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Impacts of the COVID-19 pandemic on deprivation-level differences in cardiovascular hospitalisations: a comparison of England and Denmark using the OpenSAFELY platform and National Registry Data

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ABSTRACT

Objectives To examine the impact of the COVID-19 pandemic on deprivation-related inequalities in hospitalisations for cardiovascular disease (CVD) conditions in Denmark and England between March 2018 and December 2021.

Design Time-series studies in England and Denmark.

Setting With the approval of National Health Service England, we used English primary care electronic health records, linked to secondary care and death registry data through the OpenSAFELY platform and nationwide Danish health registry data.

Participants We included adults aged 18 and over without missing age, sex or deprivation information. On 1 March 2020, 16 234 700 people in England and 4 491 336 people in Denmark met the inclusion criteria.

Primary outcome measures Hospital admissions with the primary reason for myocardial infarction (MI), ischaemic or haemorrhagic stroke, heart failure and venous thromboembolism (VTE).

Results We saw deprivation gradients in monthly CVD hospitalisations in both countries, with differences more pronounced in Denmark. Based on pre-pandemic trends, in England, there were an estimated 2608 fewer admissions than expected for heart failure in the most deprived quintile during the pandemic compared with an estimated 979 fewer admissions in the least deprived quintile. For all other outcomes, there was little variation by deprivation quintile. In Denmark, there were an estimated 1013 fewer admissions than expected over the pandemic for MI in the most deprived quintile compared with 619 in the least deprived quintile. Similar trends were seen for stroke and VTE, though absolute numbers were smaller. Heart failure admissions were similar to pre-pandemic levels with little variation by deprivation quintile.

Conclusions Overall, we did not find that the pandemic substantially worsened pre-existing deprivation-related differences in CVD hospitalisations, though there were exceptions in both countries.

STRENGTHS AND LIMITATIONS OF THIS STUDY

⇒ This was one of the largest studies of the impact of the pandemic on deprivation-related inequalities, covering 20 million people in two countries (England and Denmark).
⇒ People were followed-up until the end of 2021 which is longer than most previous studies examining pandemic-related healthcare utilisation.
⇒ We compared the impact of the pandemic in two countries that have similar free at the point of use healthcare systems but had different responses to the pandemic.
⇒ The measures of deprivation were different in the two countries with the measure in England (Index of Multiple Deprivation 2019) capturing more aspects of deprivation compared with the Danish measure (income) which may have resulted in misclassification.
⇒ Our results are descriptive so can help generate hypotheses into the causes of observed differences to be formally explored in future research.

INTRODUCTION

Cardiovascular disease (CVD) is the leading cause of death worldwide accounting for one in four deaths in the UK.[1] CVD is known to be associated with important ethnic and socioeconomic health inequalities. Individuals living in deprived areas are more likely to have CVD and have a higher risk of dying from CVD compared with those living in less deprived areas.[2–4]

While the direct effects of the COVID-19 pandemic have been found to disproportionately affect older people, global majority ethnic groups and deprived populations, inequalities in the indirect effects of the pandemic have yet to be fully explored.[5–8] Diversion of healthcare resources to pandemic management has negatively affected non-COVID-related healthcare provision including prevention activities, potentially worsening physical and mental health.[9] The negative impacts of the pandemic have been compounded by the rising cost-of-living crisis which has further widened socioeconomic inequalities.[10 11] During the early pandemic period (2020), there were reports of fewer CVD admissions.[7 12–14] One systematic review examining the impact of the COVID-19 pandemic on CVD-related care[15] highlighted reduced and delayed CVD-related hospital admissions, except for cardiac arrests and increased CVD mortality. In the UK, there were steeper drops in unscheduled hospital admissions in the most deprived compared with the least deprived groups, though this was not specific to CVD admissions.[7] However, a Swiss study of deprivation and CVD found that there were no changes in the relative patterning of inequalities resulting from the pandemic.[16]

The UK experienced one of the worst COVID-19 outbreaks and some of the most severe outcomes from COVID-19.[17] In contrast, several Scandinavian countries experienced better COVID-19 outcomes and faster healthcare system recovery.[18] Denmark imposed strict restrictions earlier than the UK and other countries. [14] Although the UK imposed more stringent and longer-lasting measures, confirmed COVID-19 deaths were higher in the UK compared with Denmark. This suggests that timeliness of intervention rather than duration was of paramount importance in preventing COVID-19 mortality in the UK compared with Denmark[19] (online supplemental figure S1, online supplemental materials). Comparing inequalities in the indirect effects of the pandemic between countries with different pandemic curves, where different measures were taken at different times, will be important for informing policy for future infectious disease outbreaks and ensuring that future mitigation measures do not exacerbate inequalities.

We aimed to examine the impact of the COVID-19 pandemic on deprivation-related inequalities in hospitalisations for CVD conditions in Denmark and England between March 2018 and December 2021.

METHODS

Using electronic health record and registry data, we conducted two time-series studies using monthly cross-sectional data separately in England and Denmark. The cohorts for each country were defined using comparable inclusion criteria, exposure and outcome definitions and the same statistical analysis techniques were applied (table 1).

Data sources

In England, we used: (1) Primary care records managed by the general practice software provider TPP; (2) Office for National Statistics death register data; and (3) secondary care data from National Health Service (NHS) Digital's Secondary Use Service data containing information on hospitalisations. All data were linked, stored and analysed securely using the OpenSAFELY platform, https://www.opensafely.org/, as part of the NHS England OpenSAFELY COVID-19 service. The population covers 43% of the UK population and is broadly representative of the English population.[20] Pseudonymised data included coded diagnoses. All code is shared openly for review and re-use under the Massachusetts Institute of Technology (MIT) open licence (https://github.com/opensafely/covid_collateral_imd). Detailed pseudonymised patient data is potentially re-identifiable and therefore not shared.

In Denmark, all residents are assigned a unique personal identification number (the CPR number) at birth or immigration which makes it possible to link individual information among different data sources. We used data from: (1) the Danish National Patient Registry[21] containing all inpatient discharge diagnoses from all Danish hospitals since 1977 and from emergency room and outpatient specialist clinic contacts since 1995 (diagnoses are coded according to the International Classification of Diseases (ICD) 8 from 1977 to 1993 and to the ICD 10 thereafter); (2) the Danish Civil Registration System including vital status and date of death for the entire Danish population; (3) socioeconomic registries maintained by Statistics Denmark including data on family and household socioeconomics, country of origin, educational level, employment status and income; and (4) The Danish Prescription Registry which has recorded all redeemed drug prescriptions from community pharmacies in Denmark since 1995.[22]

Study population

In England, the study population included adults aged 18 and over registered at a general practice using TPP software with at least 3 months of continuous registration with the practice prior to study entry. In Denmark, the study population included all adults aged 18 and over registered in the Danish Civil Registration System. In both countries, we excluded people with missing age, sex or deprivation information (defined in the exposures section) as this could indicate poor data quality. In England, people were also excluded if their household

Table 1 Summary of English and Danish study designs

	England	Denmark
Inclusion criteria	Adults aged 18 and over, registered with a GP for at least 3 months prior to study entry.	Adults aged 18 and over, recorded and alive at cohort entry according to the Civil Registration System.
Exclusion criteria	Missing age, sex or patient level IMD, household size>15 or household size missing.	Missing age, sex or income.
Denominator population entry point	Latest of: Meeting inclusion criteria or 1 March 2018.	Latest of: Meeting inclusion criteria or 1 March 2018.
Denominator population exit point	Earliest of death, deregistering with their GP or end of study period.	Earliest of death, emigration according to the Civil Registration System or end of study period.
Exposure		
Deprivation measurement	Deprivation quintiles based on IMD in the month of interest.	Deprivation quintiles based on household income in 2020.
Outcomes		
Hospital admissions	Hospital admissions with ICD-10 code for heart failure, MI, stroke or VTE as the primary reason for admission (this refers to primary reason for spell in hospital).	Hospital admissions with ICD-10 code for heart failure, MI, stroke or VTE as the primary reason for admission.

GP, general practitioner; ICD-10, International Classification of Diseases: Version 2010; IMD, Index of Multiple Deprivation; MI, myocardial infarction; VTE, venous thromboembolism.

size was greater than 15 to exclude people living in institutions such as care homes who may have different hospital admission patterns. The measure of household size was a maximum of 15 in Denmark.

In both settings, the study period was 1 March 2018 and 31 December 2021. This was to give 2 years of data prior to the start of the pandemic for comparison. The study ended on 31 December 2021 as Danish data were only available up until this date. People entered the study at any time point during the study period as counts of outcomes were measured monthly. Follow-up continued until death or the end of the study period. In England, to measure denominators, people would also end follow-up if they deregistered with their general practitioner.

Study measures

Exposures

The primary exposure was socioeconomic deprivation which was measured by proxy. In England, deprivation was measured using quintiles of the patient-level Index of Multiple Deprivation (IMD) 2019.[23] IMD is a lower super output area level (comprising 400 to 1200 people) which is a measure of relative deprivation based on a person's postcode. The IMD score is based on indicators related to income, education, employment, health, crime, barriers to housing and services and living environment. We were unable to access an equivalent deprivation index in Denmark, so we used one aspect of deprivation; annual household income derived from the Danish Income Statistics Registry and divided into quintiles by year of age due to the variations in income by age (see online supplemental materials for details).[24]

Differences in outcomes by deprivation quintile were compared before and after the start of the pandemic restrictions. In England, pandemic restrictions were imposed on 23 March 2020,[25] equivalent restrictions were imposed in Denmark on 11 March 2020.[26] Since behaviours were likely to have changed prior to these dates, we used 1 March 2020 as the cut-off for both countries with time before this date referred to as the pre-pandemic period.

Outcomes

In both countries, we identified CVD-related hospital admissions based on recorded ICD-10 codes for myocardial infarction (MI), ischaemic or haemorrhagic stroke, heart failure and venous thromboembolism (VTE) assigned as the primary reason for admission.

Demographic and clinical characteristics

Demographic characteristics were identified at three time-points to describe the cohorts, these included age categorised into 20 year age bands, sex and, in England only, rural-urban classification. In England, comorbidities were identified from primary care records. People with a Systematized Nomenclature of Medicine Clinical Terms (SNOMED CT) code for type 1 or type 2 diabetes mellitus on or before each time-point were considered to have diabetes. People with a SNOMED CT code for asthma in the 3 years prior to each time-point were considered to have asthma. People aged 40 years or over with a SNOMED CT code for chronic obstructive pulmonary disease (COPD) were considered to have COPD. In Denmark, where clinical diagnosis data from primary care are not available, definitions for diabetes, asthma and COPD were based on hospital discharge diagnoses as well as primary-care prescribing data from the Prescription Registry.

Statistical analysis

The characteristics of each cohort, overall and by deprivation quintile, were described on 1 March 2019, 2020 and 2021. On the first day of each month of follow-up (from March 2018 to December 2022, inclusive), the inclusion criteria were assessed and the denominator adult population who met the inclusion criteria was extracted from respective national databases. Each outcome was analysed separately and individuals with outcomes were counted once each month. Individuals with records for the same outcome in multiple months were included each time.

The percentage of people experiencing each outcome was calculated for every study month. We plotted the monthly percentage and the percentage change compared with the previous month (first derivative) by deprivation quintile. To estimate the absolute impact of the pandemic on each outcome, we used Poisson regression adjusted for an indicator of whether it was pre-pandemic or during the pandemic (binary), deprivation quintile, the interaction of both pandemic time and deprivation quintile. We further adjusted for population as an offset and time as a monthly continuous variable to estimate the average count of each outcome, by deprivation quintile, in the 22 months pre-pandemic (May 2018–February 2020) and the 22 months during the pandemic (March 2020–December 2021). We accounted for autocorrelation by including first-order lagged residuals. We used the estimated average counts from the Poisson model to generate rate differences in the numbers of each monthly outcome stratified by deprivation quintile.

We used Python V.3.9.12 for data management and Stata V.17 and R V.4.2.1 for analyses. Code for data management and analysis as well as codelists are archived online https://github.com/opensafely/covid_collateral_imd. All iterations of the prespecified study protocol are archived with version control https://github.com/opensafely/covid_collateral_imd/tree/main/docs.

Information governance and ethical approval

In England, NHS England is the data controller of the NHS England OpenSAFELY COVID-19 service; TPP is the data processor; all study authors using OpenSAFELY have the approval of NHS England.[27] This implementation of OpenSAFELY is hosted within the TPP environment which is accredited to the ISO 27001 information security standard and is NHS IG Toolkit compliant.[28] Further information can be found in the supplementary materials.

RESULTS

On first March 2020, 16 239 645 people in England and 4 491 336 people in Denmark met the inclusion criteria. The characteristics of the study populations were similar, though there were differences in the recorded prevalence of comorbidities. There was a higher recorded prevalence of diabetes in England (England: 7.9% vs Denmark: 6.5%) and a higher recorded prevalence of asthma and COPD in Denmark (table 2). Study population characteristics were similar in 2019 and 2021 (online supplemental material).

When stratified by deprivation quintile, in England people in the most deprived quintile were younger with 44% aged 18–40 years old versus 28.8% of the least deprived quintile. In Denmark, age was taken into account in the deprivation quintiles, therefore age distributions were similar across deprivation quintiles. In both countries, COPD and diabetes were more prevalent in the most deprived quintile (COPD: England: Most deprived: 4.6% vs least deprived: 2.3%, Denmark: Most deprived: 11.5% vs least deprived: 7.6%, diabetes: England: Most deprived: 9.5% vs least deprived: 6.7%, Denmark: Most deprived: 8.8%, least deprived: 4.3%) (tables 3 and 4).

Hospital admissions overall

In both countries, there were similar proportions of the population admitted to hospital for each CVD outcome, although patterns by deprivation level differed between countries.

In England, across all outcomes, differences by deprivation level were small, although people in the most deprived quintile had the highest percentage of admissions for all outcomes. Across all outcomes, we observed a drop in admissions at the start of the pandemic and then a recovery to at least pre-pandemic levels by August 2020. This pattern did not vary by deprivation level. The largest decline in admissions was for heart failure. (Figure 1A and online supplemental figure S2), (online supplemental materials).

In Denmark, variation by deprivation quintile was more pronounced than in England for all outcomes. Overall, individuals in the most deprivation quintile had the highest proportion of admissions with admissions decreasing with decreasing deprivation. The biggest deprivation-related differences were seen for heart failure. The drop in admissions in March 2020 was greatest for individuals in the most deprived quintile with smaller drops seen in the less deprived quintiles. (Figure 1B and online supplemental figure S3), (online supplemental materials).

Hospitalisations during the pandemic

Poisson regression models indicated that, within deprivation quintiles, the number of admissions during the pandemic (1 March 2020 to 31 December 2021) was lower than expected and that there were small deprivation gradients in both England and Denmark.

England

In England, admissions for heart failure, MI and VTE were lower than expected with the gap between observed and expected largest for people in the most deprived

Table 2 Characteristics of English and Danish study populations as of 1 March 2020

Characteristic		England* N=16 439 645 n (%)	Denmark N=4 491 336 n (%)
Age category	18–40 years	5 908 145 (35.9)	1 600 989 (35.7)
	41–60 years	5 390 450 (32.8)	1 543 305 (34.4)
	61–80 years	4 094 795 (24.9)	1 145 112 (25.5)
	>80 years	1 046 255 (6.4)	201 930 (4.5)
Sex	Female	8 330 335 (50.7)	2 209 312 (49.1)
	Male	8 109 310 (49.3)	2 282 024 (50.8)
Deprivation†	1 (most deprived)	3 230 685 (19.7)	864 398 (19.3)
	2	3 297 365 (20.1)	903 277 (20.1)
	3	3 570 705 (21.7)	906 819 (20.2)
	4	3 324 625 (20.2)	908 303 (20.2)
	5 (least deprived)	3 016 270 (18.3)	908 539 (20.2)
Rural-urban	Rural	3 513 405 (21.4)	–
	Urban	12 926 245 (78.6)	–
Diabetes mellitus¶		1 309 600 (7.9)	292 027 (6.5)
Asthma‡		1 439 760 (8.8)	619 136 (13.8)
COPD§		533 645 (3.2)	417 649 (9.3)

*England data is rounded to the nearest 5.
†Deprivation measured by Index of Multiple Deprivation in England and income in Denmark.
‡Asthma definition: England: Asthma code in primary care record in the 3 years prior to study entry, Denmark: Hospital diagnosis code or asthma medication prescribing.
§COPD definition: England: Age>40 with COPD code in primary care record prior to study entry, Denmark: Hospital diagnosis code or COPD medication prescribing.
¶Diabetes definition: Type 1 or type 2 diabetes mellitus code in primary care record prior to study entry, Denmark: Hospital diagnosis code or diabetes medication prescribing.
COPD, chronic obstructive pulmonary disease.

quintile and smallest for those in the least deprived quintile. For heart failure admissions, the gap between observed and expected admissions was largest for individuals in the most deprived quintile and narrowed with decreasing deprivation. For people living in areas classified in the most deprived quintile, heart failure admissions were 17.8% lower than expected which in absolute terms translated to an estimated 2608 fewer admissions

Table 3 Characteristics of the English cohort on 1 January 2020, stratified by IMD quintile, n (column %)

		Deprivation quintile				
		1 (most deprived) N=3 230 685 (n, %)	2 N=3 297 365 (n, %)	3 N=3 570 705 (n, %)	4 N=3 324 625 (n, %)	5 (least deprived) N=3 016 270 (n, %)
Age category	18–40 years	1 423 295 (44.1)	1 324 355 (40.2)	1 244 865 (34.9)	1 048 195 (31.5)	867 440 (28.8)
	41–60 years	1 051 715 (32.6)	1 058 660 (32.1)	1 153 495 (32.3)	1 103 400 (33.2)	1 023 180 (33.9)
	61–80 years	613 970 (19)	734 080 (22.3)	931 390 (26.1)	929 165 (27.9)	886 185 (29.4)
	>80 years	141 705 (4.4)	180 270 (5.5)	240 955 (6.7)	243 865 (7.3)	239 465 (7.9)
Sex	Female	1 604 200 (49.7)	1 654 535 (50.2)	1 816 130 (50.9)	1 704 095 (51.3)	1 551 370 (51.4)
	Male	1 626 485 (50.3)	1 642 830 (49.8)	1 754 575 (49.1)	1 620 525 (48.7)	1 464 895 (48.6)
Rural-urban	Rural	141 420 (4.4)	486 290 (14.7)	1 044 165 (29.2)	999 265 (30.1)	842 265 (27.9)
	Urban	3 089 265 (95.6)	2 811 075 (85.3)	2 526 540 (70.8)	2 325 360 (69.9)	2 174 005 (72.1)
Diagnosis of diabetes mellitus		305 005 (9.5)	281 840 (8.5)	281 325 (7.9)	241 485 (7.3)	199 945 (6.7)
Diagnosis of asthma		298 250 (9.2)	287 435 (8.7)	309 400 (8.7)	285 885 (8.6)	258 790 (8.6)
Diagnosis of COPD		147 645 (4.6)	116 180 (3.5)	110 425 (3.1)	90 675 (2.7)	68 720 (2.3)

COPD, chronic obstructive pulmonary disease; IMD, Index of Multiple Deprivation.

Table 4 Characteristics of the Danish cohort on 1 January 2020, stratified by deprivation quintile

		Deprivation quintile				
		1 (most deprived) N=864 398 (n, %)	2 N=903 377 (n, %)	3 N=906 819 (n, %)	4 N=908 303 (n, %)	5 (least deprived) N=908 539 (n, %)
Age category	18–40 years	292 006 (33.8)	324 187 (35.9)	327 324 (36.1)	328 475 (36.2)	328 997 (36.2)
	41–60 years	303 906 (35.2)	309 437 (34.3)	309 854 (34.2)	310 154 (34.1)	309 954 (34.1)
	61–80 years	228 127 (26.4)	229 234 (25.4)	229 232 (25.3)	229 289 (25.2)	229 230 (25.2)
	>80 years	40 359 (4.7)	40 419 (4.5)	40 409 (4.5)	40 385 (4.4)	40 358 (4.4)
Sex	Female	448 832 (51.9)	495 897 (54.9)	454 872 (50.2)	444 284 (48.9)	438 139 (48.2)
	Male	415 566 (48.1)	407 380 (45.1)	451 947 (49.8)	464 019 (51.1)	470 400 (51.8)
Rural-urban	Rural	–	–	–	–	–
	Urban	–	–	–	–	–
Diagnosis of diabetes mellitus		76 420 (8.8)	67 905 (7.5)	59 439 (6.6)	49 510 (5.5)	38 753 (4.3)
Diagnosis of asthma		113 871 (13.2)	126 173 (14.0)	128 184 (14.1)	127 351 (14.0)	123 557 (13.6)
Diagnosis of COPD		99 289 (11.5)	91 384 (10.1)	82 567 (9.1)	75 052 (8.3)	69 357 (7.6)

COPD, chronic obstructive pulmonary disease.

between 1 March 2020 and 31 December 2021. In the least deprived quintile, heart failure admissions were 9% lower than expected translating to an estimated 979 fewer admissions between 1 March 2020 and 31 December 2021. For MI, variation by deprivation level followed a similar pattern, although differences were smaller. For VTE, there were estimated to be fewer admissions than expected, though there was little variation by deprivation quintile. For stroke, there were slightly more admissions than expected, also with little variation by deprivation quintile (figure 2 and online supplemental table S4), (online supplemental materials).

Denmark

In Denmark, admissions for MI were lower than expected. As a proportion of the number of expected admissions, the gap between observed and expected admissions over the pandemic period was largest for people in the least deprived quintile where admissions were 24% lower than expected compared with the most deprived quintile where admissions were 22% lower than expected. However, in absolute terms, differences were greatest in the most deprived quintile with 1013 fewer admissions during the pandemic compared with 619 fewer admissions in the least deprived quintile. For all other outcomes admissions during the pandemic were similar to pre-pandemic levels with little variation by deprivation level (figure 3 and online supplemental table S5), (online supplemental materials).

DISCUSSION

In this descriptive observational study set in England and Denmark, we found that deprivation-level differences in cardiovascular hospitalisations were not exacerbated by the pandemic, with a few exceptions. In England, overall, there were fewer heart failure admissions during the pandemic than expected and reductions increased with increasing deprivation. In Denmark, there were fewer stroke and VTE admissions than expected during the pandemic in the most deprived quintile. In England, overall cardiovascular admissions increased over time whereas in Denmark admissions remained stable.

In both England and Denmark, people in the most deprived quintile had a higher prevalence of diabetes and COPD; in England, the mean age of people in the most deprived group was lower than for those in other deprivation quintiles. In England, we observed a deprivation gradient across our outcomes which was comparable to that observed for other health outcomes.[3] However, differences by deprivation level were substantially more marked in Denmark. This could be due to the different measures of deprivation used. In Denmark, we used household-level income, while in England, we used IMD (a small area level measure based on the average deprivation level of an area assessed across a range of seven domains including income). IMD's sensitivity and specificity to income deprivation is low,[29] some people's deprivation levels could have been misclassified. Assuming such misclassification was not differential, this could bias any differences towards the null which could explain the smaller differences between deprivation levels in England compared with Denmark.

Compared with the expected admissions, reductions in actual admissions between the pre-pandemic and pandemic periods were greater in England compared with Denmark which generally experienced little change. This is consistent with other studies of CVD admissions and specifically for non-ST-elevation acute coronary syndromes in 2020.[7 14] Our study updates these findings to demonstrate that this pattern continued into 2021. There are potential explanations for this; the speed of response was quicker in Denmark which resulted in less stringent

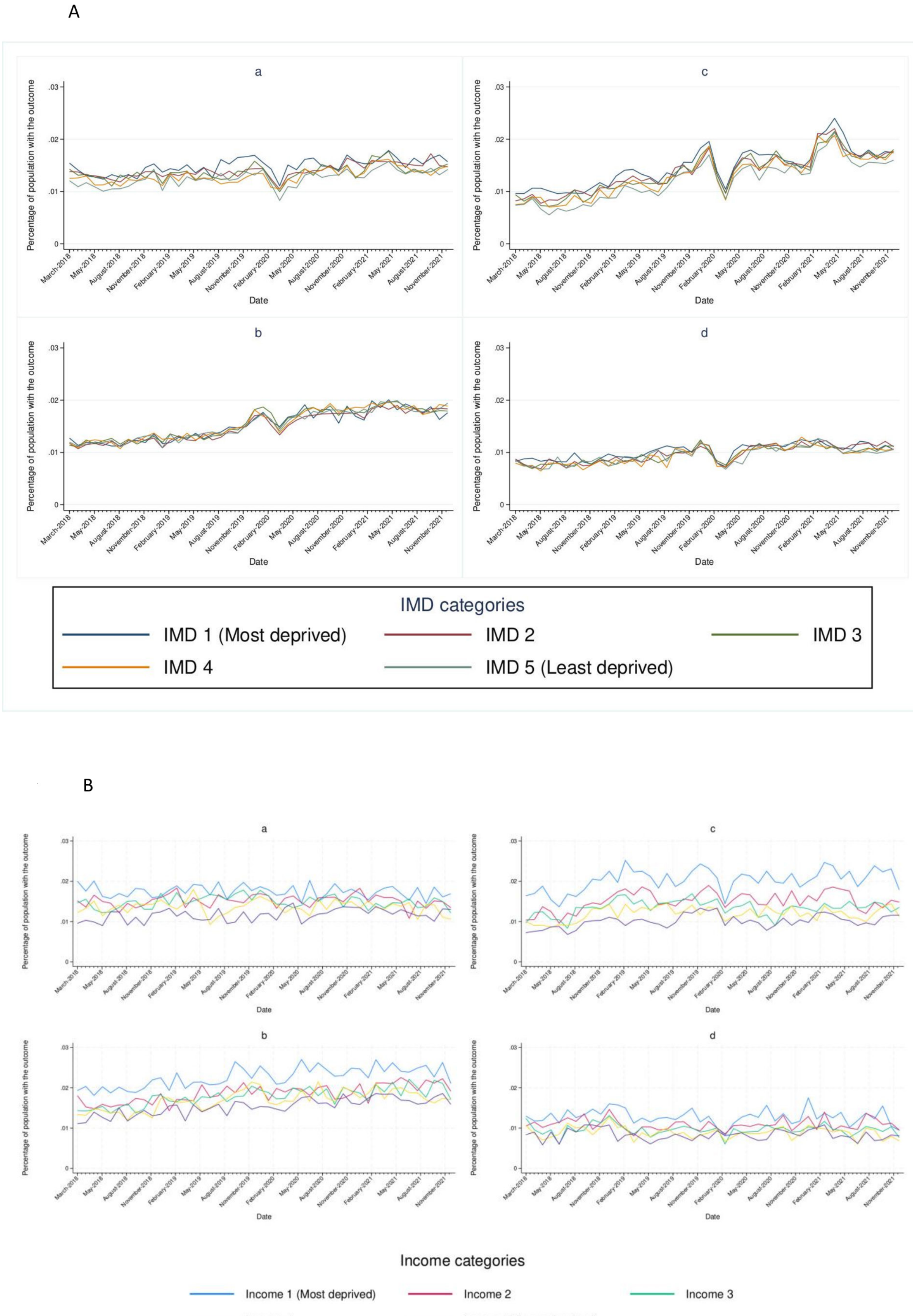

Figure 1 (A) Monthly percentage of population with hospital admissions for (a) myocardial infarction, (b) stroke, (c) heart failure, (d) venous thromboembolism, by deprivation quintile, in England. (B) Monthly percentage of population with hospital admissions for (a) myocardial infarction, (b) stroke, (c) heart failure, (d) venous thromboembolism, by deprivation quintile, in Denmark.

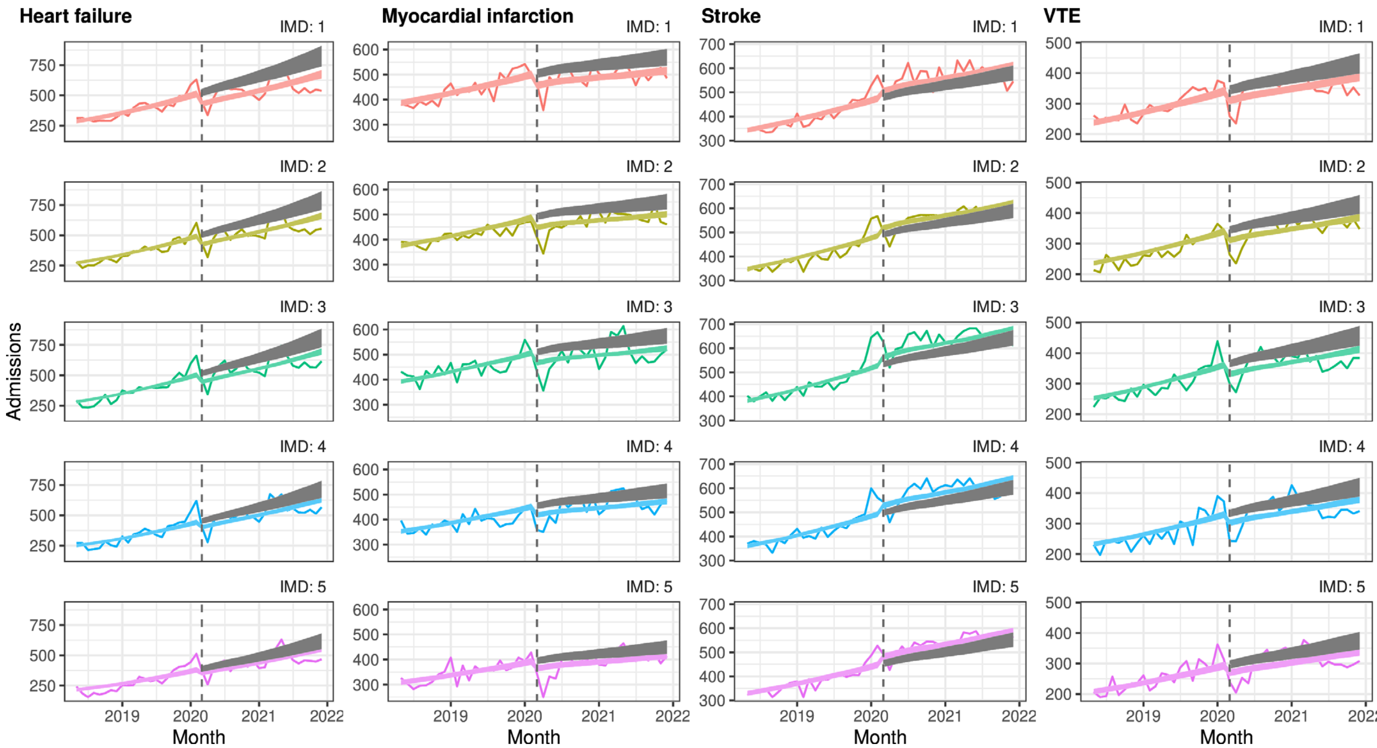

Figure 2 Interrupted time-series analysis of changes in hospital admissions in England before the pandemic (May 2018–February 2020) compared with during the pandemic (March 2020–December 2021), by deprivation quintile. Coloured lines indicate the estimated number of admissions per month with COVID-19 restrictions, grey lines indicate the estimated number of admissions per month without COVID-19 restrictions. IMD, Index of Multiple Deprivation; VTE, venous thromboembolism.

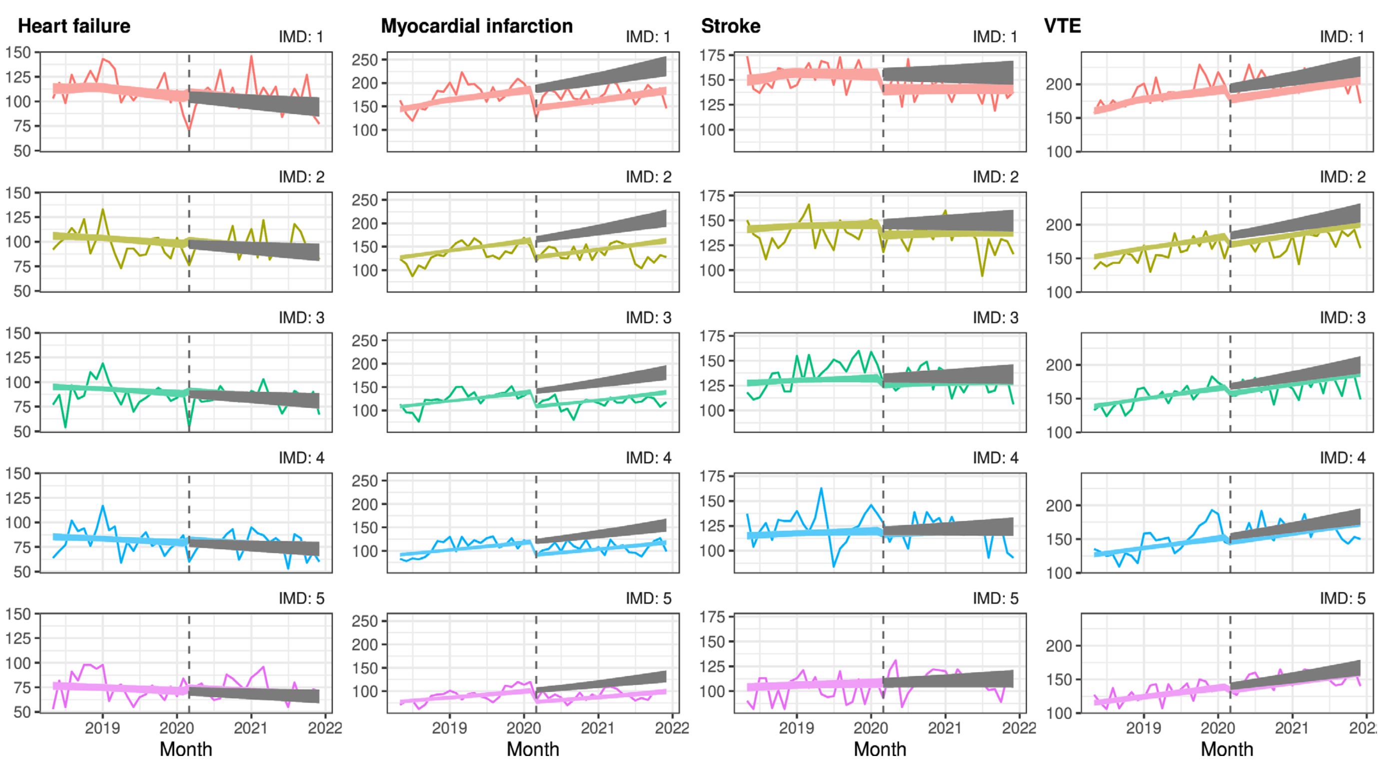

Figure 3 Interrupted time-series analysis of changes in hospital admissions in Denmark before the pandemic (May 2018–February 2020) compared with during the pandemic (March 2020–December 2021), by deprivation quintile. Coloured lines indicate the estimated number of admissions per month with COVID-19 restrictions, grey lines indicate the estimated number of admissions per month without COVID-19 restrictions. IMD, Index of Multiple Deprivation; VTE, venous thromboembolism.

restrictions in Denmark compared with England (online supplemental materials). There were fewer COVID-19 deaths in Denmark compared with England.[30] This may have meant cardiology services in hospitals remained similar during the pandemic as the health service may not have been so overwhelmed, whereas in England there was extreme disruption to primary care and secondary care cardiology services which would affect preventative care[31] and health-seeking for acute CVD events. In addition, some heart failure services moved into the community in England which may have resulted in fewer hospital admissions.[32]

Although studies have investigated the impact of the pandemic on cardiovascular admissions,[7 14] only a few studies have specifically investigated whether the pandemic impacted cardiovascular admissions by deprivation level.[33–35] Two studies, in the USA and Catalonia, compared socioeconomic differences in heart failure admissions between 2019 and 2020 found that the impact of the pandemic was similar across income groups.[30 33] These results are similar to our findings from Denmark where the impact of the pandemic was similar across deprivation groups in contrast to England where the reduction in heart failure admissions during the pandemic was larger in the most deprived. One study set in the USA found that the impact of the pandemic on stroke admissions was similar across income groups.[34] This was consistent with our findings in England, whereas in Denmark there were slightly fewer admissions during the pandemic in the most deprived group but differences were small. As these studies are set in different countries, there could be many reasons for the observed differences in admissions.

Strengths and limitations

Our study was large, encompassing 20 million people across two countries. Our study period ran until the end of 2021, longer than most previous studies (which largely ended in 2020),[33–35] allowing us to describe the longer-term impacts of the pandemic, although we acknowledge there could still be impacts later than 2021. Our study design allowed us to compare the impact in two countries that both have a free-at-the-point-of-use health service but different responses to the pandemic. This is important for future pandemic preparedness and understanding the optimal response that does not further inequalities. However, an important limitation was that our measures of deprivation were different in the two countries with the measure in England capturing more aspects of deprivation than the Danish measure resulting in potential misclassification. Another limitation was that some information was not available in both countries, thus we could not examine cardiovascular mortality or ethnicity as this was unavailable in Denmark. Finally, since our results are descriptive, they help to generate hypotheses of potential mechanisms of differences observed but do not provide insight into the causes of any observed differences.

CONCLUSIONS

During the pandemic, we did not observe a worsening of the socioeconomic gradient on cardiovascular admissions in England and Denmark. There were some exceptions, most notably greater reductions in heart failure admissions in the most deprived groups in England. While it is positive that the pandemic has not worsened socioeconomic differences in cardiovascular admissions, further work is needed to understand the reasons for the differences seen in heart failure admissions in England.

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Contributors REC, JT, ADH, LAP, SL, SVK, HC, PB and RM made substantial contributions to the design of the study. REC, ADH, JT, LP, HTS, VM, BZ, BM, SB and RM had access to the data. REC, ADH, JT, VM, BZ and RM verified the underlying data. REC, ADH and JT were responsible for data management and statistical analysis. All authors made substantial contributions to interpreting the data. REC and RM wrote the first draft of the manuscript. All authors critically revised the draft manuscript and approved the final manuscript. All authors accept responsibility to submit for publication. RM is the guarantor.

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Competing interests REC has personal shares in AstraZeneca (AZ) unrelated to this work. BM is also employed by National Health Service (NHS) England (all declarations are openly available at: https://www.whopaysthisdoctor.org/doctor/491/active). JH has grant funding from UKRI and the Wellcome Trust, has a patent with Juli Health unrelated to this work and has received consultancy fees from Juli Health and the Wellcome Trust unrelated to this work. RM is supported by Barts Charity (MGU0504), receives salary contributions from Genes & Health and has received consultancy fees from Amgen. JKQ has grants from MRC, HDR UK, GlaxoSmithKline (GSK), BI, Asthma + Lung UK and AZ and has received fees from GSK, Evidera, AZ and Insmed. SL was co-founder and co-chair of the RECORD steering committee and has a leadership role at Health Data Research UK. KM has received consultancy fees from Amgen. LAT has grant funding from MRC, the Wellcome Trust, has consulted for Bayer and is on the MHRA expert advisory group (Women's health) and is a member of four non-industry funded trial advisory committees (unpaid). AYSW is funded by British Heart Foundation (FS/19/19/34175) and AIR@InnoHK administered by Innovation and Technology Commission. AM has received consultancy fees from induction health and is a member of RCGP health informatics group and the NHS Digital GP data Professional Advisory Group. Department of Clinical Epidemiology, Aarhus University, receives funding for other studies from companies in the form of research grants to (and administered by) Aarhus University. None of these studies have any relation to the present study. All other authors declare no competing interests.

Patient and public involvement Patients and/or the public were not involved in the design, or conduct, or reporting, or dissemination plans of this research.

Patient consent for publication Not applicable.

Ethics approval This study was approved by the Health Research Authority (REC reference 20/LO/0651) and by the London School of Hygiene and Tropical Medicine Ethics Board (reference 21863). In Denmark, registry studies do not require ethical approval, but are reported to the Data Protection Board (Case number: 2016-051- 000001/1793).

Provenance and peer review Not commissioned; externally peer reviewed.

Data availability statement No data are available. Access to the underlying identifiable and potentially re-identifiable pseudonymised electronic health record data is tightly governed by various legislative and regulatory frameworks and restricted by best practice. The data in the National Health Service (NHS) England OpenSAFELY COVID-19 service is drawn from general practice data across England TPP is the data processor. TPP developers initiate an automated process to create pseudonymised records in the core OpenSAFELY database which are copies of key structured data tables in the identifiable records. These pseudonymised records are linked onto key external data resources that have also been pseudonymised via SHA-512 one-way hashing of NHS numbers using a shared salt. University of Oxford, Bennett Institute for Applied Data Science developers and PIs, who hold contracts with NHS England, have access to the OpenSAFELY pseudonymised data tables to develop the OpenSAFELY tools. These tools in turn enable researchers with OpenSAFELY data access agreements to write and execute code for data management and data analysis without direct access to the underlying raw pseudonymised patient data and to review the outputs of this code. All code for the full data management pipeline—from raw data to completed results for this analysis—and for the OpenSAFELY platform as a whole is available for review at github.com/OpenSAFELY.

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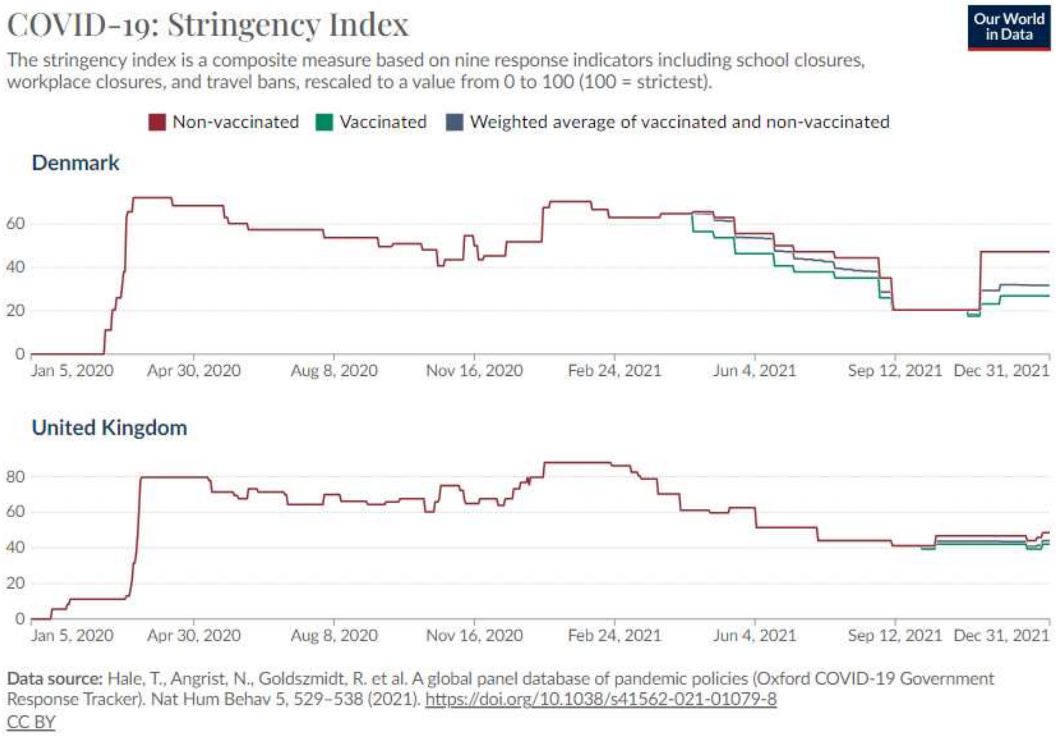
Supplementary materials

Table of contents

Figure S1: COVID-19 stringency index and confirmed COVID-19 deaths in the United Kingdom and Denmark



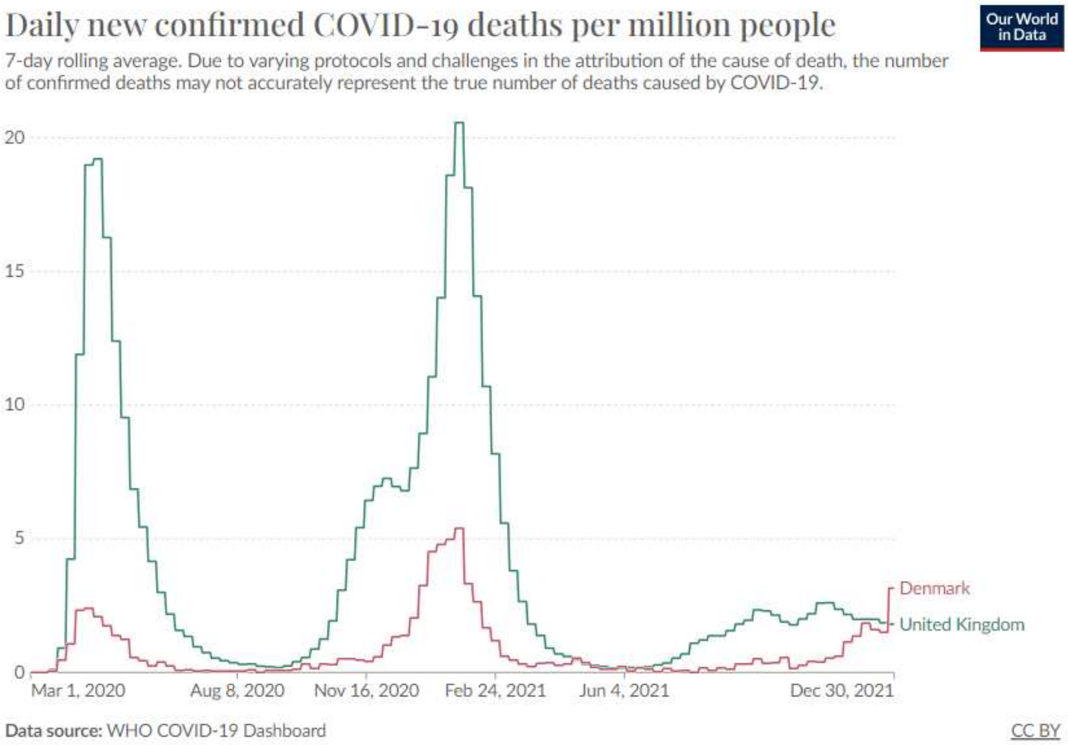


Table S1: Danish income quintile thresholds by age

Age	p20_EUR	p40_EUR	p60_EUR	p80_EUR
18	25182	72916	113666	150954
19	16410	45070	93213	141443
20	13808	26629	52777	111849
21	13584	23915	39847	75574
22	14709	24972	40259	69040
23	16221	27728	43680	70735
24	16392	28706	43212	66016

25	19506	34540	51115	75810
26	22470	40495	59474	84861
27	27020	45627	66811	91558
28	30462	50242	73609	97650
29	33471	54836	80029	103119
30	36405	59234	84719	107529
31	38774	63156	88893	111923
32	40835	66083	92045	115296
33	42702	68970	94971	119104
34	44419	71603	97645	122261
35	45197	73873	99855	125086
36	46870	75894	101873	128082
37	48078	78599	104282	131261
38	48998	79903	105971	133703
39	50160	81780	107947	136459
40	50379	82324	109129	138591
41	51080	83139	109933	139837
42	51717	84015	111295	142179
43	51668	84826	112578	144983

44	51499	84458	112709	146030
45	51923	85140	113956	147824
46	51986	85092	114176	148753
47	51048	84006	113080	148934
48	50309	83096	112877	148588
49	50456	83042	112546	148340
50	50419	82667	111829	148155
51	50217	82488	110889	146641
52	49285	80909	109046	144300
53	48459	79177	106941	141183
54	48745	78956	106260	139949
55	47567	76712	103671	136536
56	47100	75951	102339	133952
57	45956	73882	100135	131312
58	46055	72543	98054	128610
59	45267	70752	95914	125318
60	44704	68828	93708	123101
61	44527	66792	90723	119574
62	41205	60450	82624	112747

63	38763	57002	76277	105089
64	37439	53745	71035	98313
65	36607	49956	65004	91186
66	35667	48443	62382	85981
67	34423	46849	59731	81559
68	34403	45971	58114	79102
69	34222	45431	56805	76917
70	33622	44319	55098	74172
71	33375	43675	53797	72148
72	32626	42808	52307	70001
73	32027	41881	50661	67358
74	31353	40825	49147	66004
75	30837	39814	47483	64164
76	30303	38894	45992	61614
77	29797	37666	44750	59413
78	29559	37001	43971	58162
79	29370	36193	43190	56651
80	28757	35022	42021	54662
81	28385	34129	40959	52711

82	27844	32924	39839	50633
83	27550	32167	39079	49887
84	27280	31707	38525	48224
85	26758	31061	37573	46637
86	26684	30875	37046	45868
87	26416	30562	36288	45061
88	26201	30239	35620	44415
89	26352	30046	35183	43689
90	26066	29829	34498	42868
91	26109	29693	33904	42409
92	25861	29545	33560	41600
93	25777	29471	33491	41447
94	25748	29217	32653	40505
95	25787	29125	32621	40789
96	25500	29017	32155	39489
97	25182	29109	32050	38953
98	26479	29237	32696	40218
99	26264	29587	32396	40124
100	25613	28769	32105	38579

Information governance and ethical approval

Patient data has been pseudonymised for analysis and linkage using industry standard cryptographic hashing techniques; all pseudonymised datasets transmitted for linkage onto OpenSAFELY are encrypted; access to the NHS England OpenSAFELY COVID-19 service is via a virtual private network (VPN) connection; the researchers hold contracts with NHS England and only access the platform to initiate database queries and statistical models; all database activity is logged; only aggregate statistical outputs leave the platform environment following best practice for anonymisation of results such as statistical disclosure control for low cell counts [1]

The service adheres to the obligations of the UK General Data Protection Regulation (UK GDPR) and the Data Protection Act 2018. The service previously operated under notices initially issued in February 2020 by the the Secretary of State under Regulation 3(4) of the Health Service (Control of Patient Information) Regulations 2002 (COPI Regulations), which required organisations to process confidential patient information for COVID-19 purposes; this set aside the requirement for patient consent [2]. As of 1 July 2023, the Secretary of State has requested that NHS England continue to operate the Service under the COVID-19 Directions 2020 [3]. In some cases of data sharing, the common law duty of confidence is met using, for example, patient consent or support from the Health Research Authority Confidentiality Advisory Group [4].

Taken together, these provide the legal bases to link patient datasets using the service. GP practices, which provide access to the primary care data, are required to share relevant health information to support the public health response to the pandemic, and have been informed of how the service operates.

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Table S2: Characteristics of English and Danish cohorts as of 1st March 2019

Characteristic		England* N=15,623,860 n (%)	Denmark N= 4514317 n (%)
Age category	18 - 40 years	5,561,685 (35.6)	1,557,900 (34.5)
	41 - 60 years	5,222,525 (33.4)	1,547,804 (34.3)
	61 - 80 years	3,918,280 (25.1)	1,179,017 (26.1)
	>80 years	921,370 (5.9)	229,596 (5.1)
Sex	Female	7,913,915 (50.7)	2,293,371 (50.8)
	Male	7,709,950 (49.3)	2,220,946 (49.2)
Deprivation*	1 (Most deprived)	3,064,460 (19.6)	885,179 (19.6)
	2	3,114,535 (19.9)	905,664 (20.1)
	3	3,387,880 (21.7)	907,145 (20.1)
	4	3,169,585 (20.3)	908,171 (20.1)
	5 (Least deprived)	2,887,405 (18.5)	908,158 (20.1)
Rural-Urban	Rural	3,376,165 (21.6)	-
	Urban	12,247,700 (78.4)	-

Diabetes		1,201,440 (7.7)	309,468 (6.9)
Asthma		1,351,940 (8.7)	627,288 (13.9)
COPD		486,310 (3.1)	440,972 (9.8)

*England data is rounded to the nearest 5.

Table S3: Characteristics of English and Danish cohorts as of 1st March 2021

Characteristic		England* N=16,139,075 n (%)	Denmark N= 4358665 n (%)
Age category	18 - 40 years	5,636,175 (34.9)	1,380,568 (31.7)
	41 - 60 years	5,333,495 (33)	1,529,705 35.1
	61 - 80 years	4,126,510 (25.6)	1,202,524 (27.6)
	>80 years	1,042,895 (6.5)	245,868 (5.6)
Sex	Female	8,157,995 (50.5)	2,218,928 (50.9)
	Male	7,981,085 (49.5)	2,139,737 (49.1)
Deprivation*	1 (Most deprived)	3,176,660 (19.7)	830,850 (19.1)
	2	3,225,975 (20)	872,689 (20.0)
	3	3,499,040 (21.7)	880,638 (20.2)
	4	3,266,395 (20.2)	886,462 (20.3)

	5 (Least deprived)	2,971,010 (18.4)	888,026 (20.4)
Rural-Urban	Rural	3,467,460 (21.5)	-
	Urban	12,671,620 (78.5)	-
Diabetes		1,316,685 (8.2)	330,801 (7.6)
Asthma		1,426,670 (8.8)	634,776 (14.6)
COPD		516,940 (3.2)	453,375 (10.4)

*England data is rounded to the nearest 5.

Table S4 Estimated number of events during the pre-pandemic period (May 2018-February 2020) and during the pandemic period (March 2020-December 2021) with and without COVID-19 restrictions in England.

Outcome	Deprivation quintile	Estimated number of events pre-pandemic	Estimated number of events during pandemic period if pre-pandemic trends continued	Estimated number of events during pandemic with COVID-19 restrictions	Difference in estimated events with and without COVID-19 restrictions	% difference in estimated events with and without COVID-19 restrictions
		n (95% confidence interval)				% (95% confidence interval)
Heart failure	1 (Most deprived)	8,512 (8,090 - 8,955)	14,636 (13,514 - 15,853)	12,028 (11,504 - 12,576)	-2608	-17.8
	2	8,168 (7,866 - 8,482)	14,035 (13,062 - 15,084)	11,832 (11,441 - 12,236)	-2203	-15.7
	3	8,378 (8,104 - 8,662)	14,375 (13,408 - 15,414)	12,431 (12,069 - 12,803)	-1944	-13.5
	4	7,398 (7,104 - 7,704)	12,671 (11,773 - 13,641)	11,240 (10,853 - 11,641)	-1431	-11.3

	5 (Least deprived)	6,355 (6,016 - 6,714)	10,878 (10,015 - 11,818)	9,899 (9,447 - 10,373)	-979	-9
Myocardial infarction	1	9,683 (9,420 - 9,954)	11,859 (11,340 - 12,402)	10,751 (10,463 - 11,046)	-1108	-9.3
	2	9,421 (9,229 - 9,617)	11,536 (11,077 - 12,016)	10,507 (10,296 - 10,723)	-1029	-8.9
	3	9,802 (9,626 - 9,982)	11,980 (11,516 - 12,462)	10,962 (10,769 - 11,160)	-1018	-8.5
	4	8,779 (8,590 - 8,973)	10,707 (10,273 - 11,159)	9,844 (9,635 - 10,056)	-863	-8.1
	5	7,651 (7,430 - 7,878)	9,320 (8,902 - 9,759)	8,609 (8,365 - 8,860)	-711	-7.6

Stroke	1	8,895 (8,661 - 9,135)	11,697 (11,222 - 12,192)	12,316 (12,026 - 12,613)	619	5.3
	2	9,068 (8,890 - 9,249)	11,921 (11,485 - 12,373)	12,580 (12,357 - 12,807)	659	5.5
	3	9,884 (9,719 - 10,053)	12,970 (12,515 - 13,443)	13,719 (13,509 - 13,932)	749	5.8
	4	9,275 (9,092 - 9,461)	12,145 (11,700 - 12,608)	12,876 (12,646 - 13,109)	731	6
	5	8,467 (8,243 - 8,698)	11,078 (10,626 - 11,549)	11,770 (11,491 - 12,056)	692	6.2
Venous thromboembolism	1	6,272 (6,046 - 6,507)	8,549 (8,063 - 9,065)	7,703 (7,441 - 7,974)	-846	-9.9
	2	6,248 (6,080 - 6,422)	8,514 (8,075 - 8,977)	7,687 (7,490 - 7,889)	-827	-9.7

	3	6,656 (6,499 - 6,816)	9,052 (8,602 - 9,528)	8,190 (8,007 - 8,377)	-862	-9.5
	4	6,103 (5,933 - 6,278)	8,284 (7,853 - 8,740)	7,510 (7,312 - 7,714)	-774	-9.3
	5	5,444 (5,241 - 5,656)	7,383 (6,957 - 7,836)	6,707 (6,471 - 6,952)	-676	-9.2

Table S5 Estimated number of events during the pre-pandemic period (May 2018-February 2020) and during the pandemic period (March 2020-December 2021) with and without COVID-19 restrictions in Denmark.

Outcome	Deprivation quintile	Estimated number of events pre-pandemic	Estimated number of events during pandemic period if pre-pandemic trends continued	Estimated number of events during pandemic with COVID-19 restrictions	Difference in estimated events with and without COVID-19 restrictions	% difference in estimated events with and without COVID-19 restrictions
		n (95% confidence interval)				

Heart failure	1	2,434 (2,327 - 2,546)	2,176 (2,013 - 2,352)	2,240 (2,131 - 2,355)	64	2.9
	2	2,249 (2,174 - 2,327)	2,045 (1,903 - 2,198)	2,110 (2,033 - 2,190)	65	3.2
	3	2,021 (1,960 - 2,085)	1,849 (1,723 - 1,984)	1,912 (1,849 - 1,977)	63	3.4
	4	1,815 (1,747 - 1,885)	1,668 (1,549 - 1,796)	1,728 (1,659 - 1,801)	60	3.6
	5	1,627 (1,546 - 1,711)	1,497 (1,380 - 1,624)	1,555 (1,471 - 1,644)	58	3.9
Myocardial infarction	1	3,660 (3,516 - 3,810)	4,626 (4,315 - 4,961)	3,613 (3,462 - 3,770)	-1013	-21.9
	2	3,200 (3,104 - 3,299)	4,116 (3,859 - 4,390)	3,190 (3,089 - 3,293)	-926	-22.5

	3	2,721 (2,645 - 2,801)	3,521 (3,304 - 3,752)	2,708 (2,628 - 2,790)	-813	-23.1
	4	2,312 (2,231 - 2,396)	3,005 (2,810 - 3,214)	2,293 (2,208 - 2,382)	-712	-23.7
	5	1,961 (1,869 - 2,058)	2,552 (2,368 - 2,750)	1,933 (1,836 - 2,035)	-619	-24.3
Stroke	1	3,409 (3,295 - 3,527)	3,433 (3,239 - 3,639)	3,097 (2,983 - 3,215)	-336	-9.8
	2	3,170 (3,090 - 3,253)	3,248 (3,078 - 3,427)	3,007 (2,924 - 3,092)	-241	-7.4
	3	2,867 (2,801 - 2,935)	2,955 (2,804 - 3,114)	2,807 (2,739 - 2,877)	-148	-5
	4	2,590 (2,518 - 2,665)	2,682 (2,539 - 2,834)	2,615 (2,538 - 2,694)	-67	-2.5

	5	2,337 (2,250 - 2,427)	2,423 (2,280 - 2,575)	2,424 (2,328 - 2,524)	1	0
Venous thromboembolism	1	3,932 (3,811 - 4,056)	4,606 (4,372 - 4,853)	4,224 (4,092 - 4,361)	-382	-8.3
	2	3,688 (3,603 - 3,776)	4,396 (4,191 - 4,612)	4,076 (3,980 - 4,174)	-320	-7.3
	3	3,365 (3,295 - 3,437)	4,034 (3,850 - 4,228)	3,782 (3,703 - 3,863)	-252	-6.2
	4	3,067 (2,989 - 3,147)	3,694 (3,517 - 3,880)	3,501 (3,413 - 3,592)	-193	-5.2
	5	2,791 (2,696 - 2,888)	3,366 (3,188 - 3,554)	3,226 (3,116 - 3,339)	-140	-4.2

Figure S2: Monthly change (first derivative) in percentage of population with hospital admissions for each outcome in England

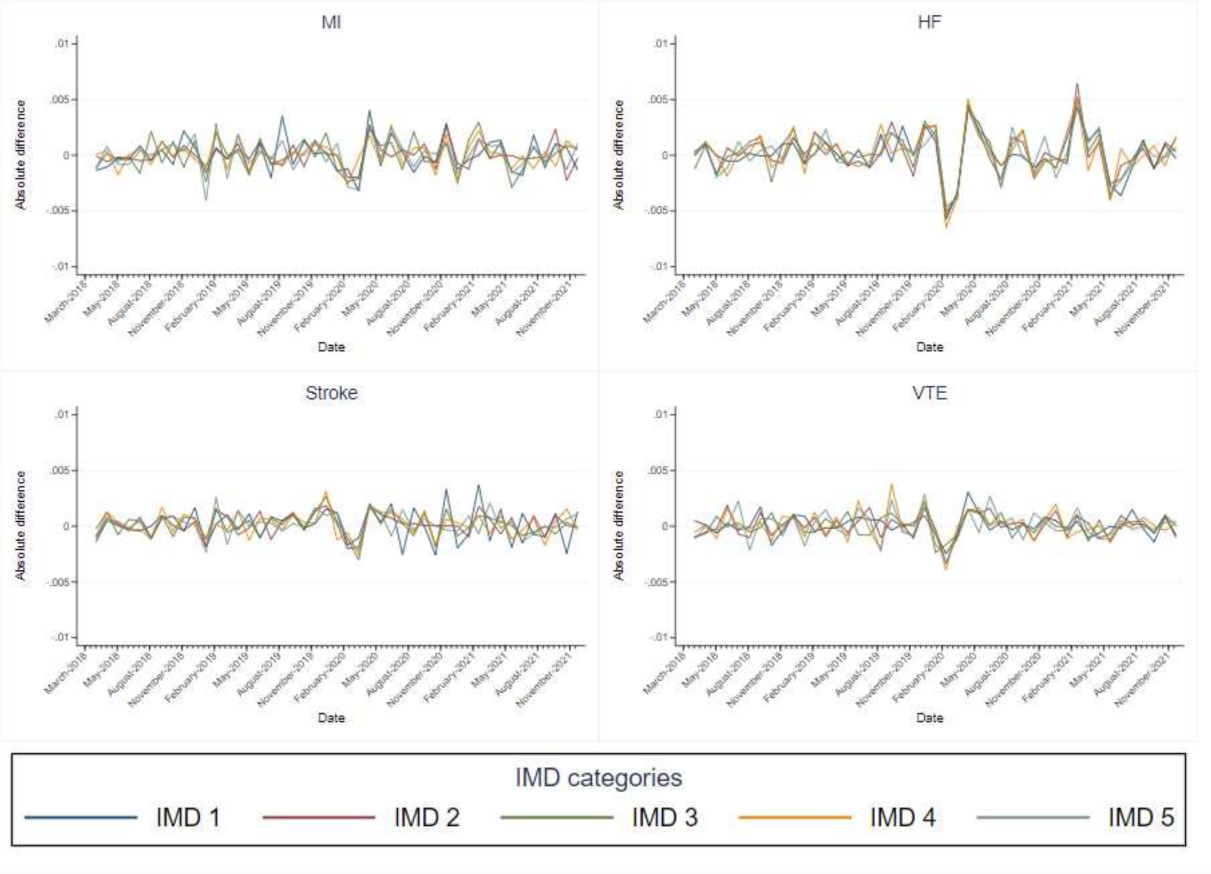

Figure S3: Monthly change (first derivative) in percentage of population with hospital admissions for each outcome in Denmark