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Impact of COVID-19 on accident and emergency attendances and emergency and planned hospital admissions in Scotland: an interrupted time series analysis

Short title: Impact of COVID-19 on secondary care in Scotland

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Dissemination: All R code scripts on the analysis and Figures will be made available on the EAVE II GitHub page (https://github.com/EAVE-II).

Abstract

Objectives

Following the outbreak of SARS-CoV-2, health systems and the populations who use them have faced unprecedented challenges. We aimed to measure the impact of COVID-19 on the uptake of hospital-based care at a national level.

Design

The study period (weeks ending 05 January to 28 June 2020) encompassed the pandemic announcement by the World Health Organization (WHO) and the initiation of the UK lockdown. We undertook an interrupted time-series analysis to evaluate the impact of these events on hospital services at a national level and across demographics, clinical specialties and NHS Health Boards.

Setting

Scotland, UK.

Participants

Patients receiving hospital care from NHS Scotland.

Main outcome measures

A&E attendances, and emergency and planned hospital admissions measured using the relative change of weekly counts in 2020 to the averaged counts for equivalent weeks in 2018 and 2019.

Results

Before the pandemic announcement, the uptake of hospital care was largely consistent with historical levels. This was followed by sharp drops in all outcomes until UK lockdown, where activity began to steadily increase. This time-period saw an average reduction of -40.7% (95% CI: -47.7 to -33.7) in A&E attendances, -25.8% (95% CI: -31.1 to -20.4) in emergency hospital admissions and -60.9% (95% CI: -66.1 to -55.7) in planned hospital admissions, in comparison to the 2018-2019 averages. All subgroup trends were broadly consistent within outcomes, but with notable variations across age groups, specialties and geography.

Conclusions

COVID-19 has had a profoundly disruptive impact on hospital-based care across NHS Scotland. This has likely led to an adverse effect on non-COVID-19 related illnesses, increasing the possibility of potentially avoidable morbidity and mortality. Further research is required to elucidate these impacts.

Keywords: COVID-19; SARS-CoV-2; A&E attendances; hospital admissions; uptake; secondary care

Introduction

Following the outbreak of the SARS-CoV-2 virus and its subsequent global spread, unprecedented challenges have been placed on health systems and the populations who use them. The initial phase of health systems response was to ensure sufficient hospital capacity was available to deal with any surges in severe COVID-19 cases. This was accompanied by the need to minimise threats to the health of healthcare workers and the risk of transmission. This response has seen a major disruption to healthcare delivery and uptake across the world, including the UK and other parts of Europe [1-5]. The extent of this disruption has not been fully quantified, particularly at a national level.

In Scotland, UK, the first positive case was announced on 01 March 2020 [6] and, within the next fortnight, the number of confirmed cases surged to 210 [7]. In this period, the World Health Organization (WHO) announced COVID-19 as a pandemic on 11 March 2020 [8] and Scotland confirmed its first death on 14 March 2020 [9]. Three days on, the Scottish Government announced that all non-urgent elective care was to be postponed [10]. This was followed by the subsequent decision by the UK and Scottish Governments to institute a lockdown on the 23 March 2020 [11], where all Scottish residents were directed to self-isolate with non-essential services closing [12].

To capture the impact of COVID-19 on the Scottish healthcare system, we sought to measure the influence of 1) the pandemic announcement by the WHO; and 2) the UK/Scottish lockdown on accident and emergency (A&E) attendances, and emergency and planned hospital admissions across Scotland. To evaluate whether groups were impacted differently, we undertook additional analyses by patient demographics, clinical specialties and geography.

Methods

Study design and setting

We carried out a population-based interrupted time-series analysis in Scotland, using the 26 weeks from the weeks ending 05 January to 28 June 2020. Scotland is ideally suited to undertake this work given that most hospital care is free at the point of care and is predominately delivered by the National Health Service (NHS) Scotland. This public service is organised into 14 territorial NHS boards, seven special NHS Boards and one public health body. The latter is known as Public Health Scotland (PHS) where most unified data on NHS Scotland are recorded.

Data sources

We obtained national data on A&E attendances and emergency and planned hospital admissions from the PHS R Shiny App ‘COVID-19 wider impacts on the health care system’ [13]. This dashboard provides an overview of weekly changes in completed contacts with NHS Scotland’s clinical services during the pandemic. These data contained both COVID and non-COVID related cases and was aggregated by patient demographics, hospital admissions clinical specialty and NHS Health Board. The underlying data sources of interest in this study are as follows.

A&E Data Mart

The A&E Data Mart to captured A&E attendances [14] from 105 emergency departments across Scotland [15]. These were hospital departments that predominately provided consultant-led 24-hour service care for emergency patients [16]. This excluded all minor injury units, community A&E departments and small A&E sites, as they only submitted aggregate level data due to the lack of support to enable the collection of detailed patient-based information. These excluded small units and predominately covered more rural areas [15].

The Rapid Preliminary In-patient Data (RAPID) Data Mart

We used the RAPID Data Mart to capture acute care for in-patient admissions in all general hospitals across Scotland [17]. This did not include maternity or neonatal care admissions and admissions to the Golden Jubilee National Hospital. This hospital is part of a special NHS Health Board 'National Waiting Times Centre' providing specialist and elective care for patients across Scotland [18]. We anticipated no overall biases to the national picture from the exclusion of these data sources.

Variables

Exposures

To evaluate differing impacts across the uptake in healthcare services, data were aggregated by patient demographics, clinical specialties and the 14 territorial NHS Health Boards in Scotland.

Demographics included; sex (Female, Male), age (under 5 years, 5-14 years, 15-44 years, 45-64 years, 65-74 years, 75-84 years, 85 years and over) and Scottish Index of Multiple Deprivation (SIMD) quintiles (1-5). SIMD is a measure of deprivation unique to Scotland and is created by ranking small areas called data zones using seven domains of what makes an area 'deprived' [19]. These ranks were grouped into quintiles, where lower quintiles represented the most deprived areas and the higher quintiles representing the least.

Clinical specialties were defined as a specific area of clinical activity and were only applicable to emergency and planned hospital admissions. We used the following categories; A&E, Cancer, Cardiology, Community, Gynaecology, Medical (excl. Cardiology and Cancer), Paediatrics (medical), Paediatrics (surgical) and Surgery. A list of the specific specialties within these groups is given in the PHS dashboard GitHub (https://github.com/Health-SocialCare-Scotland/covid-wider-impact).

The NHS Health Boards in Scotland were: Ayrshire and Arran, Borders, Dumfries and Galloway, Fife, Forth Valley, Grampian, Greater Glasgow and Clyde, Highland, Lanarkshire, Lothian, Orkney, Shetland, Tayside and Western Isles.

Outcomes

We were interested in the impact on A&E attendances, and emergency and planned hospital admissions. An A&E attendance was defined as a record of whether a patient attended for the first time or a follow-up attendance to an NHS emergency department [16]. An emergency hospital admission was defined as an unexpected admission either following a visit to a doctor, an emergency ambulance call or A&E attendance [20]. Planned (or elective) care was defined as an admission where the patient was given a date to attend the hospital for a planned procedure or treatment [20]. These were measured using the relative change of weekly counts in 2020 to the averaged counts for equivalent weeks in 2018 and 2019. The weekly counts for these two years were combined because they were similar and to provide a more stable baseline for comparison.

Statistical methods

The interrupted time-series analysis used two change-points: 11 March 2020 (WHO announcing pandemic) and 23 March 2020 (UK lockdown). Three time-periods were therefore considered: before the pandemic announcement (weeks ending 05 January to 05 March 2020); between change-points (weeks ending 15 to 22 March); and after UK lockdown (weeks ending 29 March to 28 June 2020). A diagram of this timeline is illustrated in Figure 1.

[insert Figure 1]

The temporal trends of the outcomes were visualised using graphs of the percentage change from the weekly 2018-2019 average and the equivalent 2020 counts for all three outcomes by each of the exposures. We also reported on the overall mean percentage changes for the three outcomes across the three time-periods alongside their 95% confidence intervals (CIs).

We undertook an interrupted time series analysis (ITSA) using segmented/piecewise linear regression [21] to assess the overall impact of the change-points on the trends of the three outcomes of interest. This technique tested for different trend lines within the time-periods, which were visualised and reported using the estimated intercepts and slopes and their 95% CIs. This meant there were only two observations for the time-period between the change-points (15 to 22 March), which gave rise to higher uncertainty around estimates fit in this time. These were still included for completeness but were not interpreted, with the main focus on the before and after time-periods.

We then took a comparative ITSA approach [22] to test whether the levels within the exposures exhibited similar trend patterns in the weekly percentage changes within the time-periods. This was repeated for each of the three outcomes.

Time was captured using the number of days from 05 January (the first week in the analysis) as opposed to the date of the week. This allowed estimates to be more interpretable, particularly for the intercept which would estimate the average percentage change for the outcomes on 05 January 2020. Details on the specific modelling techniques used in the analyses can be found in S1 Appendix.

To protect patient confidentiality, the data supplied on specific groups were suppressed if a weekly count was below five, despite being included in the aggregate total for Scotland. Therefore, if a specific group had at least one suppressed value for a particular week then the whole group was omitted when analysing the relevant subgroup trends. This only occurred in the planned hospital admissions for the specialty A&E and NHS Health Boards with small populations, including NHS Orkney, NHS Shetland and NHS Western Isles. NHS Forth Valley was also omitted for emergency and planned hospital admissions, due to a known data issue of the lowest completion rates in returning hospital-level data [23]. We anticipated little bias in this as according to the National Records of Scotland's 2019 mid-year estimates, NHS Forth Valley only contained 5% of the Scottish population [24].

Reporting guideline

We used the Reporting of studies Conducted using Observational Routinely-collected Data (RECORD) extended from the Strengthening the Reporting of Observational Studies in Epidemiology (STROBE) statement on reporting guidelines to support the communication of findings. This is found in S2 Appendix.

Ethics, software and dissemination

We obtained approval from the National Research Ethics Service Committee, Southeast Scotland 02 under the EAVE II study. We used R/R Studio (R version 3.6.3) to carry out the analyses and to produce Figures. All R code scripts will be made available on the EAVE II GitHub page (https://github.com/EAVE-II).

Results

A&E attendances, emergency and planned hospital admissions drop substantially during the pandemic across Scotland

The fitted temporal trends of A&E attendances, emergency and planned hospital admissions before the WHO announcement were broadly consistent across the three outcomes and with the 2018-2019 baseline (Figure 2). This was followed by a sharp fall until the UK implemented lockdown following which there was a further decline; thereafter, trends have begun to return to the 2018-2019 average baseline (Figure 2). Emergency hospital admissions and A&E attendances appeared to be returning quicker than planned hospital admissions, which continued to fall further until the week ending 19 April 2020 (Figure 2). The overall mean percentage change to the 2018-2019 average after UK lockdown was -40.7% (95% CIs: -47.7 to -33.7) in A&E attendances, -25.8% (95% CIs: -31.1 to -20.4) in emergency hospital admissions and -60.9% (95% CIs: -66.1 to -55.7%) in planned hospital admissions. See S4 for temporal trends in the counts and S5 Appendix for further information.

[insert Figure 2]

Age was the main demographic characteristic with differential impacts across services

Trends in all three categories of hospital use across sex, age and SIMD, displayed similar patterns to the Scotland level trends albeit with some variations (S3 Appendix, Figures 2-4). For sex, there was little variation between levels for trends which was confirmed when there was no important effect in the modelling.

For age, there was an effect with the final chosen model capturing the same slope for each age group, which differed across the time-periods. These parallel trend lines changed in order depending on the time-period (Model 3, S1 Appendix). Plots of the fitted model suggested that younger age groups, particularly those under 15, were slower to recover for A&E attendances and emergency hospital admissions having gone down to much lower levels (Figure 3A and 3B). The youngest age group was the quickest to improve for planned hospital admissions (Figure 3C). See S6 Appendix for further information.

[insert Figure 3]

For SIMD, only emergency hospital admissions saw any substantial difference in the groups. This difference was only slight and it seemed to be driven by differences before the pandemic announcement. See S7 Appendix for further information.

Variations by clinical specialties were different among hospital admissions

Investigating the differentiating impact of specialties for hospital admissions saw differing trends between emergency and planned admissions (S3 Appendix, Figure 5). There was a differing impact by speciality for both outcomes, with the final model having the same structure to the age models (Model 3, S1 Appendix).

For emergency hospital admissions, higher rates before the WHO announcement in A&E and Cancer specialties had been captured. In terms of the trends back to the baseline after UK lockdown, most clinical specialties were very similar, with Paediatric (medical) being notably lower (Figure 4A). There was also evidence of A&E, Cardiology and Gynaecology specialties returning to the 2018-2019 baseline averages by the end of the study (Figure 4A).

[insert Figure 4]

For planned hospital admissions, there was a lot of variability due to small numbers, particularly for Community and Cancer (S4 Appendix, Figure 5B). Visualising the fitted lines showed that specialties before the 1st change-point were more similar than after the last change-point (Figure 4B). Specialties such as Cardiology, Gynaecology, Paediatrics (surgical) and Surgery remained at very low measurements and therefore little evidence of a quick return to the baseline (Figure 4B). Whereas Cancer and Paediatrics (medical) were captured having quicker returns (Figure 4B). See S8 Appendix for further information.

NHS Health Boards were fairly consistent with the overall Scotland level trends

The percentage changes across NHS Health Boards for all outcomes were fairly similar to the overall Scotland changes (S3 Appendix, Figure 6). This was particularly evident in A&E attendances, where the map of the differences in the mean percentage changes before and after the change-points was mainly consistent (Figure 5A). Similarities between NHS Health Boards are shown for emergency hospital admission, where differences in the means spanned between a range of approximately 20% (~-35% to ~-15%) (Figure 5B). For planned hospital admissions, all areas displayed consistent differences geographically, except for NHS Tayside which had a much larger decrease (Figure 5C). This potential outlier can be explained by the unique temporal pattern of a consistent fall from the start of the study (S3 Appendix, Figure 6). See S9 Appendix for further information.

[insert Figure 5]

Discussion

Following the WHO announcement, there were overall sharp drops in A&E attendances, and emergency and planned hospital admissions and further drops until Scotland entered into lockdown. By the end of the study, these services were in the process of returning to historical levels, with some well below anticipated levels particularly elective care. These impacts were seen equally for both sexes and across deprivation quintiles. Age demonstrated some variation, with children under 15 being particularly affected for emergency care (attendances and admissions). Across clinical specialties and NHS Health Boards, there were broadly consistent findings with the national data but with some notable variations.

Our data sources included almost all A&E and in-patient hospital care activity across Scotland. As far as we are aware, this analysis is the most inclusive investigation into the impact of COVID-19 on the uptake of hospital-care on a national level. This in turn provides useful information for the NHS to plan for future services since, to an extent, results reflected the lack of pandemic preparedness in NHS Scotland.

Despite this, there are limitations to this study. Firstly, there are gaps in the overall population, including minor injury units. Monthly attendances for minor injury units in Scotland exhibited similar patterns to the analyses, where attendances dropped in April 2020 and increased thereafter [25], further enhancing the results of our study. Secondly, the study may also have uncovered some data artefacts where there was a high spike in A&E specialties for emergency hospital admissions before the WHO announcement. This could be explained by the way hospitals organise and classify services, where those 'held' for a period of time in A&E generated an admission record. Alternatively, this could have been the result of a spike in influenza corresponding to this time [26]. Using the RAPID Data Mart to capture hospital admissions also has limitations. RAPID records are provided quickly to PHS so that the data can be used with minimum delay. This means that data have limited granularity – for example, there is no clinical coding of patient diagnoses or procedures. Alternative data sources should be sought out if this detailed information is required. Lastly, the aggregated structure of the data meant we were unable to adjust for confounding by the demographic variables. Although we note that substantial changes in the population structure of Scotland over the observed time-period are an extremely unlikely explanation for our findings.

Similar findings have been observed in other parts of the UK and Europe, albeit studying a more limited set of outcomes or focusing on sub-samples of the population. In England, The Health Foundation showed that the average number of daily A&E visits and emergency admissions dropped from February to April 2020 [1]. This drop was also noted in NHS England's statistical commentary for emergency care in March 2020 [2]. In France, the number of out-of-hospital cardiac arrest (OHCAs) hospital admissions substantially reduced, which has led to a major rise in OHCA-related deaths [3]. In Italy, the overall number of urgent surgical procedures performed in a sample of surgical centres dropped substantially from February to March 2020 in comparison to 2019 [4]. In Austria, the number of hospital admissions for acute coronary syndrome in a sample of public primary percutaneous coronary centres had significantly declined throughout the pandemic [5].

We believe the drop between the pandemic announcement and lockdown is therefore a true effect. For elective care, the slow recovery reflected changes to service provision implemented as part of pandemic preparedness planning, where all non-urgent elective care was postponed in Scotland from 17 March [10]. This excluded all vital cancer treatments, emergency, maternity and urgent care [10], which were captured in our data except maternity care. For emergency care, changes to population health-seeking behaviour from fear of contracting the virus or overwhelming the NHS could have played a role in this decline. Additionally, the non-essential movement constraints and physical distancing introduced during lockdown [12] may have also contributed to this. Google mobility data for this time-period showed an overall reduction of 63% in movement [27], suggesting reduced risks of accidents and other infections. The lack of public awareness that medical help should be sought in an emergency could also help drive this, particularly during the early stages of the pandemic. With an increase in serious complications in-patients who were avoiding or delaying medical help, the Government launched a campaign to reassure the public that NHS services remained 'open for business' [28], which could reflect the increasing activity.

The disruptive impact in emergency care for those under 15, which is also correlated with Paediatric care, could be explained by a few potential reasons. Social distancing in children could have reduced the risk of non-COVID-19 infections and injuries, which are the most common reasons for emergency admissions in children [29]. Other more speculative reasons could be the change in behaviour from parents, who may have avoided attending medical facilities to protect their children from the virus, or possible alternative routes set up by hospitals to avoid Paediatric admissions.

To give further explanation to our findings in emergency care, we compared results to COVID-19 related hospitalisations. Information on the number of A&E attendances for COVID-19 in Scotland is currently unavailable due to variable quality of diagnostic coding on A&E records and we would not expect COVID-19 to have contributed to elective care. Data on COVID-19 hospitalisations are supplied by PHS's weekly statistical reports and were defined as patients who tested positive 14 days prior to admission to hospital, on the day of their admission or during their stay in hospital [30]. The number of COVID-19 admissions gradually rose from early March, peaked in April and steadily decreased thereafter. During the peak week (ending 05 April) 1,272 COVID-19 admissions were recorded [30], comprising of 17% of all emergency hospital admissions in that week (7,521) [13]. This illustrates the extent of the COVID-19's contribution on emergency care seen in the period immediately following UK lockdown. Over time, the COVID-19 activity has fallen and remained low, while non-COVID-19 conditions will have contributed proportionally more.

Future analyses should focus on all aspects of the patient journey from GP consultations, out-of-hours care, community care and the use of specialised care such as mental health services. Given that the overall trends for neither A&E nor in-patient care had returned to baseline levels by the end of the study, there is a need to continue monitoring these trends. This includes the long-term impacts on potentially avoidable morbidity and mortality across Scotland.

Conclusions

COVID-19 has led to profound drops in A&E attendances, and emergency and planned hospital admissions across Scotland during the first few months of the pandemic. Our findings also raise important questions about the resilience of hospital services in NHS Scotland. There is now a need to investigate the impact of this disruption on preventable morbidity and mortality.

Abbreviations: A&E: Accident & Emergency; CI: Confidence Interval; ITSA: Interrupted Time Series Analysis; NHS: National Health Service; PHS: Public Health Scotland; RAPID: Rapid Preliminary In-patient Data; SIMD: Scottish Index of Multiple Deprivation; WHO: World Health Organisation

References

1. Kelly E, Firth Z. The Health Foundation. How is COVID-19 changing the use of emergency care? 15 May 2020. Available from: https://www.health.org.uk/news-and-comment/charts-and-infographics/how-is-covid-19-changing-the-use-of-emergency-care (accessed 30 June 2020)
2. NHS England. A&E Attendances and Emergency Admissions. March 2020 Statistical Commentary. Available from: https://www.england.nhs.uk/statistics/wp-content/uploads/sites/2/2020/04/Statistical-commentary-March-2020-jf8hj.pdf (accessed 10 July 2020)
3. Marijon E, Karam N, Jost D, Perrot D, Frattini B, Derkenne C et al. Out-of-hospital cardiac arrest during the COVID-19 pandemic in Paris, France: a population-based, observational study. Lancet Public Health. 2020. doi: 10.1016/S2468-2667(20)30117-1
4. Patriti A, Baiocchi GL, Catena F, Marini P, Catarci M et al. Emergency general surgery in Italy during the COVID-19 outbreak: first survey from the real life. World Journal of Emergency Surgery. 2020.15; 36. doi: 10.1186/s13017-020-00314-3
5. Metzler B, Siostrzonek P, Binder RK, Bauer A, Reinstadler SJ. Decline of acute coronary syndrome admissions in Austria since the outbreak of COVID-19: the pandemic response causes cardiac collateral damage. European Heart Journal. 41; 19. 2020. doi: 10.1093/eurheartj/ehaa314
6. Scottish Government. News, Coronavirus (COVID-19) confirmed in Scotland. 1 March 2020. Available from: https://www.gov.scot/news/coronavirus-covid-19/ (accessed 30 June 2020)
7. Health Protection Scotland and Public Health Scotland. Total Scotland COVID-19 Cases Dashboard. Available from:

https://www.arcgis.com/apps/opsdashboard/index.html#/658feae0ab1d432f9fdb53aa082e4130 (accessed 30 June 2020)
8. World Health Organization. WHO Director-General's opening remarks at the media briefing on COVID-19 - 11 March 2020. Available from: https://www.who.int/dg/speeches/detail/who-director-general-s-opening-remarks-at-the-media-briefing-on-covid-19---11-march-2020 (accessed 26 June 2020)
9. Scottish Government. News, First death of patient from Coronavirus (COVID-19). 13 March 2020. Available from: https://www.gov.scot/news/first-death-of-patient-from-coronavirus-covid-19/ (accessed 30 June 2020)
10. Scottish Government. News, NHS Scotland placed on emergency footing. 17 March 2020. Available from: https://www.gov.scot/news/nhs-scotland-placed-on-emergency-footing/ (accessed 30 June 2020)
11. GOV.UK. Coronavirus (COVID-19). Guidance and Support. PM address to the nation on coronavirus: 23 March 2020. Available from: https://www.gov.uk/government/speeches/pm-address-to-the-nation-on-coronavirus-23-march-2020 (accessed 26 June 2020)
12. Scottish Government. News, Social distancing enforcement measures in place. 27 March 2020. Available from: https://www.gov.scot/news/social-distancing-enforcement-measures-in-place/ (accessed 30 June 2020)
13. Public Health Scotland. COVID-19 wider impacts on health care system. Available from: https://scotland.shinyapps.io/phs-covid-wider-impact/_w_c89e0e10/#tab-5169-2 (accessed 09 July 2020)
14. Public Health Scotland. Accident and Emergency Data Mart. Available from: https://www.isdscotland.org/Health-Topics/Emergency-Care/Accident-and-Emergency-Data-Mart/#:~:text=The%20A%26E%20data%20mart%20gives,or%20elsewhere%20in%20NHS%20Scotland. (accessed 26 June 2020)
15. Public Health Scotland. Emergency Care. NHS Scotland Accident & Emergency Sites. Available from: https://www.isdscotland.org/Health-Topics/Emergency-Care/Emergency-Department-Activity/Hospital-Site-List/ (accessed 10 July 2020)
16. Public Health Scotland. Emergency Department Statistics Background Information and Glossary. Available from: https://www.isdscotland.org/Health-Topics/Emergency-Care/ED_Background_Glossary.pdf (accessed 10 July 2020)
17. ISD Scotland. National Data Catalogue. Rapid Preliminary In-patient Data (RAPID). Available from: https://www.ndc.scot.nhs.uk/National-Datasets/data.asp?SubID=37 (accessed 26 June 2020)
18. NHS Golden Jubilee. Available from: https://hospital.nhsgoldenjubilee.co.uk/ (accessed 10 July 2020)
19. Scottish Government. Scottish Index of Multiple Deprivation 2020. Available from: https://www.gov.scot/collections/scottish-index-of-multiple-deprivation-2020/ (accessed 26 June 2020)
20. Public Health Scotland. Acute Hospital Activity & NHS Beds Information. Available from: https://www.isdscotland.org/Health-Topics/Hospital-Care/Publications/2019-05-28/Acute-Hospital-Publication/glossary/ (accessed 10 July 2020)
21. Bernal JB., Cummins S., Gasparrini A. Interrupted time series regression for the evaluation of public health interventions: a tutorial, International Journal of Epidemiology, 46;1, 2017, pp348–355. doi: 10.1093/ije/dyw098
22. Linden A. Conducting interrupted time-series analysis for single- and multiple-group comparisons. The Stata Journal. 15;2. 2015. pp480-500. doi: 10.1177%2F1536867X1501500208

23. Public Health Scotland. Data Support and Monitoring. SMR Completeness. Available from: https://www.isdscotland.org/products-and-Services/Data-Support-and-Monitoring/SMR-Completeness/ (accessed 10 July 2020)
24. National Records of Scotland. Mid-2019 Population Estimates Scotland. 2020. Available from: https://www.nrscotland.gov.uk/statistics-and-data/statistics/statistics-by-theme/population/population-estimates/mid-year-population-estimates/mid-2019 (accessed 15 July 2020)
25. Public Health Scotland. A&E activity and waiting times. 04 August 2020. URL: https://beta.isdscotland.org/find-publications-and-data/health-services/hospital-care/ae-activity-and-waiting-times/ (accessed 21 August 2020)
26. Public Health England. PHE Weekly National Influenza Report. 2020. Available from: https://assets.publishing.service.gov.uk/government/uploads/system/uploads/attachment_data/file/863975/Weekly_national_influenza_report_week_6_2020.pdf (accessed 15 July 2020)
27. Drake TM, Docherty AB., Weiser TG, Yule S, Sheikh A, Harrison EW. The effects of physical distancing on population mobility during the COVID-19 pandemic in the UK. Lancet Digital Health. 2020. doi: 10.1016%2FS2589-7500(20)30134-5
28. Public Health England. NHS 'Open for business' campaign materials. URL: https://coronavirusresources.phe.gov.uk/nhs-resources-facilities/resources/open-for-business/
29. Public Health Scotland. Diagnoses. Hospital Care. URL: https://www.isdscotland.org/Health-Topics/Hospital-Care/Diagnoses/
    Public Health Scotland. COVID-19 statistical report. 02 September 2020. URL: https://beta.isdscotland.org/find-publications-and-data/population-health/covid-19/covid-19-statistical-report/

Figure Legends

Figure 1. Timeline of time-periods and change-points

Before indicates weeks before pandemic announcement (weeks ending 05 Jan to 08 Mar 2020); Between indicates weeks between change-points (weeks ending 15 to 22 Mar 2020); After indicates weeks after UK lockdown (weeks ending 29 Mar to 28 Jun 2020).

Figure 2. Fitted lines of segmented regression models for A&E attendances and emergency and planned hospital admissions across Scotland

Points represent weekly percentage changes between 2020 and 2018-2019 average weeks ending 05 Jan to 28 Jun 2020 for A&E attendances, emergency and planned hospital admissions. Vertical lines represent change-point 1 (WHO announcing pandemic on 11 Mar) and change-point 2 (UK lockdown on 23 Mar). Horizontal line is the 2018-2019 average at 0. Fitted lines represent segmented regression models of the interaction between the number of days since 05 January and the two change-points for each outcome. Shaded areas around lines represent 95% confidence intervals.

Figure 3. Fitted lines of segmented regression models by age group for A) A&E attendances and B) emergency and C) planned hospital admissions

Points represent weekly percentage changes between 2020 and 2018-2019 average weeks ending 05 Jan to 28 Jun 2020 by age group for A) A&E attendances, B) emergency and C) planned hospital admissions. Vertical lines represent change-point 1 (WHO announcing pandemic on 11 Mar) and change-point 2 (UK lockdown on 23 Mar). Horizontal line is the 2018-2019 average at 0. Fitted lines represent segmented regression models of the baseline model (the number of days since 05 Jan and the two change-points) and the interaction between age and the change-points for each outcome. Shaded areas around lines represent 95% confidence intervals.

Figure 4. Fitted lines of segmented regression models by specialty for A) emergency and B) planned hospital admissions

Points represent weekly percentage changes between 2020 and 2018-2019 average weeks ending 05 Jan to 28 Jun 2020 by specialty for A) emergency and B) planned hospital admissions. Vertical lines represent change-point 1 (WHO announcing pandemic on 11 Mar) and change-point 2 (UK lockdown on 23 Mar). Horizontal line is the 2018-2019 average at 0. Fitted lines represent segmented regression models of the baseline model (the number of days since 05 Jan and the two change-points) and the interaction between specialty and change-points for each outcome. Shaded areas around lines represent 95% confidence intervals.

Figure 5. Map of differences in mean percentage changes before pandemic announcement and after UK lockdown by NHS Scotland Health Board

The difference in the mean percentage changes before the pandemic announcement (weeks ending 05 Jan to 08 Mar 2020) and mean percentage changes after UK lockdown (weeks ending 29 Mar to 28 Jun 2020) for A) A&E attendances, B) emergency and C) planned hospital admissions. Note: Orkney, Shetland and Western Isles excluded for planned hospital admissions due to small numbers. Forth Valley excluded for emergency and planned hospital admission due to data issues. Shapefile for map found on Scottish Government SpatialData.gov.scot, URL: https://data.gov.uk/dataset/27d0fe5f-79bb-4116-aec9-a8e565ff756a/nhs-health-boards

Supplementary Material

S1 Appendix. Statistical methods details. Further details on statistical methodology used in the study

S2 Appendix. STROBE and RECORD reporting guideline

S3 Appendix. Temporal trends of percentage change of 2020 counts vs 2018-2019 average of A&E attendances and hospital admissions. Plots of the percentage change temporal trends across Scotland and by demographics, clinical specialities and NHS Health Board

S4 Appendix. Temporal trends of counts of A&E attendances and hospital admissions. Plots of the count temporal trends across Scotland and by demographics, clinical specialities and NHS Health Board

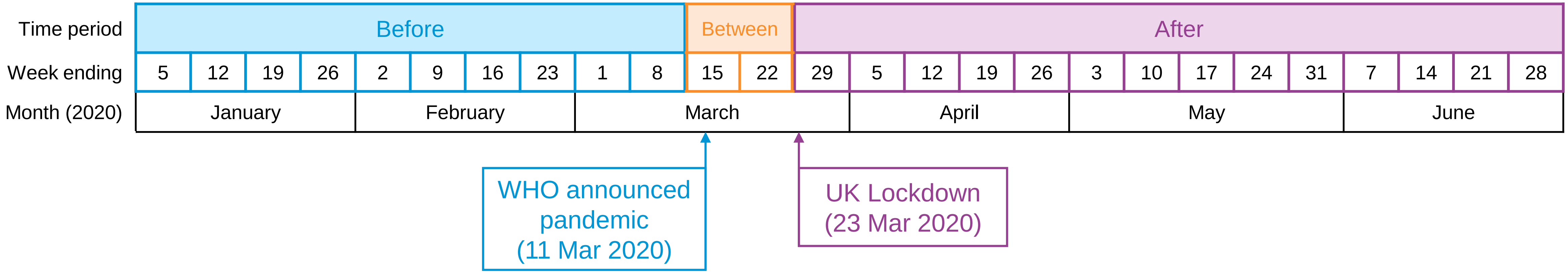
S5 Appendix: Supplementary information on baseline model per outcome. Contains means in the differences between before and after time-period, estimated slopes and intercepts and model diagnostics for the baseline model for each outcome

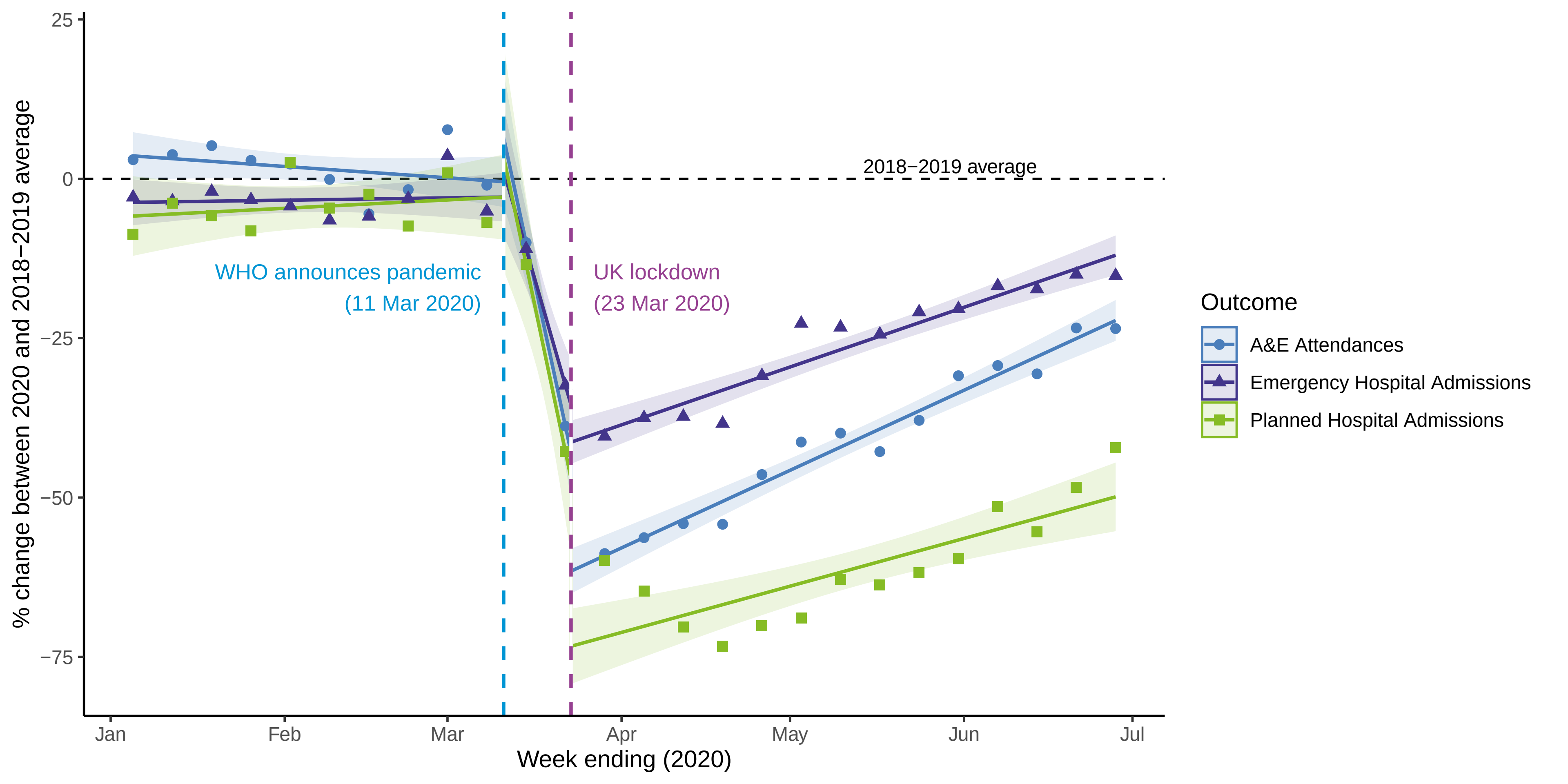
S6 Appendix. Supplementary information on interaction with age. Contains estimated slopes and intercepts and model diagnostics for the age models for each outcome of interest

S7 Appendix. Supplementary information on interaction with SIMD quintile. Contains fitted plot, estimated slopes and intercepts and model diagnostics for the SIMD model for emergency hospital admissions

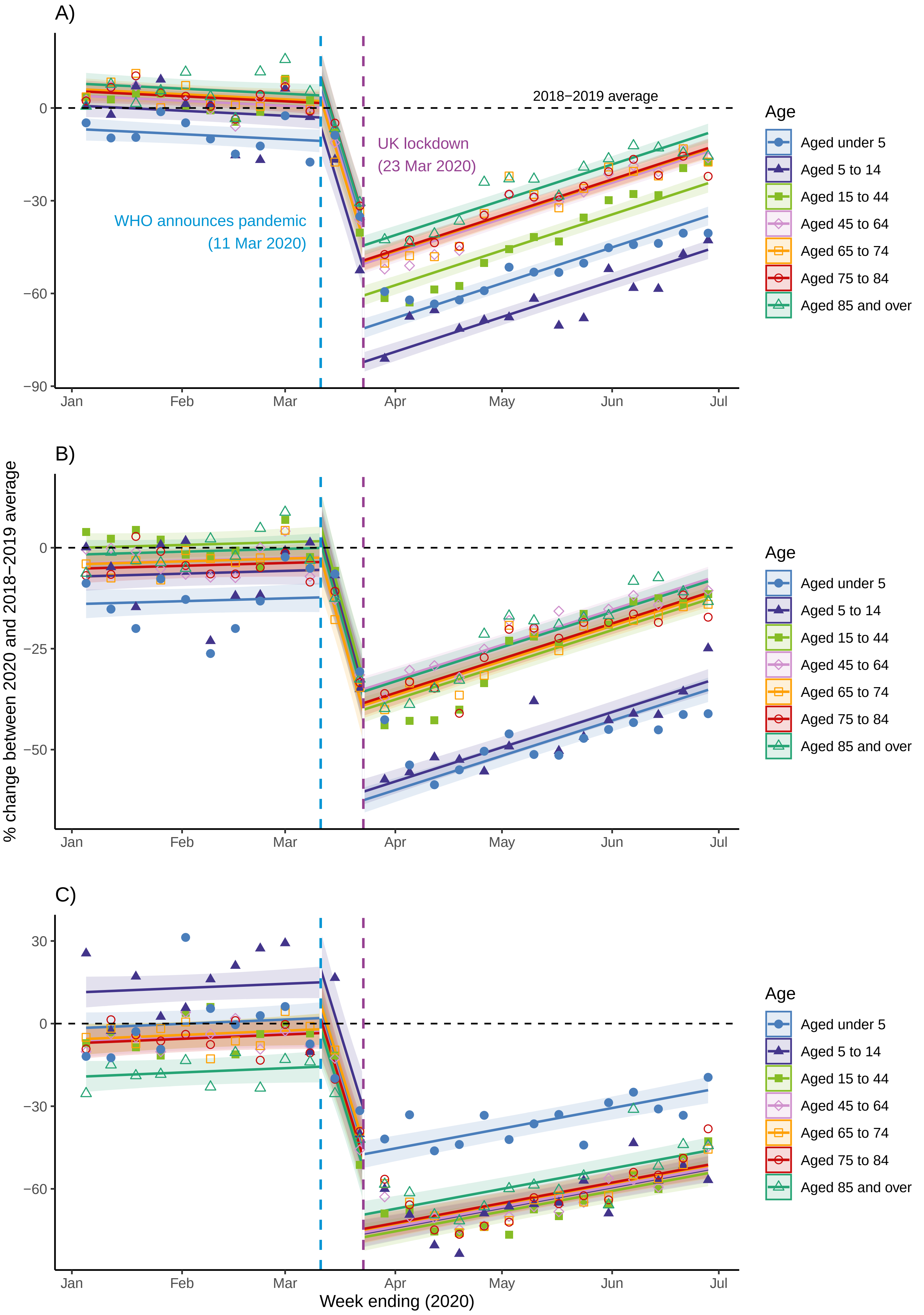
S8 Appendix. Supplementary information on interaction with speciality. Contains estimated slopes and intercepts and model diagnostics for the speciality models for hospital admissions

S9 Appendix. Supplementary information on interaction with NHS Health Board. Contains fitted plots and detailed description of findings for NHS Health Boards. Also contains estimated slopes and intercepts and model diagnostics for the NHS Health Board models for each outcome of interest

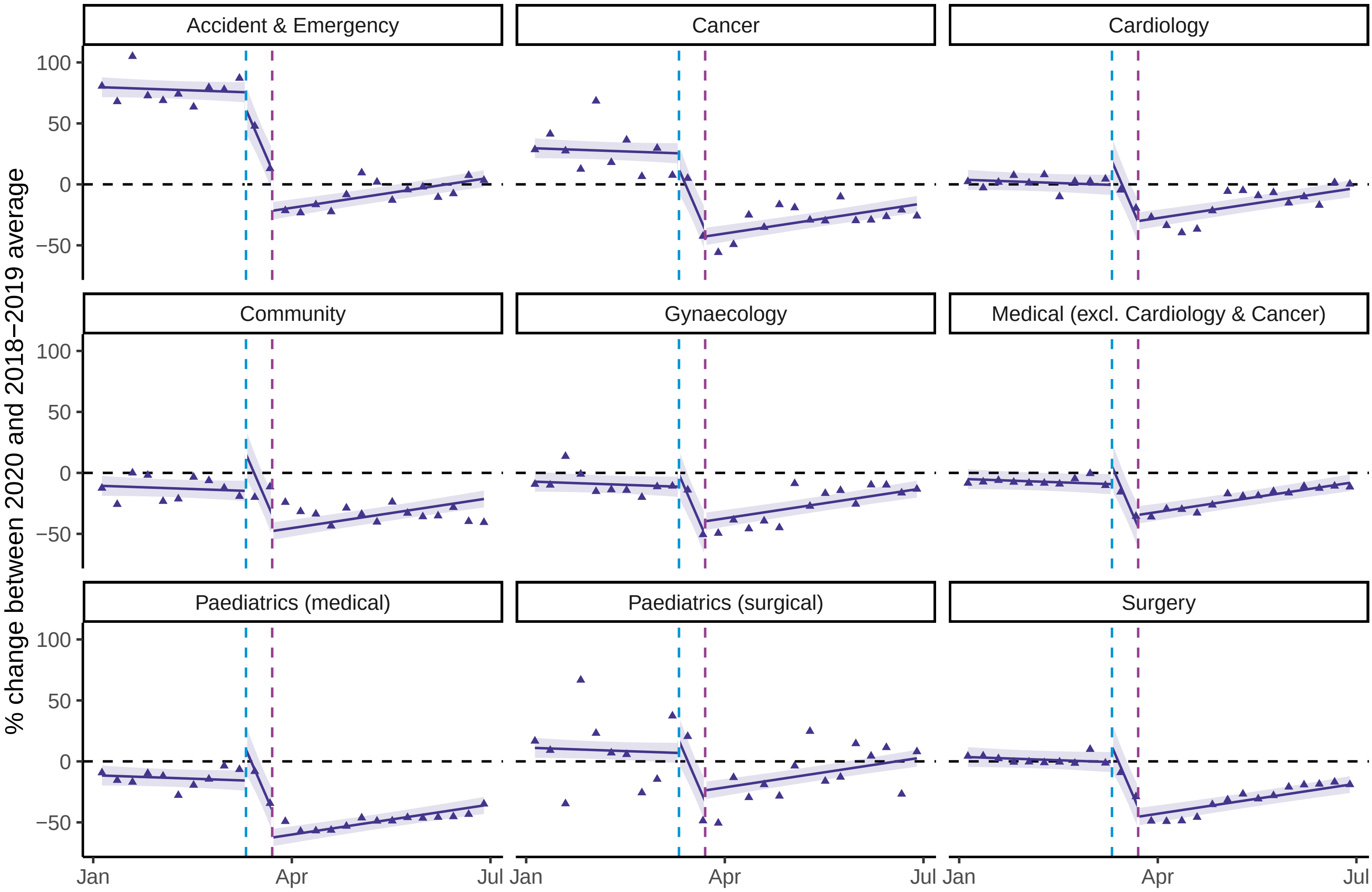

Time period
Before
Between
After
Week ending
5 12 19 26 2 9 16 23 1 8 15 22 29 5 12 19 26 3 10 17 24 31 7 14 21 28
Month (2020)
January
February
March
April
May
June
WHO announced pandemic (11 Mar 2020)
UK Lockdown (23 Mar 2020)



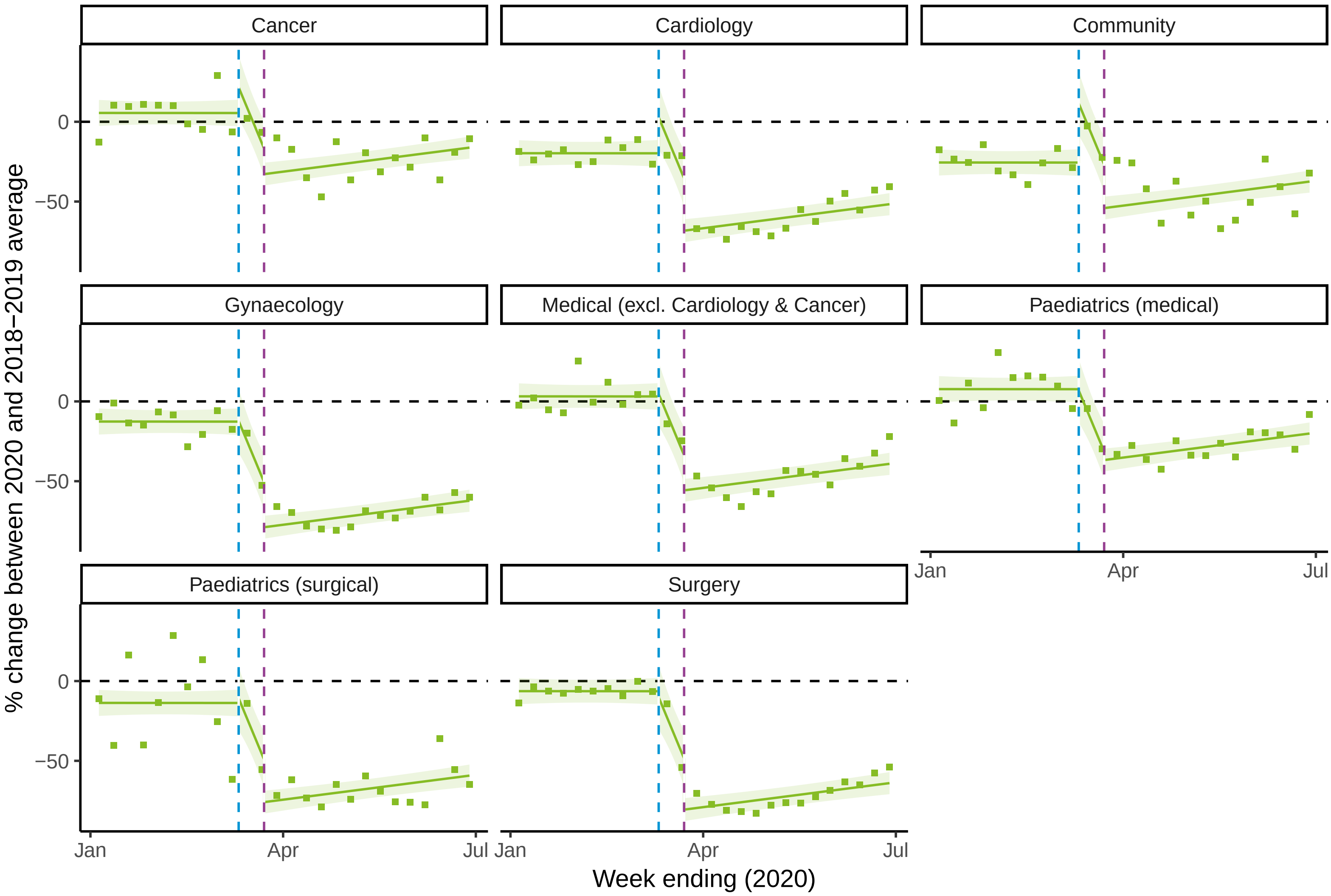
25
0
−25
−50
−75
% change between 2020 and 2018−2019 average
2018−2019 average
WHO announces pandemic
(11 Mar 2020)
UK lockdown
(23 Mar 2020)
Jan
Feb
Mar
Apr
May
Jun
Jul
Week ending (2020)
Outcome
A&E Attendances
Emergency Hospital Admissions
Planned Hospital Admissions

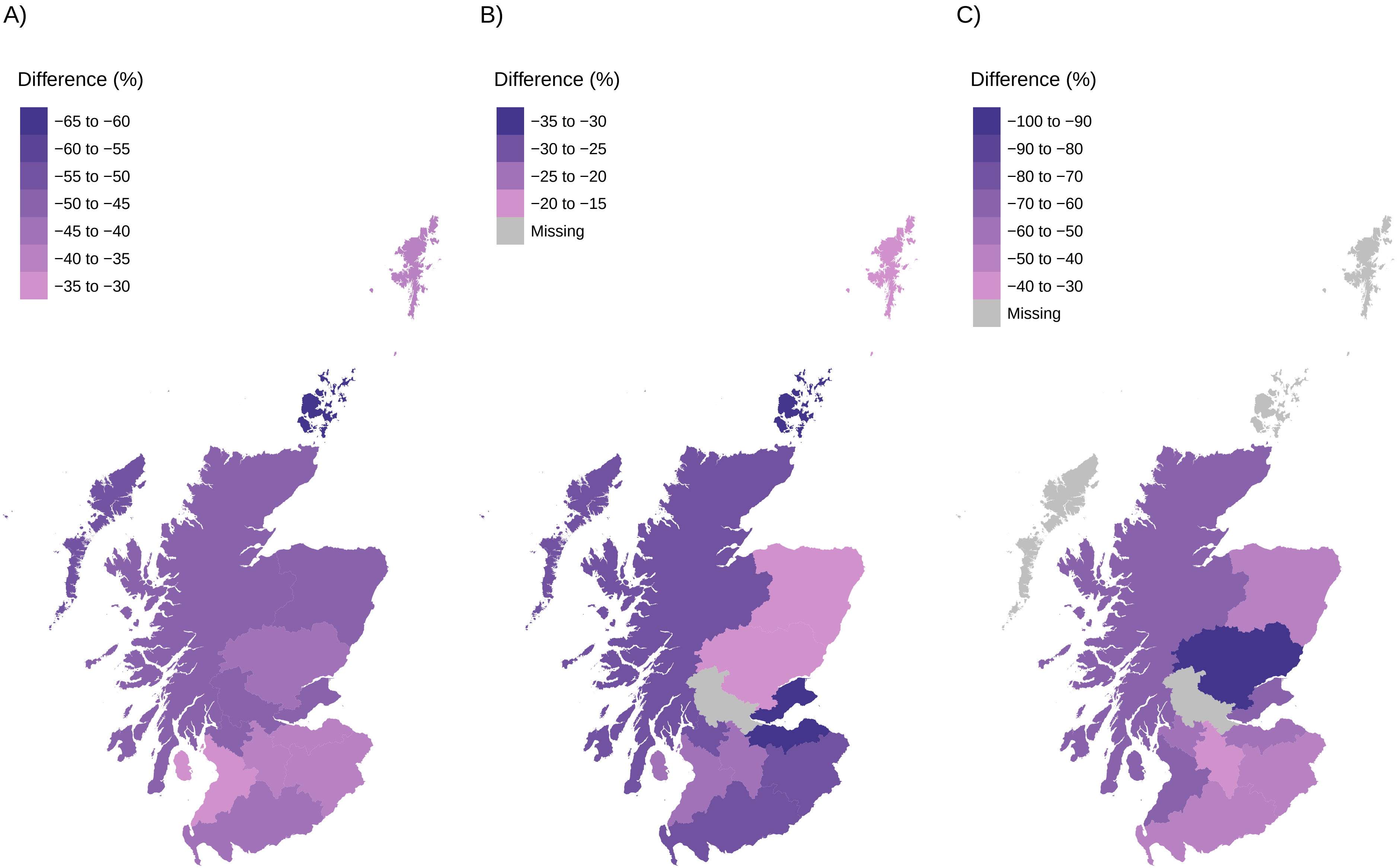

A)
B)
C)
2018−2019 average
UK lockdown
(23 Mar 2020)
WHO announces pandemic
(11 Mar 2020)
% change between 2020 and 2018−2019 average
Week ending (2020)
Jan
Feb
Mar
Apr
May
Jun
Jul
0
−30
−60
−90
−25
−50
30
Age
Aged under 5
Aged 5 to 14
Aged 15 to 44
Aged 45 to 64
Aged 65 to 74
Aged 75 to 84
Aged 85 and over

A)


Accident & Emergency
Cancer
Cardiology
Community
Gynaecology
Medical (excl. Cardiology & Cancer)
Paediatrics (medical)
Paediatrics (surgical)
Surgery
100
50
0
−50
% change between 2020 and 2018−2019 average
Jan
Apr
Jul

B)


Cancer
Cardiology
Community
Gynaecology
Medical (excl. Cardiology & Cancer)
Paediatrics (medical)
Paediatrics (surgical)
Surgery
0
−50
% change between 2020 and 2018−2019 average
Jan
Apr
Jul
Week ending (2020)


A)
Difference (%)
−65 to −60
−60 to −55
−55 to −50
−50 to −45
−45 to −40
−40 to −35
−35 to −30
B)
Difference (%)
−35 to −30
−30 to −25
−25 to −20
−20 to −15
Missing
C)
Difference (%)
−100 to −90
−90 to −80
−80 to −70
−70 to −60
−60 to −50
−50 to −40
−40 to −30
Missing

Supporting Material

S1 Appendix. Statistical methods details

We used segmented/piecewise linear regression [1] to assess the impact of the change-points on the trends. We repeated the following statistical methods for each of the three outcomes.

Overall trends

To capture the overall trend in each of the outcomes, a two-way interaction between the number of days from 05 January (the first week in the analysis) and the two change-points was fit. This was our 'baseline model'. This fitted an overall temporal trend for each of the three time-periods, which was reported using the estimated intercepts and slopes and their 95% CIs. An intercept of 0 suggested the level on 05 January 2020 was the same as the equivalent week for the 2018-2019 average. A slope of 0 suggested the segmented temporal trend had the same slope as the 2018-2019 average trend.

We were aware that including the two observations seen between the change-points (15 to 22 March) would cause a high amount of uncertainty around estimates. We therefore included these measurements in the modelling for completeness, but focussed more on the interpretation of the before and after time periods. We expected this to have little impact since the high uncertainty around the between time period would suggest it was very unlikely the estimates would be statistically different to the before and/or after time-periods. Therefore, it is highly likely that any statistical significance in the models will be driven by the difference in the before and after time-period estimates.

Trends by the exposures

We then undertook a comparative interrupted time series analysis approach [2] to test whether the levels within the exposures (the three demographics, clinical specialties for hospital admissions and NHS Health Board) exhibited similar trend patterns within the time periods, for each of the three outcomes.

We done this by firstly testing for a three-way interaction between the baseline model (as described above) and the exposure of interest. The three-way interaction captured whether the trends in the time-periods differed between the groups in the exposure [2]. To test whether this three-way interaction was suitable to the data, an Analysis of Variance (ANOVA) was performed. The p-value of the final three-way interaction was tested against a Bonferroni corrected significance level to account for multiple testing. This divided the standard significance level of 0.05 by the number of terms in the model (N=7). These included the three main effects for each of the three variables (N=3), the three two-way interactions between these three variables (N=3) and the three-way interaction between all three variables (N=1). This meant the Bonferroni corrected significance level was $0.05 / 7 \approx 0.007$.

In the case where this three-way interaction p-value was > 0.007 the remaining combinations of the baseline model and the exposure variable were tested. An illustration of these different models are given as follows.

Let A = time, B = change-points and C = exposures, then the baseline model would be defined as:

$$\text{Baseline model} = A{:}B = A + B + A{:}B$$

The full three-way interaction model described would be defined as:

Three-way interaction = A:B:C = A + B + C + A*B + A*C +B*C + A*B*C

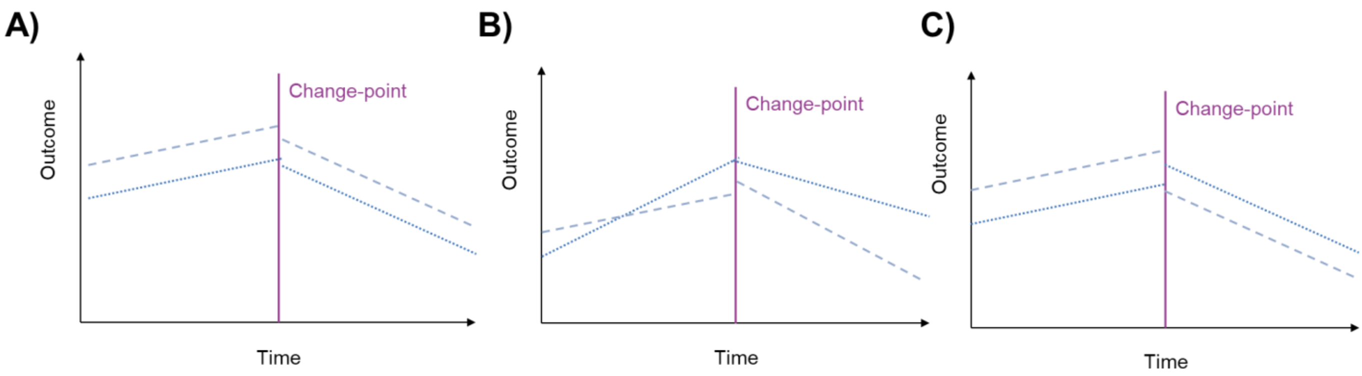
The remaining models that were therefore tested are given in **Table 1.**

Table 1. Remaining models tested for the exposures

Model No.	Description	Notation	Interpretation
1	The baseline model plus the main effect for the exposure	A:B + C	Captured the overall difference in the level (intercept) of the outcome between the groups of the additional variable [2]
2	The baseline model plus the two-way interaction between time and the exposure	A*B + A*C	Tested the difference in the slope of the outcome between groups in the exposure [2]
3	The baseline model plus the two-way interaction between the change-points and the exposure	A*B + B*C	Captured the difference between the groups in the exposure in the intercept of the outcome in the time-periods [2]
A = time, B = change-points and C= exposure variable			

To understand what the trend lines for these models may look like, an example is given in **Figure 1**. This assumes the exposure has 2 groups.

Plot



Equations

A)

	Before	After
dashed	$y = 3 + 0.3x$	$y = 9 - 0.9x$
dotted	$y = 2 + 0.3x$	$y = 8 - 0.9x$

B)

	Before	After
dashed	$y = 2 + 0.3x$	$y = 10 - 0.9x$
dotted	$y = 1 + x$	$y = 7 - 0.2x$

C)

	Before	After
dashed	$y = 3 + 0.3x$	$y = 8 - 0.9x$
dotted	$y = 2 + 0.3x$	$y = 9 - 0.9x$

Interpretation

A)

	Intercept	Slope
By exposure	Different	Same (parallel)
By time period	Order of exposure groups the same	Different

B)

	Intercept	Slope
By exposure	Different	Different
By time period	Order of exposure groups the same	Order of exposure groups the same
Note order of exposure levels in intercepts can differ from order in slope		

C)

	Intercept	Slope
By exposure	Different for exposure group	Same (parallel)
By time period	Order of exposure groups different	Different

Figure 1. Examples of the alternative models for A) Model 1, B) Model 2 and C) Model 3 Contains examples of plots for each of the types of fitted models (Plots), example linear equations (Equations) and how to interpret the intercept and slope estimates by the exposure groups and time periods (Interpretation).

To select which of these model fit the data best, the model with the lowest Akaike Information Criterion (AIC) and the lowest Bayesian Information Criterion (BIC) [3] was chosen as the final model. In the case where the lowest AICs and BICs were very close, the simplest model was chosen i.e. the model with the lowest degrees of freedom.

All final models were tested against the assumptions of linearity. Residuals were tested for normality using histograms and QQ-Plots. The assumption of constant variance with mean zero was tested by plotting the residuals against the fitted values. To assess whether there was any remaining autocorrelation, autocorrelation plots (ACF) and partial autocorrelation plots (PACF) were used [4].

References

1. Bernal JB., Cummins S., Gasparrini A. Interrupted time series regression for the evaluation of public health interventions: a tutorial, International Journal of Epidemiology, 46;1, 2017, pp348–355. doi: 10.1093/ije/dyw098
2. Linden A. Conducting interrupted time-series analysis for single- and multiple-group comparisons. The Stata Journal. 15;2. 2015. pp480-500. doi: 10.1177%2F1536867X1501500208
3. Kuha J. AIC and BIC: Comparisons of Assumptions and Performance. Sociological Methods & Research. 33;2. pp188–229. doi: 10.1177/0049124103262065
4. Yaffee RA, McGee M. Introduction to Time Series Analysis and Forecasting. Academic Press. 2000. pp 210. Available from: https://books.google.co.uk/books?id=LSojZBiBZBgC&pg=PA210&lpg=PA210&dq=acf+and+pacf+residuals++google+scholar&source=bl&ots=MqtPJaUVVZ&sig=ACfU3U3pJTALYho1s0QXpG4x7eptfL1p3A&hl=en&sa=X&ved=2ahUKEwjBw7WVpcrqAhV8WhUIHfqVBpsQ6AEwAnoECAkQAQ#v=onepage&q=citation&f=false

S2 Appendix. STROBE and RECORD reporting guideline

Table 1. The RECORD statement – checklist of items, extended from the STROBE statement, that should be reported in observational studies using routinely collected health data

	Item No.	STROBE items	Location in manuscript where items are reported	RECORD items	Location in manuscript where items are reported
Title and abstract					
	1	(a) Indicate the study's design with a commonly used term in the title or the abstract (b) Provide in the abstract an informative and balanced summary of what was done and what was found	Title and Abstract (Pg 1-2)	RECORD 1.1: The type of data used should be specified in the title or abstract. When possible, the name of the databases used should be included. RECORD 1.2: If applicable, the geographic region and timeframe within which the study took place should be reported in the title or abstract. RECORD 1.3: If linkage between databases was conducted for the study, this should be clearly stated in the title or abstract.	Abstract (Pg 2)
Introduction					
Background rationale	2	Explain the scientific background and rationale for the investigation being reported	Introduction (Pg 3)		
Objectives	3	State specific objectives, including any prespecified hypotheses	Introduction (Pg 3)		

Methods					
Study Design	4	Present key elements of study design early in the paper	Methods, Study design and setting (Pg 3)		
Setting	5	Describe the setting, locations, and relevant dates, including periods of recruitment, exposure, follow-up, and data collection	Methods, Study design and setting (Pg 3)		
Participants	6	*(a) Cohort study* - Give the eligibility criteria, and the sources and methods of selection of participants. Describe methods of follow-up *Case-control study* - Give the eligibility criteria, and the sources and methods of case ascertainment and control selection. Give the rationale for the choice of cases and controls *Cross-sectional study* - Give the eligibility criteria, and the sources and methods of selection of participants *(b) Cohort study* - For matched studies, give matching criteria and number of exposed and unexposed *Case-control study* - For matched studies, give matching	N/A	RECORD 6.1: The methods of study population selection (such as codes or algorithms used to identify subjects) should be listed in detail. If this is not possible, an explanation should be provided. RECORD 6.2: Any validation studies of the codes or algorithms used to select the population should be referenced. If validation was conducted for this study and not published elsewhere, detailed methods and results should be provided. RECORD 6.3: If the study involved linkage of databases, consider use of a flow diagram or other graphical display to demonstrate the data linkage process, including the number of individuals with linked data at each stage.	N/A

		criteria and the number of controls per case			
Variables	7	Clearly define all outcomes, exposures, predictors, potential confounders, and effect modifiers. Give diagnostic criteria, if applicable.	Methods, Variables (Pg 4)	RECORD 7.1: A complete list of codes and algorithms used to classify exposures, outcomes, confounders, and effect modifiers should be provided. If these cannot be reported, an explanation should be provided.	Methods, Variables (Pg 4)
Data sources/ measurement	8	For each variable of interest, give sources of data and details of methods of assessment (measurement). Describe comparability of assessment methods if there is more than one group	Methods, Data sources (Pg 3-4)		
Bias	9	Describe any efforts to address potential sources of bias	Methods, Data sources (Pg 3-4)		
Study size	10	Explain how the study size was arrived at	N/A		
Quantitative variables	11	Explain how quantitative variables were handled in the analyses. If applicable, describe which groupings were chosen, and why	N/A		
Statistical methods	12	(a) Describe all statistical methods, including those used to control for confounding (b) Describe any methods used to examine subgroups and interactions	Methods, Statistical methods (Pg 4-5) and S1 Appendix		

		(c) Explain how missing data were addressed (d) *Cohort study* - If applicable, explain how loss to follow-up was addressed *Case-control study* - If applicable, explain how matching of cases and controls was addressed *Cross-sectional study* - If applicable, describe analytical methods taking account of sampling strategy (e) Describe any sensitivity analyses			
Data access and cleaning methods		..		RECORD 12.1: Authors should describe the extent to which the investigators had access to the database population used to create the study population. RECORD 12.2: Authors should provide information on the data cleaning methods used in the study.	Methods, Data sources (Pg 3-4)
Linkage		..		RECORD 12.3: State whether the study included person-level, institutional-level, or other data linkage across two or more databases. The methods of linkage and methods of linkage quality evaluation should be provided.	N/A
Results					

Participants	13	(a) Report the numbers of individuals at each stage of the study (*e.g.*, numbers potentially eligible, examined for eligibility, confirmed eligible, included in the study, completing follow-up, and analysed) (b) Give reasons for non-participation at each stage. (c) Consider use of a flow diagram	S4 Appendix	RECORD 13.1: Describe in detail the selection of the persons included in the study (*i.e.*, study population selection) including filtering based on data quality, data availability and linkage. The selection of included persons can be described in the text and/or by means of the study flow diagram.	N/A
Descriptive data	14	(a) Give characteristics of study participants (*e.g.*, demographic, clinical, social) and information on exposures and potential confounders (b) Indicate the number of participants with missing data for each variable of interest (c) *Cohort study* - summarise follow-up time (*e.g.*, average and total amount)	S3 and S4 Appendix		
Outcome data	15	*Cohort study* - Report numbers of outcome events or summary measures over time *Case-control study* - Report numbers in each exposure category, or summary measures of exposure	S3-S5 Appendix		

		Cross-sectional study - Report numbers of outcome events or summary measures			
Main results	16	(a) Give unadjusted estimates and, if applicable, confounder-adjusted estimates and their precision (e.g., 95% confidence interval). Make clear which confounders were adjusted for and why they were included (b) Report category boundaries when continuous variables were categorized (c) If relevant, consider translating estimates of relative risk into absolute risk for a meaningful time period	Results (Pg 6) and S5 Appendix		
Other analyses	17	Report other analyses done—e.g., analyses of subgroups and interactions, and sensitivity analyses	Results (Pg 6-7) and S6-S9 Appendix		
Discussion					
Key results	18	Summarise key results with reference to study objectives	Discussion (Pg 7)		
Limitations	19	Discuss limitations of the study, taking into account sources of potential bias or imprecision. Discuss both direction and magnitude of any potential bias	Discussion (Pg 7-8)	RECORD 19.1: Discuss the implications of using data that were not created or collected to answer the specific research question(s). Include discussion of misclassification bias, unmeasured confounding, missing data,	Discussion (Pg 7-8)

				and changing eligibility over time, as they pertain to the study being reported.	
Interpretation	20	Give a cautious overall interpretation of results considering objectives, limitations, multiplicity of analyses, results from similar studies, and other relevant evidence	Discussion (Pg 8-9)		
Generalisability	21	Discuss the generalisability (external validity) of the study results	Discussion (Pg 8-9)		
Other Information					
Funding	22	Give the source of funding and the role of the funders for the present study and, if applicable, for the original study on which the present article is based	Methods, Ethics, software and dissemination (Pg 5)		
Accessibility of protocol, raw data, and programming code		..		RECORD 22.1: Authors should provide information on how to access any supplemental information such as the study protocol, raw data, or programming code.	N/A

*Reference: Benchimol EI, Smeeth L, Guttmann A, Harron K, Moher D, Petersen I, Sørensen HT, von Elm E, Langan SM, the RECORD Working Committee. The REporting of studies Conducted using Observational Routinely-collected health Data (RECORD) Statement. *PLoS Medicine* 2015; in press.

S3 Appendix. Temporal trends of percentage change of 2020 counts vs 2018-2019 average of A&E attendances and hospital admissions

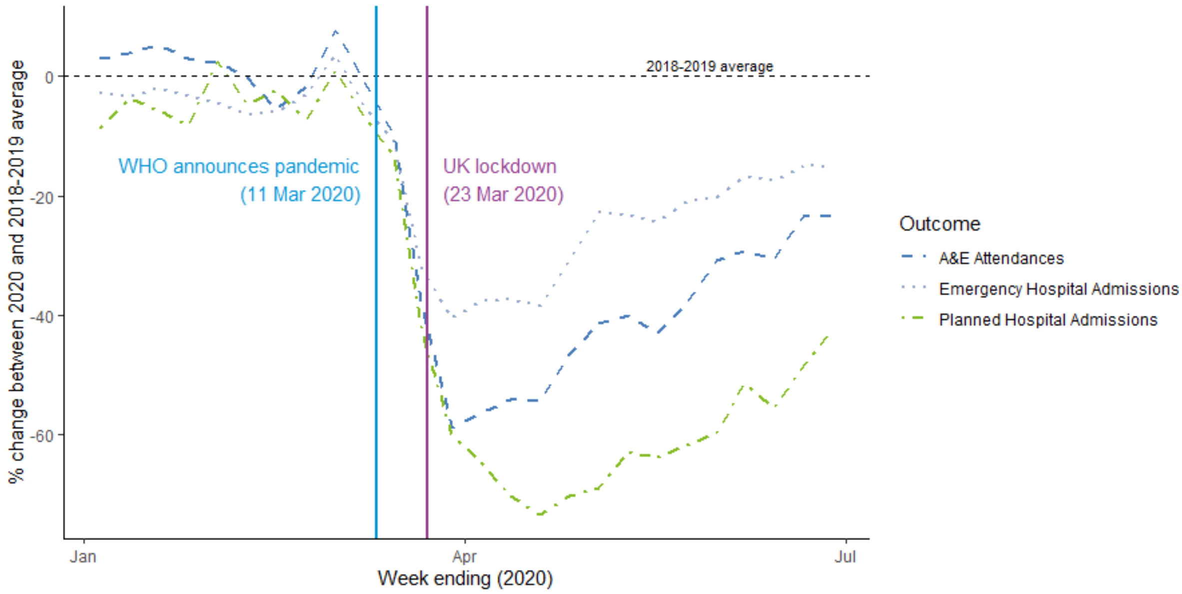


Figure 1. Temporal trends of percentage change for A&E attendances and hospital admissions across Scotland

Weekly percentage changes between 2020 and 2018-2019 average for A&E attendances, emergency and planned hospital admissions for weeks ending 05 Jan to 28 Jun 2020. Includes change-point 1 (WHO announcing pandemic on 11 Mar) and change-point 2 (UK lockdown on 23 Mar).

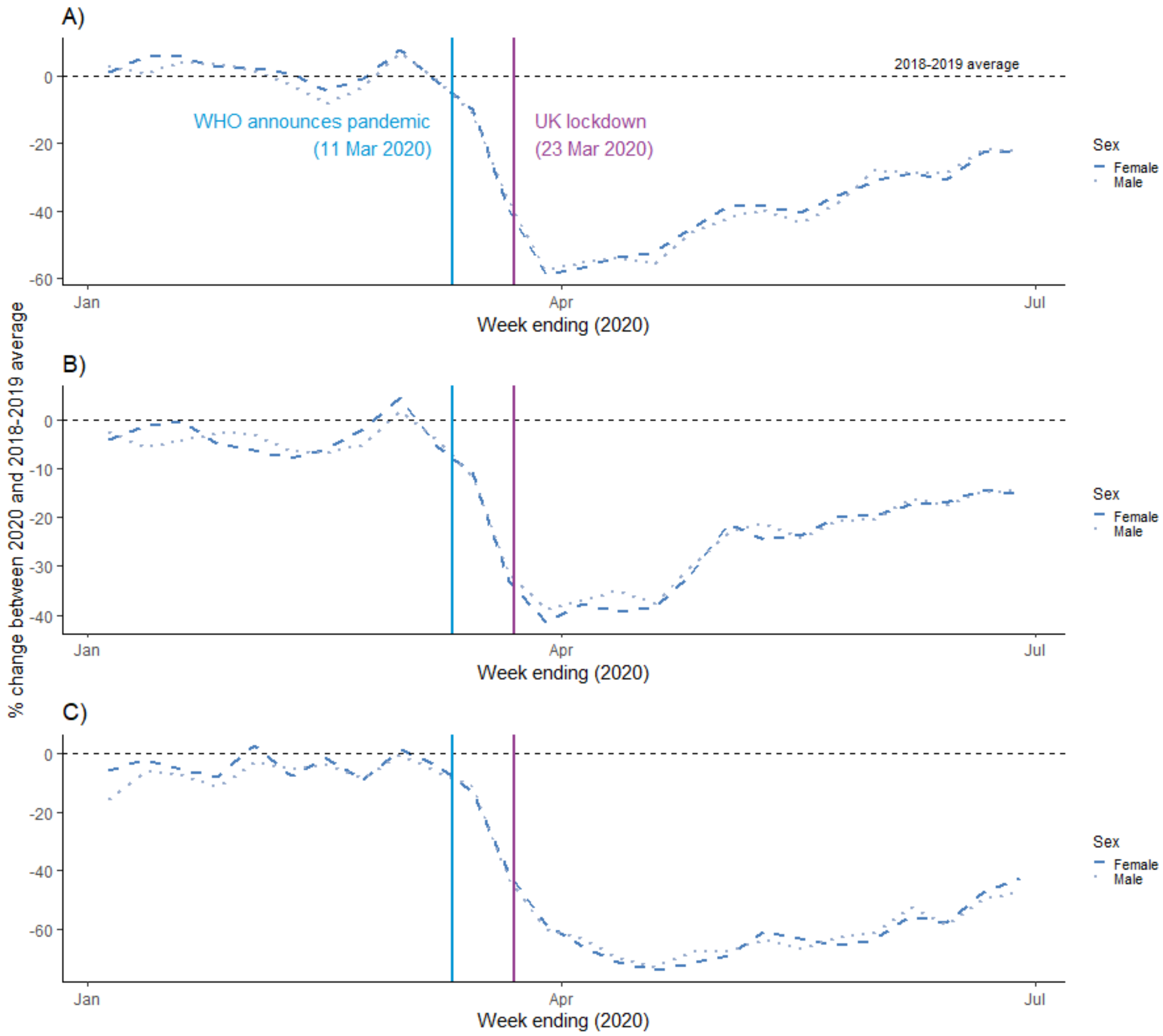


Figure 2. Temporal trends of percentage change in A&E attendances and hospital admissions by sex

Weekly percentage changes between 2020 and 2018-2019 average split by sex for A) A&E attendances, B) emergency and C) planned hospital admissions for weeks ending 05 Jan to 28 Jun 2020. Includes change-point 1 (WHO announcing pandemic on 11 Mar) and change-point 2 (UK lockdown on 23 Mar).

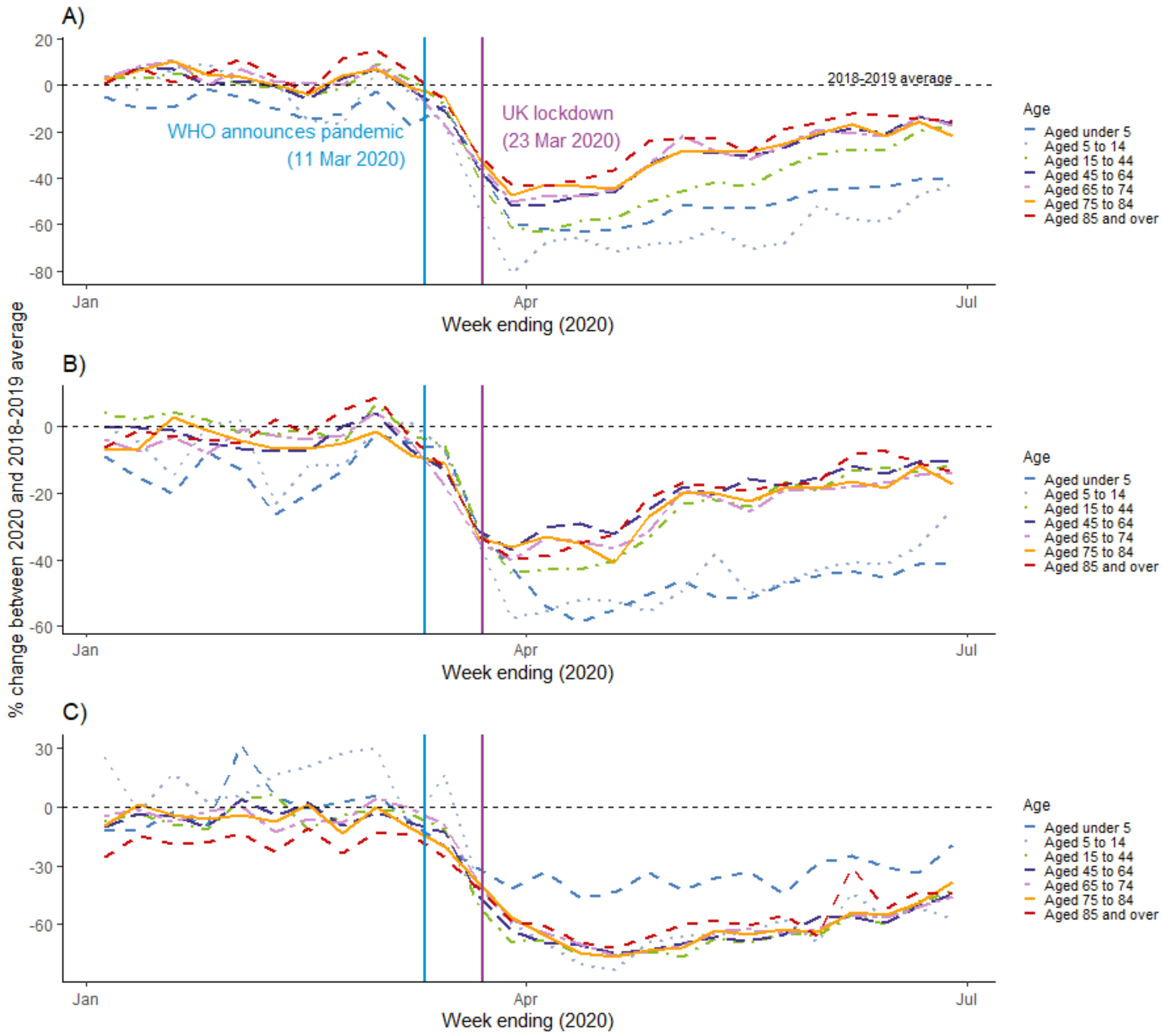


Figure 3. Temporal trends of percentage change in A&E attendances and hospital admissions by age

Weekly percentage changes between 2020 and 2018-2019 average split by Age for A) A&E attendances, B) emergency and C) planned hospital admissions for weeks ending 05 Jan to 28 Jun 2020. Includes change-point 1 (WHO announcing pandemic on 11 Mar) and change-point 2 (UK lockdown on 23 Mar).

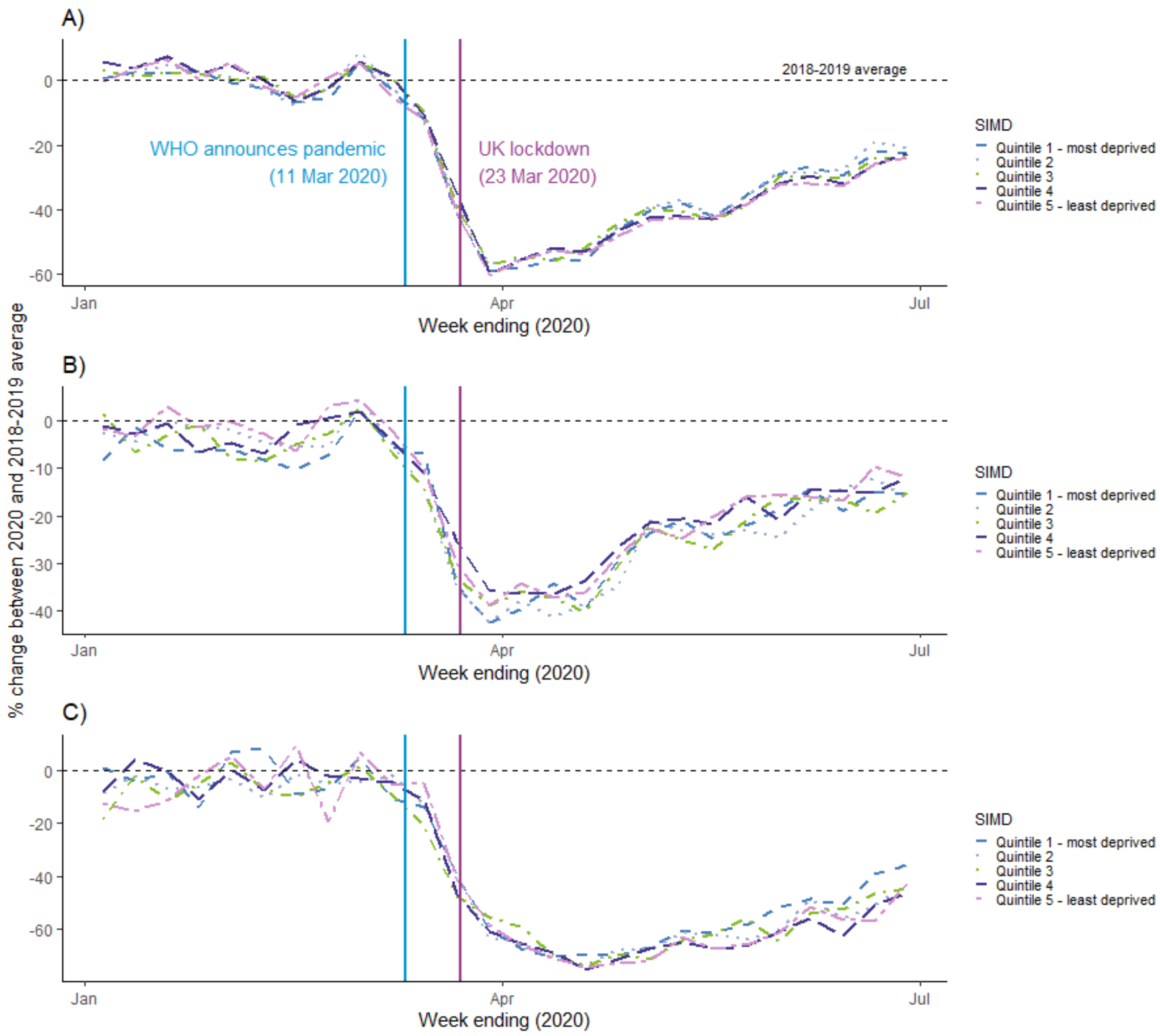


Figure 4. Temporal trends of percentage change in A&E attendances and hospital admissions by SIMD quintile

Weekly percentage changes between 2020 and 2018-2019 average split by SIMD Quintile for A) A&E attendances, B) emergency and C) planned hospital admissions for weeks ending 05 Jan to 28 Jun 2020. Includes change-point 1 (WHO announcing pandemic on 11 Mar) and change-point 2 (UK lockdown on 23 Mar).

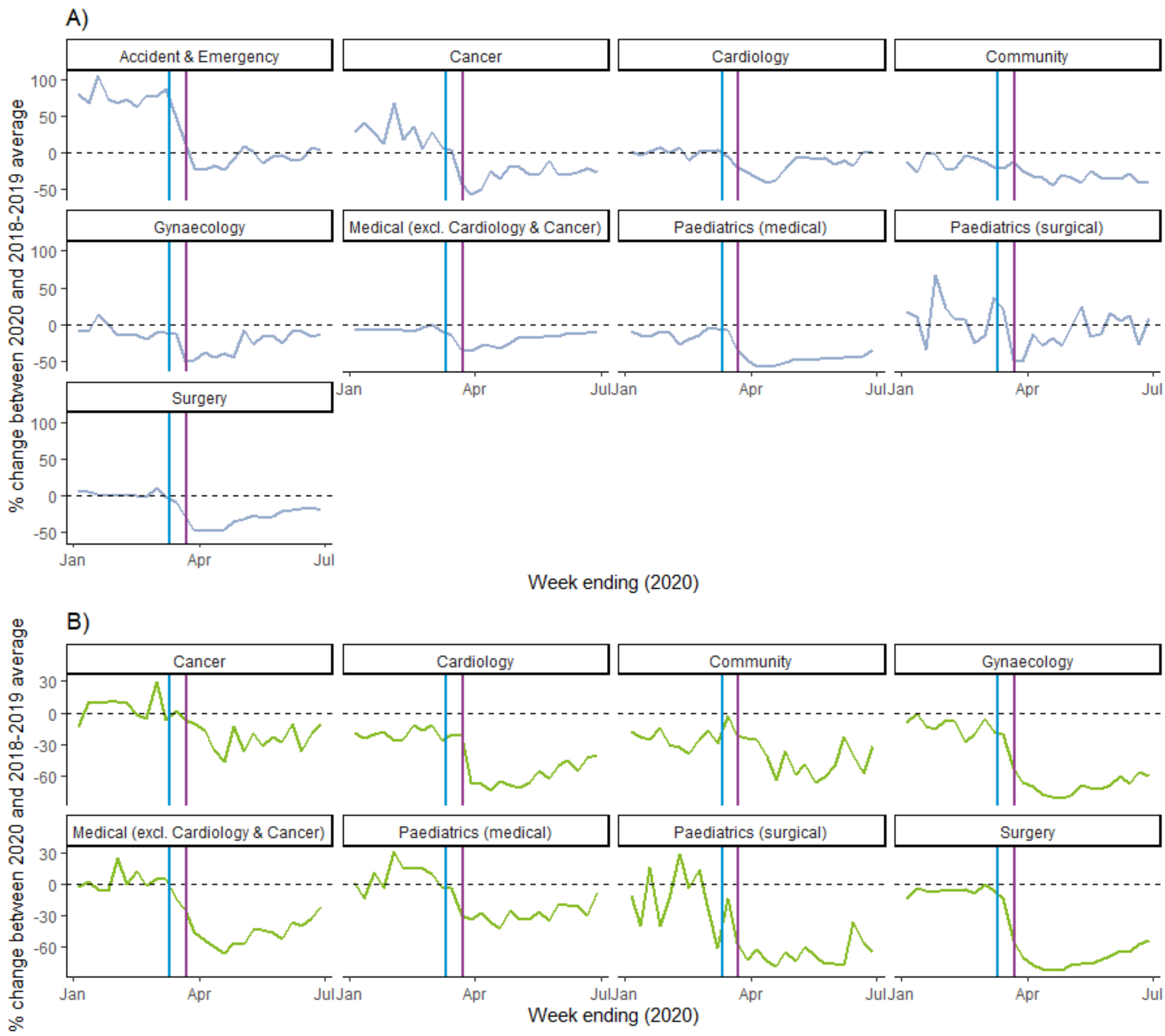


Figure 5. Temporal trends of percentage change in A&E attendances and hospital admissions by specialty

Weekly percentage changes between 2020 and 2018-2019 average split by Speciality for A) emergency and B) planned hospital admissions for weeks ending 05 Jan to 28 Jun 2020. Includes change-point 1 (WHO announcing pandemic on 11 Mar) and change-point 2 (UK lockdown on 23 Mar). Note: A&E is missing for planned hospital admissions due to small numbers.

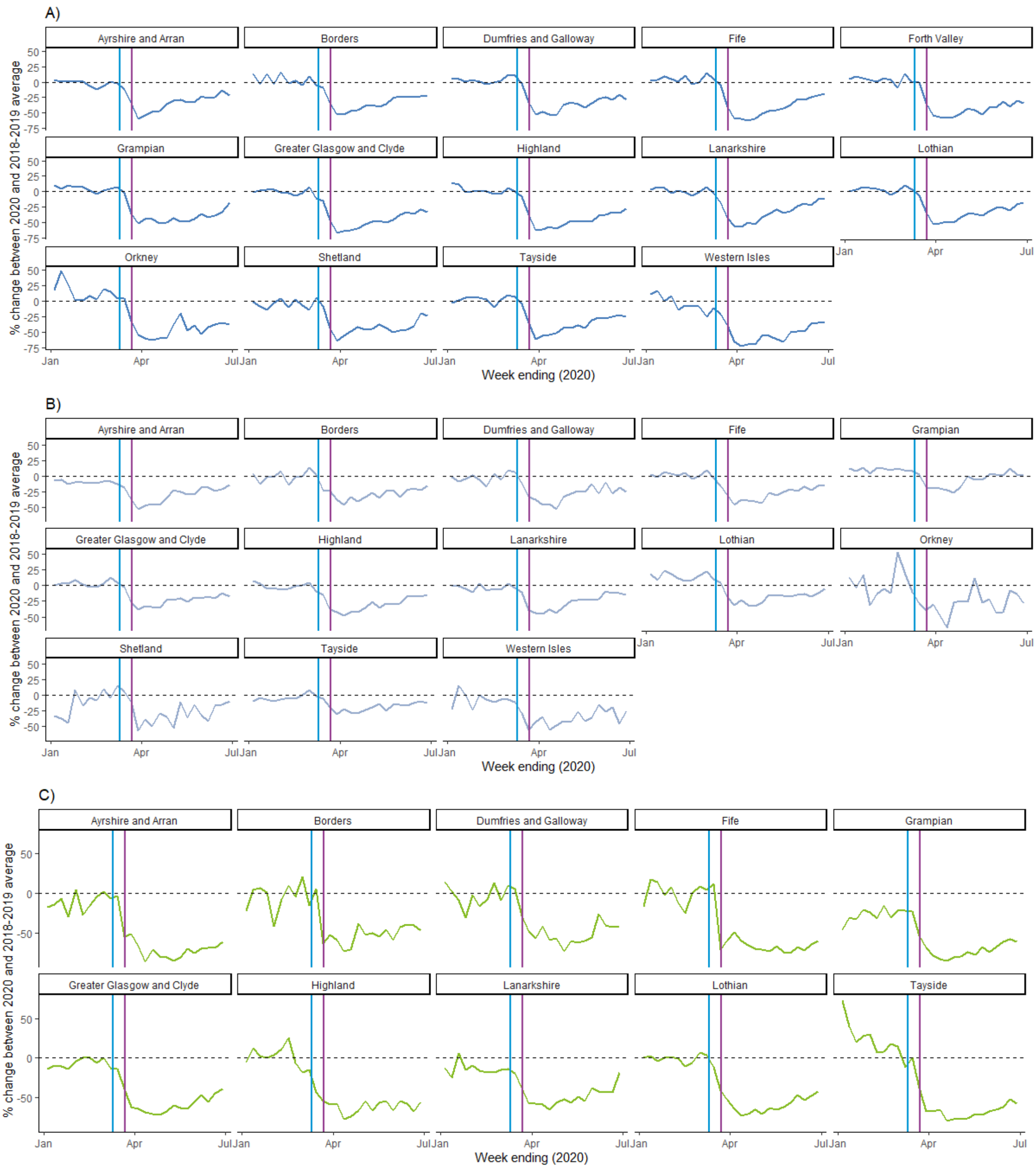


Figure 6. Temporal trends of percentage change in A&E attendances and hospital admissions by NHS Health Board

Weekly percentage changes between 2020 and 2018-2019 average split by NHS Health Board for A) A&E attendances, B) emergency and C) planned hospital admissions for weeks ending 05 January to 28 June 2020. Includes change-point 1 (WHO announcing pandemic on 11 Mar) and change-point 2 (UK lockdown on 23 Mar). Note: Orkney, Shetland and Western Isles excluded for planned hospital admissions due to small numbers. Forth Valley excluded for emergency and planned hospital admission due to data issues.

S4 Appendix. Temporal trends of counts of A&E attendances and hospital admissions

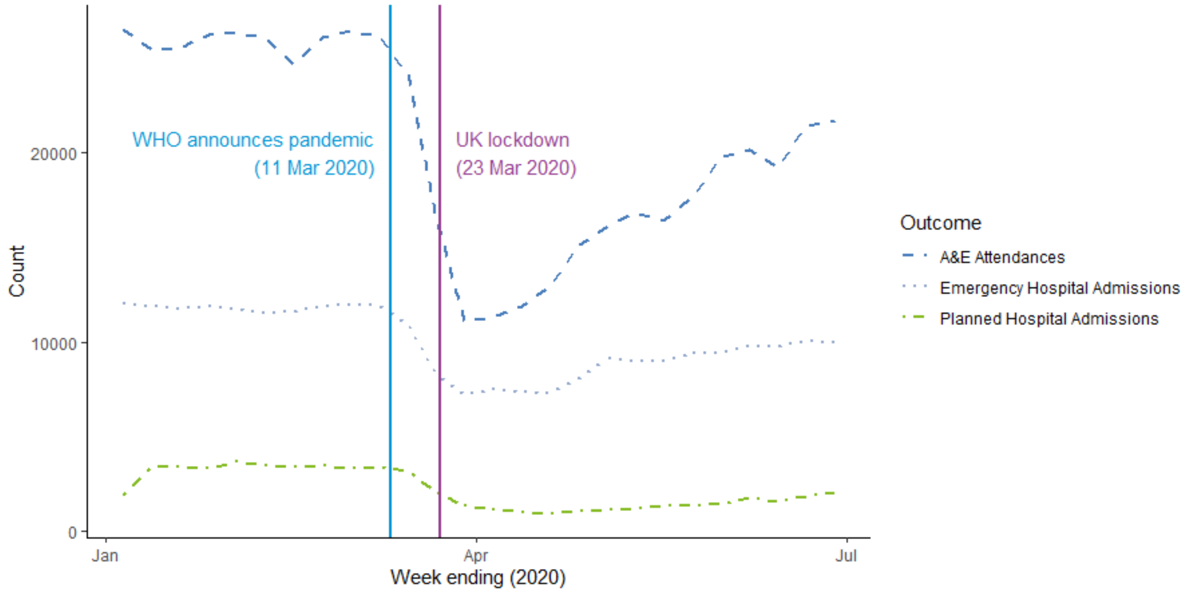


Figure 1. Temporal trends of counts in A&E attendances and hospital admissions across Scotland
Weekly counts of A&E attendances, emergency and planned hospital admissions for weeks ending 5 January to 28 June 2020. Includes change-point 1 (WHO announcing pandemic on 11th March) and change-point 2 (UK lockdown on 23rd March).

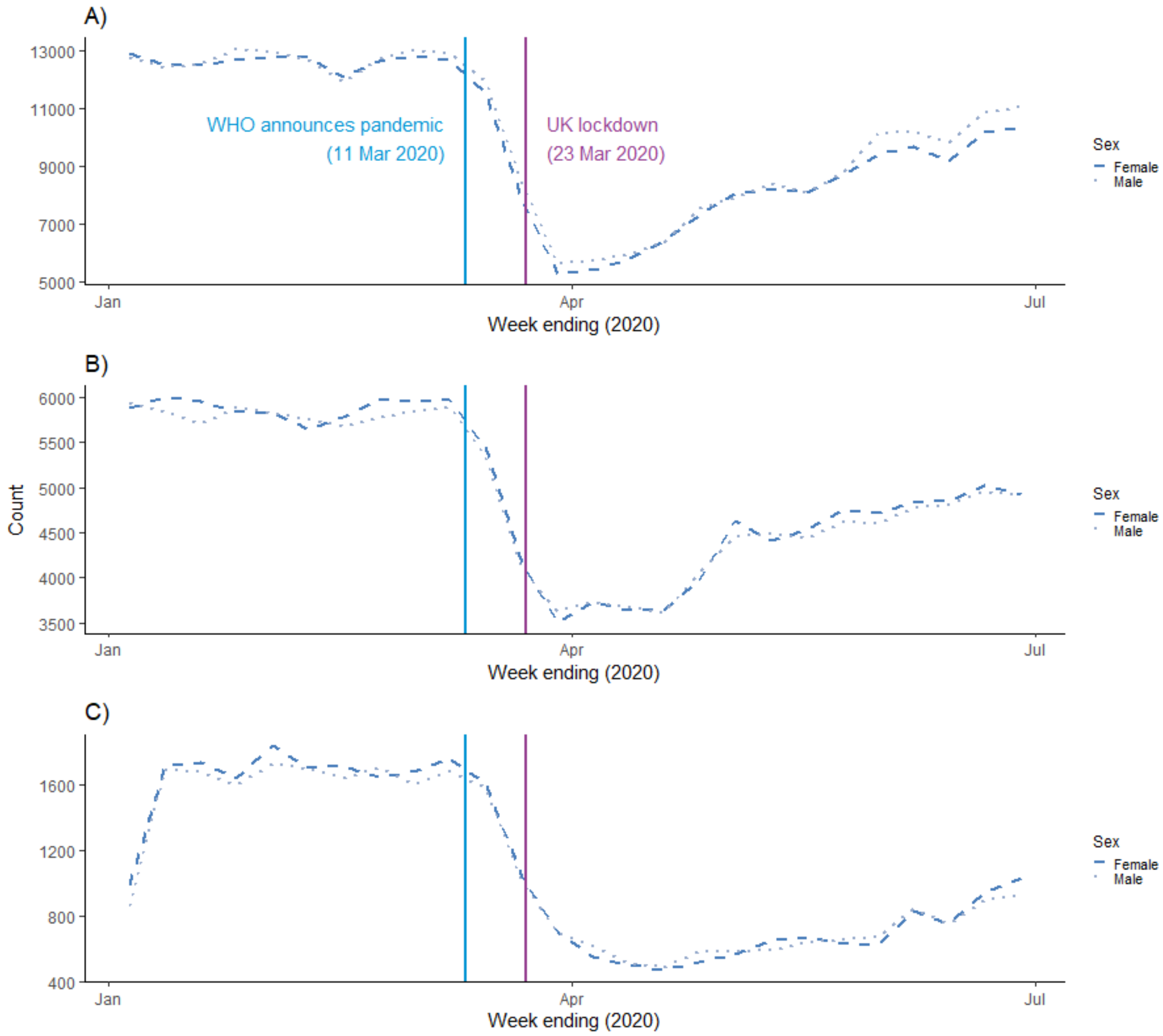


Figure 2. Temporal trends of counts in A&E attendances and hospital admissions by sex

Weekly percentage changes between 2020 and 2018-2019 average split by sex for A) A&E attendances, B) emergency and C) planned hospital admissions for weeks ending 05 Jan to 28 Jun 2020. Includes change-point 1 (WHO announcing pandemic on 11 March) and change-point 2 (UK lockdown on 23 March).

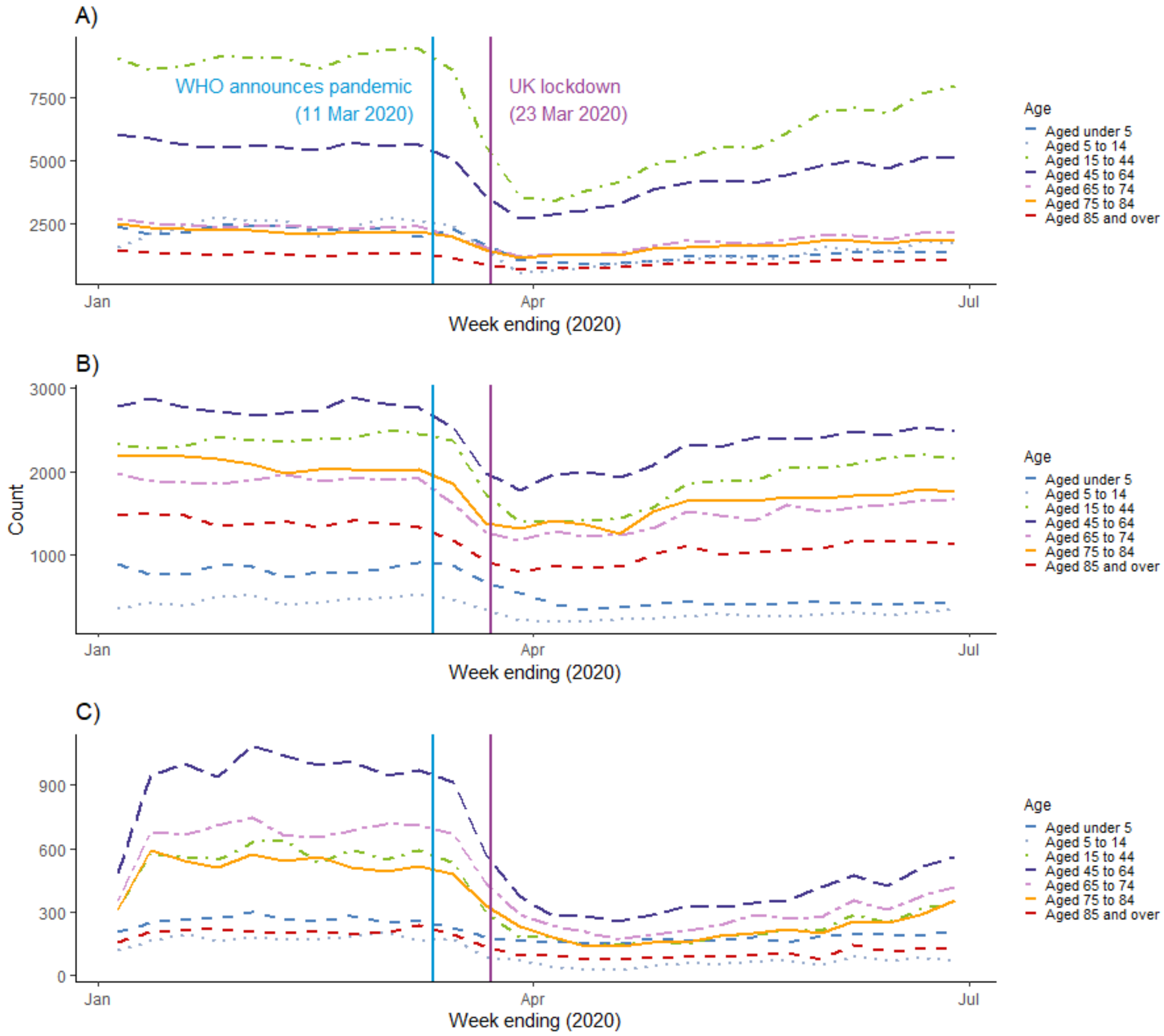


Figure 3. Temporal trends of counts in A&E attendances and hospital admissions by age group

Weekly percentage changes between 2020 and 2018-2019 average split by age for A) A&E attendances, B) emergency and C) planned hospital admissions for weeks ending 05 Jan to 28 Jun 2020. Includes change-point 1 (WHO announcing pandemic on 11 March) and change-point 2 (UK lockdown on 23 March).

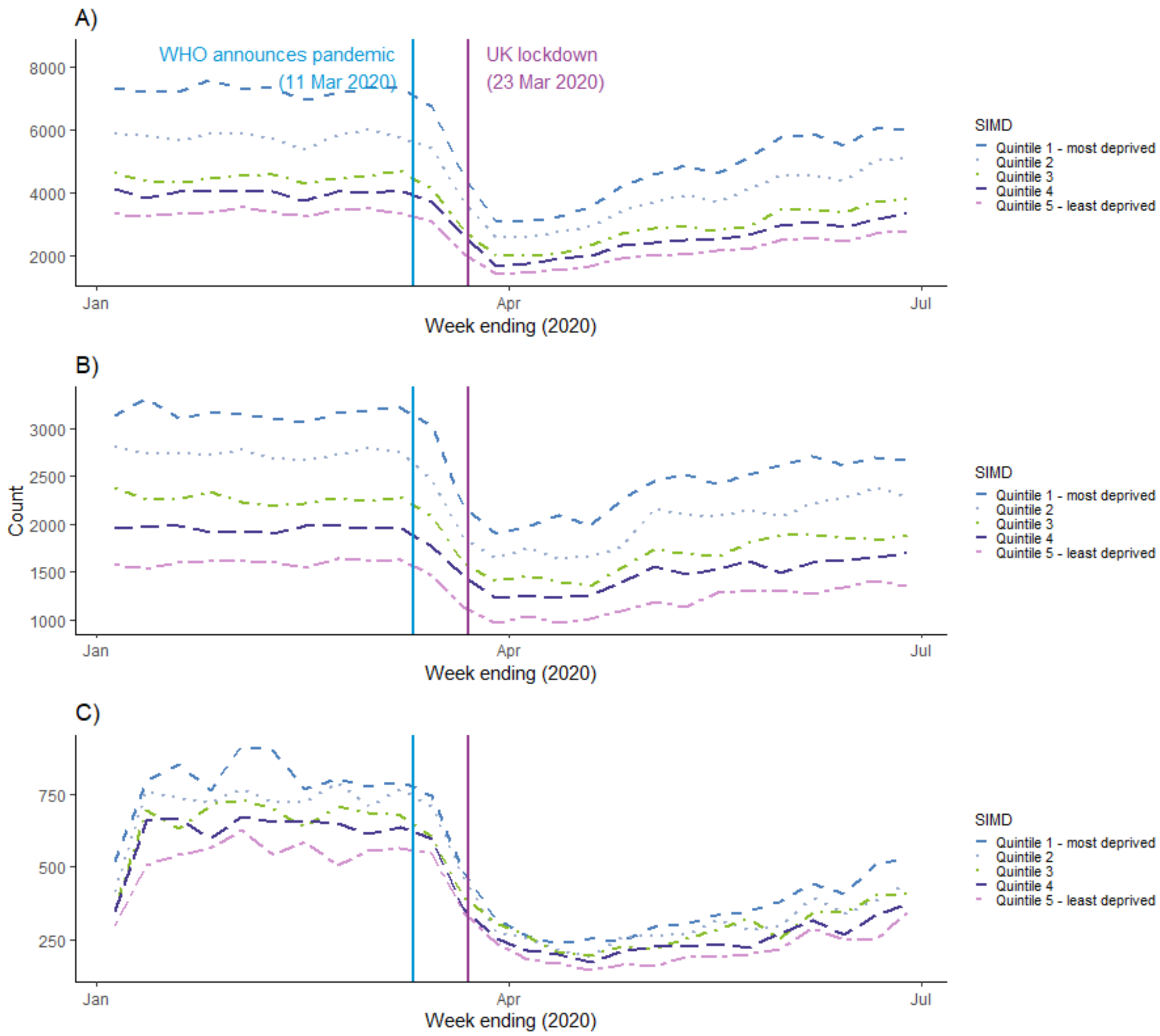


Figure 4. Temporal trends of counts in A&E attendances and hospital admissions by SIMD quintile

Weekly percentage changes between 2020 and 2018-2019 average split by SIMD quintile for A) A&E attendances, B) emergency and C) planned hospital admissions for weeks ending 05 Jan to 28 Jun 2020. Includes change-point 1 (WHO announcing pandemic on 11 March) and change-point 2 (UK lockdown on 23 March).

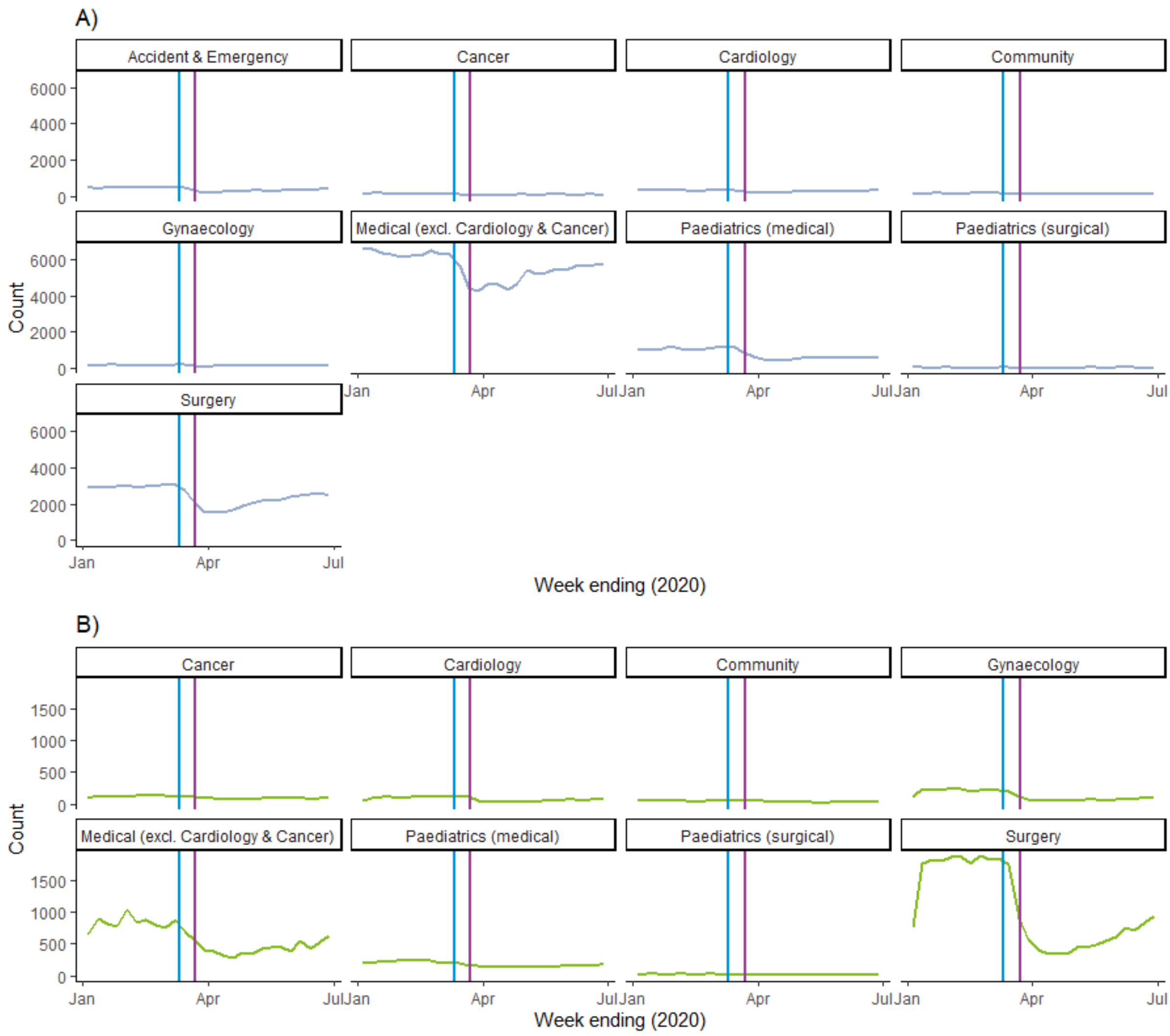


Figure 5. Temporal trends of counts hospital admissions by speciality
Weekly percentage changes between 2020 and 2018-2019 average split by speciality for A) emergency and B) planned hospital admissions for weeks ending 05 Jan to 28 Jun 2020. Includes change-point 1 (WHO announcing pandemic on 11 March) and change-point 2 (UK lockdown on 23 March).
Note: A&E is missing for planned hospital admissions due to small numbers.

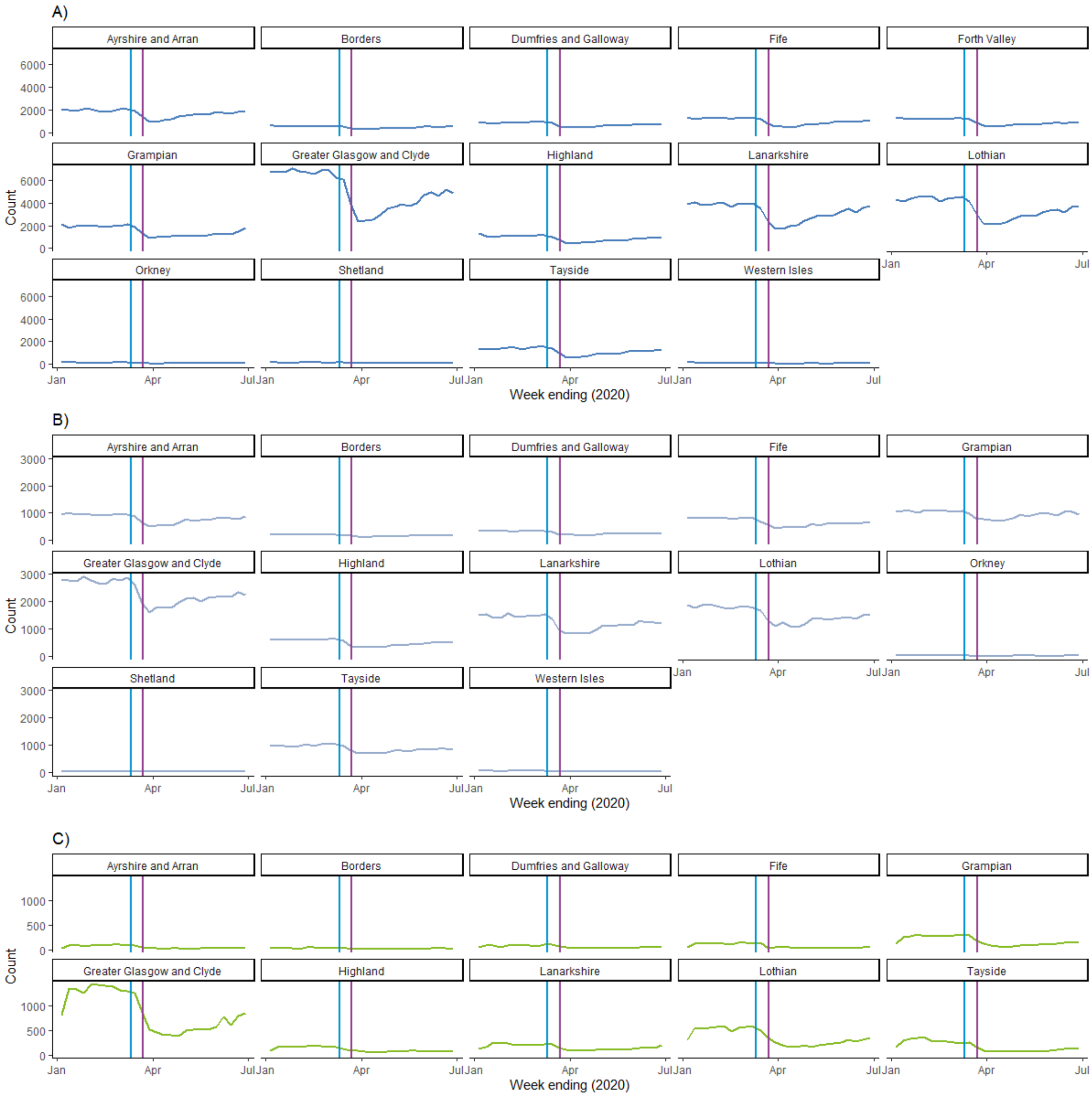


Figure 6. Temporal trends of counts in A&E attendances and hospital admissions by NHS Health Board

Weekly percentage changes between 2020 and 2018-2019 average split by NHS Health Board for A) A&E attendances, B) emergency and C) planned hospital admissions for weeks ending 5 January to 28 June 2020. Includes change-point 1 (WHO announcing pandemic on 11th March) and change-point 2 (UK lockdown on 23rd March).

Note: Orkney, Shetland and Western Isles excluded for planned hospital admissions due to small numbers. Forth Valley excluded for emergency and planned hospital admission due to data issues.

S5 Appendix. Supplementary information on baseline model per outcome

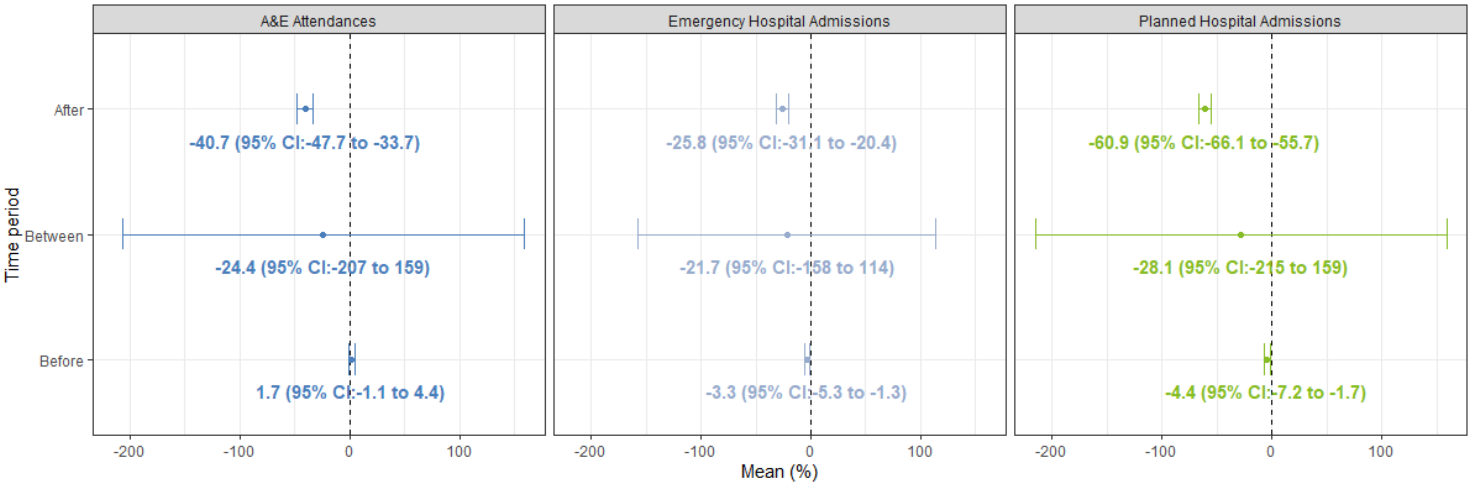


Figure 1. Mean percentage change of 2020 to 2018-2019 average for A&E attendances and hospital admissions
Before indicates weeks before pandemic announcement (weeks ending 05 Jan to 08 Mar 2020); Between indicates weeks between change-points (weeks ending 15 to 22 Mar 2020); After indicates weeks after UK lockdown (weeks ending 29 Mar to 28 Jun 2020). Lines represent 95% confidence intervals.

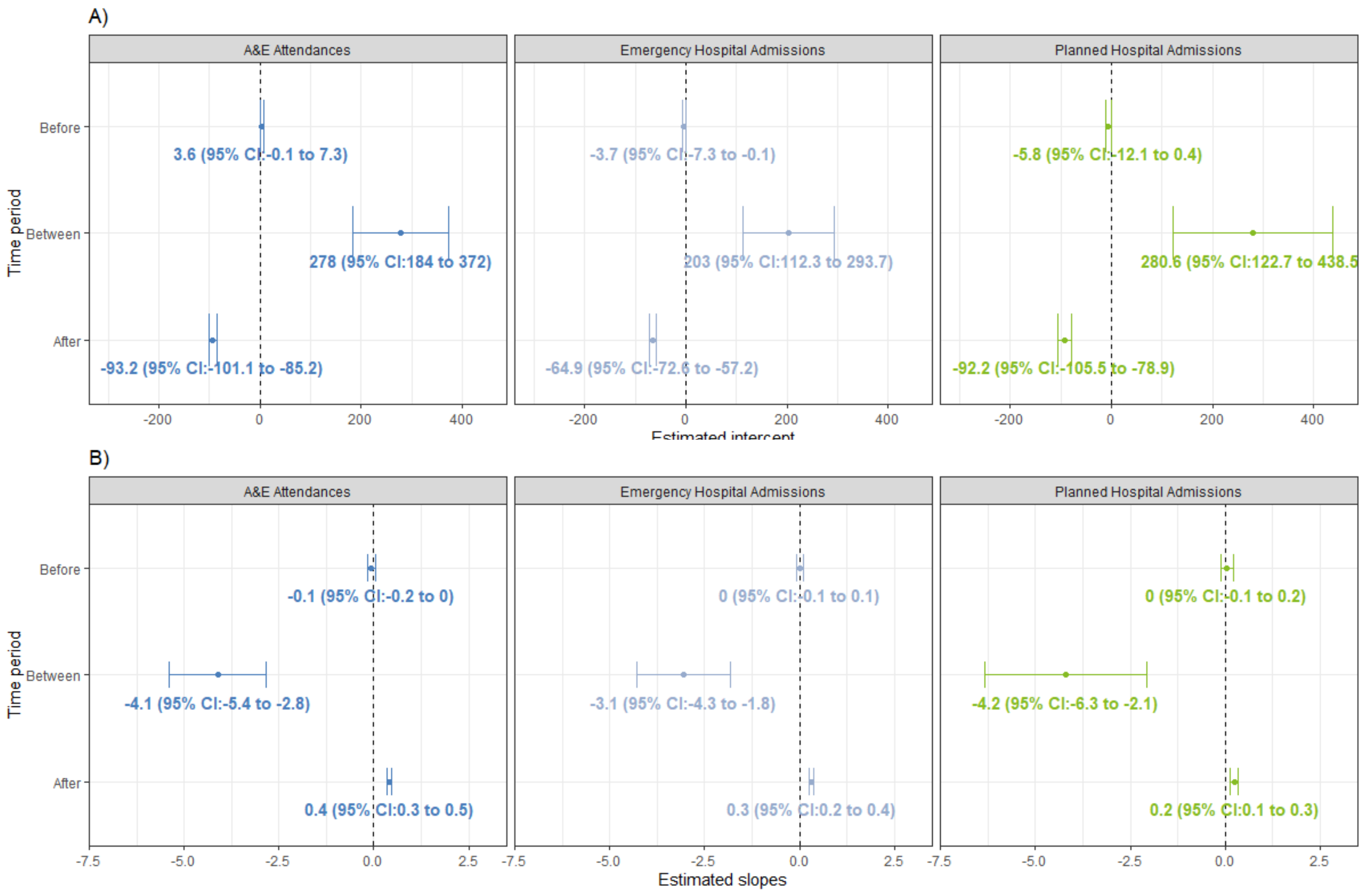


Figure 2. Estimated intercepts and slopes for baseline models for A&E attendances, emergency and planned hospital admissions
Baseline model is the interaction between the number of days since 5th January and the two change-points. Before indicates weeks before pandemic announcement (weeks ending 05 Jan to 08 Mar 2020); Between indicates weeks between change-points (weeks ending 15 to 22 Mar 2020); After indicates weeks after UK lockdown (weeks ending 29 Mar to 28 Jun 2020). Lines represent 95% confidence intervals.

Comparing estimates showed that slopes in the before period were similar across the outcomes, which was also seen in the after time period (Figure 2B). The slopes between the two time-periods were different within the three outcomes (Figure 2B), with slopes in the time-period after the UK lockdown showing evidence of an increasing trend to return to the 2018-2019 average baseline. Accompanying this with the estimated intercepts (Figure 2A) highlighted the drop in the levels before and after.

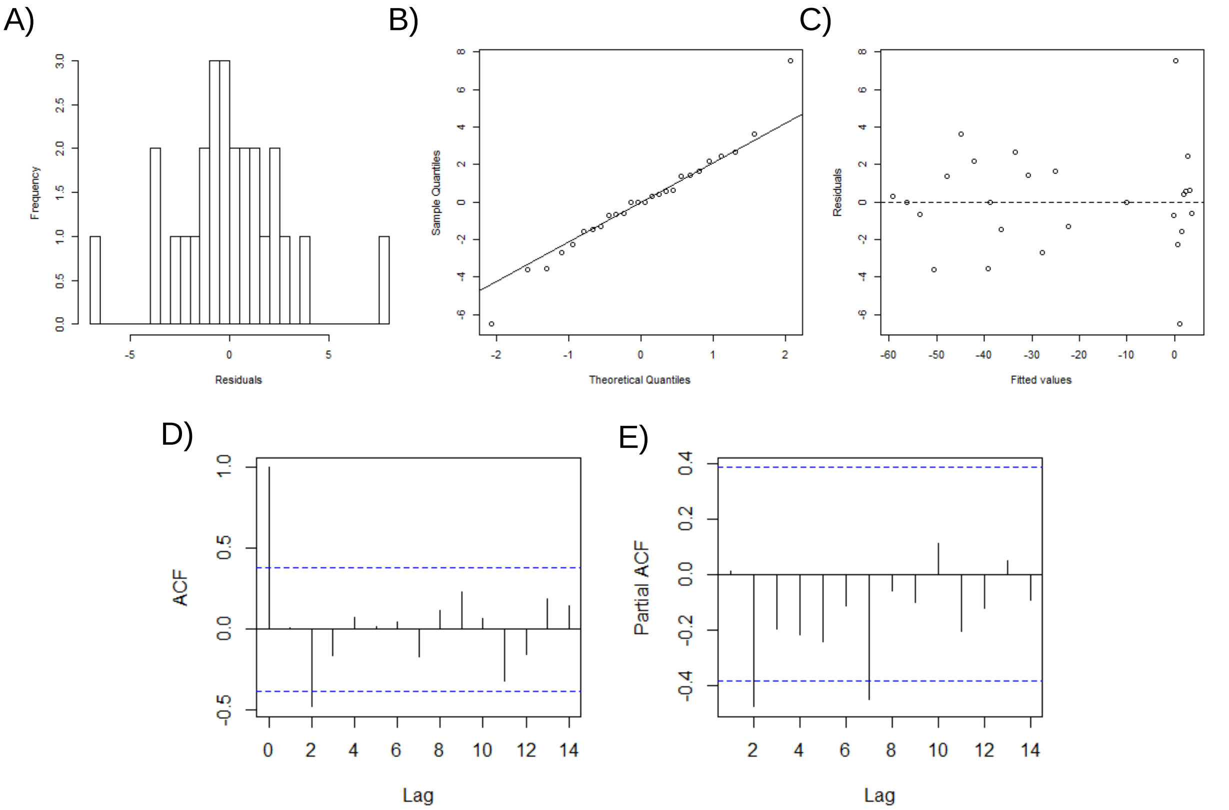


Figure 2. Baseline model diagnostics for A&E attendances
Baseline model of the interaction between the number of days since 05 January and the two change-points for A&E attendances. Contains A) histogram of residuals, B) QQ Plot of residuals, C) residuals vs fitted values plot, D) ACF of residuals and E) PACF of residuals

Strong evidence that normality can be safely assumed with the bell-shaped pattern in A) and the linearity in B). Residuals are scattered above and below mean zero line, with slight skewing due to the large drop in the fitted values C). No temporal autocorrelation is detected since both D) and E) are mostly within the blue dashed line of the 95% confidence intervals.

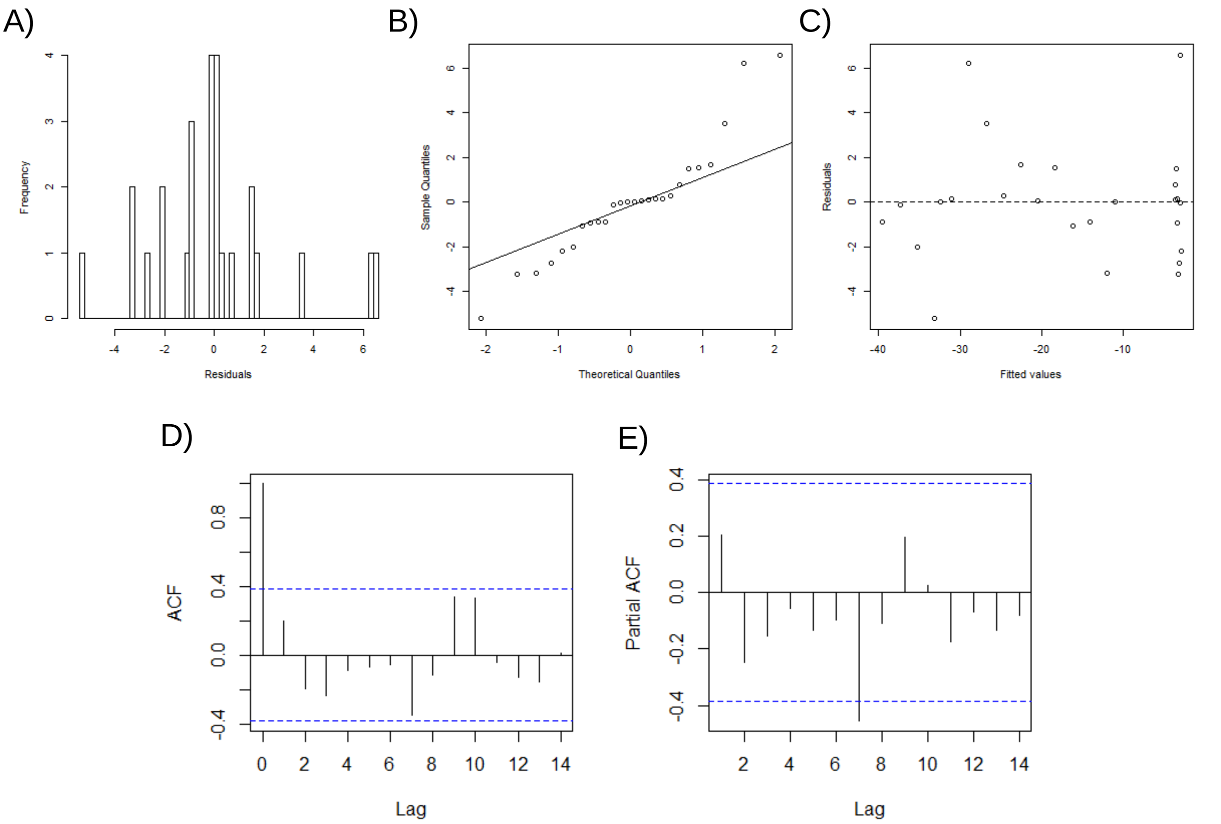


Figure 3. Baseline model diagnostics for emergency hospital admissions
Baseline model of the interaction between the number of days since 05 January and the two change-points for emergency hospital admissions. Contains A) histogram of residuals, B) QQ Plot of residuals, C) residuals vs fitted values plot, D) ACF of residuals and E) PACF of residuals

Moderate evidence that normality can be safely assumed with the bell-shaped pattern in A) and the linearity in B). Residuals are scattered above and below mean zero line, with slight skewing due to the large drop in the fitted values C). No temporal autocorrelation is detected since both D) and E) are mostly within the blue dashed line of the 95% confidence intervals.

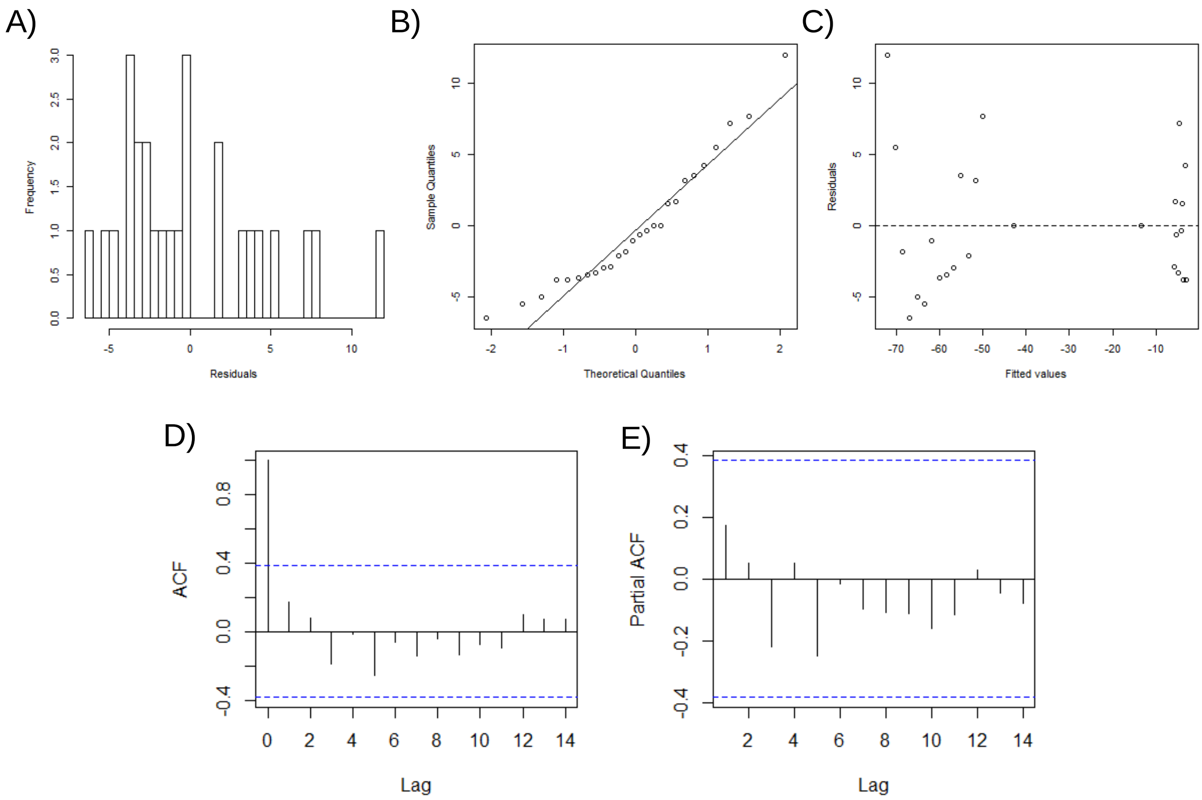


Figure 4. Baseline model diagnostics for planned hospital admissions
Baseline model of the interaction between the number of days since 05 January and the two change-points for planned hospital admissions. Contains A) histogram of residuals, B) QQ Plot of residuals, C) residuals vs fitted values plot, D) ACF of residuals and E) PACF of residuals.

Moderate to weak evidence that normality can be safely assumed with the lack of a bell-shaped pattern in A) and little linearity in B). Residuals are scattered above and below mean zero line, with skewing due to the large drop in the fitted values C). No temporal autocorrelation is detected since both D) and E) are within the blue dashed line of the 95% confidence intervals.

S6 Appendix: Supplementary information on interaction with age

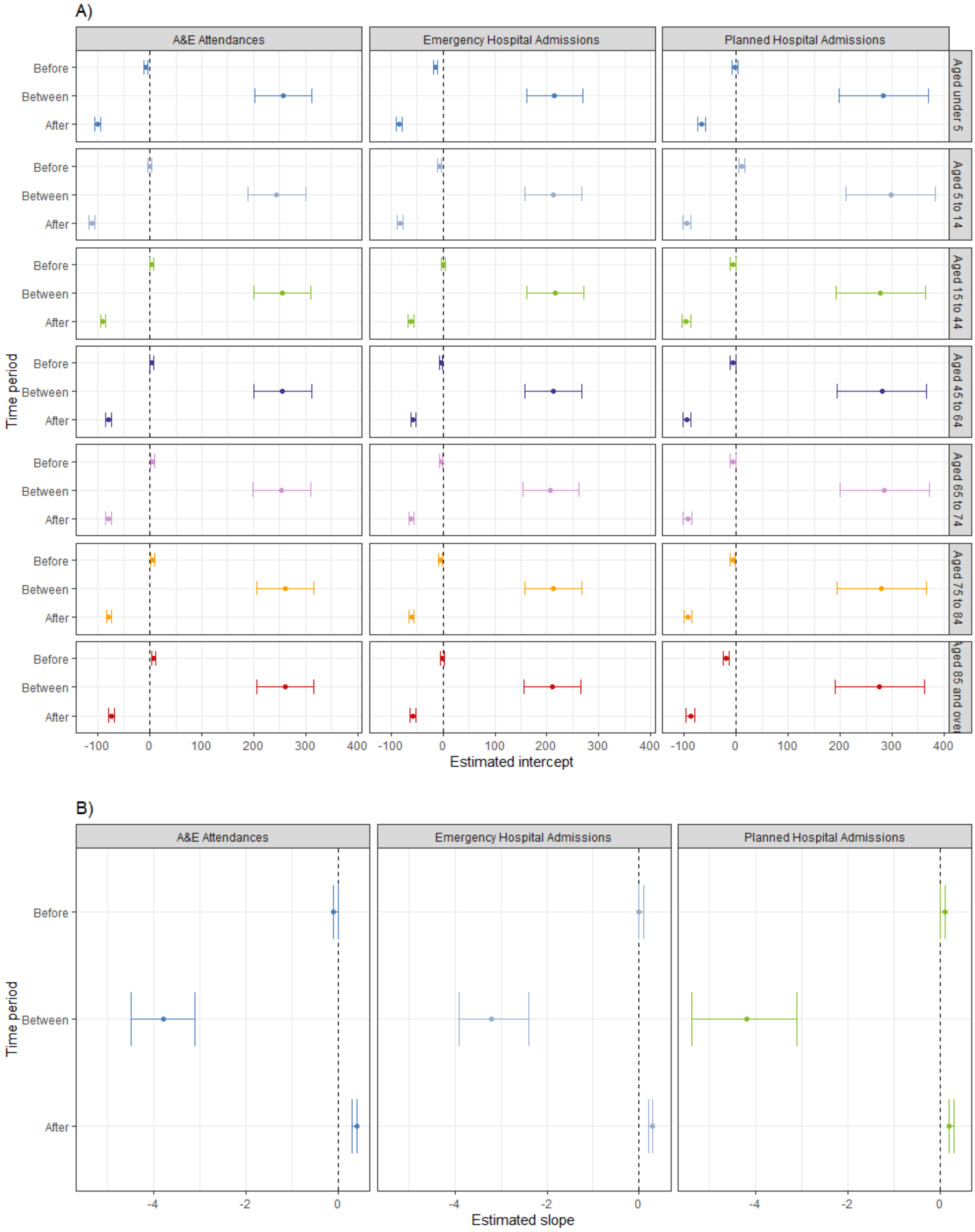


Figure 1. Estimated intercepts (A) and slopes (B) for age model for A&E attendances and hospital admissions

Points represent estimated intercepts (A) and estimated slopes (B) for the fitted model of the baseline model (the number of days since 05 January and the two change-points) and an interaction between age and change-points. Lines represent 95% confidence intervals.

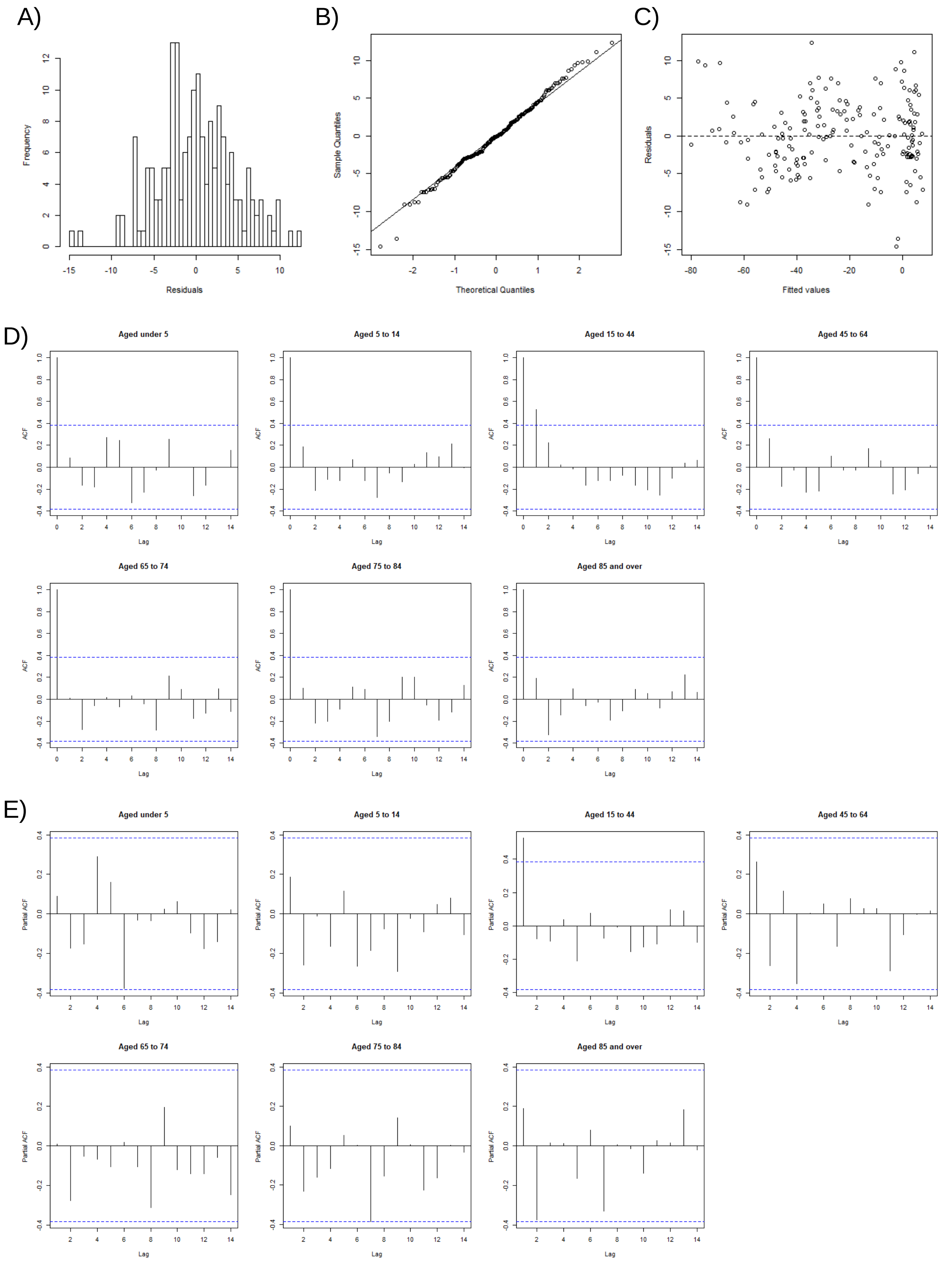


Figure 2. Age model diagnostics for A&E attendances
Fitted model of the baseline model (the number of days since 05 January and the two change-points) and an interaction between age and change-points for A&E attendances. Contains A) histogram of residuals, B) QQ Plot of residuals, C) residuals vs fitted values plot, D) ACF of residuals for age group and E) PACF of residuals for age group.

Strong evidence that normality can be safely assumed with the bell-shaped pattern in A) and the linearity in B). Residuals are scattered above and below mean zero line, with slight skewing due to the large drop in the fitted values C). No temporal autocorrelation is detected since both D) and E) are mostly within the blue dashed line of the 95% confidence intervals.

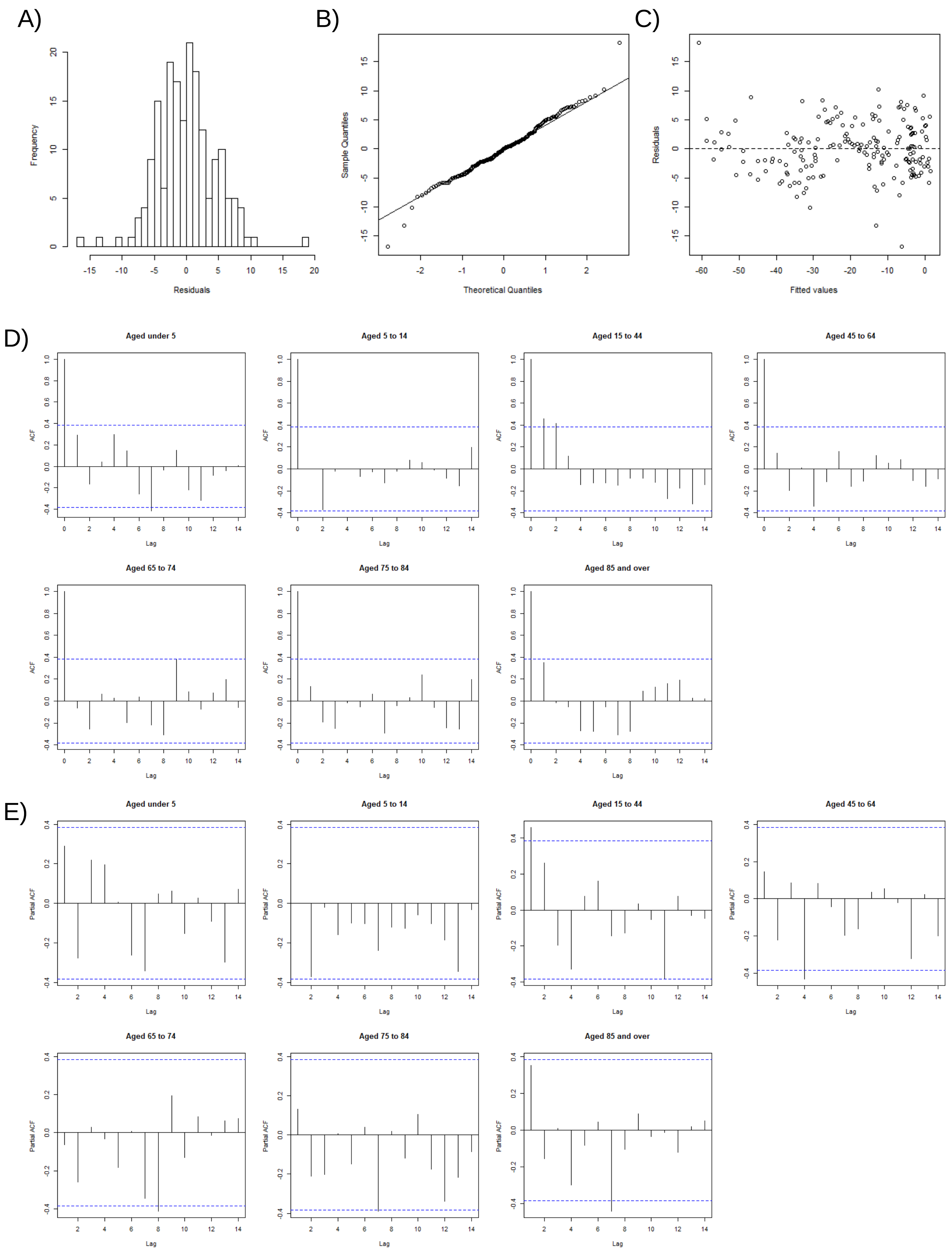


Figure 3. Age model diagnostics for emergency hospital admissions
Fitted model of the baseline model (the number of days since 05 January and the two change-points) and an interaction between age and change-points for emergency hospital admissions. Contains A) histogram of residuals, B) QQ Plot of residuals, C) residuals vs fitted values plot, D) ACF of residuals for age group and E) PACF of residuals for age group.

Strong evidence that normality can be safely assumed with the bell-shaped pattern in A) and the linearity in B). Residuals are scattered above and below mean zero line, with slight skewing due to the large drop in the fitted values C). No temporal autocorrelation is detected since both D) and E) are mostly within the blue dashed line of the 95% confidence intervals.

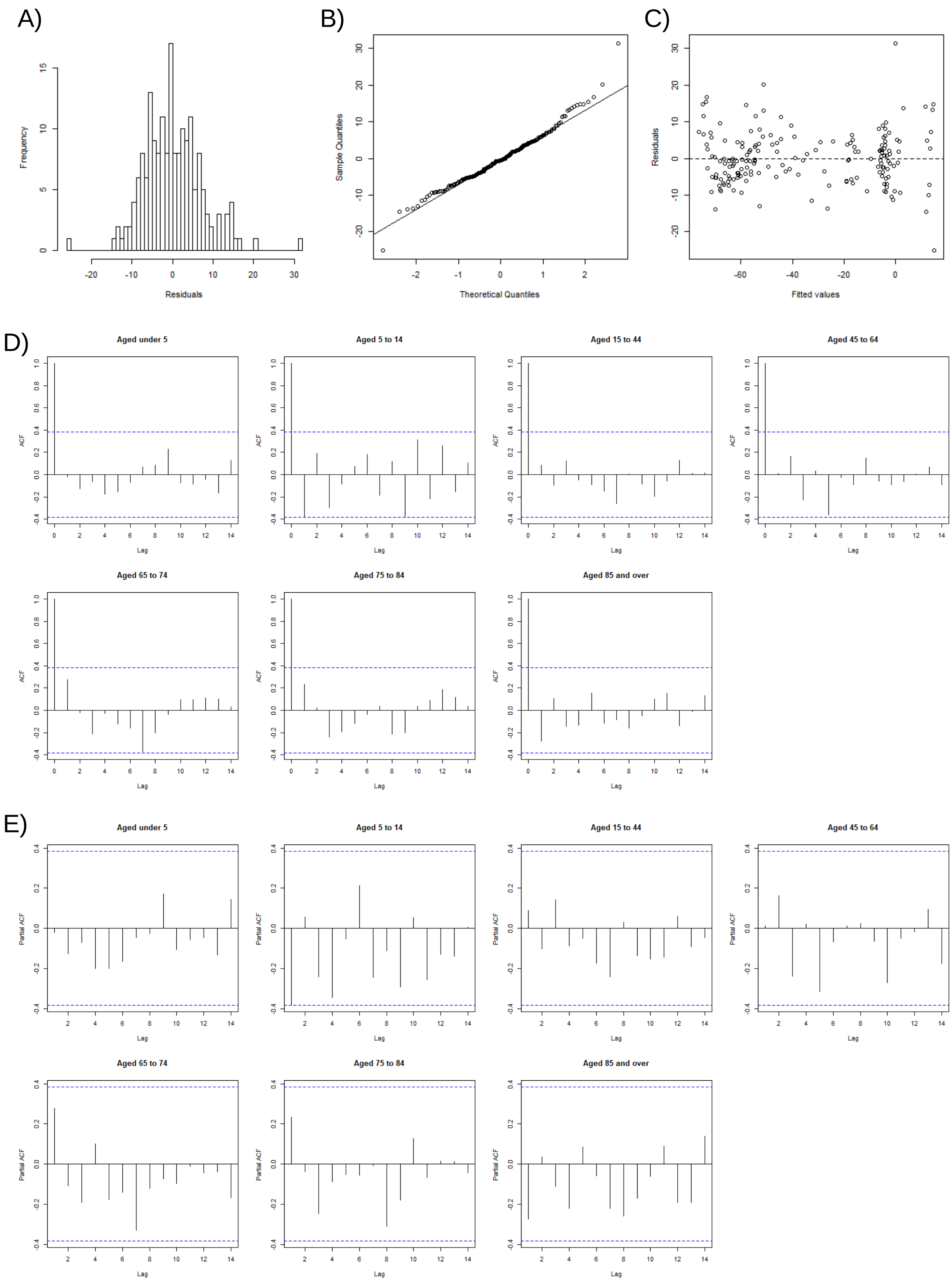


Figure 4. Age model diagnostics for planned hospital admissions
Fitted model of the baseline model (the number of days since 05 January and the two change-points) and an interaction between age and change-points for planned hospital admissions. Contains A) histogram of residuals, B) QQ Plot of residuals, C) residuals vs fitted values plot, D) ACF of residuals for age group and E) PACF of residuals for age group.

Strong evidence that normality can be safely assumed with the bell-shaped pattern in A) and the linearity in B). Residuals are scattered above and below mean zero line, with slight skewing due to the large drop in the fitted values C). No temporal autocorrelation is detected since both D) and E) are mostly within the blue dashed line of the 95% confidence intervals.

S7 Appendix: Supplementary information on interaction with SIMD

Detailed description

For SIMD, only emergency hospital admissions saw any substantial difference in the groups. The final chosen model fit parallel trend lines for each SIMD quintile, where the slopes differed by the time period. The order of the SIMD quintiles were consistent throughout the time periods (Model 1, S1 Appendix). The plot of the fitted model suggested that those most deprived (Quintiles 1-3) were affected the most, where the trend lines were slightly lower than the most deprived (Figure 1, S7 Appendix). This difference was only slight and it seemed to be driven by differences before the pandemic announcement. This therefore may suggest that, in general, those from deprived areas had lower emergency admissions to previous years for reasons unrelated to COVID-19.

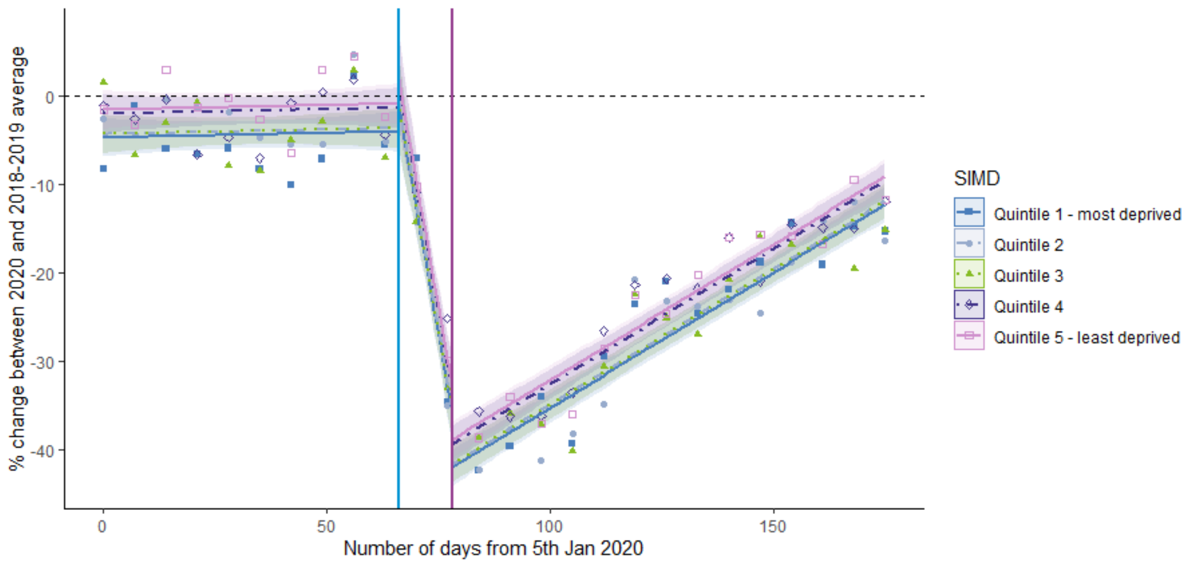


Figure 1. Fitted lines of SIMD model for emergency hospital admissions
Lines represent fitted model of the baseline model (the number of days since 05 January and the two change-points) with adjustment for SIMD Quintile. Shaded areas around lines represent 95% confidence intervals. Points represent weekly percentage changes between 2020 and 2018-2019 average for emergency hospital admissions for weeks ending 05 Jan to 28 Jun 2020. Includes change-point 1 (WHO announcing pandemic on 11 March) and change-point 2 (UK lockdown on 23 March).

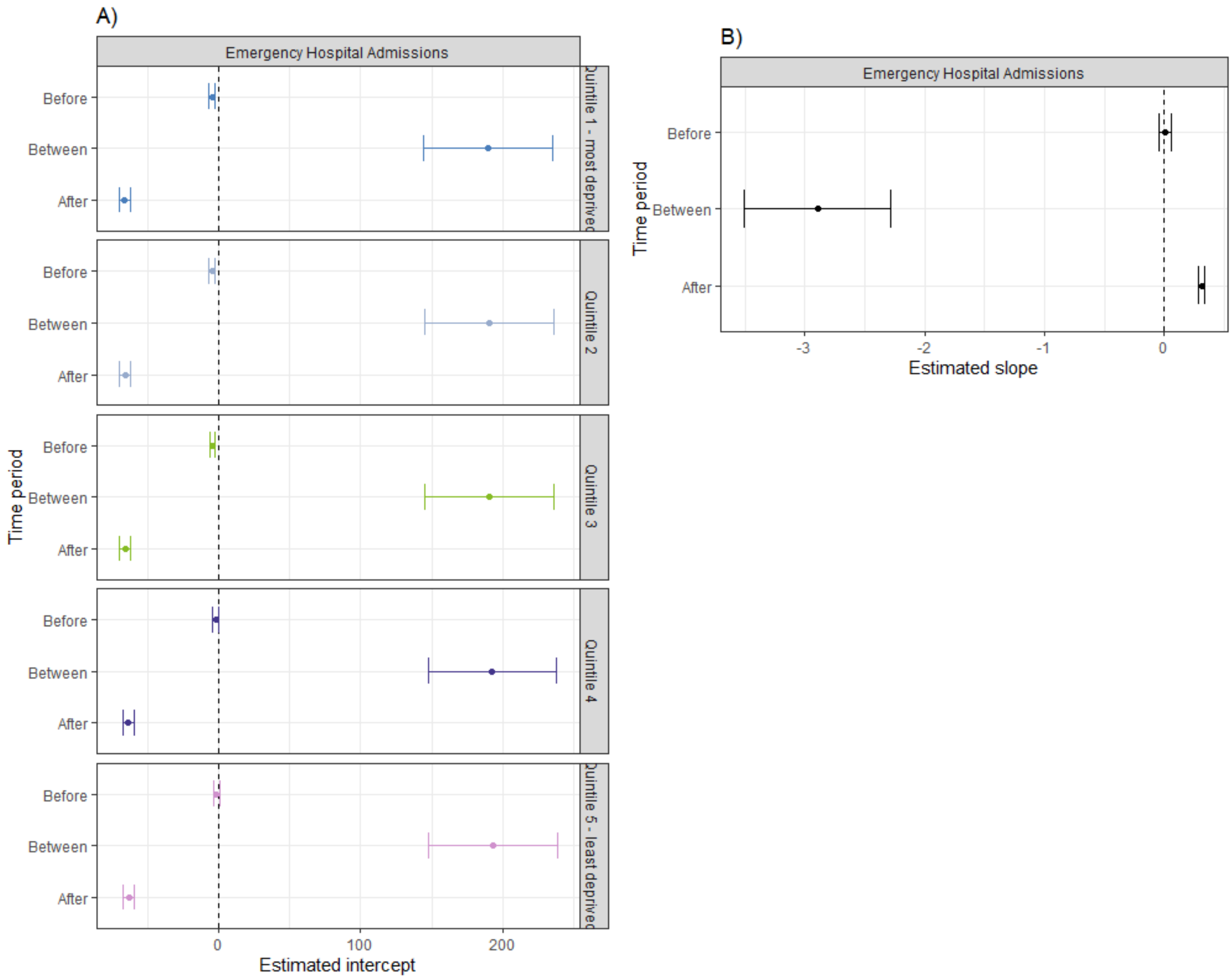


Figure 2. Estimated intercepts (A) and slopes (B) for SIMD model for emergency hospital admissions

Points represent estimated intercepts (A) and estimated slopes (B) for the fitted model of the baseline model (the number of days since 05 January and the two change-points) with adjustment for SIMD Quintile. Lines represent 95% confidence intervals.

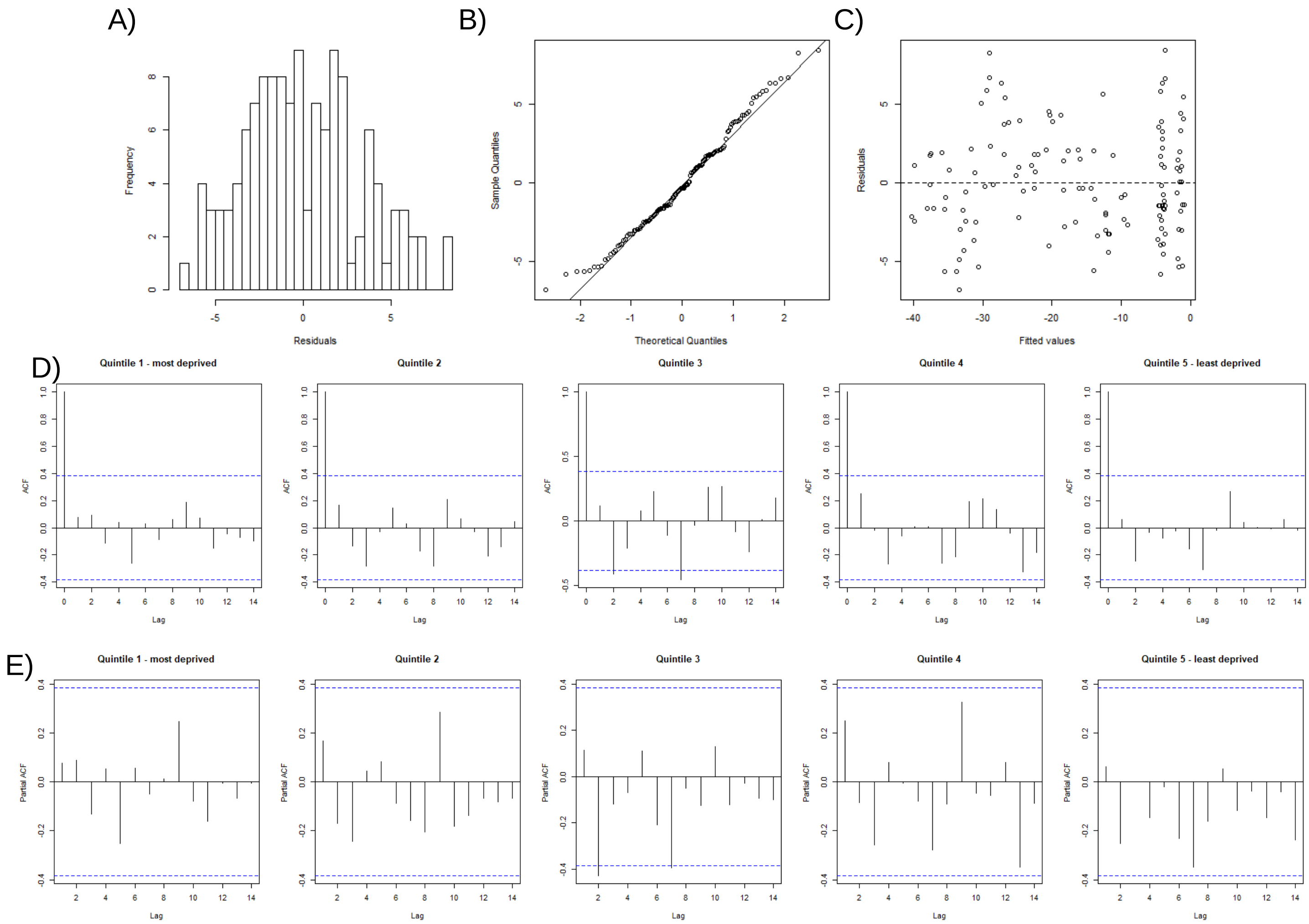


Figure 3. SIMD model diagnostics for planned hospital admissions

Fitted model of the baseline model (the number of days since 05 January and the two change-points) with adjustment for SIMD Quintile. Contains A) histogram of residuals, B) QQ Plot of residuals, C) residuals vs fitted values plot, D) ACF of residuals for SIMD quintile and E) PACF of residuals for SIMD quintile.

Moderate evidence that normality can be safely assumed with the bell-shaped pattern in A) and the linearity in B). Residuals are scattered above and below mean zero line, with slight skewing due to the large drop in the fitted values C). No temporal autocorrelation is detected since both D) and E) are mostly within the blue dashed line of the 95% confidence intervals.

S8 Appendix: Supplementary information on interaction with Speciality

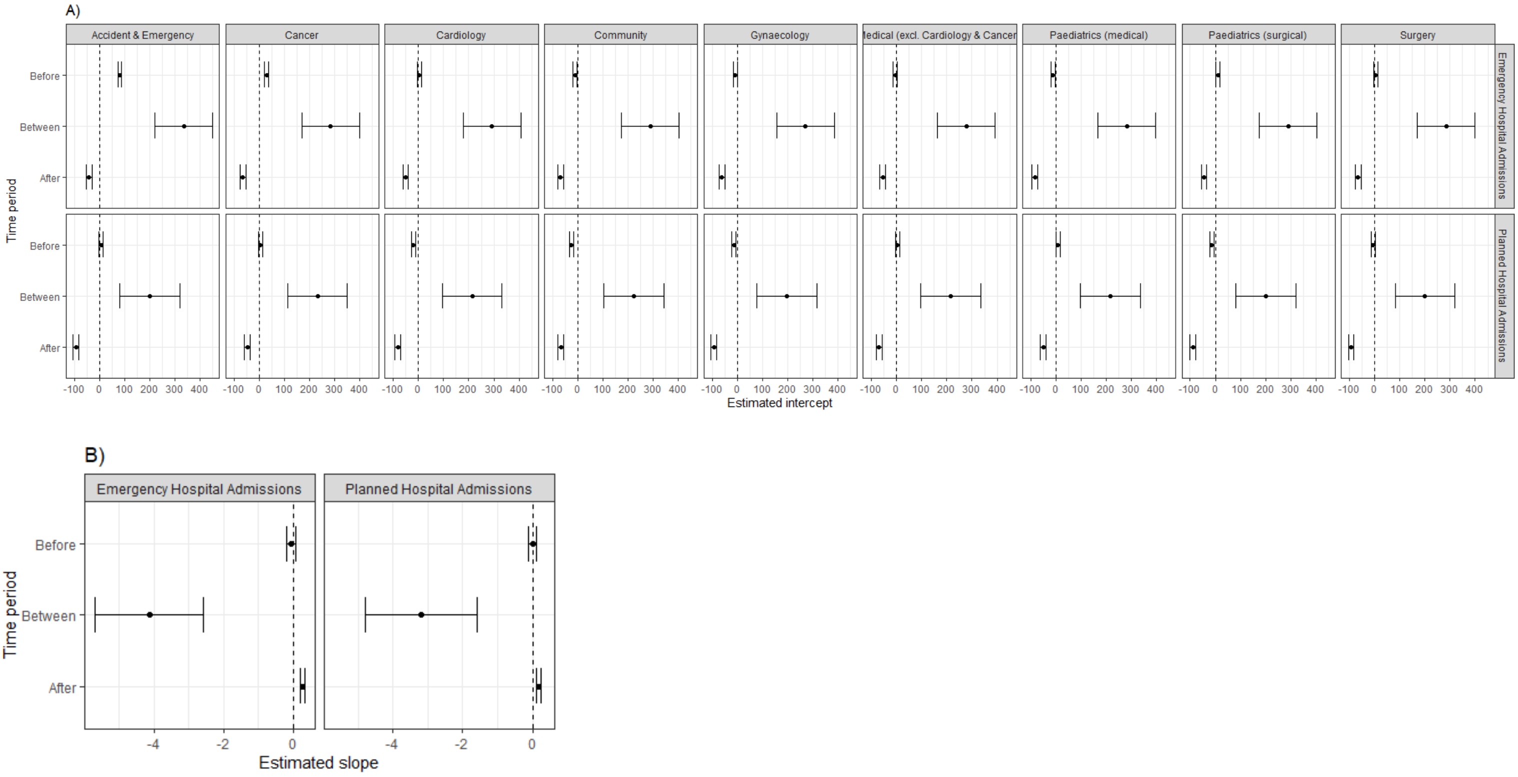


Figure 1. Estimated intercepts (A) and slopes (B) for speciality model for A&E attendances and hospital admissions
Points represent estimated intercepts (A) and estimated slopes (B) for the fitted model of the baseline model (the number of days since 05 January and the two change-points) and an interaction between speciality and change-points. Lines represent 95% confidence intervals.

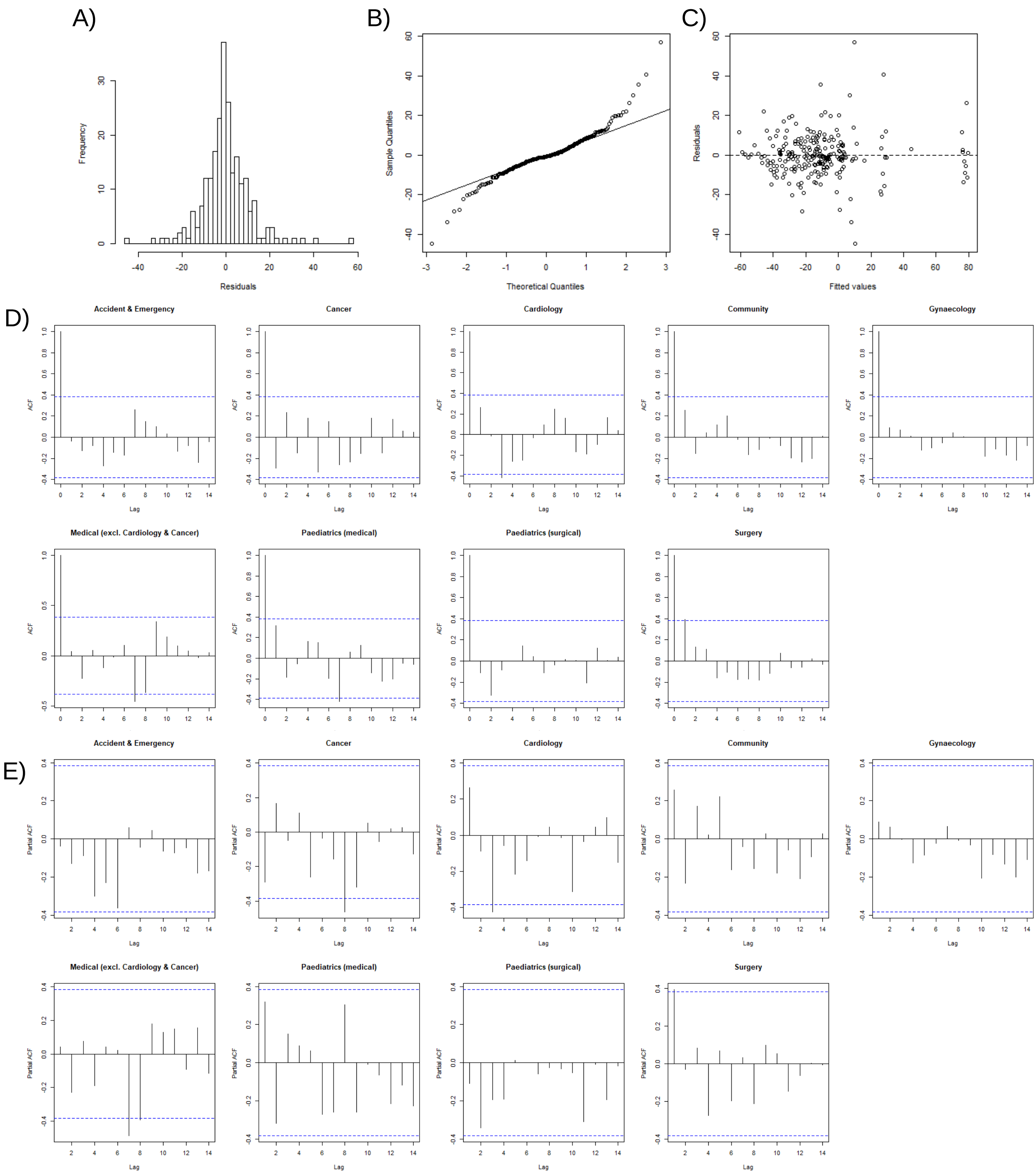


Figure 2. Speciality model diagnostics for emergency hospital admissions
Fitted model of the baseline model (the number of days since 05 January and the two change-points) and an interaction between speciality and change-points for emergency hospital admissions. Contains A) histogram of residuals, B) QQ Plot of residuals, C) residuals vs fitted values plot, D) ACF of residuals for speciality and E) PACF of residuals for speciality.

Moderate to strong evidence that normality can be safely assumed with the bell-shaped pattern in A) and the linearity in B) with fanning of the ends. Residuals are scattered above and below mean zero line, with slight skewing due to the large drop in the fitted values C). No temporal autocorrelation is detected since both D) and E) are mostly within the blue dashed line of the 95% confidence intervals.

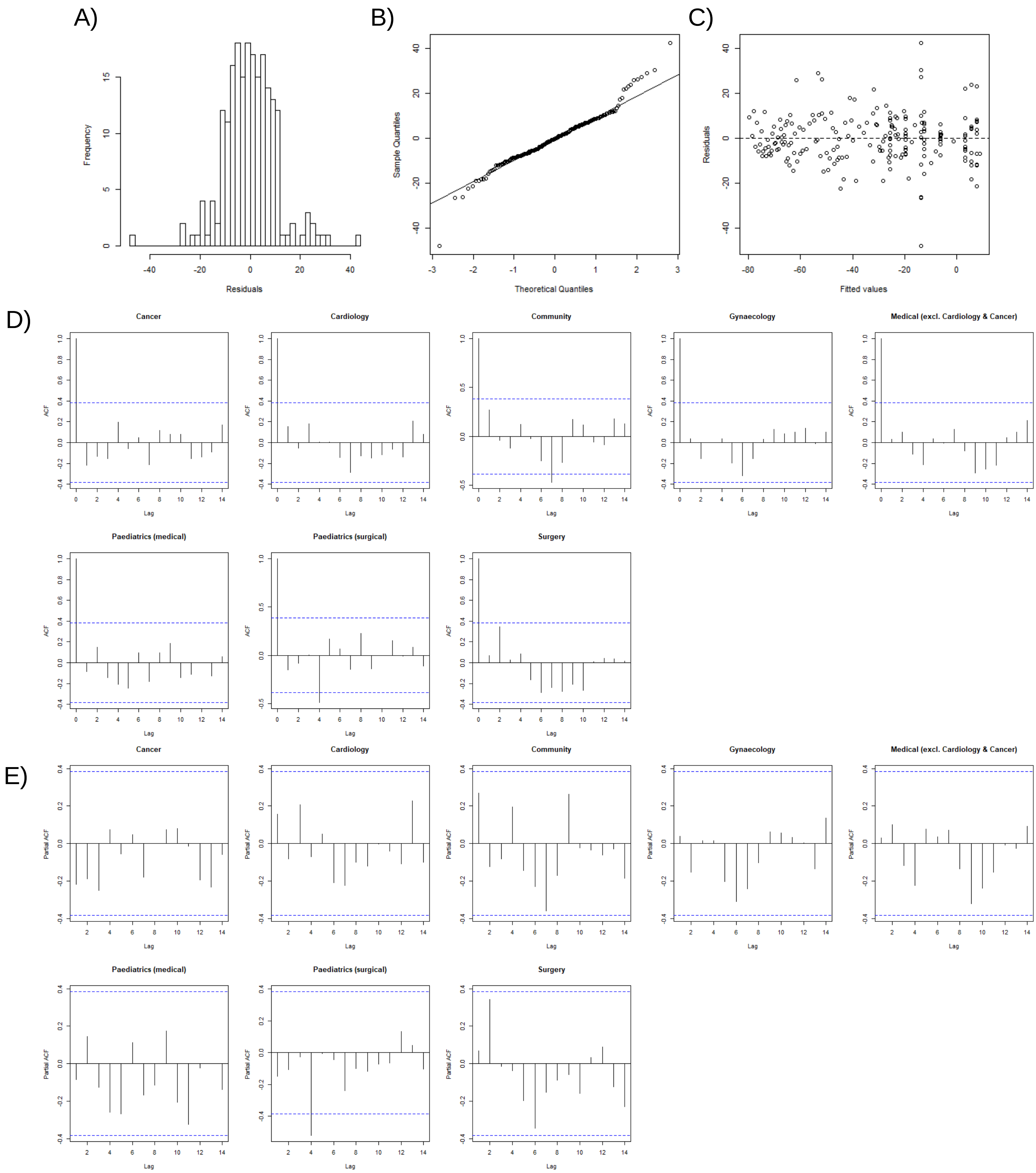


Figure 3. Speciality model diagnostics for planned hospital admissions
Fitted model of the baseline model (the number of days since 05 January and the two change-points) and an interaction between speciality and change-points for planned hospital admissions. Contains A) histogram of residuals, B) QQ Plot of residuals, C) residuals vs fitted values plot, D) ACF of residuals for speciality and E) PACF of residuals for speciality.

Strong evidence that normality can be safely assumed with the bell-shaped pattern in A) and the linearity in B). Residuals are scattered above and below mean zero line, with slight skewing due to the large drop in the fitted values C). No temporal autocorrelation is detected since both D) and E) are mostly within the blue dashed line of the 95% confidence intervals.

S9 Appendix: Supplementary information on interaction with NHS Health Board

Detailed description

The percentage changes across NHS Health Boards for all outcomes were fairly similar to the overall Scotland changes. This was particularly evident in A&E attendances, where all trends were similar to the 2018-2019 baseline before the 1st change-point, followed by a drop until the 2nd change-point and then followed by a steady incline back to recovery (Figure 6A, S3 Appendix). This consistency is seen in the map of the differences in the mean percentage changes before and after the change-points (Figure. 5A). Using regression to test whether there were differences between NHS Health Boards in A&E attendances, showed that there existed a difference in the slopes between NHS Health Boards (Model 2, S1 Appendix). Plots of the fitted model showed all Health Boards began to increase after the latter change-point at very similar rates with NHS Western Isles having a slightly flatter trend (Figure 1A, S9 Appendix). It also highlighted areas such as NHS Lanarkshire being back at the baseline at the end of the study.

Similar results were shown for emergency hospital admissions, where the trends after lockdown began to increase closer to the 2018-2019 baseline (Figure 6B, S3 Appendix). The smaller Health Boards should be interpreted with caution with high variability due to small numbers; this includes NHS Orkney, NHS Shetland and NHS Western Isles (Figure 6B, S3 Appendix). Spatially visualising the differences shows no major clustering occurring, with the East to South East coast having the biggest decreases (Figure. 5B). A similar model to the A&E attendance outcome was fitted for emergency hospital admissions (Model 2, S1 Appendix), which showed that there was a substantial recovery after lockdown across all NHS Health Boards (S8 Appendix – Figure 1B). Most areas were very close to the baseline at the end of the study, particularly NHS Grampian (Figure 1B, S9 Appendix).

For planned hospital admissions the remaining boards that had all weekly counts >5, displayed fairly consistent trends again, where not many areas saw an increase in planned admissions after the last change-point (Figure 6C, S3 Appendix). The map of these differences show little spatial correlation, with more rural areas such as NHS Borders and NHS Tayside showing larger decreases (Figure. 5C), although noting the unique temporal trend of NHS Tayside (Figure 6C, S3 Appendix). When modelling the differentiating affect across Health Boards for planned hospital admissions, a three-way interaction was proven to be important to the outcome. This captured more variability in the slopes before the 1st change-point, where most were showing increasing trends and others such as NHS Highland and NHS Tayside beginning to show decreasing trends (Figure 1C, S9 Appendix). The drops between these change-points did not seem substantially different from the slopes before and after for areas such as NHS Highland and NHS Lanarkshire. All slopes after the last change-point were very flat, with NHS Ayrshire and Arran and NHS Fife showing no evidence of a return to the baseline (Figure 1C, S9 Appendix).

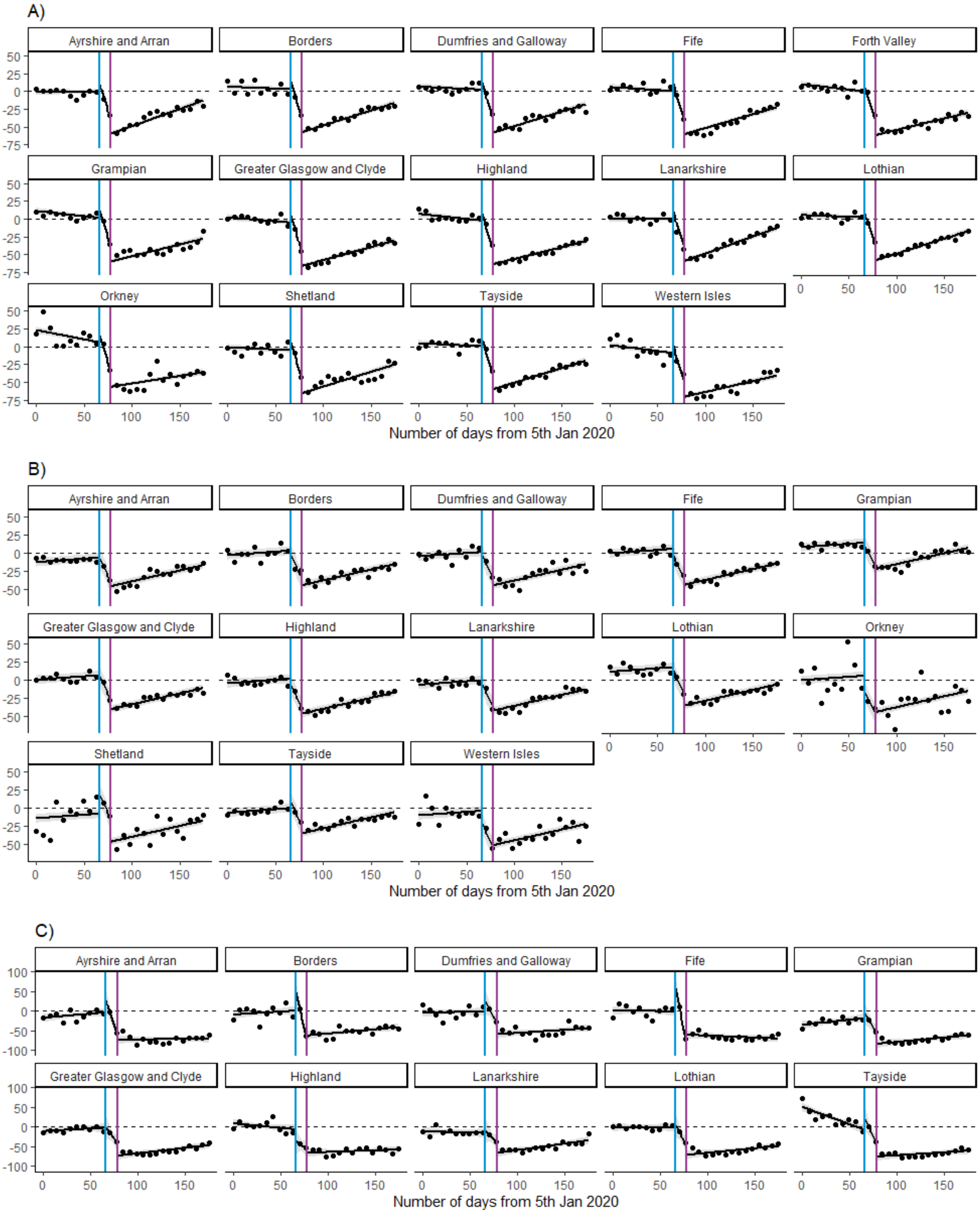


Figure 1. Fitted lines of NHS Health Board model for A&E attendances and hospital admissions

Lines for A&E attendances (A) and emergency hospital admissions (B) represent fitted model of the baseline model (the number of days since 05 January and the two change-points) and an interaction between NHS Health Board and the number of days since 05 January. Lines for planned hospital admissions (C) represent fitted model of the three-way interaction between the baseline model and NHS Health Board. Shaded areas around lines represent 95% confidence intervals. Points represent weekly percentage changes between 2020 and 2018-2019 average for emergency and planned hospital admissions for weeks ending 05 Jan to 28 Jun 2020. Includes change-point 1 (WHO announcing pandemic on 11 March) and change-point 2 (UK lockdown on 23 March).

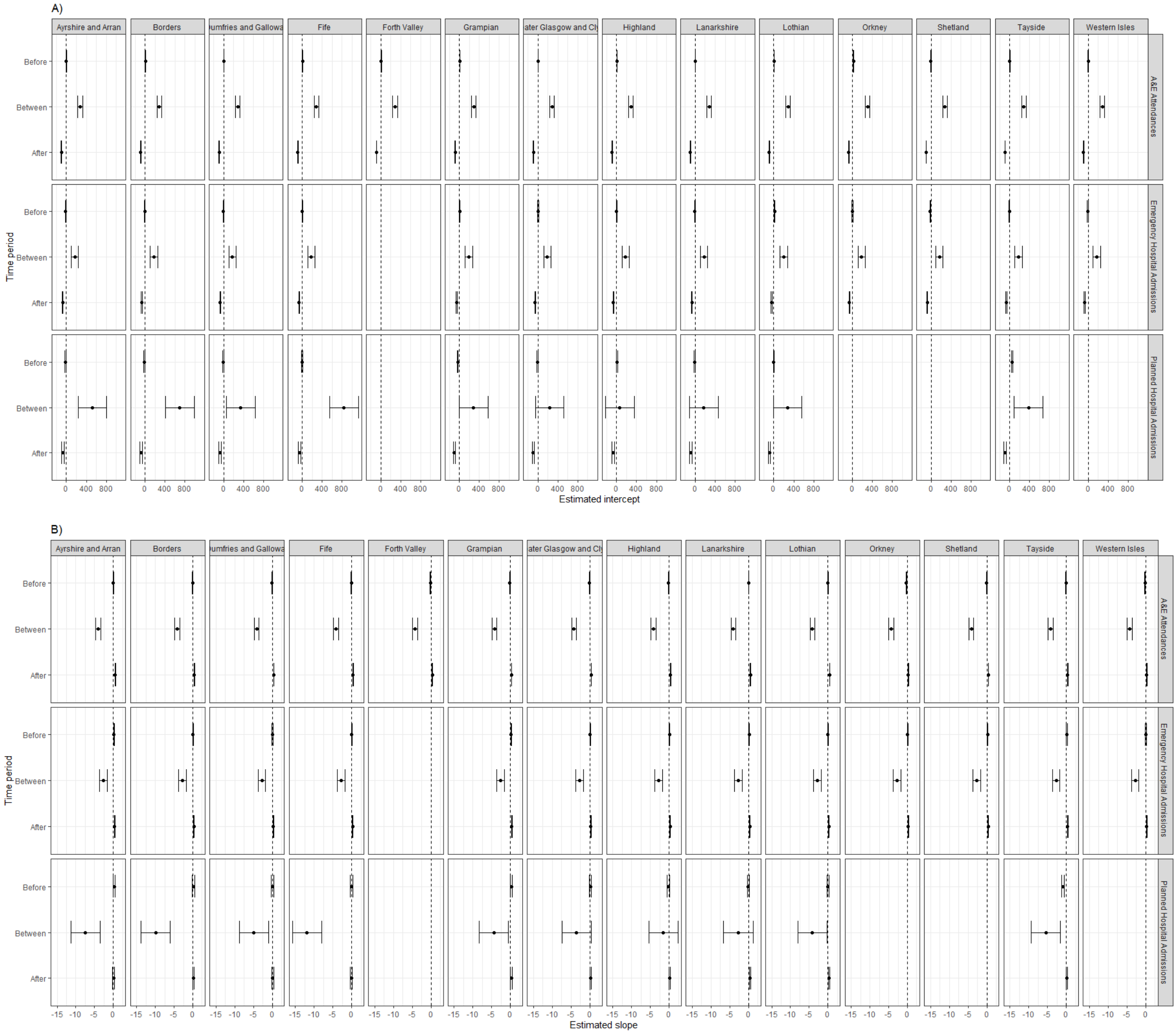


Figure 2. Estimated intercepts (A) and slopes (B) for NHS Health Board model for A&E attendances and hospital admissions

Points represent estimated intercepts (A) and estimated slopes (B) for A&E attendances and emergency hospital admissions fitted model of the baseline model (the number of days since 05 January and the two change-points) and an interaction between NHS Health Board and the number of days since 05 January. Points represent estimated intercepts (A) and estimated slopes (B) for planned hospital admissions represent fitted model of the three-way interaction between the baseline model and NHS Health Board. Lines represent 95% confidence intervals.

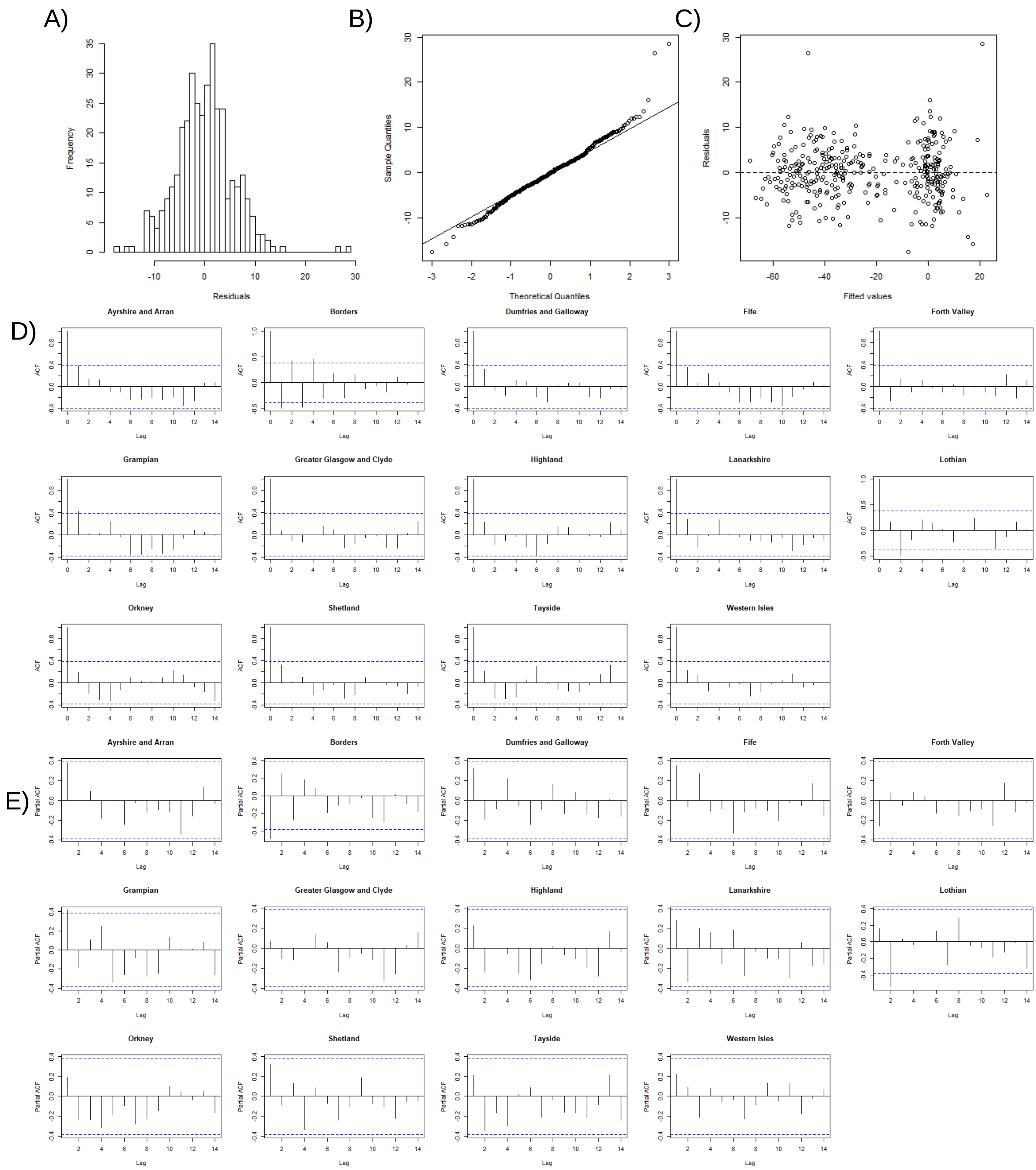


Figure 3. NHS Health Board model diagnostics for A&E Attendances
Fitted model of baseline model (the number of days since 05 January and the two change-points) and an interaction between NHS Health Board and the number of days since 05 January for A&E attendances. Contains A) histogram of residuals, B) QQ Plot of residuals, C) residuals vs fitted values plot, D) ACF of residuals for health boards and E) PACF of residuals for health boards.

Strong evidence that normality can be safely assumed with the bell-shaped pattern in A) and the linearity in B). Residuals are scattered above and below mean zero line, with slight skewing due to the large drop in the fitted values C). No temporal autocorrelation is detected since both D) and E) are mostly within the blue dashed line of the 95% confidence intervals.

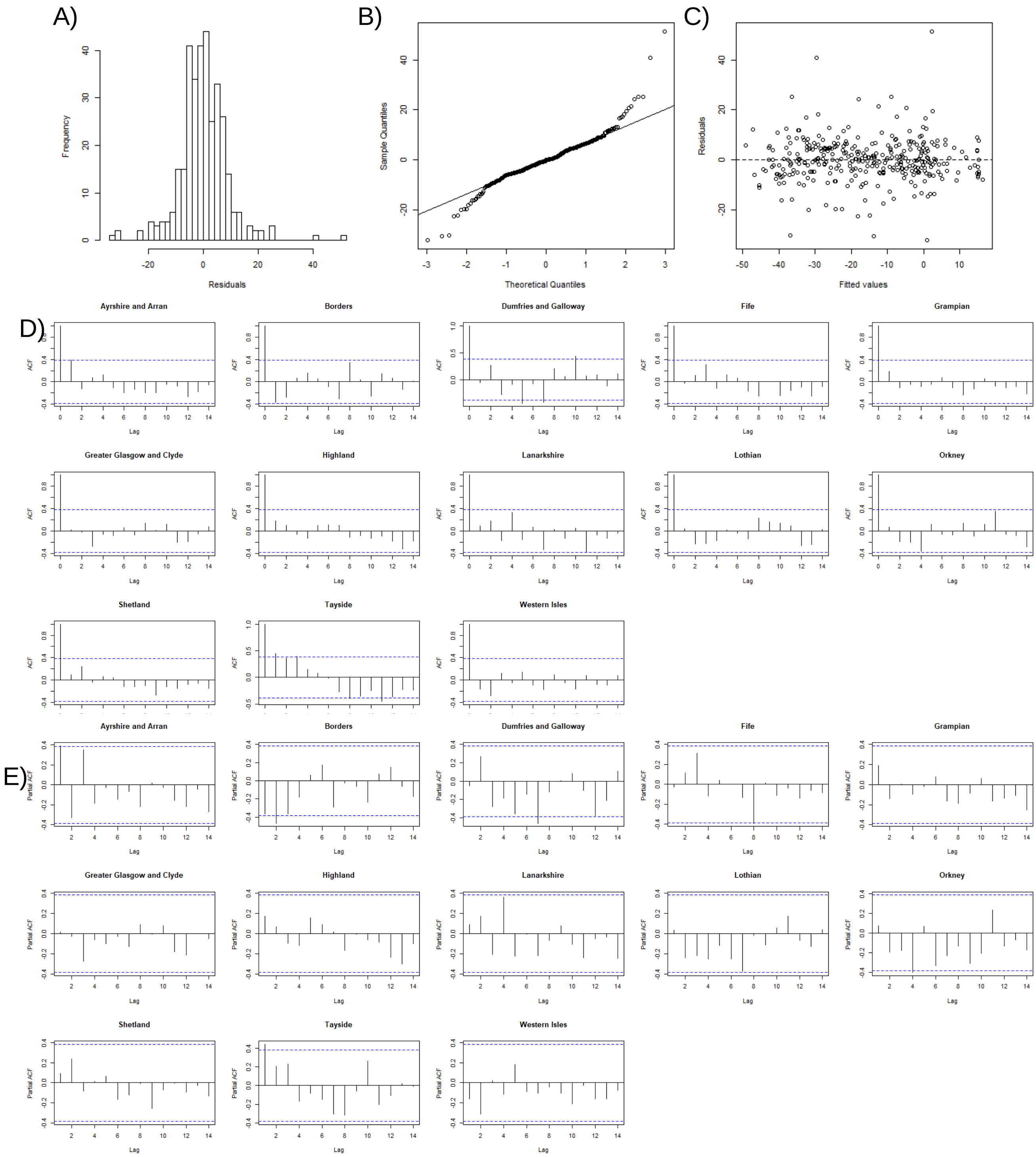


Figure 4. NHS Health Board model diagnostics for emergency hospital admissions
Fitted model of baseline model (the number of days since 05 January and the two change-points) and an interaction between NHS Health Board and the number of days since 05 January for emergency hospital admissions. Contains A) histogram of residuals, B) QQ Plot of residuals, C) residuals vs fitted values plot, D) ACF of residuals for health boards and E) PACF of residuals for health boards.

Strong evidence that normality can be safely assumed with the bell-shaped pattern in A) and the linearity in B) with fanning in the tails. Residuals are scattered above and below mean zero line C). No temporal autocorrelation is detected since both D) and E) are mostly within the blue dashed line of the 95% confidence intervals.

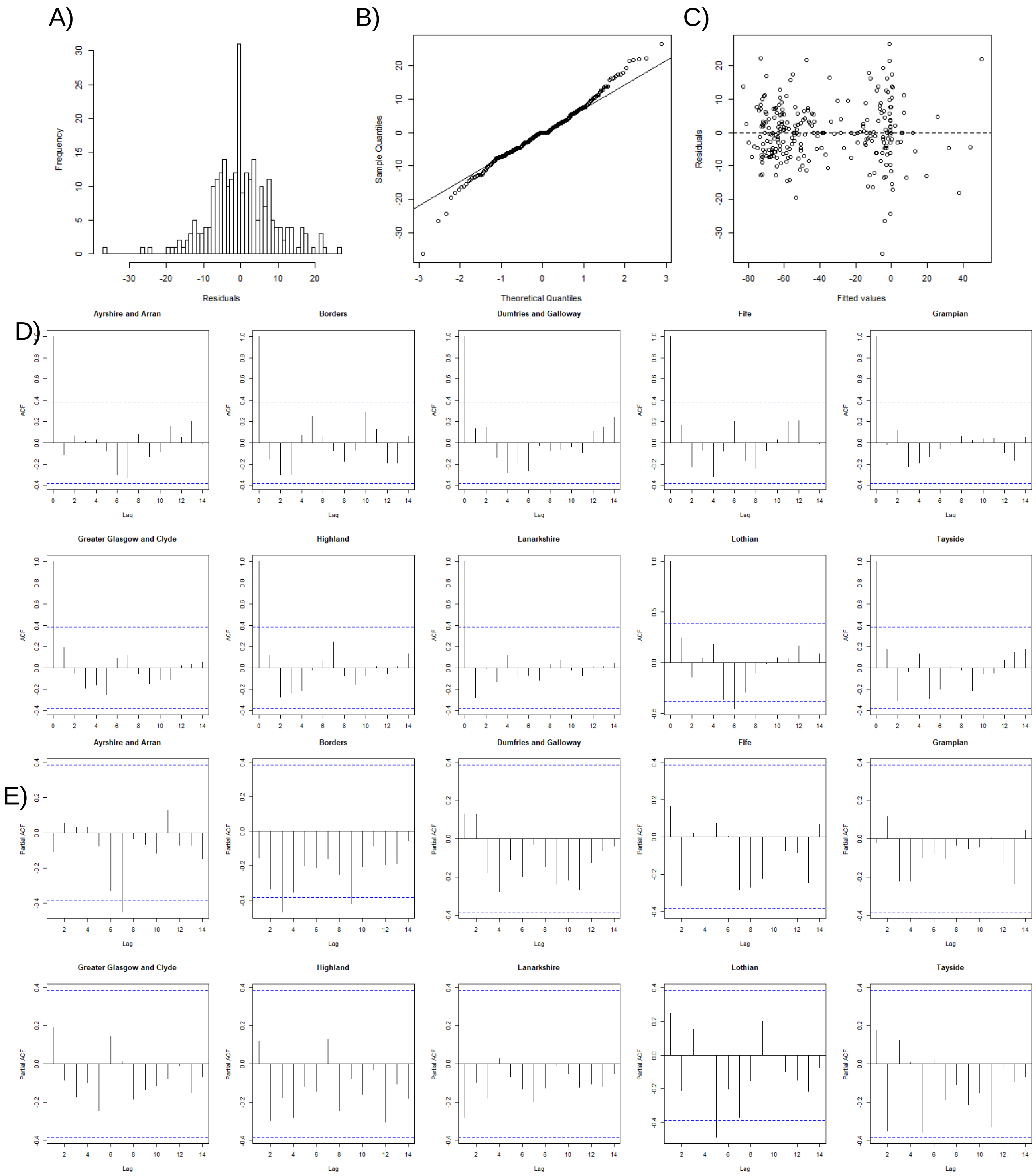


Figure 5. NHS Health Board model diagnostics for planned hospital admissions
Fitted model of the three-way interaction between the baseline model and NHS Health Board for planned hospital admissions. Contains A) histogram of residuals, B) QQ Plot of residuals, C) residuals vs fitted values plot, D) ACF of residuals for health boards and E) PACF of residuals for health boards.

Strong evidence that normality can be safely assumed with the bell-shaped pattern in A) and the linearity in B) with slight fanning of the tails. Residuals are scattered above and below mean zero line, with slight skewing due to the large drop in the fitted values C). No temporal autocorrelation is detected since both D) and E) are mostly within the blue dashed line of the 95% confidence intervals.