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Abstract: Preliminary evidence points to higher morbidity and mortality of covid-19 in certain racial and ethnic groups but population-based studies using micro-level data are so far lacking. We examined disparities in covid-19 deaths by region/country of birth and studied whether migrants' socioeconomic and living conditions attenuated such disparities. A register-based cohort including all adults living in Stockholm, Sweden (n=2,365,434) between January 31st (date of first confirmed case) and May 4th 2020 was utilized. Poisson regressions with region/country of birth as exposure and underlying cause of death by Covid-19 was performed. Migrants from Middle-Eastern countries (RR 3.2, 95% CI: 2.6-3.8), Africa (RR 3.0, 95% CI: 2.2-4.3) and the Nordic countries (RR 1.5, 95% CI: 1.2-1.8) had higher mortality in covid-19 when compared to Swedish born. Especially high mortality risks from covid-19 was found among individuals born in Somalia (RR 8.9, 95% CI: 5.6-14.0), Lebanon (RR 5.9, 95% CI: 3.4-10.3), Syria (RR 4.7, 95% CI: 3.3-6.6), Turkey (RR 3.1, 95% CI: 2.1-4.4), Iran (RR 2.6, 95% CI: 1.7-3.8) and Iraq (RR 2.4, 95% CI: 1.7-3.5). Socioeconomic status, number of working age household members and neighborhood population density attenuated up to half of the increased covid-19 mortality risks among foreign born, although a sizable amount of excess mortality remained in all groups. We found large disparities in covid-19 mortality by country of birth in Stockholm, one of the most affected regions in the world. Disadvantaged socioeconomic and living conditions may increase infection rates in migrants and contribute to their higher covid-19 mortality risk.

Keywords: covid-19, mortality, migrants, migration, Sweden

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INTRODUCTION

The covid-19 pandemic has led to a worldwide increase in morbidity and mortality. Despite the widely adopted message that the virus 'does not discriminate', preliminary evidence suggests that the interaction between covid-19 and the social environment does (1), pointing to higher morbidity and mortality among low socioeconomic status and minority groups in some countries (2-5). In response, scholars have highlighted the urgent need to study social and ethnic disparities in covid-19 morbidity and mortality (6-10) and understand the mechanisms behind them. Sweden experienced its first covid-19 case on January 31 and is one of the countries with the highest death rates per capita in the world (11). The Swedish strategy of keeping society open and promoting individual responsibility in lieu of lockdown is unique and could have unintended consequences for vulnerable groups including migrants (12). This fact, combined with our ability to take advantage of the detailed and reliable population registers, provides a unique and timely setting for the study of covid-19 mortality among international migrants according to their country of birth.

There are a few studies on disparities in covid-19 deaths according to country of birth, with nearly all of the evidence so far concerned with ethnic and racial disparities. Nevertheless, some studies have documented important disparities. A county-level study in the US found that counties with higher proportions of black residents had more covid-19 diagnoses and deaths, after adjusting for county-level characteristics such as age, poverty, comorbidities, and epidemic duration (2). A UK study documented an increased risk of covid-19 death for Black African, Black Caribbean, Indian, Pakistani, and Bangladeshi ethnic groups in the UK after adjusting for age and broad geographic regions (3). Another UK study found that compared to White study members, Black individuals had a 4-fold increased risk of covid-19 infection and there was a

doubling of risk among Asians and other ‘non-whites’. Neighborhood deprivation, household crowding, smoking, body size, inflammation, glycated haemoglobin attenuated these effect estimates (4). Niedzwiedz et al. (5) found that Blacks and South Asian migrants were more likely to test positive for covid-19 and more likely to be hospitalized than white British. Adjustment for health and behavioral risk factors led to little change with only modest attenuation by socioeconomic variables. Nevertheless, the findings so far are not based on total-population based micro data which would provide the most reliable knowledge base for health policy intervention.

Improving knowledge on disparities in covid-19 deaths across migrant groups and the factors explaining such disparities is needed in order to prevent excess morbidity and mortality in these groups. Using micro-level registry data covering the total population in Stockholm, Sweden, the aims of this study are to:

(1) document disparities in covid-19 deaths by country of birth (2) compare said disparities with all-cause mortality disparities excluding covid-19 deaths during the pandemic and; 3) study whether socioeconomic status (education, income and employment status), number of working age household members, housing type, and neighborhood population density attenuate disparities in covid-19 mortality by country of birth.

METHODS

Data material

We performed a register-based cohort study that included the adult population aged 21+ living in Stockholm that were alive on 31 January 2020, when the first case of covid-19 was diagnosed in Sweden, until 4th May 2020, the last date that reliable covid-19 deaths were available in our data. Only individuals who have lived in Sweden for at least two years are included. This strategy excludes asylum seekers and newly arrived migrants with no or limited information in the registers. The cohort included 1,778,670 individuals, of which 30% were foreign born. There is a wealth of register-based information linked to each individual, such as socio-economic, geographic, housing, and household related variables.

Variables

Covid-19 mortality was identified through the Swedish cause of death registry using ICD-10 U07.1 and U07.2. Region of origin/ country of birth was identified by using information on specific country of birth available in the registers. The initial phase was an exploratory data analysis aiming to identify predictors for covid-19. The final models include sex, age, disposable income, education, employment status, type of housing, number of working age members in the household, and population density in the residential area (DeSO), as these were deemed to be the strongest and most stable predictors. Individual disposable income was grouped into quartiles, with a separate category for missing. Education was classified into primary, secondary, and post-secondary schooling, with a separate category for missing, while employment status was coded as a binary variable. Type of housing was grouped into apartment/houses and special housing (which includes elderly care homes), with a separate category for missing, and the number of

working age members of the household was grouped into 0, 1-2, and 3+. Population density at the DeSO levels was grouped into five quintiles. DeSO stands for demographic statistical areas, and is a geographic subdivision of Sweden into 5,984 DeSo areas with approximately 700-2,700 inhabitants each.

Statistical analyses

The follow-up time was defined by the time between the start date, 31st January 2020 (date of first confirmed case in Sweden), and stop date due to death, or end of follow-up, 4th May 2020. We performed Poisson regressions with covid-19 death as an event, with the log of the follow-up as an offset in the models. When population density was included a random intercept multi-level Poisson model was used, with DeSO as the grouping variable. In the multi-level models, aggregated data was used to decrease computation time. We also ran the corresponding models with all-cause mortality excluding covid-19 as a comparison to ensure that the excess risks that were observed was a consequence of the pandemic. We nested three models; Model 1 only adjusted for age and sex, Model 2 added the socio-economic variables income, education, and employment status, and Model 3 also included housing type, number of working age members in the household, and population density on the DeSO level. To identify which specific countries of origin were driving the grouped region of origin results, we also ran models 1-3 on specific countries of origin.

We also fitted some sensitivity analyses to complement our main results. First, we fitted models considering the independent contribution of the mediating variables of interest to assess their relative contribution to immigrants' excess mortality risk from covid-19. Second, to examine gender differences in migrant groups, we fitted models 1-3, specifying an interaction between

sex and immigrants' region of origin. Third, because we were concerned about restricting the available data to Stockholm, rather than all of Sweden (even though Stockholm is the worst hit region thus far), we fitted models 1-3 with the whole of Sweden. Specifically, we specified an interaction with Stockholm county and immigrants' region of origin. All these analyses are available in the supplementary online materials and are described briefly at the end of the results section.

Role of the funding source

The funding source had no role in study design; in the collection, analysis, and interpretation of data; in the writing of the report; and in the decision to submit the paper for publication

RESULTS

Table 1 presents descriptive statistics for covid-19 deaths, deaths due to all other causes, and for predictor variables: income, education, employment, number of working age household members, housing type and neighborhood population density. Data are provided for the total population of Stockholm by region of birth, showing considerable variation. Online Figures S1-S3 provide information on the distribution of covid-19 deaths over age and date by nativity status.

Figure 1 describes initial elevated mortality risk ratios from covid-19 in Model 1 among migrants from the Middle East (RR 3.2, 95% CI: 2.6-3.8), Africa (RR 3.0, 95% CI: 2.2-4.3), and the other Nordic countries (RR 1.5, 95% CI: 1.2-1.8), when compared to the Swedish born population living in Stockholm. These excess risks are attenuated for all three migrant groups when socio-

economic, housing, and neighborhood characteristics are considered. Mortality risks ratios fall considerably among migrants from the Middle East (RR 2.0, 95% CI: 1.6-2.5), Africa (RR 1.7, 95% CI: 1.2-2.5) and the other Nordic countries (RR 1.3, 95% CI: 1.0-1.5) in Model 3. Table S6 shows that 45% of the overall excess mortality is explained in other Nordics (largely due to the addition of socio-economic factors between M1 and M2), 56% in Middle East (again largely between M1 and M2), and 66% in Africa (split more equally between the addition of socio-economic factors between M1 and M2 and neighborhood and household factors between M2 and M3). Table S7 indicates that, of the predictors included in the models, disposable income, employment status and population density primarily contribute to the associations found while housing type does not.

In the right-hand panel of Figure 1, we present similar analysis for all-cause mortality excluding covid-19. Initially, we find no excess risk for the migrant groups except for immigrants from the other Nordic countries who have a slightly elevated mortality risk in Model 1 (RR 1.1, 95% CI: 1.0-1.3). As in the case with Covid-19 deaths, adjusting for socioeconomic status reduces the death risk of migrants. For all-cause mortality excluding covid-19, this leads to the emergence of sizeable mortality advantages in nearly all groups compared to the Swedish population in Model 3; Europe (RR 0.8, 95% CI: 0.7-0.9), Middle East (RR 0.7, 95% CI: 0.6-0.8), Africa (RR 0.7, 95% CI: 0.5-0.9), and the Rest of the World (RR 0.6, 95% CI: 0.5-0.8). In contrast to the covid-19 model, risk factors specific to covid-19 mortality did not significantly affect all-cause without covid-19 mortality. Full regression tables for the models in Figure 1 can be found in Tables S1 and S2.

Figure 2 shows a more granular origin variable for immigrants, showing mortality risk ratios for individual origin countries that have recorded at least ten deaths from covid-19 in Stockholm.

The number of deaths, population sizes, and time-at-risk can be found in online Table S3. We find elevated mortality risk ratios from covid-19 among migrants from Finland (RR 1.6, 95% CI:1.3-1.9), Iran (RR 2.6, 95% CI: 1.7-3.8), Iraq (RR 2.4, 95% CI: 1.7-3.5), Lebanon (RR 5.9, 95% CI: 3.4-10.3), Somalia (RR 8.9, 95% CI: 5.6-14.0), Syria (RR 4.7, 95% CI: 3.3-6.6), and Turkey (RR 3.1, 95% CI: 2.1-4.4), but not for Baltic States, Chile, Germanic States, Greece, Norway or Poland. These excess risks are attenuated to varying degrees when socio-economic, housing, and neighborhood characteristics are considered, ranging from 38% of the excess risk explained for Lebanon up to 70% for Iran (see Table S6). This is reflected in comparatively lower excess risks in Model 3 among migrants from Iran (RR 1.5, 95% CI: 0.9-2.3), Finland (RR 1.3, 95% CI: 1.1-1.7), Iraq (RR 1.7, 95% CI: 1.1-2.6), Lebanon (RR 4.1, 95% CI: 2.3-7.3), Somalia (RR 4.5, 95% CI: 2.6-7.8), Syria (RR 3.0, 95% CI: 2.0-4.5), and Turkey (RR 2.0, 95% CI: 1.4-3.0).

In the right-hand panel, the analysis for all-cause mortality (excluding covid-19) only shows an initial excess among migrants from Finland (RR 1.2, 95% CI: 1.1-1.4) in Model 1. As for the regions of origin, we find lower mortality compared to the Swedish population after adjusting for socioeconomic status, housing, and neighborhood characteristics in Model 3, including for those countries in which we observe large covid-19 death risks such as Iran (RR 0.6, 95% CI: 0.4-0.9), Iraq (RR 0.7, 95% CI: 0.5-0.9), and Turkey (RR 0.7, 95% CI: 0.4-0.9). Partial regression tables for the models presented in Figure 2 can be found in online Tables S4 and S5.

In additional analyses (available in the supplementary materials), we included all of Sweden, and interacted country of birth with a dichotomous variable indicating whether an individual lived in the Stockholm area or not. These analyses, shown in Table S8, yielded robust results, with very similar risk ratios. Further, these analyses indicated that outside of Stockholm, migrants from the

Middle East and Africa had even higher risk ratios compared to Swedes; they were lower for the Nordics.

Interacting country of birth with gender (shown in online Table S9) revealed that the female populations of the migrant groups generally had lower risk ratios relative to the men in the same group, but that the socioeconomic and living conditions attenuated the risks more in the male populations than the females ones, leading to smaller gender differences after adjustments. In the Nordic case, the risk ratio for the females was even higher than the males in the fully adjusted model.

DISCUSSION

This study examined disparities in covid-19 deaths by region and country of birth in Stockholm, Sweden and investigated whether any disparities could be explained by socioeconomic and living conditions. We also analyzed all-cause mortality minus covid-19 during the pandemic to determine whether migrants are particularly overrepresented in covid-19 mortality. We found markedly higher covid-19 mortality in migrants from Middle-Eastern countries and Africa but also among migrants from the Nordic countries when compared to Swedish born individuals. When studying specific countries of birth, we found especially high and persistent covid-19 mortality risks among individuals born in Somalia, Lebanon, Syria and Turkey. We also found that the risk of covid-19 death was more than doubled among people born in Iran, Iraq, Lebanon and a moderately higher risk in migrants from Finland. The addition differences in socio-economic, household and neighborhood characteristics explained between half to two thirds of the excess risk. All this is in sharp contrast to all-cause mortality excluding covid-19, where most

immigrant groups have a lower mortality than native Swedes during the pandemic. Lower mortality in foreign-born has also been found previously (13,14). Taken together, these findings suggest that many foreign-born groups are particularly vulnerable during the covid-19 pandemic and that infection and death rates are higher among them.

In the literature, two main explanations for higher covid-19 mortality among certain ethnic groups can be distinguished (9,15). The first relates to vulnerabilities due to a generally lower socioeconomic status among many immigrant groups, which in turn implies poorer living conditions. Not being able to successfully socially isolate, due to low income or crowded housing, is likely to amplify both infection- and, subsequently, deaths rates. The second explanation relates to the higher prevalence of underlying risk factors in migrants or higher genetic vulnerability for infectious diseases leading to a higher fatality rate.

Our findings suggested that some of the increased covid-19 mortality risk was attenuated after adjustment for education, disposable income and employment status, which suggests that poorer socioeconomic conditions could explain some of the higher covid-19 mortality in foreign-born. Lower socioeconomic status translates into occupations that are more precarious (16), and more often found in the service sector, where personal contact is more frequent and the possibility of working from home is limited. It is well-known that socioeconomic position is also strongly associated with several diseases, health problems and health risk behaviors in Sweden and elsewhere (17). Previous studies have also found higher risk of cardiovascular risk factors and diseases, high blood pressure, diabetes, smoking and obesity in foreign born individuals in Sweden, especially among Middle-Eastern migrants (18-22). Such health risks could relate to migrant's lower socioeconomic position (23) and the adjustment for socioeconomic position

could hence account for both risk factors inherent in low status occupations with more personal contact and underlying co-morbidities, explaining the higher covid-19 mortality in foreign-born.

When models were additionally adjusted for the number of working age people in the household and population density, excess covid-19 mortality risks were additionally reduced across migrant groups. Overall, these findings suggest that migrants' living- and social conditions could make social distancing more difficult which could lead to a higher risk of virus transmission. Accordingly, previous Swedish studies have found that foreign-born are overrepresented in crowded housing conditions (24) which are more prevalent in neighborhoods with high population density. Having family members in working age could especially increase the risk of virus transmission in migrants since they are more likely to be employed in low paid essential occupations, within health care or the service sector, which makes working from home and social distancing much more difficult. Individuals who continue to work and commute to work could increase the risk of virus transmission to other household members. A higher proportion of foreign-born live in families across generations which could increase the risk of virus transmission to elderly family members belonging to risk groups (24). Finally, living in specialized institutionalized care has a strong overall association with covid-19 mortality. Findings suggest that Sweden has experienced high contagion rates in elderly care facilities during the pandemic (25). However, our findings suggest that living in institutionalized care does not account for migrant's excess mortality risk in covid-19. This could indicate a lower overall number of migrants in elderly care facilities or lower fatality rates in foreign-born living in such institutions. Interestingly, our most important mediating variables, number of working age members in the household and population density accounted only for increased risks in covid-19 related deaths by country of birth and not all-cause mortality disparities excluding covid-19

which suggests that these could be considered determinants of virus transmission and not overall mortality.

Strengths and limitations

This study utilized high quality registry data from Sweden including detailed individual-level information on socioeconomic status and living conditions. However, some limitations should be noted. The remaining excess risk of covid-19 mortality found in foreign-born could indicate a higher fatality rate in foreign-born due to a higher prevalence of underlying adverse health conditions and risk factors found in the previous literature (19-23). Although socioeconomic position could be considered a proxy for some of these risk factors, we could not directly study underlying risk factors for covid-19 and how they vary across migrant groups in our registry data. Furthermore, there is a risk of an underestimation of the number of covid-19 deaths in registries since patients have to receive a diagnosis by a physician before death. Covid-19 diagnoses could be missing in patients with a rapid disease progression. Nonetheless, this is probably still a much smaller constraint in our study when compared to many others because of the high quality registry data used. Furthermore, information on genetic predisposition and genetic vulnerability, social interaction patterns, language proficiency, adherence to guidelines and information, and cultural and religious attitudes and norms regarding virus transmission could contribute to the understanding of disparities in covid-19 by country of birth. Unfortunately, such information is not available in our registry data.

CONCLUSIONS

This first total population study in the field found large disparities in covid-19 mortality by country of birth in Stockholm, Sweden – the worst affected region in Sweden and one of the

most affected regions in the world. Migrants' disadvantaged socioeconomic and living conditions explained a considerable share of their higher mortality risk in covid-19. Policies aiming to reduce covid-19 disparities by ethnicity/country of birth should consider such conditions when designing health interventions. However, it is crucial to continue to study risk factors explaining migrant's higher prevalence in covid-19 deaths in order to prevent such disparities both in Sweden and other countries with substantial migrant populations.

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Table 1. Distribution of predictors for the total population of Stockholm and by specific regions of birth of residents.

Characteristics	Total		Region of birth											
			Sweden		Other Nordic		Europe		Middle East		Africa		Rest of World	
Population (n, %)	1 778 670	100	1 232 511	70	58 206	3	165 988	9	127 125	7	63 461	4	131 379	7
Time-at-risk in years (n, %)	452 348	100	313 336	69	14 772	3	42 219	9	32 432	7	16 151	4	33 438	7
Covid-19 deaths (n, %)	1 454	100	1 016	70	129	9	106	7	135	9	35	2	33	2
All other cause deaths (n, %)	4 211	100	3 313	79	324	8	299	7	149	4	45	1	81	2
Sex (n, %)														
Male	881 429	50	622 584	51	36 258	62	81 765	49	59 080	46	29 310	46	68 687	52
Female	898 021	50	609 927	49	21 948	38	84 223	51	68 045	54	34 151	54	62 692	48
Age (μ, σ)	49	18	50	18	61	17	46	17	46	15	43	13	42	14
Disposable income (μ, σ)	3 361	17 794	3 757	20 916	2 997	7 736	2 542	6 331	2 249	2 983	2 132	1 606	2 351	6 356
Missing	27 487	2	2 455	0	1 094	2	8 772	5	2 702	2	2 556	5	9 908	8
Education level (n, %)														
Tertiary	830 298	47	610 761	50	22 152	38	73 862	44	46 185	36	18 132	29	58 982	45
Secondary	650 746	37	485 916	39	21 846	38	45 917	28	39 849	31	23 820	38	33 156	25
Basic	217 328	12	126 875	10	11 279	19	14 420	9	32 044	25	15 290	24	17 330	13
Missing	81 078	5	8 959	1	2 929	5	31 789	19	9 047	7	6 219	10	21 911	17
Employed (n, %)														
Yes	1 322 761	74	959 242	78	31 952	55	111 738	67	84 677	67	44 632	70	90 006	69
No	456 689	26	273 269	22	26 254	45	54 250	33	42 448	33	18 829	30	41 373	31
Housing (n, %)														
Apartment or house	1 167 643	66	754 130	61	37 980	65	122 599	74	95 084	75	54 392	86	102 856	78
Special housing including care	19 668	1	12 836	1	1 199	2	1 324	1	1 834	1	1 418	2	1 049	1
Missing	592 139	33	465 545	38	19 027	33	42 065	25	30 207	24	7 651	12	27 474	21
Working age hh members (n, %)														
0	284 882	16	231 143	19	21 212	37	18 164	11	7 435	6	1 629	3	5 295	4
1-2	1 100 315	64	797 752	66	29 269	52	90 104	57	71 525	58	34 075	56	77 208	61
3+	347 380	20	177 104	15	6 256	11	50 550	32	43 817	36	25 273	41	44 038	35
Population density (DeSO) (μ, σ)	7 678	9 512	7 484	9 706	7 049	9 220	8 124	9 349	7 629	8 285	8 924	8 163	8 670	9 597

Source: authors' calculations based upon Swedish registers from "Ageing Well" project.

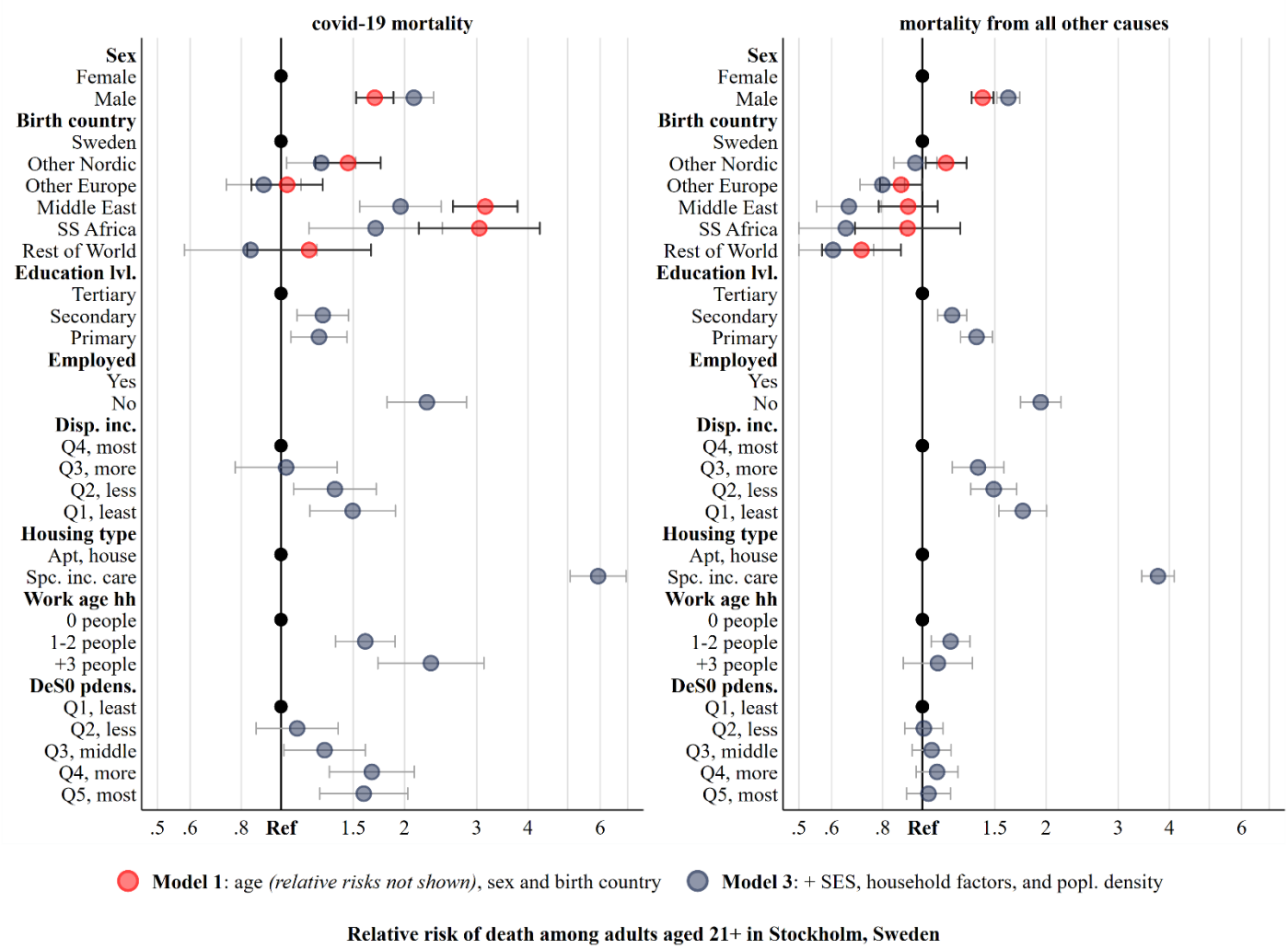

Figure 1. Relative risk of mortality from covid-19 and all other causes of death among major immigrant groups by regions of origin in Stockholm county, Sweden, 31 Jan – 4 May 2020, unadjusted and adjusted for predictor variables.

Source: authors' calculations based upon Swedish registers from "Ageing Well" project.

Notes:

1. Model 1 adjusts for the region of birth only; Model 2 (not shown) additionally adjusts for education level, being employed, and disposable income; Model 3 finally adjusts for the housing type, number of working age individuals in household and population density at the DeSO level. Full regressions tables available online.
2. Missing categories in education level, disposable income, and housing type are not shown in Figure 1, but details on the proportions and relative risks can be found in the regression tables available in the online materials.

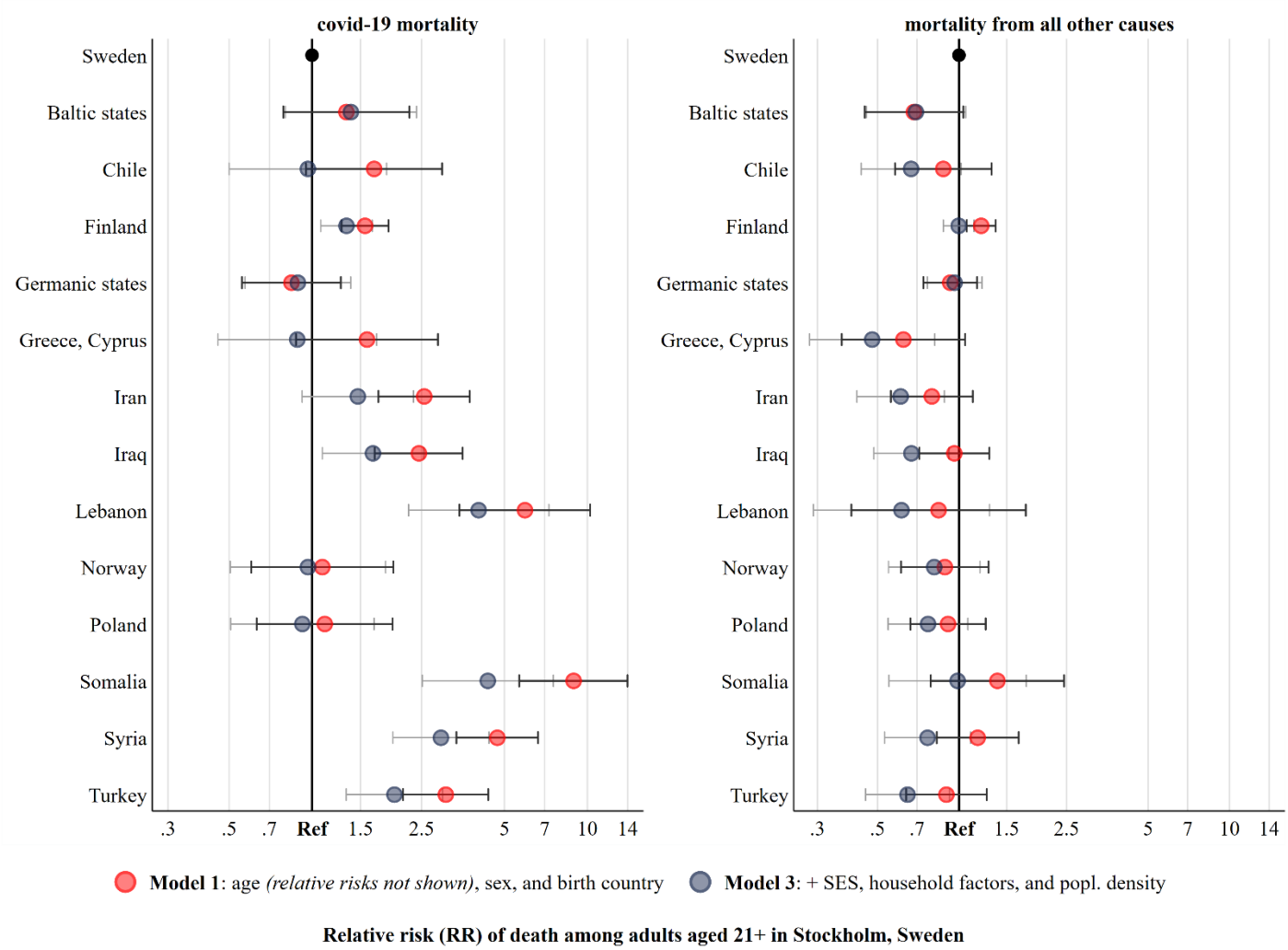

Figure 2. Relative risk of mortality from covid-19 and all other causes of death among major immigrant groups by countries of origin in Stockholm county, Sweden, 31 Jan – 4 May 2020, unadjusted and adjusted for predictor variables.

Source: authors' calculations based upon Swedish registers from "Ageing Well" project.

Notes:

1. We only show the countries of origin that recorded at least 10 covid-19 deaths between 31 Jan and 4 May 2020.
2. Model 1 adjusts for the region of birth only; Model 2 (not shown) additionally adjusts for education level, employment status, and disposable income; Model 3 finally adjusts for housing type, number of working age individuals in household and population density at the DeSO level. Country-specific RRs in available online materials.
3. Model 1 adjusts for the region of birth only; Model 2 (not shown) additionally adjusts for education level, being employed, and disposable income; Model 3 finally adjusts for the housing type, number of working

age individuals in household and population density at the DeSO level. Full regressions tables available online.

4. Missing categories in education level, disposable income, and housing type are not shown in Figure 1, but details on the proportions and relative risks can be found in the regression tables available in the online materials.

Supplementary materials

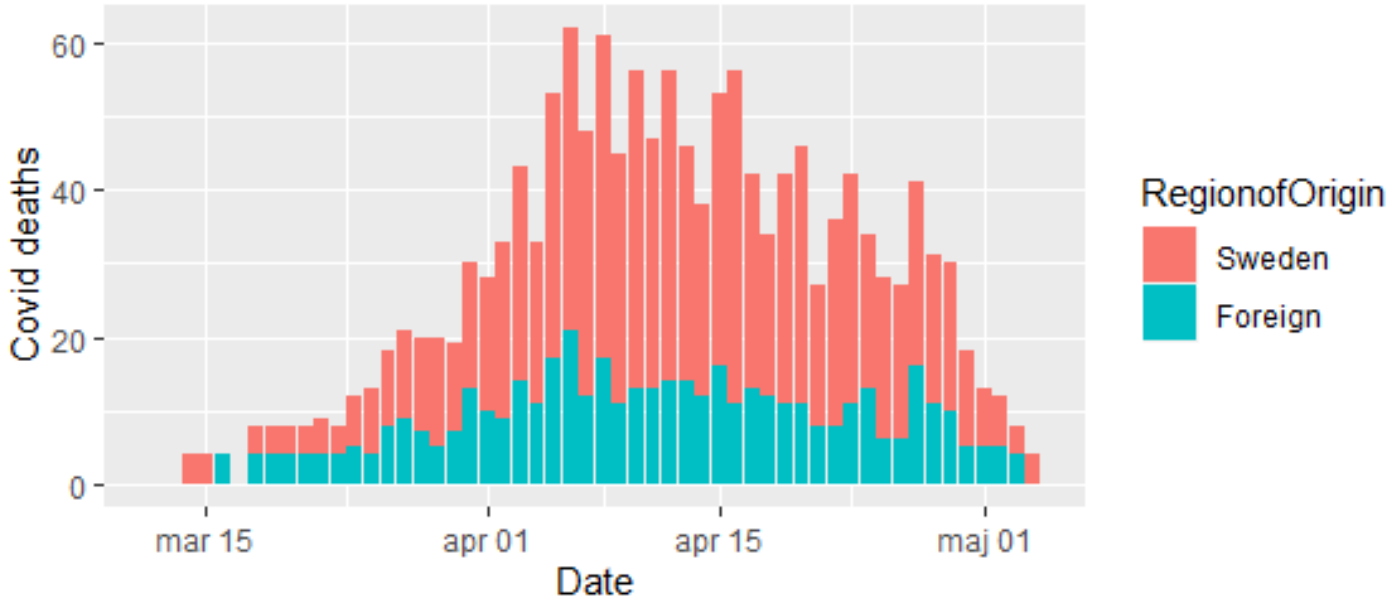

Figure S1. Distribution of covid-19 deaths by day between the 1st recorded death in Stockholm county (March 14) and May 4 by nativity status (born in Sweden vs. born in any other country).

Source: authors' calculations based upon Swedish registers from "Ageing Well" project.

Notes: single dates with less than 5 deaths are set to 4 so as to meet the requirements of the data provider

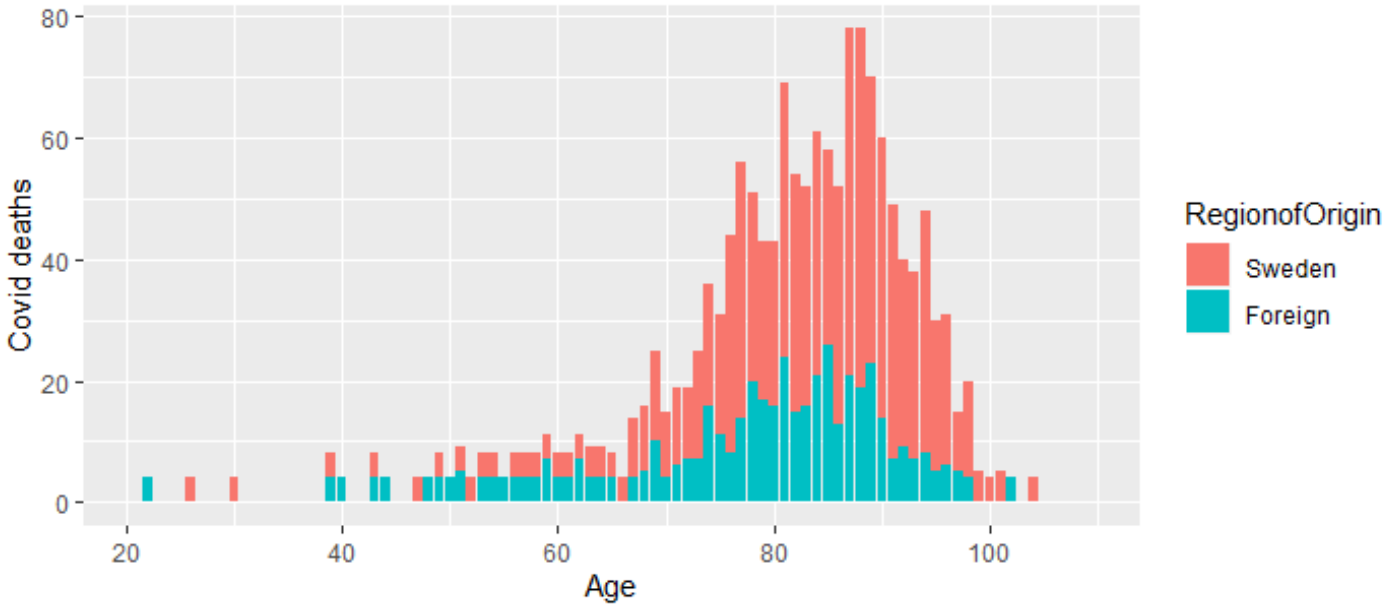

Figure S2. Distribution of covid-19 deaths over age in Stockholm Country between by nativity status (born in Sweden vs. born in any other country).

Source: authors' calculations based upon Swedish registers from "Ageing Well" project.

Notes: single dates with less than 5 deaths are set to 4 so as to meet the requirements of the data provider

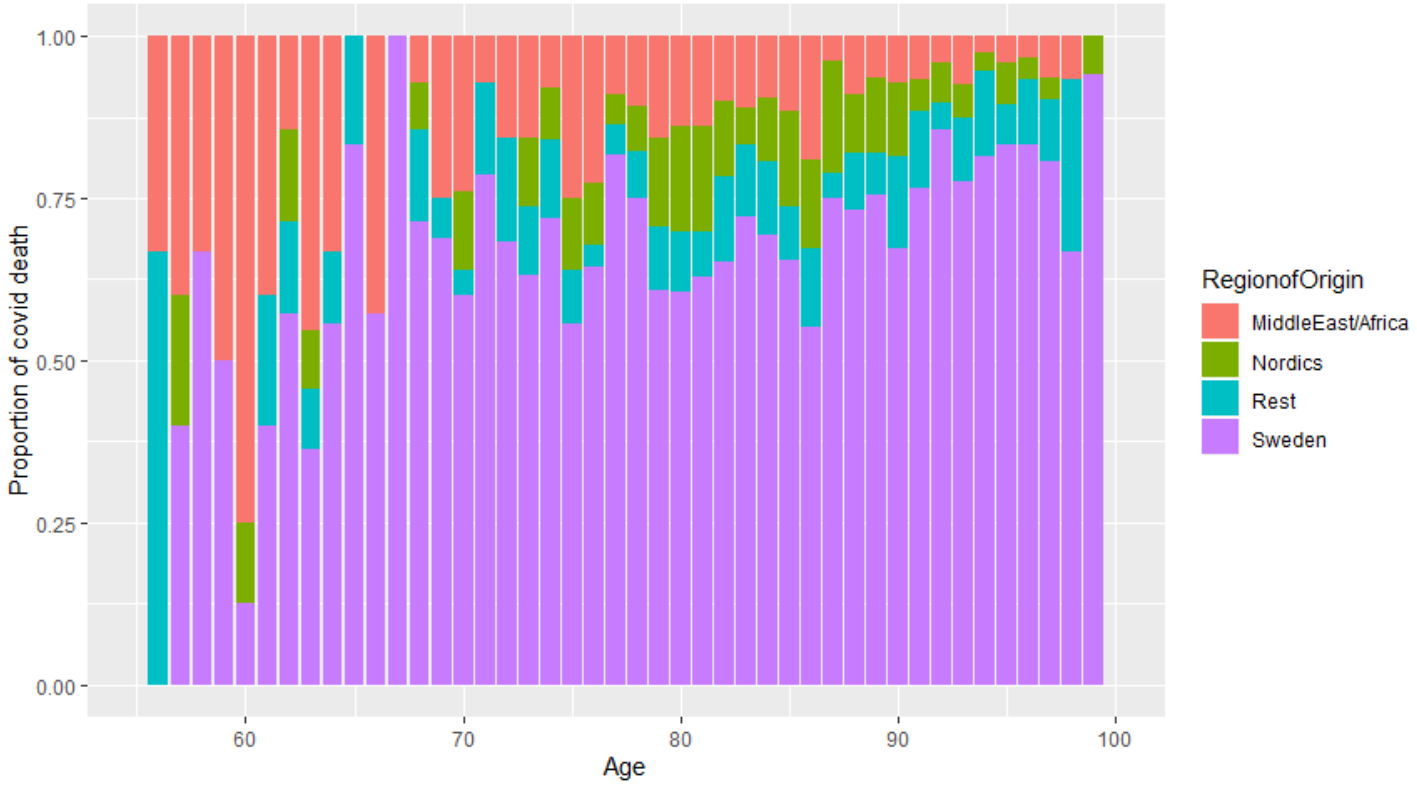

Figure S3. Proportion of covid-19 deaths in each age group in Stockholm County between by individuals' regions of origin.

Source: authors' calculations based upon Swedish registers from "Ageing Well" project.

Table S1. Multilevel Poisson regression models for covid-19 death in Stockholm (RRs in Figure 1).

Outcome:	Model 1			Model 2			Model 3		
Covid-19 death	RR	95%CIs	Sig.	RR	95%CIs	Sig.	RR	95%CIs	Sig.
Sex									
Female	**1**			**1**			**1**		
Male	1·69	1·53 -	1·88 **	1·82	1·64 -	2·02 **	2·10	1·88 -	2·35 **
Age									
18-39	**1**			**1**			**1**		
40-49	3·09	1·10 -	8·68 *	3·43	1·22 -	9·64 *	2·94	0·99 -	8·77 *
50-59	16·46	7·00 -	38·72 **	16·78	7·12 -	39·55 **	16·51	6·99 -	38·98 **
60-64	40·93	17·35 -	96·57 **	35·06	14·82 -	82·91 **	37·26	15·75 -	88·15 **
65-69	89·59	38·96 -	206·04 **	56·39	24·35 -	130·58 **	83·56	35·84 -	194·83 **
70-74	167·09	73·63 -	379·15 **	85·85	37·47 -	196·70 **	144·16	62·37 -	333·21 **
75-79	452·55	201·04 -	1 018·73 **	211·80	93·06 -	482·03 **	358·51	155·86 -	824·65 **
80-84	960·58	427·51 -	2 158·33 **	414·84	182·37 -	943·64 **	655·24	284·83 -	1 507·39 **
85+	2 430·04	1 085·83 -	5 438·35 **	993·07	437·84 -	2 252·41 **	1 197·74	521·72 -	2 749·72 **
Region of birth									
Sweden	**1**			**1**			**1**		
Other Nordic	1·46	1·21 -	1·75 **	1·29	1·07 -	1·55 **	1·25	1·03 -	1·52 *
Europe	1·03	0·85 -	1·26	0·94	0·76 -	1·15	0·91	0·74 -	1·12
Middle East	3·15	2·63 -	3·77 **	2·37	1·92 -	2·93 **	1·96	1·56 -	2·46 **
Africa	3·04	2·17 -	4·28 **	2·40	1·68 -	3·41 **	1·70	1·17 -	2·47 **
Rest of the World	1·17	0·83 -	1·66	1·02	0·71 -	1·45	0·84	0·58 -	1·22
Education level									
Tertiary				**1**			**1**		
Secondary				1·29	1·12 -	1·48 **	1·26	1·09 -	1·46 **
Primary				1·32	1·14 -	1·53 **	1·24	1·06 -	1·45 **
Missing				1·39	1·06 -	1·82 *	1·21	0·91 -	1·61
Disposable Income									
Most				**1**			**1**		
More				0·83	0·63 -	1·09	1·03	0·77 -	1·37
Less				1·21	0·97 -	1·50 +	1·35	1·07 -	1·71 **
Least				1·33	1·06 -	1·66 **	1·49	1·18 -	1·90 **
Missing				0·32	0·04 -	2·34	0·42	0·06 -	3·21
Employed									
Yes				**1**			**1**		
No				2·67	2·15 -	3·32 **	2·27	1·81 -	2·84 **
Housing type									
House or apartment							**1**		
Special housing inc. care							5·93	5·07 -	6·94 **
Missing							0·86	0·71 -	1·03
No. of working age in HH									
0·00							**1**		
1-2							1·61	1·36 -	1·90 **
3+							2·32	1·72 -	3·12 **
Population density (DeSO)									
Least							**1**		
Less							1·10	0·87 -	1·38
Middle							1·28	1·02 -	1·61 *
More							1·67	1·31 -	2·11 **
Most							1·59	1·24 -	2·04 **

Source: authors' calculations based upon Swedish registers from "Ageing Well" project.

Notes: values significant to p<0.01 **, p<0.05 *, and p <0.10 +

Table S2. Multilevel Poisson regression models for deaths from all other causes in Stockholm (RRs in Figure 1).

Outcome: all-cause mortality less Covid-19	Model 1			Model 2			Model 3		
	RR	95%CIs	Sig.	RR	95%CIs	Sig.	RR	95%CIs	Sig.
Sex									
Female	**1**			**1**			**1**		
Male	1·40	1·32 -	1·49 **	1·50	1·41 -	1·59 **	1·62	1·52 -	1·73 **
Age									
18-39	**1**			**1**			**1**		
40-49	1·70	1·26 -	2·29 **	1·95	1·44 -	2·64 **	1·96	1·43 -	2·68 **
50-59	5·13	4·02 -	6·53 **	5·46	4·27 -	6·96 **	5·83	4·54 -	7·48 **
60-64	11·43	8·92 -	14·64 **	10·42	8·12 -	13·38 **	10·87	8·42 -	14·04 **
65-69	18·77	14·85 -	23·73 **	13·02	10·23 -	16·57 **	15·38	11·90 -	19·87 **
70-74	32·62	26·15 -	40·69 **	18·68	14·83 -	23·54 **	23·03	17·91 -	29·62 **
75-79	55·27	44·42 -	68·77 **	28·94	22·99 -	36·43 **	35·02	27·19 -	45·11 **
80-84	110·97	89·39 -	137·77 **	53·81	42·78 -	67·70 **	62·27	48·35 -	80·22 **
85+	331·60	269·33 -	408·26 **	151·28	121·04 -	189·09 **	143·36	111·88 -	183·70 **
Region of birth									
Sweden	**1**			**1**			**1**		
Other Nordic	1·14	1·02 -	1·28 *	1·00	0·89 -	1·12	0·96	0·85 -	1·08
Europe	0·89	0·79 -	1·00 *	0·79	0·70 -	0·89 **	0·80	0·70 -	0·90 **
Middle East	0·92	0·78 -	1·09	0·66	0·55 -	0·78 **	0·66	0·55 -	0·79 **
Africa	0·92	0·68 -	1·24	0·69	0·51 -	0·93 **	0·65	0·48 -	0·89 **
Rest of the World	0·71	0·57 -	0·89 **	0·59	0·47 -	0·74 **	0·60	0·48 -	0·76 **
Education level									
Tertiary				**1**			**1**		
Secondary				1·23	1·13 -	1·33 **	1·18	1·09 -	1·28 **
Primary				1·45	1·33 -	1·59 **	1·35	1·24 -	1·48 **
Missing				1·41	1·16 -	1·71 **	1·34	1·10 -	1·63 **
Disposable Income									
Most				**1**			**1**		
More				1·26	1·09 -	1·45 **	1·37	1·18 -	1·58 **
Less				1·40	1·23 -	1·58 **	1·49	1·31 -	1·70 **
Least				1·66	1·46 -	1·88 **	1·76	1·54 -	2·01 **
Missing				0·19	0·05 -	0·76 *	0·24	0·06 -	0·91 *
Employed									
Yes				**1**			**1**		
No				2·19	1·96 -	2·45 **	1·94	1·73 -	2·18 **
Housing type									
House or apartment							**1**		
Special housing inc. care							3·75	3·42 -	4·11 **
Missing							0·86	0·78 -	0·94 **
No. of working age in HH									
0·00							**1**		
1-2							1·17	1·05 -	1·31 **
3+							1·09	0·90 -	1·32
Population density (DeSO)									
Least							**1**		
Less							1·01	0·91 -	1·12
Middle							1·05	0·94 -	1·17
More							1·09	0·97 -	1·22
Most							1·03	0·91 -	1·17

Source: authors' calculations based upon Swedish registers from "Ageing Well" project.

Notes: values significant to p<0.01 **, p<0.05 *, and p <0.10 +

Table S3. Deaths from covid-19 and all other causes minus covid-19, population, and time-at-risk for specific immigrant origin countries with at least ten covid-19 deaths.

Country of origin	Covid-19 deaths			All-cause deaths minus Covid-19		
	Deaths	Population	Time-at-risk	Deaths	Population	Time-at-risk
Baltic States	14	12 540	3 189	22	12 540	3 189
Chile	12	13 842	3 521	23	13 842	3 521
Finland	111	47 079	11 945	278	47 079	11 945
Germanic States	23	14 565	3 697	76	14 565	3 697
Greece	11	8 737	2 222	14	8 737	2 222
Iran	27	28 236	7 185	32	28 236	7 185
Iraq	29	41 054	10 446	44	41 054	10 446
Lebanon	13	6 289	1 600	7	6 289	1 600
Norway	11	6 251	1 588	28	6 251	1 588
Poland	12	32 436	8 253	38	32 436	8 253
Somalia	19	10 522	2 676	12	10 522	2 676
Sweden	1 016	1 232 511	313 336	3 313	1 232 511	313 336
Syria	34	24 349	6 194	32	24 349	6 194
Turkey	31	22 915	5 828	33	22 915	5 828

Source: authors' calculations based upon Swedish registers from "Ageing Well" project.

Notes: Germanic States include Austria, Germany, and Switzerland; Baltic States include Estonia, Latvia, and Lithuania

Table S4. Multilevel Poisson regression models for covid-19 death in Stockholm by specific countries of origin (RRs in Figure 2).

Outcome:	**Model 1**			**Model 2**			**Model 3**		
Covid-19 death	RR	95% CIs	Sig.	RR	95% CIs	Sig.	RR	95% CIs	Sig.
Sweden	**1**			**1**			**1**		
Baltic States	1·33	0·78 - 2·26		1·29	0·76 - 2·19		1·38	0·80 - 2·39	
Chile	1·68	0·95 - 2·97	+	1·40	0·79 - 2·48		0·97	0·50 - 1·86	
Finland	1·56	1·28 - 1·89	**	1·37	1·12 - 1·67	**	1·33	1·08 - 1·65	**
Germanic States	0·84	0·56 - 1·27		0·80	0·53 - 1·22		0·89	0·57 - 1·38	
Greece, Cyprus	1·58	0·87 - 2·87		1·26	0·69 - 2·29		0·88	0·46 - 1·72	
Iran	2·55	1·74 - 3·74	**	2·14	1·45 - 3·17	**	1·47	0·92 - 2·34	
Iraq	2·43	1·68 - 3·52	**	1·86	1·25 - 2·77	**	1·66	1·09 - 2·54	*
Lebanon	5·92	3·42 - 10·2	**	4·48	2·58 - 7·80	**	4·03	2·24 - 7·25	**
Norway	1·09	0·60 - 1·97		1·03	0·57 - 1·86		0·97	0·50 - 1·85	
Poland	1·11	0·63 - 1·96		1·02	0·57 - 1·80		0·92	0·51 - 1·68	
Somalia	8·88	5·63 - 14·0	**	6·74	4·14 - 10·9	**	4·35	2·51 - 7·52	**
Syria	4·70	3·34 - 6·62	**	3·49	2·42 - 5·03	**	2·94	1·97 - 4·39	**
Turkey	3·05	2·14 - 4·37	**	2·35	1·62 - 3·40	**	1·99	1·33 - 2·98	**

Source: authors' calculations based upon Swedish registers from "Ageing Well" project.

Notes:

1. We only show the countries of origin that recorded at least 10 covid-19 deaths between 31 Jan and 4 May 2020.
2. Model 1 adjusts for the region of birth only; Model 2 (not shown) additionally adjusts for education level, employment status, and disposable income; Model 3 finally adjusts for housing type, number of working age individuals in household and population density at the DeSO level. We do not show the specific RRs for these control variables because their values are practically identical to those shown in the online Table S1.
3. Values significant to $p<0.01$ **, $p<0.05$ *, and $p<0.10$ +
4. Germanic States include Austria, Germany, and Switzerland; Baltic States include Estonia, Latvia, and Lithuania.

Table S5. Multilevel Poisson regression models for deaths from all other causes in Stockholm by specific countries of origin (RRs in Figure 2).

Outcome: all-cause mortality less Covid-19	**Model 1**		**Model 2**		**Model 3**	
	RR	95% CIs Sig.	RR	95% CIs Sig.	RR	95% CIs Sig.
Sweden	**1**		**1**		**1**	
Baltic States	0·68	0·45 - 1·04 +	0·65	0·43 - 0·99 *	0·69	0·45 - 1·06 +
Chile	0·88	0·58 - 1·32	0·69	0·46 - 1·04 +	0·67	0·44 - 1·02 +
Finland	1·21	1·07 - 1·37 **	1·04	0·92 - 1·18	1·00	0·88 - 1·14
Germanic States	0·93	0·74 - 1·17	0·90	0·72 - 1·13	0·96	0·76 - 1·22
Greece, Cyprus	0·62	0·37 - 1·05 +	0·46	0·27 - 0·77 **	0·48	0·28 - 0·81 **
Iran	0·79	0·56 - 1·13	0·64	0·45 - 0·90 **	0·61	0·42 - 0·88 **
Iraq	0·96	0·71 - 1·30	0·67	0·49 - 0·91 **	0·67	0·48 - 0·92 **
Lebanon	0·84	0·40 - 1·77	0·58	0·27 - 1·22	0·61	0·29 - 1·30
Norway	0·89	0·61 - 1·29	0·84	0·58 - 1·21	0·81	0·55 - 1·20
Poland	0·91	0·66 - 1·26	0·80	0·58 - 1·10	0·77	0·55 - 1·08
Somalia	1·39	0·79 - 2·45	0·93	0·52 - 1·65	0·99	0·55 - 1·77
Syria	1·17	0·83 - 1·66	0·77	0·54 - 1·10	0·77	0·53 - 1·10
Turkey	0·90	0·64 - 1·27	0·62	0·44 - 0·87 **	0·65	0·45 - 0·92 *

Source: authors' calculations based upon Swedish registers from "Ageing Well" project.

Notes:

1. We only show the countries of origin that recorded at least 10 covid-19 deaths between 31 Jan and 4 May 2020.
2. Model 1 adjusts for the region of birth only; Model 2 (not shown) additionally adjusts for education level, employment status, and disposable income; Model 3 finally adjusts for housing type, number of working age individuals in household and population density at the DeSO level. We do not show the specific RRs for these control variables because their values are practically identical to those shown in the online Table S2.
3. Values significant to $p<0.01$ **, $p<0.05$ *, and $p<0.10$ +
4. Germanic States include Austria, Germany, and Switzerland; Baltic States include Estonia, Latvia, and Lithuania.

Table S6. Proportion of excess covid-19 mortality risk explained across models for both region and country of origin.

	M1	M2		M3		Total excess explained over models
	OR	OR	Excess explained by M2	OR	Excess explained by M3	
Region of origin						
Other Nordic	1·46	1·29	36%	1·25	8%	45%
Europe	1·03	0·94	100%	0·91	-	100%
Middle East	3·15	2·37	36%	1·96	19%	56%
Africa	3·04	2·40	32%	1·70	34%	66%
Rest of the World	1·17	1·02	91%	0·84	9%	100%
Country of origin						
Baltic States	1·33	1·29	11%	1·38	-28%	-16%
Chile	1·68	1·40	41%	0·97	59%	100%
Finland	1·56	1·37	34%	1·33	6%	40%
Germanic States	0·84	0·80	-24%	0·89	53%	30%
Greece, Cyprus	1·58	1·26	56%	0·88	44%	100%
Iran	2·55	2·14	26%	1·47	43%	70%
Iraq	2·43	1·86	40%	1·66	13%	54%
Lebanon	5·92	4·48	29%	4·03	9%	38%
Norway	1·09	1·03	69%	0·97	31%	100%
Poland	1·11	1·02	84%	0·92	16%	100%
Somalia	8·88	6·74	27%	4·35	30%	57%
Syria	4·70	3·49	33%	2·94	15%	48%
Turkey	3·05	2·35	34%	1·99	17%	52%

Source: authors' calculations based upon Swedish registers from "Ageing Well" project.

Table S7. Multilevel Poisson models adjusting for each factor in turn with corresponding % change in the RR for region of birth.

Age and sex-adjusted bivariate associations between the region of birth and other factors	RR	95%CIs	Sig.	% change in region of birth RRs
Region of birth only				
Sweden	**1**			
Other Nordic	1·46	1·21 - 1·75	**	-
Europe	1·03	0·85 - 1·26		-
Middle East	3·15	2·63 - 3·77	**	-
Africa	3·04	2·17 - 4·28	**	-
Rest of the World	1·17	0·83 - 1·66		-
Disposable income				
Sweden	**1**			
Other Nordic	1·34	1·12 - 1·62	**	7·75
Europe	0·94	0·77 - 1·15		8·79
Middle East	2·53	2·09 - 3·06	**	19·62
Africa	2·51	1·78 - 3·55	**	17·41
Rest of the World	1·01	0·71 - 1·43		14·11
Disposable income				
Most	**1**			
More	0·89	0·68 - 1·17		-
Less	1·58	1·28 - 1·95	**	-
Least	1·93	1·56 - 2·39	**	-
Missing	0·68	0·09 - 4·90		-
Education level				
Sweden	**1**			
Other Nordic	1·37	1·14 - 1·65	**	5·68
Europe	1·02	0·83 - 1·25		1·47
Middle East	2·88	2·35 - 3·52	**	8·53
Africa	2·84	2·00 - 4·02	**	6·86
Rest of the World	1·16	0·81 - 1·64		1·22
Tertiary	**1**			
Secondary	1·47	1·28 - 1·68	**	-
Primary	1·59	1·37 - 1·83	**	-
Missing	1·56	1·19 - 2·04	**	-
Employed				
Sweden	**1**			
Other Nordic	1·39	1·15 - 1·66	**	4·91
Europe	0·99	0·81 - 1·21		4·39
Middle East	2·79	2·33 - 3·35	**	11·27
Africa	2·74	1·95 - 3·86	**	9·85
Rest of the World	1·10	0·77 - 1·56		6·22
Yes	**1**			
No	3·12	2·53 - 3·86	**	-

Model	RR	95%CIs	Sig.	% change in region of birth RRs
Housing type				
Sweden	**1**			
Other Nordic	1·42	1·18 - 1·70	**	2·65
Europe	1·05	0·86 - 1·29		-1·91
Middle East	3·26	2·71 - 3·91	**	-3·38
Africa	3·09	2·20 - 4·35	**	-1·56
Rest of the World	1·19	0·84 - 1·68		-1·31
House or apartment	**1**			
Special housing inc. care	5·15	4·51 - 5·89	**	-
Missing	0·91	0·80 - 1·04		-
Working age HH				
Sweden	**1**			
Other Nordic	1·46	1·21 - 1·77	**	-0·44
Europe	1·07	0·87 - 1·31		-2·93
Middle East	3·00	2·47 - 3·63	**	4·78
Africa	2·86	2·01 - 4·07	**	5·97
Rest of the World	1·12	0·78 - 1·61		4·28
0	**1**			
1-2	1·22	1·04 - 1·43	*	-
3+	1·61	1·20 - 2·15	**	-
Population density				
Sweden	**1**			
Other Nordic	1·43	1·18 - 1·74	**	1·75
Europe	1·03	0·84 - 1·26		0·54
Middle East	2·53	2·05 - 3·11	**	19·78
Africa	2·34	1·64 - 3·35	**	23·08
Rest of the World	1·04	0·72 - 1·49		11·29
Least	**1**			
Less	1·14	0·90 - 1·45		-
Middle	1·42	1·12 - 1·80	**	-
More	1·80	1·42 - 2·27	**	-
Most	1·63	1·28 - 2·08	**	-

Source: authors' calculations based upon Swedish registers from "Ageing Well" project.

Notes: values significant to p<0.01 **, p<0.05 *, and p <0.10 +; age and sex adjusted in all of the models

Table S8. Multilevel Poisson models for the entire Swedish population, with a Stockholm vs. region of origin interaction.

Outcome: all-cause mortality less Covid-19	**Model 1**				**Model 2**				**Model 3**			
	RR	95% CIs		Sig.	RR	95% CIs		Sig.	RR	95% CIs		Sig.
Stockholm												
Sweden	**1**				**1**				**1**			
Other Nordic	1·46	1·21 -	1·75	**	1·29	1·08 -	1·55	**	1·27	1·05 -	1·54	**
Europe	1·04	0·85 -	1·26		0·96	0·78 -	1·17		0·96	0·78 -	1·18	
Middle East	3·13	2·61 -	3·75	**	2·35	1·93 -	2·88	**	2·10	1·71 -	2·59	**
Africa	3·00	2·14 -	4·21	**	2·41	1·70 -	3·41	**	1·96	1·37 -	2·80	**
Rest of the World	1·16	0·82 -	1·64		1·06	0·75 -	1·50		0·91	0·63 -	1·31	
Rest of Sweden												
Sweden	**1**				**1**				**1**			
Other Nordic	1·29	1·02 -	1·63	**	1·19	0·94 -	1·51		1·10	0·86 -	1·42	
Europe	1·20	0·93 -	1·54		1·12	0·87 -	1·44		1·07	0·82 -	1·39	
Middle East	3·75	2·79 -	5·02	**	2·85	2·10 -	3·87	**	2·58	1·89 -	3·53	**
Africa	8·46	5·63 -	12·70	**	6·72	4·44 -	10·18	**	5·58	3·64 -	8·56	**
Rest of the World	1·52	0·90 -	2·58		1·43	0·84 -	2·43		1·31	0·75 -	2·27	

Source: authors' calculations based upon Swedish registers from "Ageing Well" project.

Notes:

1. Model 1 adjusts for the region of birth only; Model 2 (not shown) additionally adjusts for education level, employment status, and disposable income; Model 3 finally adjusts for housing type, number of working age individuals in household and population density at the DeSO level. We do not show the specific RRs for these control variables because their values are practically identical to those shown in the online Table S1.
2. Values significant to $p<0.01$ **, $p<0.05$ *, and $p<0.10$ +

Table S9. Multilevel Poisson models for Stockholm country, with a gender vs. region of origin interaction.

Outcome: all-cause mortality less Covid-19	Model 1			Model 2			Model 3		
	RR	95% CIs	Sig.	RR	95% CIs	Sig.	RR	95% CIs	Sig.
Women									
Sweden	**1**			**1**			**1**		
Other Nordic	1·37	1·08 - 1·75	**	1·26	0·99 - 1·61	+	1·28	0·99 - 1·65	+
Europe	0·85	0·62 - 1·16		0·80	0·58 - 1·10		0·79	0·57 - 1·10	
Middle East	2·71	2·04 - 3·61	**	2·04	1·49 - 2·79	**	1·75	1·24 - 2·47	**
Africa	2·10	1·09 - 4·07	*	1·64	0·83 - 3·22		1·39	0·69 - 2·78	
Rest of the World	0·91	0·51 - 1·61		0·83	0·47 - 1·49		0·66	0·35 - 1·25	
Men									
Sweden	**1**			**1**			**1**		
Other Nordic	1·55	1·17 - 2·04	**	1·32	1·00 - 1·74	+	1·20	0·89 - 1·61	
Europe	1·21	0·93 - 1·57		1·09	0·84 - 1·42		1·00	0·77 - 1·31	
Middle East	3·53	2·79 - 4·45	**	2·63	2·03 - 3·40	**	2·08	1·59 - 2·72	**
Africa	3·66	2·46 - 5·45	**	2·95	1·97 - 4·42	**	1·91	1·25 - 2·91	**
Rest of the World	1·41	0·91 - 2·18		1·25	0·80 - 1·94		0·98	0·63 - 1·54	

Source: authors' calculations based upon Swedish registers from "Ageing Well" project.

Notes:

1. Model 1 adjusts for the region of birth only; Model 2 (not shown) additionally adjusts for education level, employment status, and disposable income; Model 3 finally adjusts for housing type, number of working age individuals in household and population density at the DeSO level. We do not show the specific RRs for these control variables because their values are practically identical to those shown in the online Table S1.
2. Values significant to $p<0.01$ **, $p<0.05$ *, and $p<0.10$ +

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