+	-	🎓	HIC	**915**
♀	65+	-	🎓	HIC	**1,461**
♂	65+	💍	-	SE	**5,545**
♂	65+	💍	🎓	SE	**8,363**
♀	65+	-	🎓	LMIC	**205**
♂	65+	-	-	HIC	**635**
♀	65+	💍	🎓	SE	**4,133**
♀	21-64	💍	-	SE	**93**
♂	65+	-	🎓	SE	**8,582**
♂	65+	💍	🎓	HIC	**770**
♀	65+	-	-	HIC	**1,289**
♀	21-64	-	🎓	LMIC	**100**
♀	65+	-	🎓	SE	**11,922**
♂	65+	-	-	SE	**7,391**
♀	65+	-	-	LMIC	**316**
♀	21-64	-	🎓	HIC	**92**
♂	21-64	-	🎓	SE	**2,024**
♂	21-64	-	-	SE	**759**
♀	65+	-	-	SE	**12,368**

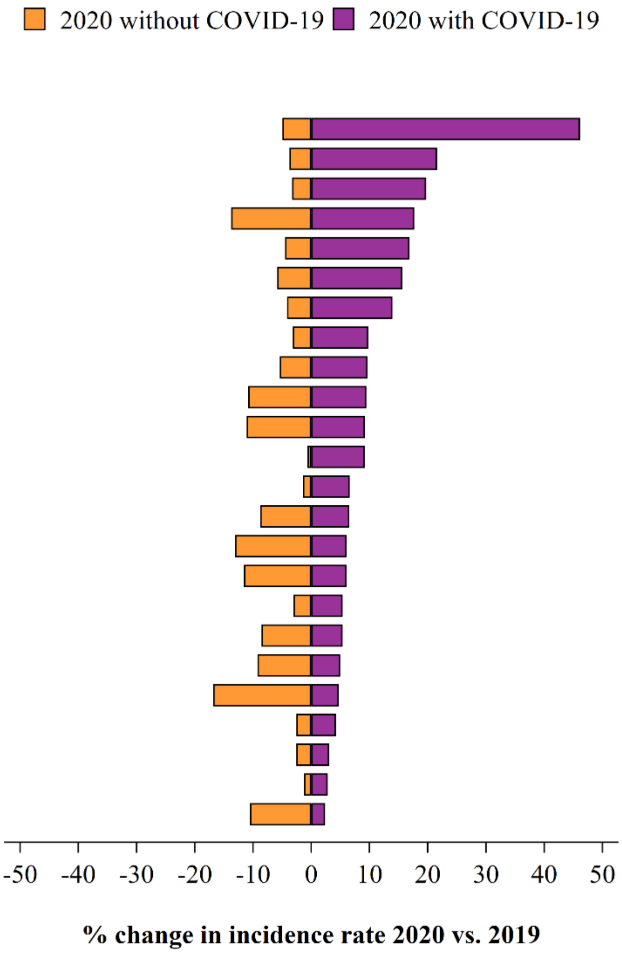

Figure 2: Excess risk of dying in 2020 as compared to 2019 with COVID-19 mortality (purple bar) and without COVID-19 mortality (orange bar) - 2020 all year
Note: Sec. - refers to primary education; LMIC = low and middle-income countries, HIC = high-income countries; SE = born in Sweden.

Figure 3 shows all groups with excess mortality in 2020 with and without COVID-19. The pattern appearing here either indicates underreporting of COVID-19 mortality or indirect effects of the COVID-19 pandemic on other causes of death, or a mixture of both. The sum of the orange and purple bars gives the total excess mortality in percent in 2020. The purple bar gives the excess mortality that is due to COVID-19 deaths. The orange bar represents the excess due to all other causes of deaths, meaning that deaths to other causes were also higher than in 2019 and those groups would have experienced excess mortality even without including COVID-19 deaths. The groups experiencing this pattern are heterogeneous and so are the effect sizes in terms of excess mortality. In total, these groups comprise 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. But the profile that experienced the largest relative amount of under-reporting or indirect COVID-19 deaths was working-age women who were unmarried, low educated, and born in LMIC.

Separating the first and second COVID-19 wave in Sweden, we found a more equal distribution of groups according to country of birth that experienced under-reporting or indirect deaths in the first wave of the pandemic. But by the second wave, the picture changed dramatically and only foreign-born groups experienced excess mortality with and without including COVID-19 deaths. This indicates continued underreporting of COVID-19 deaths or indirect effects of the COVID-19 pandemic on other causes of death for these groups, particularly those born in LMIC. No Sweden-born group continued to experience this in the second half of 2020 (see Appendix Figure A3).

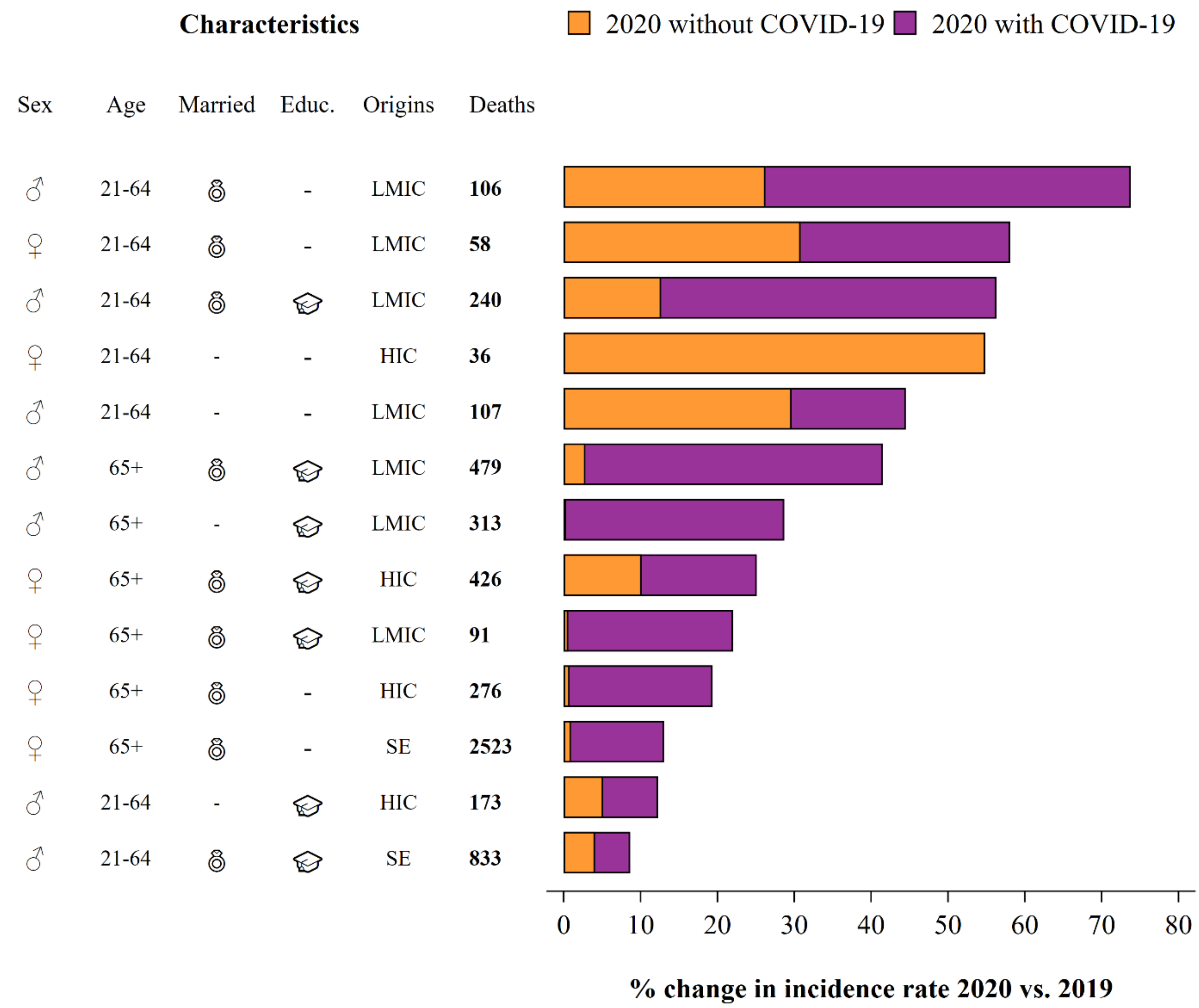

Figure 3: Excess risk of dying in 2020 as compared to 2019 with COVID-19 mortality (purple bar) and without COVID-19 mortality (orange bar) - 2020 all year
Note: Sec. - refers to primary education; LMIC = low and middle-income countries, HIC = high-income countries; SE = born in Sweden.

Lastly, in Figure 4 and 5 we explore relative changes in mortality observed in Figures 1-3 translate into changes in the absolute risk of dying. These figures therefore show us the magnitude of changes, which of the groups were driving the overall excess in Sweden, and whether these changes impact the sociodemographic inequalities observed before the COVID-19 pandemic. Groups are organized so that all shared characteristics are differentiated only 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 deaths in 2020, with the mortality observed in 2019. The main take-away is that the mortality among Swedes and immigrants from high-income countries tend to be similar both before and during the COVID-19 pandemic. However, for some of the profiles this means that the gap between migrants (in particular from LMIC) and natives in terms of mortality was reduced in 2020. For example, at the top of the figure, it is apparent that 2020 absolute rates are more similar for women from Sweden, HIC and LMIC than in 2019. Comparing to figure 3, Figure 4 shows that the large relative changes are happening in the context of low levels of absolute mortality.

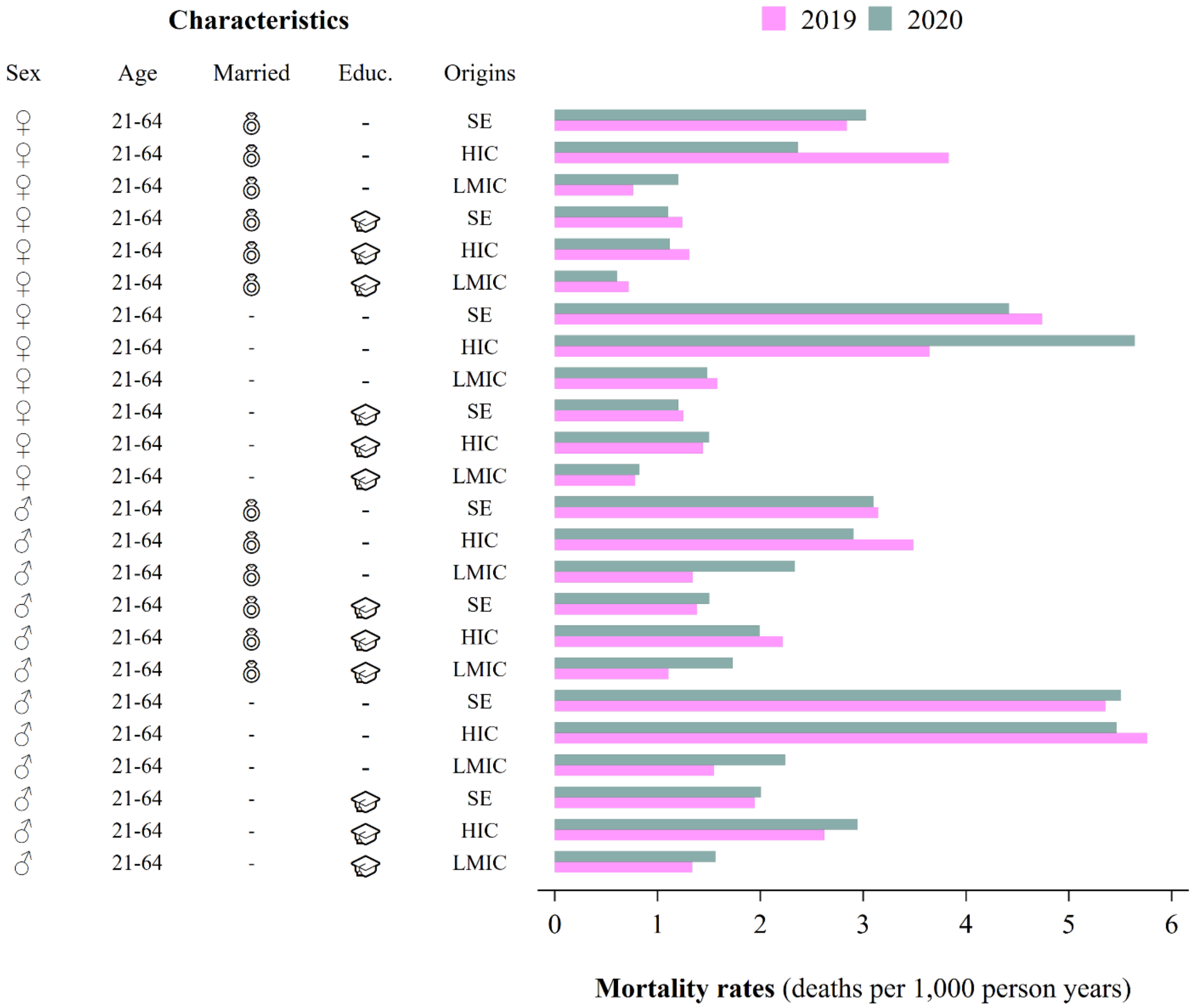

Figure 4: Absolute risk of dying in 2019 and 2020 ages 21-65
Note: Sec. - refers to primary education; LMIC = low and middle-income countries, HIC = high-income countries; SE = born in Sweden.

Figure 5 shows the same results for the population in retirement ages (65+). This figure confirms the higher mortality across almost the entire group in 2020 compared to 2019, when looking at all causes of deaths. In 2020, we observed stronger relative increases in mortality among migrant groups than among natives. For most profiles, however, we still observe high absolute mortality for those from high-income countries as compared to the natives. For those from low- and middle-income countries, we continue to observe an overall mortality advantage also in 2020, which reflects the usual healthy migrant effect (Wallace and Wilson 2019).

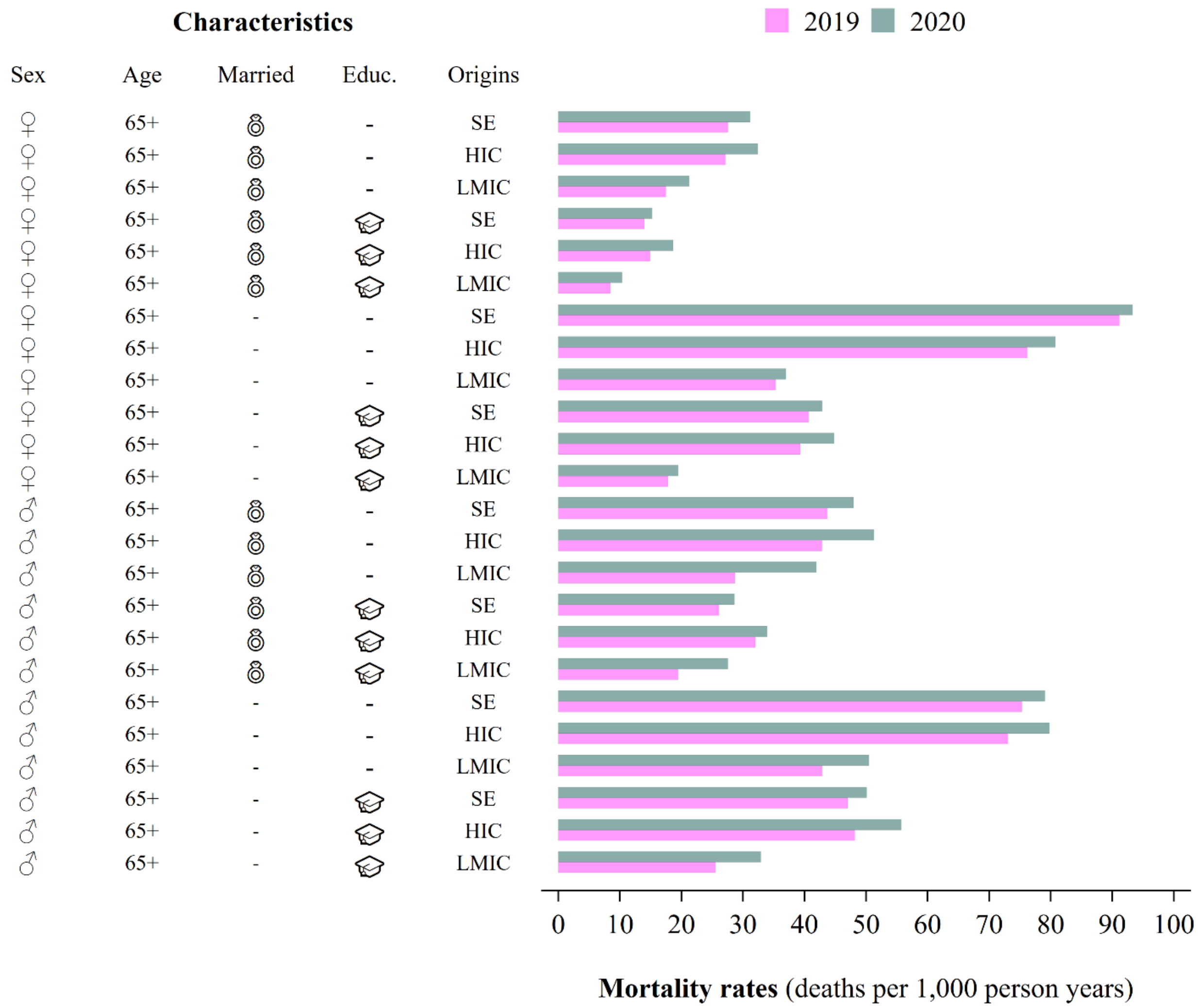

Figure 5: Absolute risk of dying in 2019 and 2020 ages 65+
Note: Sec. - refers to primary education; LMIC = low and middle-income countries, HIC = high-income countries; SE = born in Sweden.

Discussion

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

To assess the entire burden associated with COVID-19, excess mortality has therefore been suggested as an important alternative to COVID-19 death rates (Karlinsky and Kobak 2021). Previous studies have shown that excess mortality, estimated as a difference in the current mortality trend from previous years, has not been uniformly distributed across the population

(Andersson et al. 2021). Cause-specific mortality data are essential to gain a better understanding of the burden associated with COVID-19 mortality. This study aimed to estimate excess mortality in Sweden, broken down by different population subgroups on the basis of age, sex, country of birth, marital status, and education, comparing previous mortality rates (2019) with those during the pandemic (2020), with and without including officially recorded COVID19 deaths. More precisely, we have used the Swedish population registers that include cause of death in 2020, including COVID-19 related mortality events. We estimated excess mortality both with and without COVID-19 deaths and compared all-cause mortality and cause-specific mortality with the same period in 2019. In this way, we should be able to estimate the real extent to which the COVID-19 epidemic increased mortality and quantify the amount of underestimation of COVID-19 mortality for specific groups.

Excess mortality varied across a variety of socio-demographic characteristics, and was not restricted to the oldest and/or foreign-born. We observed groups for which the overall effect was a decline in death rates, other groups for which COVID-19 outpaced the effect of a decline in other causes of mortality, and groups for which both COVID-19 and other causes of death increased. This study supports previous research (e.g Stokes et al. 2021): many of those who died in 2020 would not have without the pandemic. In addition, we found that the share of COVID-19 deaths that would have occurred even without the pandemic varies considerably by socio-demographic group. The two main patterns we found were that 1) when there was a substantial portion of deaths that were avoided, these were usually replaced by very little COVID-19 mortality, and 2) overall excess mortality usually was accompanied by very little reduction, if at all, in other causes of mortality. Our results indicate strong underestimation / underreporting of COVID-19 mortality mainly among individuals with a migrant background, however we are not able to distinguish whether this was due to direct COVID-19 related deaths or collateral deaths due to pandemic conditions. In addition, the experience of high relative excess mortality for some migrant groups continued into the later COVID-19 wave.

Despite the high quality of the Swedish data, our study has a limitation: our socio-demographic information are 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 and education statuses more frequently. However, neither of these characteristics would be expected to change regularly, unlike other measures of SES such as income. Additionally, when looking at the absolute risks, we should keep in mind that the age profiles of immigrants according to LMIC and HIC might be different. With the HIC dominated by, e.g., Finnish (older migrant group with generally higher mortality) while LMIC dominated by, e.g., Syrians with a younger age structure and generally lower mortality. This difference, however, does not influence our findings related to relative changes.

The findings from this study contribute to the literature in multiple ways: First, our results show remarkable diversity in how the pandemic impacted death rates across socio-demographic groups, and not just in terms of the size of effects. Once again this study confirms the importance of age in estimating excess COVID-19 mortality, as well as the effect of the country of origin, civil status, and educational attainment (Drefahl et al. 2020; Rostila et al. 2021).

Second, we identified profiles according to combinations of characteristics that were particularly likely to be represented in the more unfavorable patterns and among groups with the greatest losses. Working age men and women from LMIC that were married and primary educated had the greatest relative excess mortality of all groups in comparison to 2019. The main pattern (89%) in the deaths observed in 2020 was reduced mortality due to other causes, but overall excess mortality that was driven by COVID-19. The profile most affected by this pattern was pension-aged, married men that were primary educated and born in LMIC. Less common (7%) was the pattern of under-reporting or collateral damage that was most prevalent for working-age women who were unmarried, low educated and born in LMIC. Reduced health-seeking behavior, an overburdened health care system, stress/anxiety due to catching the coronavirus, as well as a widowhood mortality effect from losing a spouse to COVID-19 are all potential indirect factors that could have inflated other causes of death and may be considered in a 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 still negative. These groups were all working age, primarily married women, and almost all born in high income countries (including Sweden). In particular, the group that benefited the most was highly educated, married women born in HIC. We interpret this to mean that these groups benefitted in a few different ways. They may have experienced less risk of infection due to the limited 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 wearing face masks or avoiding public spaces. The pandemic may have brought about general changes in daily living that could have particularly decreased these groups' exposure to risk, such as through driving less. However, the recommendations and lockdowns did not lead to fewer deaths for other causes e.g. road accidents and less spread of influensa, in the first wave in Sweden (Yasin, Grivna, and Abu-Zidan 2021), which is in line with results in other countries (e.g.US National Safety Council 2021). These groups also may have been at a lower risk of dying from an infection due to having overall better health and the long-term effects of a higher social status and better health behavior.

Our results provide evidence that COVID-19 mortality was underestimated or underreported in Sweden, a country that is generally regarded as having excellent data on its population. There was some indication already that, especially early in the pandemic, registration of COVID-19 related mortality was insufficient, leading to underestimation of deaths associated with COVID-19 (Mungmunpuntipantip and Wiwanitkit 2021; Rozenfeld et al. 2021; Salottolo et al. 2021).

Finally, disaggregated rates across waves 1 and 2 of the pandemic in Sweden provide some insight into the developments across time, when testing had become more widespread and the healthcare system had had more time to adjust to the new demands. Over time we found that more groups joined the "protected" pattern of mortality rates, by which we mean that they reached 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 the first: substantially fewer groups exhibited lower mortality rates from other cause at the same time that they had high enough COVID-19 mortality to generate net excess mortality. Even the small amount of replacement mortality we found, therefore, peaked in the first wave and declined in the second. And also as expected, we found less under-reporting of COVID-10 mortality in the second wave compared to the first. The improvements in testing capacity likely brought about great improvements in assigning cause of death correctly. We still found some groups with substantial excess mortality in the second wave that was not attributed to COVID-19, which points to the possibility of the pandemic indirectly increasing mortality. Why there is around a 50% increase in mortality for working age, unmarried, low educated men and women born in foreign countries in the second wave is an important public health question and may potentially give a more holistic picture of the pandemic effect. It remains for future research to uncover the mortality differentials that occurred in the last wave of the pandemic during 2021, as well as the possible long-term effects on all-cause and cause-specific mortality during the post-pandemic period.

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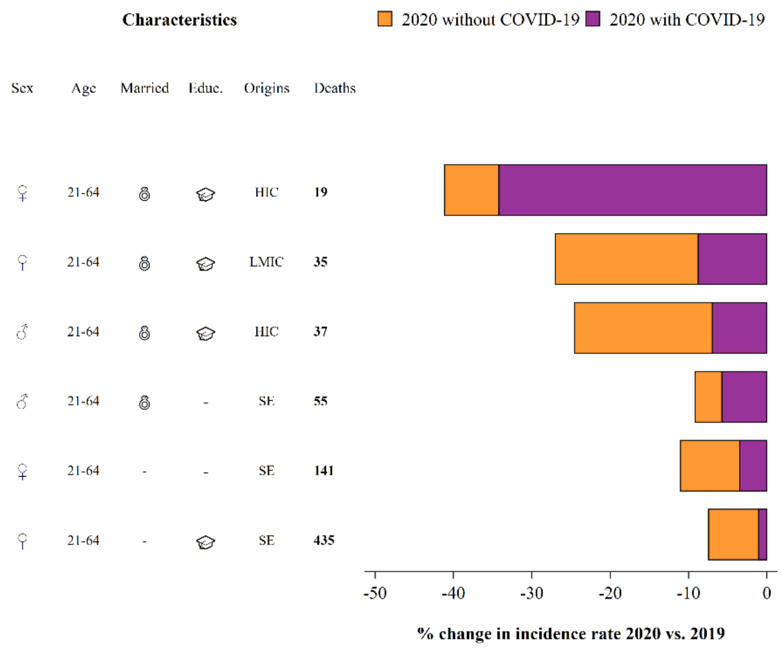
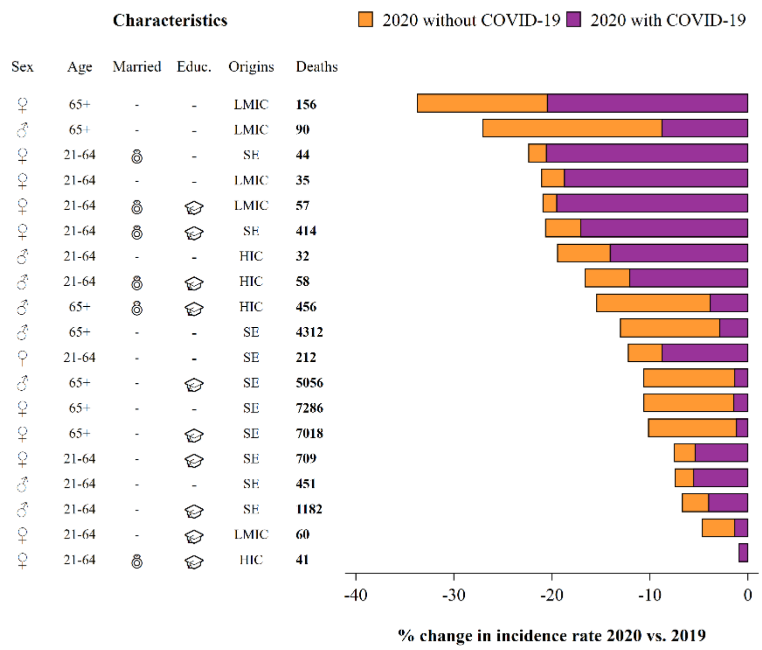
Figure A1: (Lack of) Excess risk of dying in 2020 as compared to 2019 with COVID-19 mortality (purple bar) and without COVID-19 mortality (orange bar)

A WAVE 1



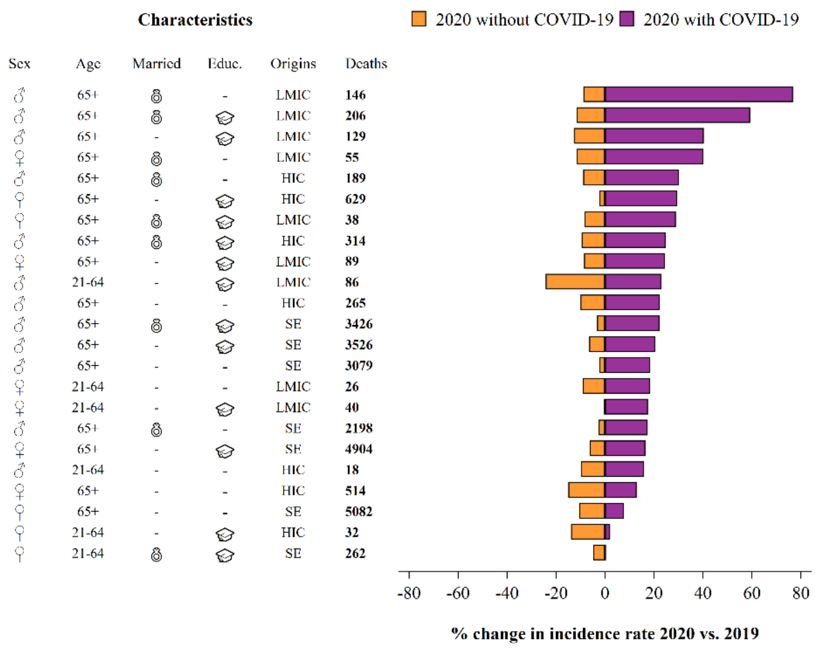
B WAVE 2



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

Figure A2: 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



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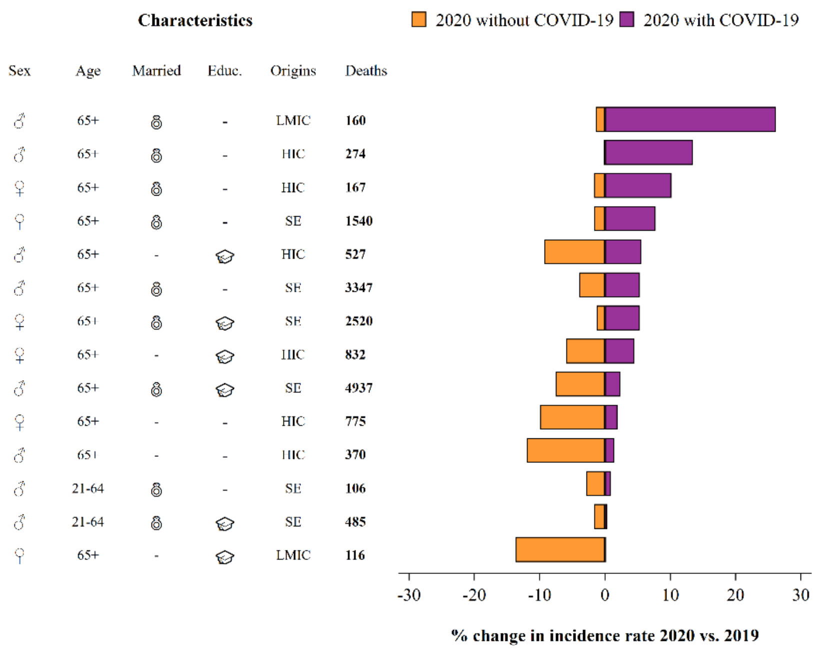
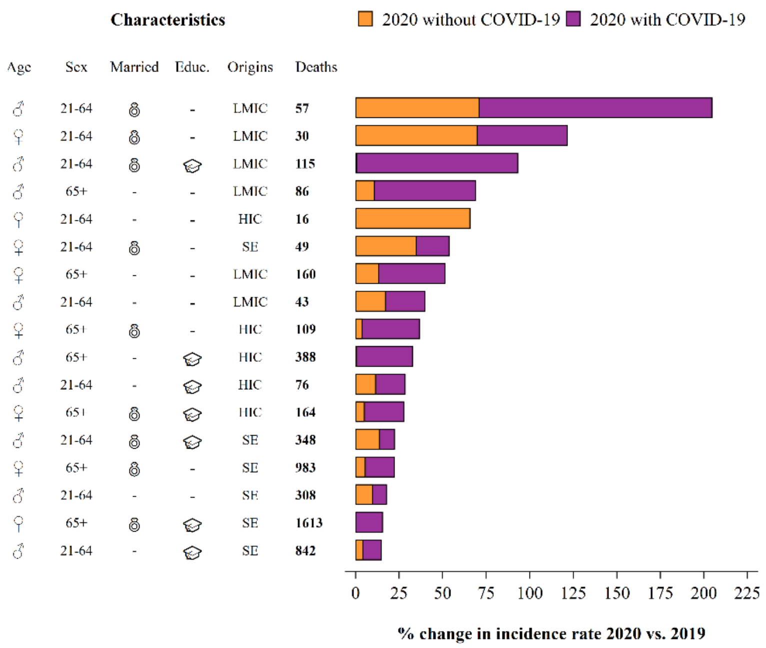


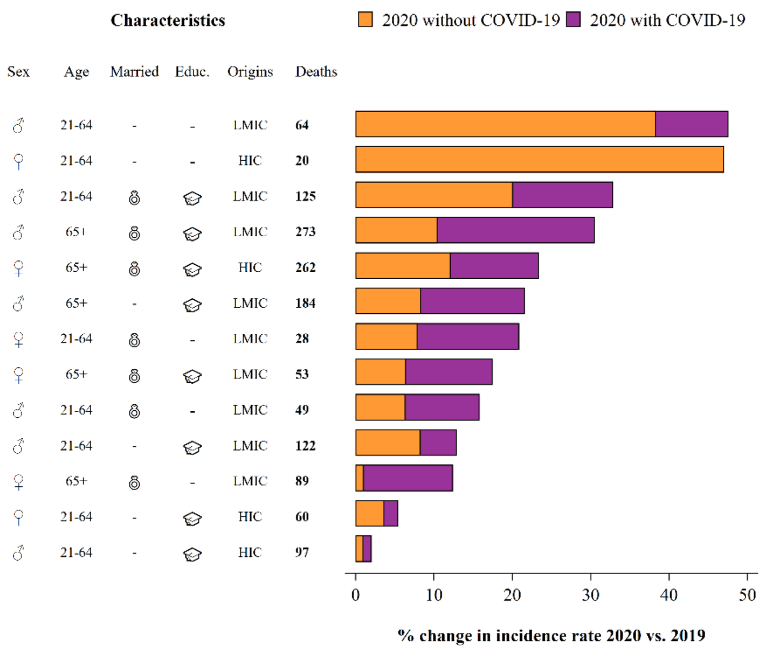
Note: Sec. - refers to primary education; LMIC = low and middle-income countries, HIC = high-income countries; SE = born in Sweden.

Figure A3: 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



B WAVE 2



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

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