Impact of first UK COVID-19 lockdown on hospital admissions: Interrupted time series study of 32 million people

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Summary

Background Uncontrolled infection and lockdown measures introduced in response have resulted in an unprecedented challenge for health systems internationally. Whether such unprecedented impact was due to lockdown itself and recedes when such measures are lifted is unclear. We assessed the short- and medium-term impacts of the first lockdown measures on hospital care for tracer non-COVID-19 conditions in England, Scotland and Wales across diseases, sexes, and socioeconomic and ethnic groups.

Methods We used OpenSAFELY (for England), EAVEII (Scotland), and SAIL Databank (Wales) to extract weekly hospital admission rates for cancer, cardiovascular and respiratory conditions (excluding COVID-19) from the pre-pandemic period until 25/10/2020 and conducted a controlled interrupted time series analysis. We undertook stratified analyses and assessed admission rates over seven months during which lockdown restrictions were gradually lifted.

Findings Our combined dataset included 32 million people who contributed over 74 million person-years. Admission rates for all three conditions fell by 34.2% (Confidence Interval (CI): -43.0, -25.3) in England, 20.9% (CI: -27.8, -14.1) in Scotland, and 24.7% (CI: -36.7, -12.7) in Wales, with falls across every stratum considered. In all three nations, cancer-related admissions fell the most while respiratory-related admissions fell the least (e.g., rates fell by 40.5% (CI: -47.4, -33.6), 21.9% (CI: -35.4, -8.4), and 19.0% (CI: -30.6, -7.4) in England for cancer, cardiovascular-related, and respiratory-related admissions respectively). Unscheduled admissions rates fell more in the most than the least deprived quintile across all three nations. Some ethnic minority groups experienced greater falls in admissions (e.g., in England, unscheduled admissions fell by 9.5% (CI: -20.2, 1.2) for Whites, but 44.3% (CI: -71.0, -17.6), 34.6% (CI: -63.8, -5.3), and 25.6% (CI: -45.0, -6.3) for Mixed, Other and Black ethnic groups respectively). Despite easing of restrictions, the overall admission rates remained lower in England, Scotland, and Wales by 20.8%, 21.6%, and 22.0%, respectively when compared to the same period (August-September) during the pre-pandemic years. This corresponds to a reduction of 26.2, 23.8 and 30.2 admissions per 100,000 people in England, Scotland, and Wales respectively.

Interpretation Hospital care for non-COVID diseases fell substantially across England, Scotland, and Wales during the first lockdown, with reductions persisting for at least six months. The most deprived and minority ethnic groups were impacted more severely.

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Keywords: SARS-CoV-2; Covid-19; Pandemic; Healthcare Disruption; Interrupted time series analysis; Healthcare Inequalities

Research in context

Evidence before this study

We searched PubMed for articles in any language published until November 03, 2021, using the search query ("COVID-19" OR "SARS-COV-2") AND ("disruption" OR "interrupted") AND ("hospital" OR "hospitalization" OR "admissions" OR "hospitalization" OR "secondary care"). Most studies were from a single hospital and reported substantial short-term reduction during the pandemic immediately after lockdowns were imposed. None of the studies assessed inequalities in healthcare provision or recovery after the lockdown restrictions were eased.

Added value of this study

To our knowledge, this is the largest study (over 74 million person-years) investigating the impact of COVID-19 and associated lockdown measures on hospital admissions. We investigated the immediate impact of the pandemic and accompanying lockdown measures, and the extent of recovery over six months following the imposition of lockdown as restrictions were gradually eased. We found substantial, persistent impact on non-COVID-19 healthcare provision. Healthcare provision did not uniformly affect population subgroups, with the most deprived and ethnic minorities more impacted.

Implications of all evidence available

Health systems have been subject to unprecedented impact following the COVID-19 pandemic and related lockdown measures. We find such impact has persisted far beyond periods of lockdown, suggesting a prolonged effect on health systems and ultimately the potential for adverse non-COVID healthcare outcomes. Inequalities in healthcare by ethnicity and socioeconomic position are likely to be exacerbated. Targeted support to reach the most socially disadvantaged groups and future monitoring are needed to mitigate healthcare inequalities.

Introduction

Coronavirus disease 2019 (COVID-19) caused by the SARS-CoV-2 virus, first identified in Wuhan China in December 2019, was declared a pandemic by the World Health Organization (WHO) on March 11, 2020.[1] To control transmission, governments across the world including the UK introduced unprecedented restrictions, such as country-wide lockdowns and diversion of finite healthcare resources to preferentially manage patients with COVID-19.[2] While these measures have demonstrably helped in controlling outbreaks,[3] they may also disrupt many facets of civil society, including healthcare provision and discouraging people from seeking healthcare.[4–10]

Early studies from the UK have suggested substantial impact of the COVID-19 pandemic on healthcare provision. However, the extent of impact on healthcare provision and whether it has been short-lived or led to detrimental effects that have persisted even when lockdown measures were lifted is unclear. In addition, pre-pandemic healthcare in the UK and internationally often did not meet the needs of all groups within society in an equitable fashion, with differences in access and quality of care seen by sex, socioeconomic position, and ethnicity. There are therefore concerns that lockdown measures may have exacerbated these pre-existing inequalities in healthcare.[5,11] It is essential to investigate the performance of the healthcare system and assess its ability to manage non-COVID-19 health conditions during the pandemic. We envisage that such investigations will facilitate data-driven, evidence-based policy decisions to help mitigate adverse knock-on healthcare impacts of the pandemic and improve healthcare system resilience during any future pandemic or climate-related stresses.[31]

In this study, we have taken three tracer health conditions, namely cancer, cardiovascular, and respiratory related conditions, and then quantified the extent of impact on healthcare provision during the lockdown measures in England, Scotland, and Wales. We have also assessed whether impacts were differential by socioeconomic position, sex, and ethnicity.

Methods

Data sources

We used the OpenSAFELY platform with the approval of NHS England,[12] EAVE II platform,[13] and SAIL Databank[14] to access secondary care data from England, Scotland, and Wales, respectively. The OpenSAFELY platform (see supplementary material for additional details), developed rapidly in response to the COVID-19 pandemic, is a secure analytics platform with linked healthcare data from across England.[12] The EAVE II platform, also rapidly developed in response to the COVID-19 pandemic, is a national surveillance system that links multiple datasets of the entire Scottish population using a unique patient identifier.[13] The SAIL Databank is a secure platform, open to bona fide researchers, with pseudo-anonymised health data of the entire Welsh population.[14]

Study design and population

We considered the complete data available in each of the databases (23.6 million people in OpenSAFELY-TPP covering 41.9% of the English population, 5.4 million people in EAVE II covering 99.9% of Scottish population, and 3.1 million people in Wales covering 99.9% of the Welsh population). We identified all weekly admissions with a primary diagnosis of cancer, cardiovascular conditions, and respiratory-related conditions (see Table S1 for a full listing of relevant diagnosis codes used) from January 1, 2019 to October 31, 2020 for England, and from January 1, 2016 to October 31, 2020 for Scotland and Wales. We stratified the weekly admissions rate by disease, socioeconomic status (most to least deprived), sex, ethnicity, and admission type (scheduled or unscheduled). We then conducted an interrupted time series (ITS) study with control using a single change point (week 12, 16−22 March, 2020).

The overall aim of the analysis was to estimate the step and trend change in 2020 when the lockdown restrictions were introduced, compared to historical admission rates (see the schematic in Figure 1). The single change point (also referred to as the "intervention" using ITS terminology) was the week when the UK Prime Minister advised the public to avoid any unnecessary travel and contact through a public address on March 16, 2020 (corresponding to week 12) that then culminated into a UK-wide, comprehensive lockdown on March 23, 2020.[15]

Consequently, we divided the 2020 follow-up period into two: weeks 1−11 (week ending January 5, 2020, to March 15, 2020) and weeks 12−43 (week ending March 22, 2020, to October 25, 2020). The pre-pandemic year (also referred to as the "control" time series using the ITS terminology) was also correspondingly divided into weeks 1−11, and weeks 12−43. For England, the control time-series was the admissions rate in 2019, and for Scotland and Wales the control time-series were the mean weekly admissions rate between 2016 and 2019.

Outcome measure

Our main outcome measure of interest, computed for every week during follow-up (January 1−October 25, 2020) was the age-standardised rate per 100,000 person years, using the European Standardized Population 2013 (ESP2013) as the standard.[16] We used the International Classification of Diseases, Tenth Revision (ICD-10) codes to identify all occurrences of admissions with a primary diagnosis related to cancer, cardiovascular and respiratory-related conditions. In ICD-10 codes, this corresponds to all codes in Chapters II, IX, and X (see Table S1 in supplementary information for a full listing). In brief, the codes used in this study are C00-C97, D00-D48, I00-I99, J00-J99. We used the total number of people at risk, at each time point (week), as the denominator and then age standardized it with ESP2013 for reference using 19 age bands (0−4 through 90+). For England and Wales, the total population number was determined for every week from the respective database (OpenSAFELY for England, and SAIL for Wales) and used as the denominator. For Scotland, mid-year population estimates for each year were used as the denominator.

Statistical analyses

We analyzed the weekly admissions rate during follow-up using controlled ITS analyses. To do this, we first formulated a regression equation with eight coefficients to be determined using Ordinary Least Squares Estimation (OLS). The eight coefficients were: an intercept term and existing trend; existing level and trend difference; post-intervention level and trend; and level change and trend change difference (see supplementary material for the equation). The OLS model was inspected for the presence of "autoregression" and "regression" type relationships using autocorrelation and partial autocorrelation plots. This step ensured that any seasonality pattern in the time-series can be adequately modeled. This step also helped identify the model order of autoregression and/or moving average to use for model adjustment. Finally, a generalized least squares (GLS) model was fitted to the data incorporating both the moving average and autoregression relationship in the data. The GLS model was then interrogated to get the change in level and trend after the intervention (imposition of lockdown). To ease interpretability and cross-comparison, we also computed the percentage change in level. This percentage change was computed as the change in

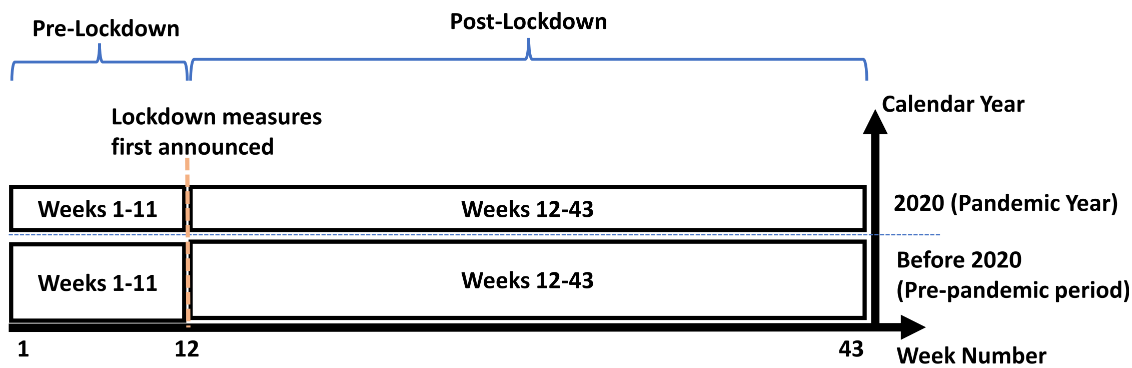

Figure 1. *Study Design Overview*. The follow-up period was divided into a pre-lockdown (weeks 1—11) and post-lockdown period (weeks 12—43) in 2020, and a historical follow-up period (2019 for England, and 2016—2019 for Scotland and Wales) was then used as the "control" in the ITS analyses.

level compared to the baseline admissions rate taken to be the mean rate during weeks 1—11 of the control period. The ITS analysis helped us to identify two potential changes that occurred because of COVID-19-related impact: the step change captured by the change in level and the gradual change during follow-up captured by the trend. We undertook independent ITS analysis for each country, overall and then stratified by sex, ethnicity, socioeconomic position, and admission type. In all cases, the unit of analysis was the weekly European Age Standardized admissions rate per 100,000 people.

We also assessed the extent of impact on healthcare provision when the strict restrictions first imposed with the first UK-wide lockdown on March 23, 2020, were gradually eased. After the first lockdown, and when COVID-19 infections rates began falling, restrictions across all the three nations were gradually eased until towards the end of September 2020 before restrictions were reintroduced due to rising rates of infections. Wales announced new restrictions on October 19, 2020, Scotland announced new restrictions on October 29, 2020, and England announced a second national lockdown on October 31, 2020. For each nation, we compared the mean admission rates in the last eight weeks (weeks 32—39 corresponding to week ending on August 9, 2020, to September 27, 2020) during the easing of restrictions with the corresponding rates in the same period during previous years by fitting a first order regression line and comparing the intercept (akin to the mean value in the period considered).

We undertook the analysis in R (version 3.6.2) using RStudio (version 1.4.1717). We used the tidyverse package for data manipulation (dplyr) and the lubridate package for date manipulation. For comparing the mean difference in admission rates, we constructed 95% confidence intervals (CI) using Welch's 2-sample t-test (modified t-test that does not assume equal variances of the two comparison groups). The 95% CI of the fitted parameter models were derived by assuming normality and using the confint command in R.

Study reporting

This study is reported following the recommendations of the REporting of studies Conducted using Observational Routinely-collected Data (RECORD).[17] All code for the OpenSAFELY platform and analysis is openly available for inspection and re-use at github.com/opensafely.

Ethics approvals and permissions

There were database-specific ethics approvals that allowed the use of the anonymised datasets for the current research study. These approvals were by the Health Research Authority (20/LO/0651) and LSHTM Ethics Board (21863) for OpenSAFELY, South East Scotland Research Ethics Committee 02 (12/SS/0201) and Public Benefit and Privacy Panel Committee of Public Health Scotland (1920-0279) for EAVE-II, and SAIL's independent Information Governance Review Panel (IGRP) for the SAIL Databank.

Role of the funding sources

The funders had no role in study design, data collection and analysis, decision to publish, or preparation of the manuscript. The views expressed are those of the authors and not necessarily those of the NIHR, NHS England, Public Health England or the Department of Health and Social Care. Sinead Brophy, John Kennedy and Roxane Cooksey had access to the SAIL databank and had checked and approved the manuscript for submission. Louis Fisher, Alex Walker, Brian Mackenna, Helen Curtis, Peter Inglesby, Simon Davy, Seb Bacon, and Ben Goldacre had access to the OpenSAFELY databank and had checked and approved the manuscript. Syed Ahmar Shah, Emily Moore, Utkarsh Agrawal,

Colin R Simpson, Aziz Sheikh and Srinivasa Vittal Katikireddi had access to the EAVE II database and had checked and approved the manuscript for submission. Syed Ahmar Shah received processed data from Louis Fisher (for OpenSAFELY), Emily Moore (EAVE II), and John Kennedy (SAIL Databank) for subsequent analyses. All authors approved the final manuscript for submission.

Results

Admission rates during follow-up

The total time in the study period was 39,258,674, 22,487,512 and 12,602,601 person-years for England, Scotland, and Wales, respectively. Figure 2 provides the admission rates during follow-up in the three nations.

For reporting the baseline characteristics, we divided both the pre-pandemic years (2019 for OpenSAFELY data and 2016–2019 for EAVE II and SAIL data) and the pandemic year (2020) in two periods: weeks 1–11, and weeks 12–43 (see Table 1 for detailed characteristics).

Interrupted time series analyses to assess impact of first lockdown

Overall, the admission rates (reported in ESP2013 per 100,000 people) in weeks 1–11 in the pre-pandemic years and the pandemic year were comparable for England (154.2 vs 147.4), Scotland (128.0 vs 122.5), and Wales (165.7 vs 165.5). However, there was a substantial difference in the mean admissions rate for weeks 12–43 between the pre-pandemic years and the pandemic years for England (139.8 vs 95.2), Scotland (116.8 vs 82.1), and Wales (152.2 vs 101.1). These observed differences were further confirmed by the ITS analysis that showed a substantial drop in overall admissions rate in England (34.2%), Scotland (20.9%), and Wales (24.7%) immediately after the lockdown in March 2020 (see Table 2). Scheduled admissions showed a greater drop in England (46.9% vs 13.6%), Scotland (34.5% vs 22.8%), and Wales (37.1% vs 11.1%) when compared to unscheduled admissions (Table 2). Further, the trend change was positive in all cases suggesting that there was some recovery after the lockdown during the follow-up period until October 2020 (Table 2).

Further ITS analyses comparing the change in admission rate after the lockdown compared to historical record (the previous year for England, and the mean of the previous four years for Scotland and Wales) in the same period stratified by disease, sex, socioeconomic position, and ethnicity showed a substantial drop in every stratum considered (see Tables S2–S4 in appendix). When stratified by disease, cancer fell the most (40.5% in England, 28.1% in Scotland, and 35.8% in Wales), followed by cardiovascular-related conditions (21.9% in England, 26.1% in Scotland, and 30.6% in Wales) and respiratory-related conditions fell the least (19.0% in England, 16.1% in Scotland, and 18.3% in Wales). For all the three diseases in the three nations, the percentage drop in scheduled admissions was higher compared to unscheduled admissions. Overall, the biggest drop was observed in scheduled respiratory-related admissions (69.5% in England, 100.3% in Scotland, 82.1% in Wales).

The drop in admissions rate, stratified by sex, were comparable for men and women with a slightly higher drop in men compared to women (33.5% vs 31.2% for England, 22.1% vs 21.6% for Scotland, and 25.7% vs 23.2% for Wales). When stratified by socioeconomic position, the percentage fall in admissions rate was also comparable between the least and most deprived in the three nations.

Reliable data for ethnicity was not available for Wales. In England, the scheduled admissions rate dropped the most for Black ethnicity (62.9%) and the unscheduled admissions rate dropped the most for Mixed ethnicity (44.3%). Asians had the least overall drop and in both scheduled and unscheduled admissions. In Scotland, non-Whites faced a substantially higher drop than Whites overall (21.5% vs 56.3%), and for both scheduled (62.7% vs 35.7%) and unscheduled admissions (37.7% vs 20.0%).

We also compared each stratum in 2020 with a reference in the same period (corresponding results for the three nations are in appendix, Tables S5–S7). For all nations, we found a substantially higher drop in scheduled cancer-related admissions (207.1% more in England, 149.3% more in Scotland, and 202.1% more in Wales), and a lower drop in cancer-related unscheduled admissions (11.5% less in England, 21.5% less in Scotland, and 18.6% less in Wales) compared to cardiovascular-related conditions. Further, we observed a higher drop in unscheduled admissions for quintile 1 (most deprived) compared to quintile 5 (least deprived) in all nations (14.0% more in England, 37.2% more in Scotland, and 14.5% more in Wales).

Impact on healthcare provision during easing of restrictions

Despite relaxations, we found that the mean admission rates in the last eight weeks during easing of restrictions (August-September 2020) were lower compared to previous years in the corresponding period for every stratum in the three nations (see Table 3). Despite easing of restrictions, the overall admission rates remained lower in England, Scotland, and Wales by 20.8%, 21.6%, and 22.0%, respectively when compared to the same period during the pre-pandemic years. This corresponds to a reduction of 26.2, 23.8 and 30.2 admissions per 100,000 people in England, Scotland, and Wales respectively.

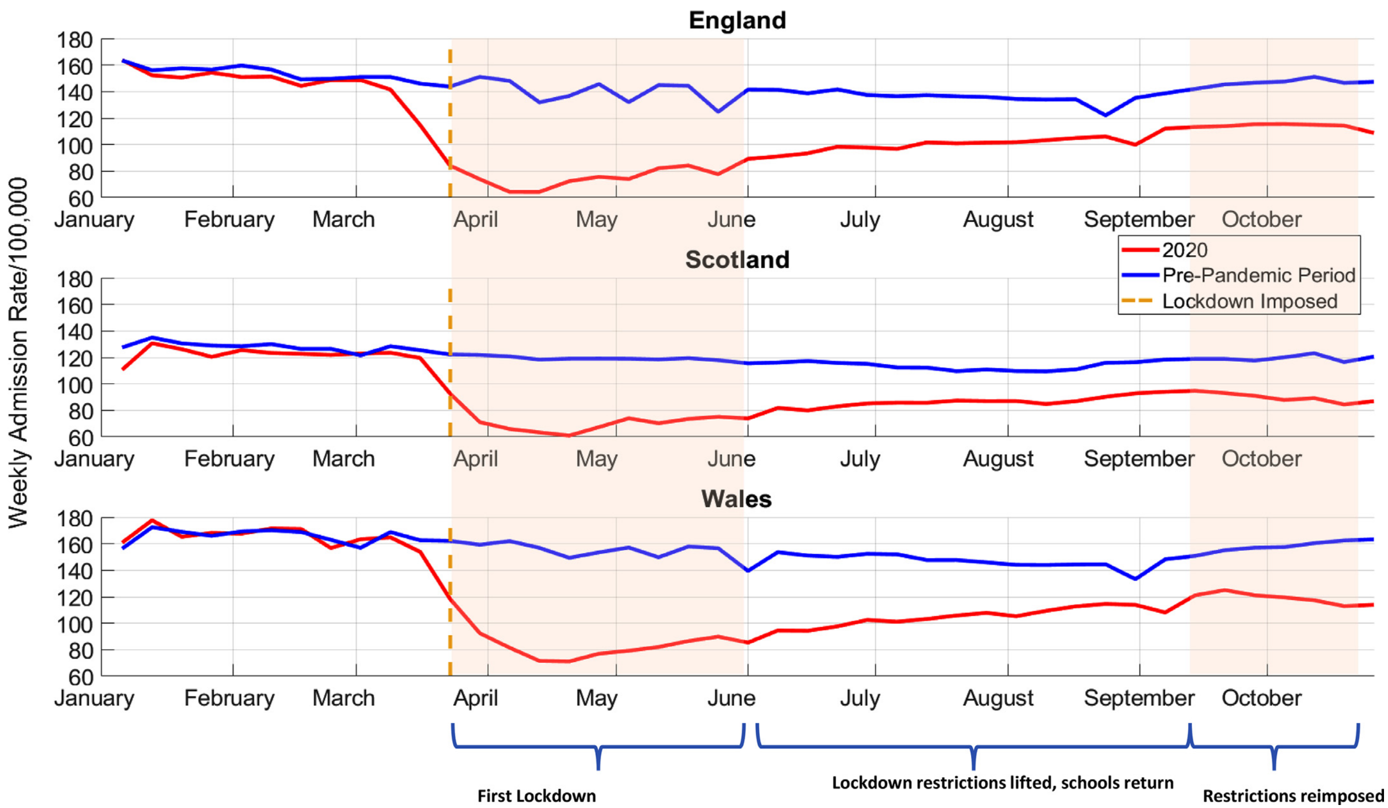

Figure 2. *Hospital Admission Rates in Each Nation During Follow-Up*. Any-cause (Cancer, Cardiovascular-related or respiratory-related excluding COVID-19) admission rates during the study follow-up in England, Scotland and Wales during the pre-pandemic and pandemic year. Imposition of lockdown imposed shown by vertical dashed line, admission rates during follow-up period until December 31, 2019 are plotted in blue (labeled as pre-pandemic period) and admission rates in 2020 are plotted in red.

Cohort	Mean of 2016–2019 (Scotland & Wales), 2019 (England); Pre-Pandemic Years		2020; Pandemic Year	
	Weeks 1–11	Weeks 12–43	Weeks 1–11 (pre-lockdown)	Weeks 12–43 (post-lockdown)
England	154.2 (150.7–157.8)	139.8 (137.3–142.4)	147.4 (139.2–155.6)	95.2 (89.5–100.9)
Scotland	128.0 (125.8–130.3)	116.8 (115.4–118.2)	122.5 (119.2–125.8)	82.1 (78.7–85.6)
Wales	165.7 (162.1–169.4)	152.2 (149.6–154.7)	165.5 (160.9–170.1)	101.1 (95.5–106.8)
Stratification by disease				
England				
Cardiovascular	32.2 (31.7–32.8)	31.2 (30.7–31.7)	31.2 (28.9–33.5)	23.6 (22.0–25.3)
Respiratory	43.5 (40.5–46.5)	31.4 (29.9–32.9)	37.3 (33.9–40.8)	15.9 (14.8–17.0)
Cancer	78.5 (77.4–79.7)	77.2 (75.9–78.5)	78.9 (76.1–82.6)	55.7 (52.5–58.8)
Scotland				
Cardiovascular	30.6 (29.5–31.7)	29.6 (29.3–29.9)	28.2 (26.6–29.9)	22.4 (21.1–23.6)
Respiratory	43.0 (40.1–45.9)	32.1 (30.9–33.4)	37.8 (35.3–40.4)	16.9 (15.8–17.9)
Cancer	54.4 (52.6–56.2)	55.0 (54.7–55.3)	56.4 (53.1–59.8)	42.9 (41.2–44.6)
Wales				
Cardiovascular	31.02 (29.86–32.19)	30.74 (30.35–31.14)	30.62 (29.18–32.07)	22.72 (21.18–24.26)
Respiratory	50.54 (48.29–52.79)	36.49 (34.61–38.37)	46.51 (42.30–50.71)	16.67 (15.26–18.08)
Cancer	84.18 (81.13–87.23)	84.93 (83.97–85.90)	88.41 (84.52–92.31)	61.75 (58.38–65.13)
Stratification by sex				
England				
Males	164.6 (161.1–168.1)	149.6 (147.0–152.3)	157.5 (149.0–166.0)	101.6 (95.3–108.0)
Females	147.1 (143.4–150.8)	133.1 (130.7–135.6)	140.4 (132.3–148.5)	91.0 (85.9–96.1)
Scotland				
Males	133.9 (131.6–136.2)	122.3 (120.9–123.6)	129.3 (125.5–133.1)	85.2 (81.5–89.0)
Females	122.2 (119.7–124.7)	111.3 (109.9–112.8)	115.6 (112.6–118.6)	79.0 (75.8–82.2)
Wales				
Males	166.0 (163.7–168.3)	152.8 (150.2–155.4)	165.1 (160.5–169.7)	101.2 (94.8–107.5)
Females	167.3 (164.1–170.5)	151.4 (149.1–153.7)	166.0 (160.9–171.1)	101.1 (96.1–106.1)
Stratification by socioeconomic status				
England				
Quintile 1	130.2 (127.1–133.3)	119.0 (116.0–122.0)	135.6 (127.1–144.0)	90.7 (83.8–97.5)
Quintiles 2–4	116.0 (113.4–118.5)	108.2 (105.9–110.5)	122.6 (115.8–129.3)	82.6 (76.3–88.8)
Quintile 5	107.6 (105.4–109.8)	100.7 (98.4–102.9)	113.0 (106.5–119.4)	75.7 (69.9–81.4)
Scotland				
Quintile 1	165.8 (162.7–168.9)	148.7 (146.6–150.9)	154.4 (150.4–158.4)	101.7 (97.0–106.4)
Quintiles 2–4	122.7 (120.4–124.9)	111.7 (110.4–113.0)	116.7 (113.1–120.2)	78.7 (75.5–81.8)
Quintile 5	107.8 (105.6–110.1)	100.3 (99.2–101.4)	104.8 (100.2–109.4)	71.2 (67.7–74.6)
Wales				
Quintile 1	166.9 (164.6–169.2)	148.6 (145.8–151.3)	160.0 (154.2–165.9)	92.7 (87.5–97.9)
Quintiles 2–4	169.9 (167.0–172.9)	155.2 (152.7–157.8)	167.4 (162.7–172.1)	102.3 (96.5–108.1)
Quintile 5	163.4 (160.1–166.7)	151.8 (149.4–154.1)	172.9 (168.3–177.5)	109.4 (103.2–115.5)
Stratification by ethnicity				
England				
White	128.3 (125.4–131.1)	119.2 (116.5–121.9)	135.4 (128.1–142.7)	91.2 (84.4–98.0)
Mixed	111.3 (103.1–119.4)	102.9 (99.1–106.7)	117.6 (108.0–127.1)	77.3 (70.6–83.9)
Asian	116.1 (113.7–118.6)	104.0 (101.8–106.2)	108.8 (99.0–118.5)	65.8 (59.8–71.7)
Black	110.2 (106.2–114.3)	104.2 (101.1–107.3)	112.3 (101.8–122.9)	71.0 (64.9–77.2)
Other	94.1 (88.8–99.3)	89.7 (86.8–92.6)	96.4 (87.0–105.8)	68.7 (61.6–75.8)
Scotland				
White	108.7 (106.6–110.9)	98.8 (97.7–100.0)	104.4 (101.3–107.4)	70.1 (66.8–73.4)
Non-White	132.7 (124.2–141.1)	126.5 (122.9–130.1)	142.1 (130.5–153.6)	93.7 (87.4–100.0)

***Table 1*: *Baseline Characteristics of the Study Population*. Mean admission rate (European Age Standardised and per 100,000 people) in the pre- and post-pandemic periods stratified by disease, sex, ethnicity, and socioeconomic position for admissions in England, Scotland, and Wales. Before lockdown corresponds to the mean rate in weeks 1–11, and the after lockdown period corresponds to the mean rate in weeks 12–43.**

Discussion

We found substantial impact on healthcare provision after the first UK-wide lockdown in March 2020 in England, Scotland, and Wales with admission rates due to cancer, cardiovascular-related conditions, and respiratory-causes (excluding COVID) falling substantially in 2020 compared to pre-pandemic levels. This reduction was observed for both males and females, all ethnicities,

Cohort	Mean (Intercept)	Change in Level after Intervention (95% CI)	Change in Trend after Intervention (95% CI)	Percentage Change in Level,% (95% CI)
England				
All admissions	161.3	−52.7 (−66.4, −39.0)	2.9 (0.6, 5.1)	**−34.2 (−43.0, −25.3)**
Scheduled admissions only	92.1	−42.7 (−50.1, −35.3)	1.8 (0.7, 2.9)	**−46.9 (−55.0, −38.9)**
Unscheduled admissions only	68.48	−8.6 (−14.9, −2.3)	−0.2 (−0.2, 2.9)	**−13.6 (−23.6, −3.6)**
Scotland				
All admissions	132.14	−26.8 (−35.6, −18.0)	1.1 (−0.7, 2.9)	**−20.9 (−27.8, −14.1)**
Scheduled admissions only	56.79	−21.22 (−27.9, −14.6)	1.1 (0.1, 2.1)	**−34.5 (−45.3, −23.7)**
Unscheduled admissions only	74.72	−15.1 (−21.3, −8.9)	0.2 (−1.2, 1.5)	**−22.8 (−32.2, −13.5)**
Wales				
All admissions	161.5	−40.90 (−60.8, −21.0)	3.2 (−1.2, 7.5)	**−24.7 (−36.7, −12.7)**
Scheduled admissions only	90.8	−35.0 (−46.4, −23.6)	1.7 (−0.1, 3.6)	**−37.1 (−49.2, −25.0)**
Unscheduled admissions only	79.72	−7.4 (−13.0, −1.8)	2.9 (1.2, 4.5)	**−11.1 (−19.4, −2.7)**

***Table 2*: *Interrupted Time Series Results*. Interrupted time series analyses of data from England, Scotland and Wales when comparing each stratum in 2020 with a control group defined by historical data of the same strata average of 2016−2019 for Scotland and Wales, and 2019 for England. The admission rates are the stated number per 100,000 standardised population.**

and across all socioeconomic groups. Compared to cardiovascular-related and respiratory-related causes, cancer-related admissions fell more throughout Great Britain (driven largely by a reduction in scheduled admissions). Further, unscheduled admissions in quintile 1 (most deprived) faced bigger impact compared to quintile 5 (least deprived) in the three nations. Some ethnic minorities in England (Black, Mixed, Other) and Scotland (non-White) faced bigger impacts compared to White. Despite gradual easing of lockdown restrictions over six months after the first lockdown, the admission rates due to cancer, cardiovascular-related, and respiratory-related causes remained considerably lower than pre-pandemic times suggesting sustained impact on healthcare provision.

To our knowledge, this is the largest study investigating the impact of COVID-19 on healthcare provision covering 99.9% of the Scottish and Welsh population, and around 42% of the English population. The key strength of this paper includes a long follow-up, covering a large geographic area, studying different healthcare conditions, being able to distinguish between scheduled and unscheduled care, being able to stratify by sex, ethnicity, and socioeconomic position, and using routine hospital records thereby mitigating the risks of both selection bias and information bias often associated with observational studies.

There are some limitations to note. While the most plausible explanation for the majority of the reduced admissions is likely due to the cancellation of many routine services usually offered by the National Health Services (NHS) to redirect staff and resources to COVID-19 patients, it is also likely that to some extent, behavior change and improved self-management may have led to a genuine reduction in healthcare need; for example patients were encouraged not to present with more minor conditions to avoid exposure to the virus and putting pressure on health services unnecessarily. Diagnostic and screening services were also severely reduced, meaning that fewer people would be attending hospital for newly diagnosed conditions. We have not measured GP appointments, outpatient services, care-at-home services or other provisions that may have in some cases adapted to provide additional services for patients who would otherwise have attended hospital. There is some evidence to suggest that respiratory-related admission reduced during the pandemic possibly due to pandemic-related non-pharmacological interventions.[18,19] However, we cannot separate out any genuine reduction in demand due to improved health from a reduction due to disruption in this study. Further, a patient can have multiple diagnoses during a single admission episode. We have, however, considered only the “primary” cause of admission when estimating admission rates. In addition, the start of the follow-up period from OpenSAFELY was from January 1, 2020, but it was January 1, 2016, for data from Scotland and Wales. The ITS model we have used consisted of linear terms only and it will not account for any non-linear changes over time, other than autoregression type relationships that are separately accounted for. Lastly, the ITS analysis is ideally suited to assess the impact of an intervention (such as imposition of lockdown) introduced at a specific time. It is likely that healthcare provision was impacted to some extent due to escalating infection rates themselves (which then led to lockdown restrictions in the UK). In this study, however, we are not able to distinguish between the impact of uncontrolled infections and the effects of lockdown itself on healthcare provision.

The substantial impact on healthcare provision we found after the first lockdown has been corroborated by additional UK studies. Wyatt et al. found a 51% reduction in attendance to emergency department in England

Cohort	Pre-pandemic years; Mean of 2016−2019 (Scotland & Wales), 2019 (England); (95% CI)	Pandemic year (2020) (95% CI)	Absolute Difference	Relative Difference (%)
England	126.1 (115.7−136.5)	99.9 (93.2−106.5)	26.2	20.8
Scotland	110.0 (106.2−113.9)	86.2 (81.3−91.1)	23.8	21.6
Wales	137.5 (126.5−148.6)	107.3 (99.2−115.4)	30.2	22.0
Stratification by Disease				
England				
Cardiovascular	28.6 (26.5−30.7)	25.4 (23.6−27.2)	3.2	11.2
Respiratory	22.2 (18.5−25.9)	15.4 (13.3−17.6)	6.8	30.6
Cancer	75.3 (68.5−82.2)	59.0 (54.8−63.2)	16.3	21.6
Scotland				
Cardiovascular	30.1 (28.2−31.9)	25.3 (23.3−27.2)	4.8	15.9
Respiratory	24.7 (22.9−26.6)	16.4 (11.6−21.1)	8.3	33.6
Cancer	55.2 (53.2−57.2)	44.6 (42.6−46.6)	10.6	19.2
Wales				
Cardiovascular	29.3 (27.3−31.4)	24.7 (23.0−26.4)	4.6	15.7
Respiratory	25.1 (20.7−29.5)	14.2 (12.0−16.4)	10.9	43.4
Cancer	83.1 (76.7−89.5)	68.3 (62.2−74.4)	14.8	17.8
Stratification by Sex				
England				
Males	135.5 (124.4−146.6)	106.9 (100.8−113.0)	28.6	21.1
Females	119.3 (109.5−129.1)	95.1 (88.0−102.1)	24.2	20.3
Scotland				
Males	115.3 (111.5−119.1)	88.3 (82.6−94.0)	27.0	23.4
Females	104.8 (100.5−109.1)	84.1 (79.0−89.2)	20.7	19.8
Wales				
Males	138.3 (126.1−150.5)	109.4 (97.9−121.0)	28.9	20.9
Females	138.5 (128.6−148.5)	105.1 (99.2−110.9)	33.4	24.1
Stratification by Socioeconomic Position				
England				
Quintile 1 (most deprived)	102.4 (92.8−112.0)	94.4 (87.1−101.7)	8.0	7.8
Quintiles 2−4	96.8 (88.3−105.4)	87.6 (81.2−93.9)	9.2	9.5
Quintile 5 (least deprived)	92.5 (83.0−102.0)	80.3 (74.3−86.3)	12.2	13.2
Scotland				
Quintile 1 (most deprived)	137.8 (132.4−143.3)	106.4 (95.7−117.2)	31.4	22.8
Quintiles 2−4	105.7 (102.1−109.3)	82.5 (77.4−87.6)	23.2	21.9
Quintile 5 (least deprived)	95.2 (91.4−99.1)	76.1 (71.2−80.9)	19.1	20.1
Wales				
Quintile 1 (most deprived)	132.3 (120.3−144.2)	95.3 (88.5−102.1)	37.0	28.0
Quintiles 2−4	141.7 (130.6−152.8)	110.4 (101.0−119.8)	31.3	22.1
Quintile 5 (least deprived)	139.5 (128.0−151.0)	115.0 (104.3−125.7)	24.5	17.6

***Table 3: Admission rates during minimal lockdown restriction*. Comparison of mean admission rates in the last 8 weeks when lockdown restrictions were minimal during the follow-up (Weeks 32−39; August − September) between the pandemic year (2020) and the pre-pandemic period (2019 for England, and 2016−2019 for Scotland, and Wales).**
CI: Confidence Interval.

after the first lockdown.[20] Mulholland et al. looking at any-cause hospital attendance and admissions in Scotland during the first lockdown found a 41% reduction in visits, 26% reduction in unscheduled and 61% reduction in scheduled admissions.[4] Unlike our study, the aforementioned studies only looked at the immediate impact of the first lockdown. Further, we were also able to stratify the analyses by several demographic categories and assess healthcare inequalities.

Substantial impact on secondary care due to COVID-19 pandemic have also been reported in other countries including Belgium,[21] South Africa,[22] China,[23] and South Korea.[24] Most of these studies looked at hospital admissions for any cause and undertook controlled ITS analysis comparing pre-pandemic and pandemic periods. These studies were relatively small and often from a single hospital. Likely explanations provided for the significant impact during the pandemic were a change in health-seeking behaviours,[18] improved self-management,[25] lifestyle,[26] improved air-quality,[25] and increasing emergency capacity to treat COVID-19 at the expense of other services.

The uneven impact across socioeconomic position and ethnicity adds to existing evidence base and aligns with findings from UK-wide survey-based studies during the COVID-19 pandemic,[11] and other studies that have reported that past pandemics exacerbate existing healthcare provision disparities.[27]

Our study has important implications for policy. While further research is needed to better characterize which clinical specialties and demographic groups have been most affected, an urgent response is required now. Although lockdown measures are becoming less common in many countries as vaccination programmes are being successfully rolled out, the removal of lockdown measures may not necessarily be accompanied by improved delivery and/or uptake of health services. Consequently, there is an urgent need to identify the most vulnerable groups, so that accessibility of healthcare services is maximized and therefore further adverse knock-on effects are mitigated.

The substantial impact on non-COVID-19 healthcare services and, at best, partial recovery despite easing of restrictions is alarming. This will likely have a knock-on impact on both medium-term and long-term health outcomes. Preliminary studies have already reported excess cardiovascular-related[28] and cancer-related[29] deaths due to impact on healthcare provision. Our study further adds to previous evidence base suggesting lack of healthcare systems resilience during a pandemic[30] and underscores the need for it to ensure unimpeded, equitable provision of essential services during any future pandemic or climate emergency-related stresses.[31]

In summary, we conducted the largest study to date assessing the impact of the pandemic on non-COVID health service provision. There was a substantial reduction in hospital care for non-COVID diseases across England, Scotland, and Wales immediately after the first lockdown. This impact on healthcare provision persisted more than six months later despite easing of restrictions. The impact on healthcare provision was not uniform with the most deprived and some ethnic minorities the most affected. This will likely have a knock-on effect on healthcare outcomes. There is therefore an urgent need to minimize impact on non-COVID healthcare services and provide targeted support to more socially disadvantaged groups to mitigate healthcare inequalities.

Contributors

SVK conceived the idea for the study. SAS led the study design, with SVK and AS. SAS drafted the paper, with all co-authors critically revising the manuscript. All authors approved the final version of the manuscript; OpenSAFELY Contributors: AW, BM, PI, SD, SB, LF, BG, HC; EAVE II Contributors: AS, EM, SAS, SVK, UA, CRS; SAIL Databank Contributors: SB, JK, RC

Data sharing statement

The data from England collected via the OpenSAFELY platform is available from their public GitHub repository. The data from Scotland and Wales is not publicly available. However, request for data access can be made to the respective data controllers (Public Health Scotland for Scotland, and The SAIL Databank for Wales).

Declaration of interests

SVK is co-chair of the Scottish Government's Expert Reference Group on ethnicity and COVID-19 and is a member of the Scientific Advisory Group on Emergencies subgroup on ethnicity. AS is a member of the Scottish Government Chief Medical Officer's COVID-19 Advisory Group and its Standing Committee on Pandemics, and NERVTAG's Risk Stratification Subgroup. All other authors declare no conflict of interest related to this work.

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Oxford and Thames Valley, the Good Thinking Foundation, the Health Foundation, the World Health Organisation, and UKRI; he also receives personal income from speaking and writing for lay audiences on the misuse of science.

Supplementary materials

Supplementary material associated with this article can be found in the online version at doi:10.1016/j.eclinm.2022.101462.

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