Socio-economic characteristics impact on covid-19 mortality in region Västra Götaland.

Degree Project in 1 year Master programme in medical microbiology, with specialization in infection prevention and control, 15 hp

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Abstract

Background: There is a well establish association between low socio-economic status and health outcomes in general. To mitigate the impact of covid-19 there is a need to identify vulnerable groups, and to create methods that can do that in real-time as the virus-spread progress in the society.

Aim: To examine if there are differences in mortality between different DeSO-areas in Västra Götaland according to these areas socio-economic characteristics. The second aim was to examine if DeSO-areas can be used in surveillance purpose and which variables that are relevant in that case.

Materials and methods: Confirmed covid-19 case in region Västra Götaland between 26th February 2020 and 18th April 2021 was linked to different residential socio-economic characteristics (quintiles of income, low education, foreign born and categories of population density) based on Demographic Statistics Area (DeSO) data.

Results: Older age and male sex was associated with covid-19 mortality. Income-level was the only of the DeSO variables that remained significant through the fully adjusted model. Living in areas in the lowest income quintile was associated with increased covid-19 mortality (hazard ratio: 1.83; 95 CI 1,358 - 2,467) compared to those that lives in the area within the highest income quintile.

Conclusion: Living in a low-income area is associated with an increased risk of death in covid-19. This DeSo variable capture the socio-economic factors that is associated with covid-19 mortality on an aggregated level. The results are in accordance to other studies based on individual-level data suggesting that aggregated information from DeSO-areas are useful and relevant to identify vulnerable groups for covid-19. Linking cases to DeSO-data can give better keys to understand the progress of the virus-spread in the society.

Implications: To emphasize the importance that covid-19 vaccination and other protective measures like testing and contact tracing are accessible irrespective of barriers that comes with social inequalities and deprivation. The Swedish surveillance system for notifiable diseases should be linked to socio-economic data.

Introduction

Ever since the emerge of covid-19 pandemic the world has struggled to mitigate the impact of the virus. All these efforts are raising questions how to best protect the most vulnerable persons, as well as creating a better understanding of who is most at risk of death or severe disease, and how to identify those groups. There is also a need to understand the transmission dynamics in society and how these corresponds with the risk of severe disease. This contagion is a social one (1), and therefore important to see this dynamic in a social context (2). Covid-19 does not discriminate, we are all in this together, have been the message (3). The idea of covid-19 as the great equalizer have though been debatable in the light of the unequal burden of severe disease. Social inequalities have been associated with a higher risk of hospitalization and covid-19 related death both in Sweden and globally.

It is known that socio-economic position is an important factor that influence health outcomes in general. The theoretical framework is based on a complex interaction between what is called social determinants of health, i.e. the conditions in which people are born, grow, work, live and the wider social context that shapes the conditions of daily life. To understand the socio-economic differences in health there is a need to see the interaction between the individual and the society. The social determinants of health that can influence health in positive and negative ways are factors such as income, education, unemployment, working conditions and housing conditions. Social deprivation have been associated with increased risk of other respiratory infections (4), and several studies from other countries shows that socio-economic factors do have an impact on the risk of contracting the virus and the outcome of covid-19. A cross-sectional study among a primary care cohort showed that deprivation, population density and ethnicity were associated with testing positive for covid-19 during the first wave in the UK. This result corresponds to what has been seen among hospital-based studies, suggesting that the pandemic have hit some groups in society harder than others (5). Those areas that had the most intense spread during the first wave could theoretically get some protection according to the logic of herd-immunity, and thus be better off in the later waves as the virus evens out the initial differences. But that does not seems to be the case according to a study from Spain. The incidence of hospitalized patients of covid-19 were higher in low-income areas in the city of Barcelona. This pattern was even more obvious during the second wave (6). There are other patterns related to this that may be relevant. There have been observed a clear difference in mobility by neighbourhood socio-economic status in New Zeeland during the nationwide lockdown (7). And a report from Transport

analysis, a Swedish government agency, showed that people with higher income reduced their travel during the first wave, and those in the lowest income quartile did not had any significant change at all (8). This might be due to that people in deprived areas is in a larger amount involved in essential work, i.e. public transport workers and supermarket employees. A smaller economic marginal to withstand restrictions and closures might also play a role.

Several studies have revealed that social disparities are associated with a higher risk of covid-19 related death in Sweden. In Sweden there has been differences in excess mortality in the first wave in March-May 2020. Among persons born in Somalia, Syria and Iraq the all-cause-mortality was 220 % higher in the first wave compared to the mean of the in 2016-2019 (9). These observations were assumed to be correlated with structural factors such as overcrowding, working conditions and a lesser opportunity to practise physical distancing and work from home. High excess mortality in the first wave have also been observed in areas with a higher proportion of younger people and socially deprived neighbourhoods. This study highlights a possible role of neighbourhood contexts, implying that individual level socio-economic factors alone only represents one dimension of vulnerability. The socio-economic status of the neighbourhood may also be a contributing factor to or an indication of more severe outcome (10).

A register-based population cohort study that examined covid-19 deaths in Stockholm found that migrants from Middle East countries, Africa and Nordic countries had a higher risk of death compared to persons born in Swedish. However, when socio-economic factors were considered this attenuated the mortality risk substantially. These findings suggest a multifactorial correlation between socio-economic position and how this confines the possibility to practice physical distance, work from home et cetera, and a higher prevalence of underlying individual risk factors (11).

It is known that people at age 70 or older are overrepresented among covid-19 deaths, and amount to approximately 90 % of all covid-19 deaths in Sweden. One study investigates the association between covid-19 mortality and individual housing conditions and neighbourhood characteristics in Stockholm among adults 70 years and older. The study found that close exposure with someone in working-age in the household and in the neighbourhood was associated with a higher risk of covid-19 related death. Older adults that lived with only other older adults had a lower risk compared to those that lived in multigenerational households. Living in a care-home were also associated with increased mortality due to poor underlying health and probably through a higher exposure to visitors and care workers. There was also an

association between risk of death and neighbourhood characteristics like the incidence of covid-19 in the borough and population density (12).

Older age is also the most manifest risk factor for covid-19 hospitalization in Sweden. Male sex and at least one known comorbidity are also strongly associated with both hospitalization and need for intensive care. A nationwide register-based study that investigate several potential risk factors for being diagnosed with covid-19 and being admitted to hospital care found that also hypertension, asthma and Down syndrome were independently associated with severe covid-19. This study also found that a higher level of education was associated with being diagnosed but a lower risk of being hospitalised, thence the lowest education level were associated with a higher risk of severe covid-19 disease after concerning other factors. The same pattern did not remain significant for disposable income after adjustment for other risk factors (13).

All these studies seems to consolidate the association between socio-economic status and risk of covid-19 related death. To this date most of these studies in Sweden have been based on data from the Stockholm area. There might be a risk that those patterns that have been showed is not comparable to other regions in Sweden for several of reasons. First, Stockholm is a more population-dense area and at the same time more geographical widespread. Secondly, the spread of the virus during the first wave was more intense in Stockholm compared to other regions in Sweden, and the patterns that evinced are not necessarily analogous to other areas. Thirdly, Stockholm has more marked structural differences as the most deprived neighbourhoods have a longer distance to the city compared to Gothenburg and Malmö, hence those inmates are more dependent up on public transport according to a geographical analysis (14). Therefore its possible that most of the Swedish studies to this date rather reflect the situation in the Stockholm area, and consequently there might be a risk that patterns in other regions may diminish in the shadow of what has been derived from that specific context.

This study will focus on the county of Västra Götaland, the Swedish heartland which range over the second largest urban area in Sweden and a vast rural area as well.

The city of Gothenburg has significant disparities in living conditions and health between different neighbourhood areas, according to a survey commissioned by the city council. The difference in average life expectancy between different areas regarding to socio-economic factors is 7.5 years for woman and 9.1 years for men. It was also obvious that individual and neighbourhood socio-economic status were each associated with self-experienced health in

Gothenburg. The survey also showed that higher neighbourhood socio-economic status was associated with a better self-experienced health than for those with lower individual socio-economic status and vice versa (15). This corresponds to other studies that have showed that contextual socio-economic characteristics is a contributor to differences in health on a individual level (16).

Most studies on the role of socio-economic factors in Sweden have focused on the outcome of covid-19 related death during the first wave in Stockholm. Since deaths is mainly affecting elderly persons there is a need for a better understanding of the role of socio-economic factors and hospitalization among adults in other regions. There is also a need to see if there are different patterns during the two waves, or if the same pattern repeat itself. Especially when the aim for the overall strategy is to avoid an overwhelmed healthcare system. And as the vaccines starting to roll-out there is a need to address who is at a higher risk for severe disease, and if there are places that is more likely to inhabit vulnerable groups.

This study has a twofold purpose. First an analysis will be undertaken to examine if there is an association between covid-19 mortality and neighbourhood socio-economic status in Västra Götaland, in the context of a county with universal healthcare. The second purpose that follows, if there is an association, is to examine which socio-economic variable (or combinations of variables) that are applicable for the covid-19 surveillance. Socio-economic data is not routinely connected to the database for notifiable diseases in Sweden. There is nevertheless a fairly simple and low-cost possibility to use open aggregated socio-economic data based on the residential area in purpose to get this dimension. Those areas are called *demografiska statistikområden*, or DeSO-areas (demographic statistical areas) and have been constructed by Statistics Sweden (SCB). Our hypothesis is that these areas are applicable for identifying vulnerable population groups for covid-19 and may contribute to find additional clues how the transmission of covid-19 develops in the community.

Aims

The overall aim for this study was to examine if there are differences in mortality between different DeSO-areas in Västra Götaland according to these areas socio-economic characteristics. The second aim was to examine if DeSO-areas can be used in surveillance purpose and which variables that are relevant in that case.

Material and methods

This study was designed as a retrospective, observational and ecological study. This means that the cases are compared on basis of aggregated data from the residential area (DeSO-area), with no knowledge about the individual socio-economic factors. DeSO-areas have been constructed by Statistics Sweden in order to get access to statistics on a close regional level that makes it possible to analyse segregation and socio-economic development. The areas are stabile over time and have also been constructed in a way that they follow spatial barriers and every area have an average population of 1 500 persons (range 600 – 3 500) (17).

Study population

All confirmed cases of SARS-CoV-2 reported between 2020-02-26 and 2021-04-18 to the Department of Communicable Control, Region Västra Götaland, and with a place of residence in Västra Götaland were included. All reported cases of covid-19 infection met the national case-definition for covid-19, which means detection of SARS-CoV-2 nucleic acid or antigen in a clinical specimen (18).

Data collection procedures

Data was obtained from the Swedish reporting system and database for notifiable infectious diseases, SmiNet. This database contains all laboratory-confirmed cases of covid-19 in Sweden and per county. The database consists of individual-level records from all laboratory confirmed cases including date of notification, which healthcare provider that performed the test, when the test was performed, and death, as well as demographic characteristics. According to the Swedish Communicable Disease Act (Smittskyddslagen), the physician that is treating the patient also obligated to notify epidemiological data such as routes of transmission and the severity of the disease. All reported cases are managed by trained nurses at the Regional Centre if Disease Control. All cases that were 70 years and older was routinely categorised if they were living in a nursing home, since this was a prioritised risk group that required an enhanced surveillance. In this study data was extracted 2021-04-20 and all cases with a place of residence in the county of Västra Götaland were selected. The dataset was controlled again for deceased cases 2021-04-30 in order to get a longer observation period for the cases that were reported close to the extraction date. Data for deceased cases is based on information reported from the treating physician or from data of the population register. All cases that deceased within 30 days from dates of notification, or were notified as deceased by treating physician were defined as covid-19 related deaths. Counting individuals who have died within 30 days following diagnosis is a recognised and evaluated method used

by Public Health Agency of Sweden. The observation period until death occurred were calculated on the basis of either date of symptom onset, date of test or date of notification, which ever came first if information was missed. 34 cases were registered as deceased the same day, or some days before diagnosis, those cases were adjusted to 0,5 days. This means that the follow-up time for most of the cases were 40 days in this study. In the analysis cases that lived in a nursing home or institutions were excluded from the analysis, since these persons did not necessarily reflect the socio-economic position of the DeSO context.

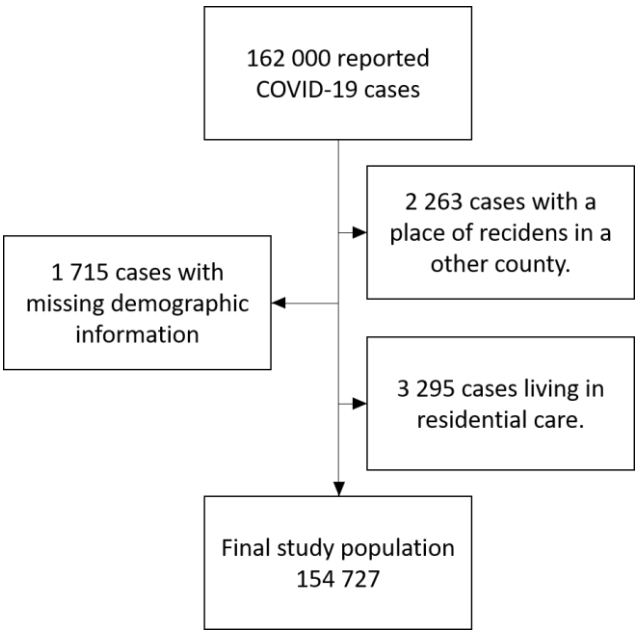

Figure 1. Flow diagram of the cohort. The diagram shows the number of cases excluded at different stages.

Variables

For each case, data on the variables age, sex, date of notification, if the case has deceased, if the case lived on a nursing home, and place of residence were taken from the Swedish electronic system for notifiable diseases (SmiNet). Every case with a known place of residence was geocoded using the FME 2020 software to a DeSO-area. Data on demographic, socio-economic and residential characteristics per DeSO-area were obtained from Statistics Sweden.

Data analysis

All data analysis was performed in IBM SPSS Statistics 26.

Statistics

Multivariable Cox proportional hazard regression was used to estimate the hazard ratios for the risk of dying between February 26, 2020 and April 18, 2021. First every variable was tested separately. Then adjusted for sex and age, and in the last analysis all variables were adjusted together. Since older age is the most important risk factor for dying of covid-19 to separately set of models were done. The first set presents results for all cases, the second set presents to separate results for individuals age 69 and below, and individuals age 70 and older. The independent variables were neighbourhood characteristics such as population density, income-level, educational-level, percentage of persons born in foreign countries. DeSO characteristics were classified into quintiles from Statistics Sweden open data 2019.

Ethics

All data was stored at Smittskydd Västra Götaland and managed according to the ordinary safety procedures and routines of secrecy in Region Västra Götaland.

Results

During the observations period 154 727 covid-19 cases with a place of residence in Västra Götaland were reported and included, 1 212 were reported as covid-19 related deaths. Table 1 presents descriptive statistics for reported covid-19 cases and deaths and for the individual variables age and sex, and for the DeSO characteristics income level, level of foreign born citizen, population density and level of low-educated citizen.

Table 1. Descriptive statistics of reported cases

Characteristics	Category	Cases		Deaths	
		Number of cases	Percentage of total number	Number of deaths	Percentage within stratum
Age	0 - 19	23 143	15.0%	4	0.0%
	20 - 39	55 102	35.6%	12	0.0%
	40 - 49	28 551	18.5%	16	0.1%
	50 - 59	25 570	16.5%	43	0.2%
	60 - 69	13 516	8.7%	116	0.9%
	70 - 79	5 561	3.6%	319	5.7%
	80+	3 284	2.1%	702	21.4%
Sex	Female	79 372	51.3%	452	0.6%
	Male	75 355	48.7%	760	1.0%
Median-income level quintile	1 Lowest	30 652	19.8%	356	1.2%
	2	26 893	17.4%	287	1.1%
	3	27 981	18.1%	222	0.8%
	4	32 477	21.0%	184	0.6%
	5 Highest	36 724	23.7%	163	0.4%
Percentage of people that are foreign born in the neighbourhood quintile	1 Lowest	23 721	15.3%	165	0.7%
	2	29 419	19.0%	211	0.7%
	3	32 127	20.8%	236	0.7%
	4	34 278	22.2%	257	0.7%
	5 Highest	35 182	22.7%	343	1.0%
Population density. Individuals per km2	0 - < 150	26 016	16.8%	216	0.8%
	150 - < 500	31 333	20.3%	213	0.7%
	500 - < 2000	38 563	24.9%	293	0.8%
	2000 - < 5000	23 767	15.4%	209	0.9%
	> 5000	35 048	22.7%	281	0.8%
Percentage of people with low education in the neighbourhood quintile	1 Lowest	36 695	23.7%	176	0.5%
	2	34 461	22.3%	224	0.7%
	3	28 523	18.4%	244	0.9%
	4	25 260	16.3%	243	1.0%
	5 Highest	29 788	19.3%	325	1.1%

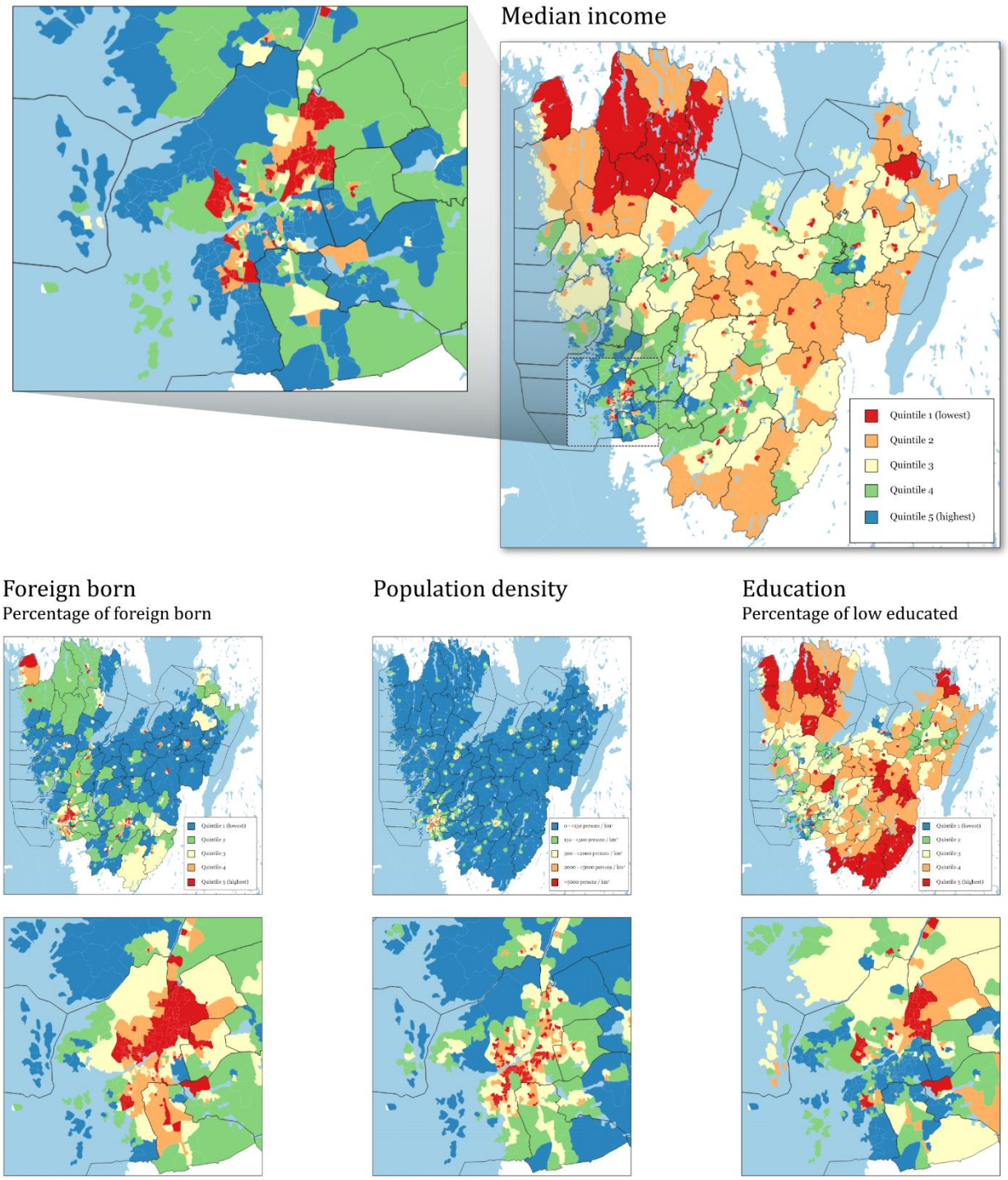

Figure 2. The geography of difference. Demographic Statistics Area (DeSO) characteristics for median income, percentage of foreign born and percentage of low educated are categorized in quintiles, and how they are allocated in the region are shown on the maps. Gothenburg area is presented with a close-up.

Population density is categorized in five categories with the most dense areas marked red. DeSO-areas within the quintile with the lowest median income, highest percetage of foreign born and highest percentage of no upper secondary school (12 years) education are marked as red areas. The blue areas was used as reference in the analysis.
DeSO are adjoining areas with aound 1500 inhabitants constructed by Statistics Sweden with the aim to caputure the socio-economic variability.

The DeSO characteristics regarding median income, percentage of foreign born and percentage of low educated are categorized in quintiles, and how they are allocated in the county are shown in figure 2. The Gothenburg area is presented with a close-up.

When the association between covid-19 mortality and the individual variables age and sex were analysed, the results showed that older age and male sex were associated with a higher risk of covid-19 related death. And this result remained the same in all three analysis.

Table 2 shows the hazard ratios of dying with covid-19. Living in a DeSO with a low income-level, low education-level and a high level of foreign born citizens where all independently associated with a higher risk of covid-19 mortality in the unadjusted analysis. The grade of population density hade no association. After adjusting for age and sex, the risk increased for DeSO with the highest level of foreign born citizens and the most population dense areas. But in the fully adjusted analysis these variables did not remain significant. Hazard ratio for living in a DeSO with a high proportion of low educated people decreased when adjusted for age and sex, and the association did not remain significant in the fully adjusted analysis.

There was an association between living in a DeSO with a lower income-level and covid-19 related death. This risk followed an increasing gradient from the highest income quintile to the lowest. This gradient remained significant for the lowest to middle income quintiles after adjustment for age and sex and in the fully adjusted model. This association were the strongest among the DeSO related variables. Figure 3 shows the cumulative incidence (deaths per 10 000 in each group) over time. DeSO with the lowest median income had more deaths per 10 000 in both the first and the second wave. The relative risk on the cumulative number of deaths per 10 000 was direct age standardized and calculated from the highest income quintile as a reference.

Table 2. Hazard ratios of dying with Covid-19

Characteristics	Category	Unadjusted				Adjusted for age and sex				Fully adjusted			
				95,0% CI for HR				95,0% CI for HR				95,0% CI for HR	
		HR	P-value	Lower	Upper	HR	P-value	Lower	Upper	HR	P-value	Lower	Upper
Age	0 - 19	0.104	0.000	0.037	0.289					0.105	0.000	0.038	0.291
	20 - 39	0.130	0.000	0.068	0.246					0.123	0.000	0.065	0.234
	40 - 49	0.334	0.000	0.188	0.593					0.335	0.000	0.189	0.596
	50 - 59	1 (ref)								1 (ref)			
	60 - 69	5.123	0.000	3.610	7.269					4.972	0.000	3.504	7.056
	70 - 79	35.029	0.000	25.477	48.163					32.790	0.000	23.842	45.096
	80+	141.651	0.000	104.109	192.730					135.693	0.000	99.659	184.757
Sex	Female	1 (ref)								1 (ref)			
	Male	1.778	0.000	1.583	1.998					1.872	0.000	1.665	2.105
Neighbourhood median-income level quintile	1 Lowest	2.628	0.000	2.183	3.163	1.775	0.000	1.473	2.138	1.830	0.000	1.358	2.467
	2	2.419	0.000	1.996	2.932	1.481	0.000	1.221	1.797	1.562	0.000	1.216	2.007
	3	1.798	0.000	1.469	2.200	1.308	0.009	1.069	1.602	1.367	0.010	1.078	1.734
	4	1.277	0.023	1.034	1.577	1.098	0.385	0.889	1.356	1.125	0.306	0.898	1.410
	5 Highest	1 (ref)				1 (ref)				1 (ref)			
Share of people that are foreign born in the neighbourhood quintile	1 Lowest	1 (ref)				1 (ref)				1 (ref)			
	2	1.030	0.774	0.840	1.263	1.044	0.676	0.852	1.280	1.006	0.959	0.812	1.245
	3	1.054	0.602	0.864	1.286	1.101	0.344	0.902	1.343	1.014	0.906	0.805	1.278
	4	1.075	0.467	0.884	1.307	1.082	0.433	0.889	1.316	0.914	0.480	0.713	1.173
	5 Highest	1.397	0.000	1.160	1.682	1.481	0.000	1.230	1.784	1.054	0.728	0.784	1.417
Population density. Individuals per km^2	0 - < 150	1 (ref)				1 (ref)				1 (ref)			
	150 - < 500	0.818	0.038	0.677	0.989	1.018	0.853	0.842	1.230	1.025	0.817	0.830	1.266
	500 - < 2000	0.911	0.300	0.764	1.086	1.081	0.386	0.907	1.289	1.086	0.473	0.867	1.359
	2000 - < 5000	1.054	0.586	0.872	1.275	1.191	0.072	0.984	1.441	1.130	0.349	0.875	1.459
	> 5000	0.960	0.654	0.804	1.147	1.181	0.067	0.989	1.410	1.074	0.590	0.828	1.393
Share of people with low education in the neighbourhood quintile	1 Lowest	1 (ref)				1 (ref)				1 (ref)			
	2	1.357	0.002	1.114	1.653	1.087	0.410	0.892	1.324	0.993	0.950	0.801	1.231
	3	1.789	0.000	1.474	2.172	1.237	0.032	1.019	1.502	1.007	0.954	0.795	1.276
	4	2.021	0.000	1.664	2.453	1.276	0.014	1.051	1.550	0.923	0.567	0.702	1.214
	5 Highest	2.284	0.000	1.901	2.744	1.538	0.000	1.280	1.848	0.932	0.643	0.690	1.258

Table 2. Cox proportional hazard regression for death from covid-19. HR = Hazard ratio, CI = Confidence intervals.

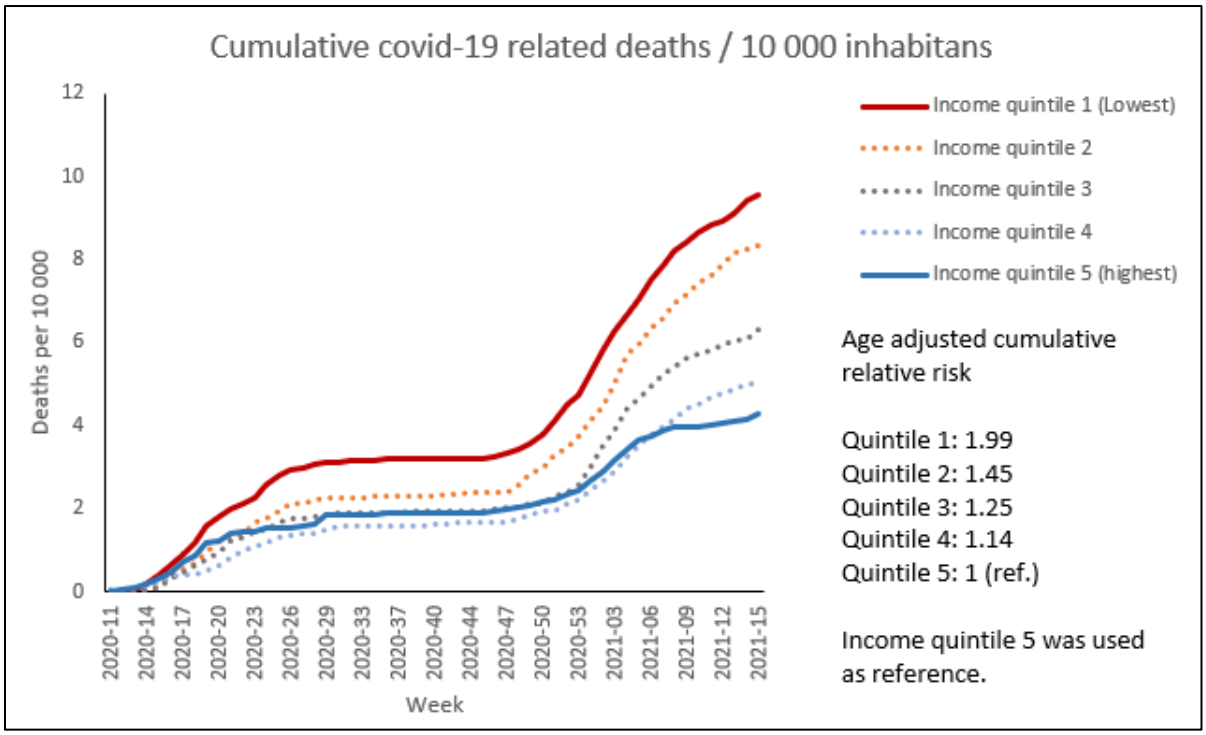

Figure 3. Deaths per income quintile over time. The diagram shows cumulative covid-19 related deaths per 10 000 inhabitants from the first laboratory-confirmed death registered week 11 March 2020 to week 15 April 2021. The relative risk on the cumulative number is direct age standardized and calculated by using Region Västra Götalands population as the reference.

In the Cox regression on mortality stratified by 70 years and older (figure 4) the strongest association in the fully adjusted model were age 80 years or older (HR 4.16; 95 % CI 3.64 – 4.76) compared to age 70 - 79, male sex (HR 1.83; 95 % CI 1.61 – 2.07) compared to female sex and DeSO area within the lowest income quintile (HR 1.61; 95 % CI 1.17 – 2.23) compared to the highest income quintile. HR across the income quintiles showed a clear gradient from the lowest to the highest. Differences between the other DeSO variables were not found to be significant.

In the Cox regression on mortality stratified by age 0 – 69 years (figure 5) the strongest association in the fully adjusted model were age 60 – 69 (HR 4.80; 95 % CI 3.38 – 6.81) compared to age 50 – 59, male sex (HR 2.09; 95 % CI 1.54 – 2.82) compared to female sex and DeSO area within the lowest income quintile (HR 3.33; 95 % CI 1.52 – 7.31) compared to the highest income quintile. Younger age was protective and so were living in an area with a population density of 150 – 500 individuals per km^2.

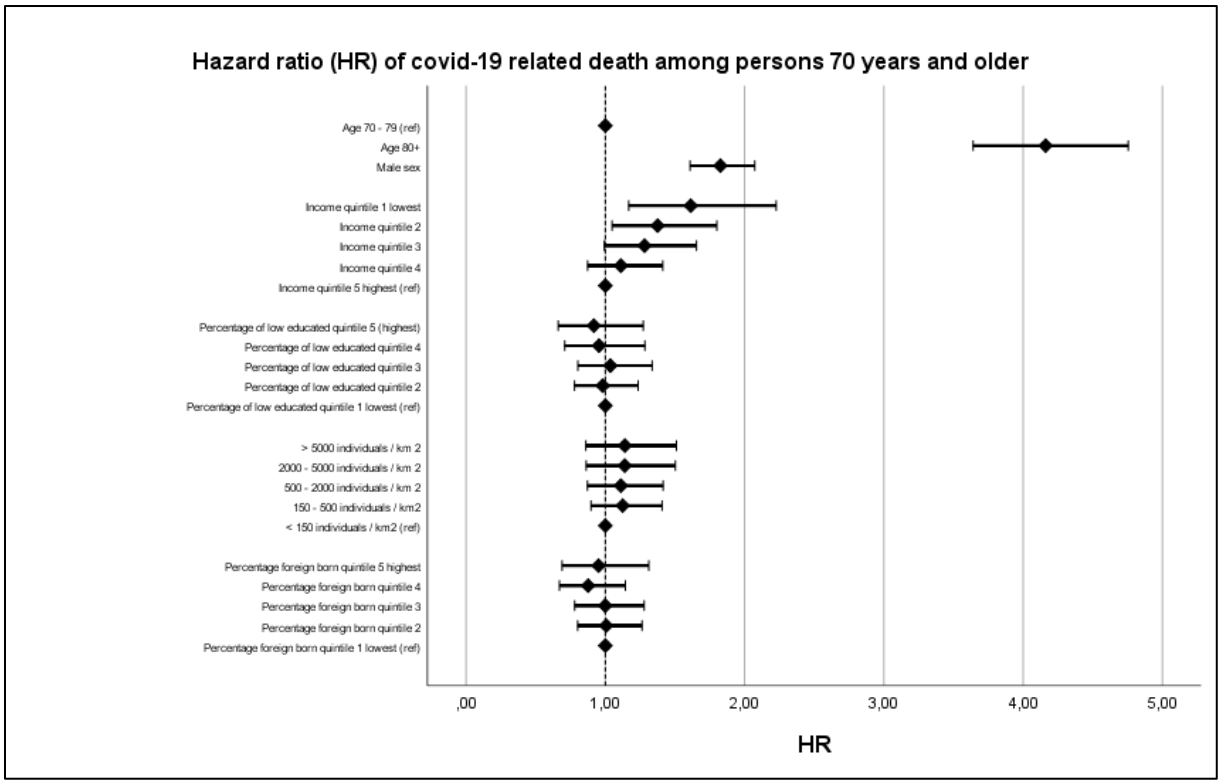

Figure 4. Fully adjust hazard ratio for covid-19 related death among cases 70 years and older, n=1021. Error bars representing 95 % confidence intervals of hazard ratios.

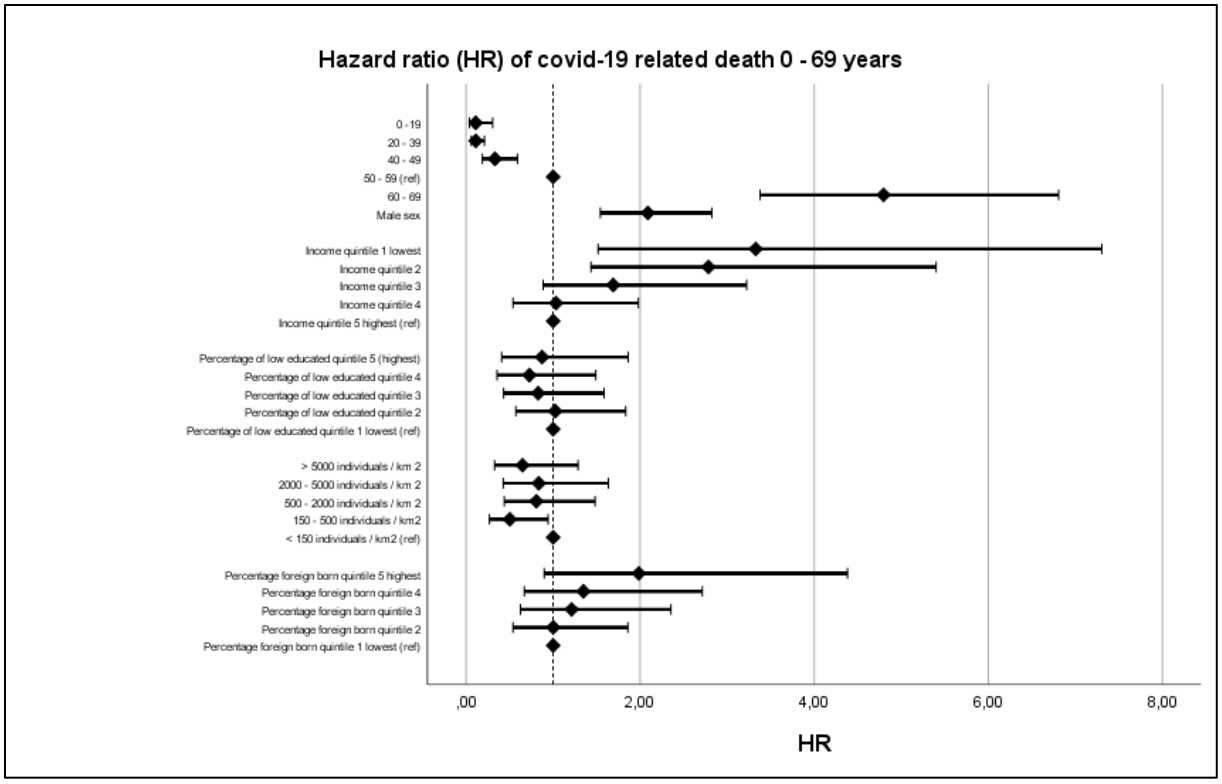

Figure 5. Fully adjust hazard ratio for covid-19 related deaths among cases 0 – 69 years, n=191. Error bars representing 95 % confidence intervals of hazard ratios.

Discussion

Older age and male sex have the strongest association with covid-19 related death in this study. The results also indicate an association between covid-19 mortality and DeSO-areas with a lower income level in Västra Götaland. And this pattern was manifest during both waves, implying that there are some things more to this than just coincidence. The results align with other Swedish studies based on individual-level data (19). Unlike what has been shown in other studies, there was no association between population density and covid-19 mortality (12). In this context the different population density categories were basically allocated in a way so they can be an approximation for living in a rural area or in an urban area.

There are obviously numerous factors that may increase the risk of being infected with covid-19 and the risk of severe disease and death. This study has examined covid-19 from a socio-economic perspective using aggregated data from the DeSO-area. The results indicate that socio-economic status might play an important role for the risk of dying of covid-19. One hypothesis is that these disparities may be related to differences in exposure to the virus and differential vulnerability to the infection.

First, difference in exposure may be associated to material and structural circumstances. Living conditions and household is often related to socio-economic status. WHO has addressed that there is a strong association between crowding and airway infections. Exposure at work is an additional factor for those that cannot work from home and live in close contact with other people. This is mainly affecting those with low-income jobs in the service sector and health care sector. These groups may also be more dependent on public transport.

Second, there was an increased risk of dying of covid-19 among those who lived in the DeSO-areas with the lowest income. This can be related to the socio-economic gradient that can be observed among individuals with underlying health conditions such as obesity, smoking and different chronic conditions. Delay in seeking care for covid-19 might be related to socio-economic factors such as differences in health literacy, which may be a potential risk for more severe disease. All these factors aggregated in the background among different groups in society may intensify the adverse effects of the virus. This relationship between covid-19 and other diseases and conditions could be addressed as a syndemic (20, 21). The syndemic approach examines how diseases interact biologically in individuals and within populations, and how different diseases, conditions and social environments and contexts interact (22).

The different socio-economic factors are often highly correlated with each other. These factors are often multifactorial and difficult to separate. Therefore, the evaluation of the relative contribution of specific factors are complicated and the consideration of confounders is essential. Ethnicity can for instance be an illusive risk-factor when it is separated from the socio-economic context according to a systematic review (23). In this study there was no association between covid-19 related death and DeSO-areas with a high level of foreign born citizen in the fully adjusted model. The results were imprecise and didn't show any clear gradient. This may be due to a high grade of heterogeneity in this broad category. And being born in other country than Sweden does not *per se* imply a higher risk for sever covid-19 disease. However, there was a strong correlation between DeSO-areas with a low income level and a high percentage of people born outside the EU28, a high percentage of people with a low education level, crowded housing conditions and people working in essential sectors such as care and public transport (24). Other studies based on individual level data have shown a more robust and clear association between covid-19 mortality and foreign born people in Sweden, but this increased risk has mainly been seen among certain immigrant groups. The relative risk for death and severe disease, in terms of being admitted to intensive care, is higher for persons born in the African region and the Middle East region compared to the Swedish born population according to a report from the Public health agency in Sweden. But when adjustment were done for different socio-economic factors the relative risk were significantly reduced (25). There are though some conflicting results in this matter. A report from the Norwegian public health agency showed that foreign born persons as a group were overrepresented in hospitalizations for covid-19. And adjustment for age, sex, medical risk factors, socio-economic factors such as income, education and overcrowding couldn't explain this association for some countries of birth (26). A similar pattern was reported in a study that estimate associations of covid-19 mortality in England and Wales. The factors of interests were ethnicity, population density, obesity, deprivation and pollution. All these factors were found to have an independent association to covid-19 related death, but in the multivariate analyses deprivation and pollution were not longer significant (27). Another study in England that examined factors associated with covid-19 related death reported a consistent pattern of increasing risk of death with greater deprivation. And this increased risk could not be explained by other diseases or clinical factors (28). In a large cohort study among 17 million adults in England some ethnic populations had a higher risk of severe outcomes compared to the white population even after adjustment for different socio-economic, clinical and

household factors. The study suggesting that ethnic differences might be explained by a higher risk of infection rather than a higher susceptibility to severe disease once infected (29).

Data on smoking and body mass index were not available. And this lack of lifestyle data is consistent in the Swedish register-based studies. There might be an important confounder between obesity and socio-economic status. According to the Swedish public health agency, 67 % of the adult population with a low education level were obese and overweight compared to 45 % of the adults with the highest education level. The gradient of overweight inversely follows the socio-economic level (30).

This project was an ecological study and the correlations between aggregated income level of the DeSO-area and covid-19 related death may not necessarily reflect the association on an individual level. Even though an ecological study is a weak form of evidence since the lack of individual data, the results in this study is likely to be relevant in this context since the results corresponds very well with other studies; the same patterns have evinced.

There are some weaknesses in this study that need to be addressed. Using place of residence as a marker for socio-economic status may be a problem though it is mainly a measurement of de jure rather than de facto. There is a risk that some cases may not actually live at the same place as recorded in the official register. There is also a risk that the risk for those living in the lowest income areas may be underestimated since 1 715 cases with no known place of residence are excluded. It is likely to assume that most of those excluded cases are living in DeSO-areas with a higher proportion of immigrants.

The mortality observations in this project have mostly been studied during the pre-covidvaccination era. The covid-19 vaccination in Region Västra Götaland started around 27th December 2020 and by 18th April 2021 7.8 % of the adult population had been fully vaccinated with two doses, and 20.6 % had been vaccinated with one dose. Older persons were prioritized, and the deaths started to decrease from mid January. Vaccination has not been a factor analysed in this study.

Ever since the global emerge of covid-19 the world has struggled to mitigate the impact of the virus. In Sweden the Public Health Agency work with covid-19 has the overall strategy to "minimise mortality and morbidity in the entire population and to minimise other negative consequences for individual persons and society". Furthermore the aims are to slow down the spread of the virus in order to avoid that the healthcare system becomes overwhelmed and to protect the most vulnerable groups. Compared to many other countries Sweden has applied a

less-restrictive approach based on recommendations rather than mandatory restrictions implemented in several other countries. As global deaths and severe disease from covid-19 still is counting, and cause a massive strain on the society, governments, institutions and agencies are still trying to "flatten the curve" by different means. Which level of restrictions, closure and the efficiency of different non-pharmaceutical interventions have been an important cause for debate. However, since the start of massive vaccine programs against covid-19, the debate is now starting to focus on which exit-strategy is plausible. Some argues that a global elimination strategy should be implemented rather then an acceptance of covid-19 as an endemic and seasonal infection. Since there are numerous uncertainties regarding the long-term efficiency of the vaccines and natural immunity, the way back to a pre-pandemic "normal" cannot rely on vaccines or herd immunity alone. Consequently, this view argues that the transmission should be repressed through further lockdowns, contact tracing and isolation until the virus have been eliminated. After that the society can open up again, area by area, country by country (31). Another exit-strategy could be to focus on preventing death and severe disease through vaccination of vulnerable groups and thinking of how to live with the virus. This view claim that a herd immunity is unrealistic given the same reasons mentioned above (32). And it is more to it. In the midst of the second wave in Europe new virus variants has gotten more attention. Causing concern that some variants may have the potential for reduced effectiveness for some of the covid-19 vaccines, just as vaccine have started to rollout. The European Centre for Disease Prevention and Control (ECDC) calls for action to ensure that further interventions are taken for control transmission and safeguard healthcare capacity and to understand of how this might affect covid-19 vaccine acceptance. Due to the risk for further spread ECDC stated that this might be a very high risk for vulnerable individuals in terms of a significant increase of covid-19 related cases and deaths (33). The results in this study underlines the importance to achieve a high vaccination coverage in the population, and especially among elderly, men and people living in low-income areas.

The findings in this study aligns with other and larger studies that have shown that there is an association between covid-19 related death and socio-economic factors. The results implying that aggregated information from DeSO-areas are useful and relevant in order to identify vulnerable groups and gives better keys to understand the progress of the virus-spread in the society. Of the examined variables distribution of income seems to be the crude measure that best capture the socio-economic factors that matter on an aggregated level.

Conclusions and implications

People living in DeSO-areas with a lower income had higher risk of dying of covid-19 compared to those living in areas with higher income. How to tackle social inequality is ultimately a political issue that can hold for different solutions. Equality can be difficult to achieve, but it should be addressed as matter of importance when planning for pandemic preparedness and resilience. In the short perspective: make sure that vaccines and other protective measures like testing and contact tracing are accessible irrespective of those barriers that comes with social inequalities and deprivation.

There is also a need to improve the Swedish surveillance system for notifiable diseases. To day the system lacks essential data regarding geographical, socio-economic and outcome variables. In this study income-level was the variable that seems to best capture the socio-economic factors that matters for covid-19 mortality. A better data system by linking these aspects are essential for a better surveillance. This should be possible to get in place without compromise the high standards of data safety and integrity.

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