

Excess Mortality during the COVID-19 pandemic:

A Case Study of Oxfordshire



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Candidate's Contributions to the Study

As a student in the Master's in International health and Tropical Medicine programme, I was given the opportunity to pivot my original research plans to address the COVID-19 pandemic. Working closely with my placement advisors, I developed a new research proposal with their approval that was achievable within the shortened timeframe. In-person activities were unfortunately limited due to the ongoing COVID-19 pandemic and I was restricted to remote communications only. I spent the first month of the placement familiarising myself with statistical methods and the literature around excess mortality and engaged with various stakeholders at Oxford University Hospitals Trust and Public Health Oxfordshire, getting an idea of their experiences to identify possible research gaps and inform my data collection process. I had the opportunity to attend an online mortality statistics workshop held by the Royal Statistical Society which provided me with great insight into the current challenges in reporting and collecting mortality statistics during the pandemic.

I received support from Bruno Holthof as my placement supervisor and Proochista Ariana and Prabin Dahal as my academic advisors throughout the process. My drafts were reviewed by them as well as by Adrian Hill as my IHTM academic advisor. Prabin Dahal provided ongoing support on the data management, statistical methods and analysis.

I certify that this thesis is my own original work and all tables, figures and images are my own work, except when otherwise referenced.

Acknowledgements

I thank my placement supervisor, Bruno Holthof for providing me with the opportunity to undertake this research, allowing me to build on his original ideas and his encouragement and support throughout the project. Special thanks to Proochista Ariana for her assistance every step of the way in refining my research outputs and creating the opportunity for me to pursue this within the IHTM programme in the first place. I also thank Prabin Dahal for his patience and teaching of statistical methods throughout the

year and in helping me with the statistical analysis. Lastly, I would like to thank my IHTM student family for their collective support during an extremely uncertain time and to my husband and parents for their patience and encouragement in getting me to this point.

I also thank Meghana Pandit from Oxford University Hospitals NHS Foundation Trust for her useful insights on the trust mortality data and Alex Clift from the Information and Governance team in helping me obtain access to inpatient data.

Research Ethics Approval

Research ethics approval was not required for this project as all data used was publicly available and/or aggregated and de-identified.

Abstract

Background:

Determination of excess mortality provides a useful measure of demonstrating the true toll of the COVID-19 pandemic by capturing both the direct and indirect causes of death. This study estimates the weekly trend in excess mortality over the first 28 weeks of 2020 in Oxfordshire and its five districts, ascertaining the contribution of COVID-19 to the observed excess mortality. This is further complemented by a review of local hospital utilisation and mortality data to understand the collateral damage of the pandemic.

Methods:

Weekly excess mortality was calculated using death registration data from the Office for National Statistics together with historical death registration data from 2015-2019. Mortality and A&E attendance and admission data for Oxford University Hospitals Trust was used to calculate monthly excess inpatient mortality and A&E attendance trends from January to June 2020.

Results:

In Oxfordshire, 642 excess deaths were registered during weeks 12-23 (the peak pandemic period), with 82% attributed to suspected or confirmed COVID-19. Vale of White Horse experienced the highest excess mortality of all districts. Care homes accounted for the largest proportion (62%) of excess deaths during the peak pandemic period, providing evidence of a neglected social care sector. The trend in weekly COVID-19 deaths were closely related to the peaks in excess mortality seen across all districts. A&E attendance for the peak pandemic months were below five-year averages and there was an increase in hospital excess mortality during the same time period.

Conclusion:

This study provides early evidence for the impact of COVID-19 on excess mortality at the county and district level in Oxfordshire, identifying the worst hit areas and indicating the disproportionate effect of the pandemic on care homes. Moreover, hospital data contributes towards the growing research on the negative effects of decreased NHS capacity during the pandemic on non-COVID-19 deaths. Further research is required to evaluate the effects on different age groups and enhance understanding of the influence of other demographic factors on excess mortality.

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ABBREVIATIONS AND ACRONYMS

ACS – Acute Coronary Syndromes

A&E – Accident and Emergency Department

CDC - Centers for Disease Control and Prevention

EuroMOMO – European Monitoring of Excess Mortality for Public Health Action

ICD-10 – International Classification of Diseases, 10th revision

LRTI – Lower Respiratory Tract Infection

NCHS – National Centre for Health Statistics

NHS – National Health Service

ONS – Office for National Statistics

OUH – Oxford University Hospitals NHS Foundation Trust

PHE – Public Health England

YLL – Years of Life Lost

Chapter 1
Introduction

The SARS-COV2 coronavirus(COVID-19) outbreak was declared a Public Health Emergency of International Concern by the World Health Organisation on 30 January 2020.(1) As of 08 August 2020, there have been 19,357,085 cases of COVID-19 reported, and 721,174 deaths worldwide.(2) The first COVID-19 cases in the UK were discovered in York, England on 29 January 2020 and the first strict lockdown measures instated from 23 March 2020.(3) Compared to previous pandemics, where metrics involving numbers of infections or case fatality rates took precedence, there has been increased emphasis on tracking the number of daily COVID-19 deaths and total cumulative deaths attributed to COVID-19 to monitor public health impact and guide policy decisions.(4) Although these metrics are easily available, they can lead to misinterpretation and incorrect deductions as they do not reflect the full impact of the pandemic.

Excess mortality represents the all-cause mortality above that which would have occurred under normal conditions which may be attributable to the pandemic/crisis.(5) The excess mortality approach has been utilised in assessing an increase in the rates of death in a large variety of contexts to date: during humanitarian emergencies(5), due to epidemic pathogens such as chikungunya(6) and HIV(7), seasonal influenza(8), natural phenomena such as heat waves(9) and hurricanes (10) and due to health conditions such as mental illness(11) and cancer(12).

The utility of excess mortality as a form of rapid mortality surveillance has risen to prominence during the COVID-19 pandemic. This is because excess mortality data presents the full picture of all-cause deaths, capturing both the ‘direct’ and ‘indirect’ deaths due to COVID-19 over and above what would have been expected in pre-pandemic conditions.(13,14) In their letter to the Lancet calling for more data on excess mortality, Leon et al (15) argue that weekly excess deaths are the most ‘objective and comparable’ way of demonstrating the impact of the pandemic and the effectiveness of strategies used to control the pandemic. Academics have therefore called on national statistical

agencies to publish and streamline excess deaths data in order to facilitate regional comparisons.(15,16)

How is Excess Mortality determined?

The number of excess deaths are calculated by the difference between observed number of deaths in the given 'crisis/pandemic' time period and the number of deaths that would have otherwise been expected in normal conditions.(13) There is no agreed-upon method for calculating the baseline of expected deaths.(17)

Excess Mortality methods are evolving with seemingly little standardisation in their calculation. Excess mortality methods were first used by Wade Hampton Frost following the 1918 pandemic influenza epidemic in the United States in order to demonstrate its true national impact, and is still used by the United States Centers for Disease Control and Prevention (CDC) today in calculating excess deaths due to COVID-19.(18,19) Further refinement of the measure was made by Dr Selwyn D Collins in the United States in the first half of the 19th century in his work on a sequence of pneumonia and influenza outbreaks and their attributable excess mortality.(18) Dr Robert E Serfling expanded the field in 1963 by developing periodic regression time-series models to project expected excess pneumonia-influenza mortality.(20) During the current COVID-19 pandemic, excess mortality measures have been used to demonstrate excess deaths compared to retrospective averages and in forecasting excess deaths based on different scenarios and using time-series regressions or Bayesian models to predict 'expected' deaths.(16,21–25) The focus of this dissertation will be on the use of excess mortality based on retrospective averages.

Current Methodologies for calculating excess mortality

To date there are no universally-accepted criteria for methods in calculating excess mortality, making geographical comparability difficult.(26) In calculating expected baseline deaths, the CDC, The New York Times and the European Monitoring of Excess Mortality for Public Health Action

(EuroMOMO) use a time-series Poisson-distributed trend.(27–29) This adjusts for previous year's deaths and demographic changes (Farrington surveillance algorithm), accounts for seasonal variation (such as deaths due to winter influenza and summer heatwaves) and in certain cases accounts for delays in death registration.(23,29) Table 1.1 summarises the different measures of excess mortality and the agencies which utilise these. As this research will be focused on drawing comparisons across districts, the advantages and disadvantages of using these methods are included. A disadvantage across all metrics is the dependency on accurate, timely death registration data, which may not always be feasible in pandemic situations.(16) In the case of this data not being available in low-resourced contexts, data on burials have also been used.(30) Interestingly, some of the first publications to represent excess deaths due to the COVID-19 pandemic were non-academic media publications.(27,31)

Muellbauer and Aron (16,26,32) have written extensively on the utility of excess mortality measures during the pandemic, comparing methodologies and highlighting further work required by national statistical agencies in order to make international comparisons. They propose use of a P-Score, which represents the percentage deviation of excess deaths above what was expected.(16) The Health Foundation agrees with this measure and its utility, although not explicitly naming it a P-Score.(33) The P-Score bears similarity to the methodologies used to calculate the Excess Winter Mortality Index, used by both the WHO Europe Regional Office and the UK Office for National Statistics (ONS) in comparing excess mortality during winter across regions.(34)

Table 1.1: Synthesis of the Methodologies and Sources Representing Excess Mortality and their Utility in Making Regional Comparisons

Observed number of deaths for time period = O Expected number of deaths for time period= E CI – Confidence Interval

Outcome metric	Methods	Sources using this measure	Advantages	Disadvantages
Raw number of excess deaths	O-E	The Financial Times The Economist The Guardian WHO The Health Foundation The New York Times	Easy to calculate using available data	Regional comparability is dependent on differences between underlying population structure
Excess deaths per capita ***Measures the increase in the absolute risk of dying across the population***	$\frac{O}{\text{population size}} - \frac{E}{population\ size}$ I.e. observed crude death rate - baseline expected crude death rate	WHO in humanitarian crises BBC The Health Foundation	Useful for rapid assessment in humanitarian settings to: • Quantify the public health impact • Assess ongoing physical health status of affected population • Tailor humanitarian response by forecasting expected excess deaths Can be age and sex-standardised to account for regional population variation	Without age-standardisation, predominance of certain age groups may mask the true extent of deaths – for example, those regions with older populations may have higher per capita excess mortality than those with younger populations
P-Score (%) ***Excess deaths as a proportion of expected or usual deaths, expressed as a percentage***	$\frac{\text{O} - \text{E}}{\text{E}}\ x\ 100$ E.g. P-Score of 0 indicates no excess deaths	Institute for New Economic Thinking/ Our World in Data. University of Oxford The Health Foundation The Financial Times The New York Times Excess Winter Mortality Index used by the WHO Europe, ONS, National Records of Scotland and Northern Ireland Statistical agency	When cumulated over the peak period weeks of a pandemic can provide a useful summary of its impact for comparison Relatively accurate in making regional comparisons, even when there are differing population age structures Can be age and sex-standardised to account for regional population variation	As above, if not age-standardised, accuracy may be compromised if mortality is concentrated in different age groups compared to baseline, although the least so of all the listed methods
Variant P-Score	$\frac{\text{O} - \ upper\ 95\%\ CI\ limit\ of\ E}{upper\ 95\%\ CI\ limit\ \text{of E}}$	United States Centers for Disease Control and Prevention (CDC) through the National Centre for Health Statistics (NCHS)	Accommodates uncertainty in the natural variation around expected deaths, producing a range of values for expected deaths	NCHS is one of the only national agencies which produces granular data sufficient for calculation of this metric at the within-country level
Z-score	$\frac{O - E}{\text{standard deviation of E}}$	EuroMOMO	EuroMOMO has produced weekly excess mortality scores for 24 countries in Europe from 2016 to present	Not as easily interpretable Z scores can lead to exaggeration of excess mortality if standard deviations are high due to low natural variability in mortality data (common in small population sizes) Requires granular data at the national level Poisson distribution to estimate expected deaths may be based on incorrect assumptions

Source: Authors own drawing on (16,29,30,33,35,36)

Advantages of using excess mortality metrics in assessing the impact of the pandemic in the United Kingdom

1. *Overcomes the limitations in under-reporting of COVID-19 deaths or misdiagnosis of COVID-19 on death certificates*

Accurate reporting of COVID-19 deaths are heavily dependent on testing infrastructure and regimes, how countries define and capture deaths in confirmed or suspected COVID-19 cases and the influence of location of death in the case of hospital-based, home-based and care-home deaths.(13,32) This renders the COVID-19 death count subject to underestimation, especially in the context of limited testing, errors made by the certifying medical professional and poor mortality surveillance systems.(37) There has been widespread criticism of countries undercounting their COVID-19 deaths, worsened by poor testing strategies.(38–40) For example, early COVID-19 deaths in the UK would have been undercounted due to hospitals being the only facilities to conduct testing.(41) Excess mortality measures are not affected by testing strategies or differences in the way in which deaths are reported or captured on death certificates as only all-cause mortality data is required for its computation.

In the United Kingdom, data on COVID-19 deaths is available from three different sources (Table 1.2).(34) The ONS provisional weekly death registrations data provides the most useful figures for calculation of excess mortality data in England. This data captures deaths from all places of death (including care homes and community), attributes deaths due to COVID-19 where there was any mention of COVID-19 on the death certificate (irrespective of a positive test) and is available within 11 days after the week ends.(34) The current average time-delay between death occurrence and death registration is five days, rendering the data for the latest week released by the ONS as highly provisional.(42) The ONS has been criticised by academics for not providing a timely comprehensive

breakdown of the underlying cause of death for death registration data, unlike other national statistical authorities such as Scotland.(43) The Department of Health and Social Care (DHSC) has been posited to overestimate deaths with its daily COVID-19 death counts as there has been no cut-off threshold between the number of days between testing positive and death.(44,45) This has resulted in an urgent review of its precision, halting publishing of the daily statistics from this source as of 17 July 2020. (45,46)

Table 1.2: Definitions of COVID-19 Deaths Between Different Sources and their Timeliness

Source	**Department of Health and Social Care COVID-19 deaths (as published on GOV.UK) *before* 29 April**	**Department of Health and Social Care COVID-19 deaths (as published on GOV.UK) *from* 29 April**	**ONS COVID-19 deaths registered**	**ONS COVID-19 death occurrence (actual date of death)**	**NHS England**
Inclusion	Deaths in hospitals	Includes any place of death, including care homes and community	Any place of death, including care homes and community	Any place of death, including care homes and community	Deaths in hospitals
	Deaths where patient has been tested for COVID-19	Deaths where patient has been tested for COVID-19	Deaths where COVID-19 has been mentioned on the death certificate	Deaths where COVID-19 has been mentioned on the death certificate	Deaths where patient has been tested for COVID-19
Timeliness	Provided daily but not officially registered	Provided daily but not officially registered	Weekly registrations are 11 days behind because of the time taken to register, process and publish	Weekly registrations are 11 days behind because of the time taken to register, process and publish	Updated daily for each date of death

Source: Office for National Statistics (34)

2. *Encompasses broader impact of COVID-19 on deaths by including indirect causes of death*

The pandemic has multisystem effects which can indirectly contribute to fluctuations in population mortality. These fluctuations may be attributed to a delay in treatment-seeking behaviour due to a patient's fear of contracting COVID-19 or fear of overwhelming already-stretched resources.(47,48) Data from NHS England regarding Accident and Emergency (A&E) utilisation supports this claim, showing a 57% reduction in A&E visits in April 2020 compared to April 2019 and the lowest monthly number since records began in 2010.(49) The social and economic consequences of lockdown

measures are likely to further impact on mortality rates due to reduced road traffic accidents, exacerbating mental illness and suicides and increased interpersonal and domestic violence.(50–52)

A directive from NHS England on 17 March 2020 ordered the postponement of all non-urgent elective operations for at least 3 months and urgent discharge of all medically fit patients with a view to potentially freeing up to 30,000 hospital beds in order to accommodate the expected surge in COVID-19 cases.(53) In addition, there was widespread closure of health facilities and postponement of cancer treatments and routine outpatient appointments.(21,40) Relating to this, in their British Medical Journal editorial, Alderwick et al (54) speculate that decisions by NHS leaders to postpone non-urgent elective operations, change to remote outpatient appointments and alter policy with regards to routine quality inspections, payments and commissioning systems, coupled with the government's general neglect of the social care system, will have unintended long-term effects on excess deaths. A preprint review of trends in excess cancer and cardiovascular deaths in Scotland (55) report a short-term increase in excess cancer and cardiovascular deaths in April, which the authors attribute to the indirect effects of COVID-19 lockdown and policy measures. While the above measures were necessary to expand pandemic capacity in the short-term, the resulting backlog is expected to manifest in increased excess deaths.

3. *A robust, understandable measure that can be used to inform policy decisions*

Professor David Peters (47), in his testimony to the UK Science and Technology Committee at the House of Commons, emphasised the usefulness of excess mortality data in demonstrating the impacts of social distancing measures, citing excess mortality data used during the 1918 influenza pandemic for the same purpose. Since excess mortality is calculated relative to the distribution of age, health-system structure and death certification standards of the same region or country, this allows for more valid comparisons to be made.(13) This is particularly useful for comparing the impact of policy responses on excess deaths among different regions or countries since demographical heterogeneity is somewhat accounted for. The speed by which this data can be used

by decision-makers is facilitated by the fact that all-cause mortality data in the UK is of a high-standard and not prone to the extensive registration delays experienced in registering COVID-19-specific deaths as seen in other countries.(34) Modelling of excess deaths for different 'worse-case' scenarios and varying levels of social distancing measures and Behavioural Social interventions during the COVID-19 pandemic have already been performed successfully by the UK Government to inform policy decisions.(21)

Research questions and objectives:

The aim of this study will be to determine the excess mortality in Oxfordshire and its districts during the COVID-19 pandemic and explore the factors that may explain the differences in excess deaths between these districts. This will be answered in the following sequence:

1. What is the excess mortality in Oxfordshire and its districts during the COVID-19 pandemic?

- Describe and critically analyse excess mortality for the 5 districts in Oxfordshire using weekly deaths from January to June 2020, employing the P-Score, raw count and per capita methodologies
    - Provide a breakdown of excess deaths in Oxfordshire from January to June 2020 by place of death
    - Assess the contribution of COVID-19 to all-cause deaths and evaluate the role of non-COVID-19 deaths

2. What are the healthcare-related factors that may explain the excess mortality observed in Oxfordshire due to COVID-19 and other causes?

- Assess the impact on hospital utilisation and hospital mortality during the COVID-19 pandemic at Oxford University Hospitals NHS Foundation Trust

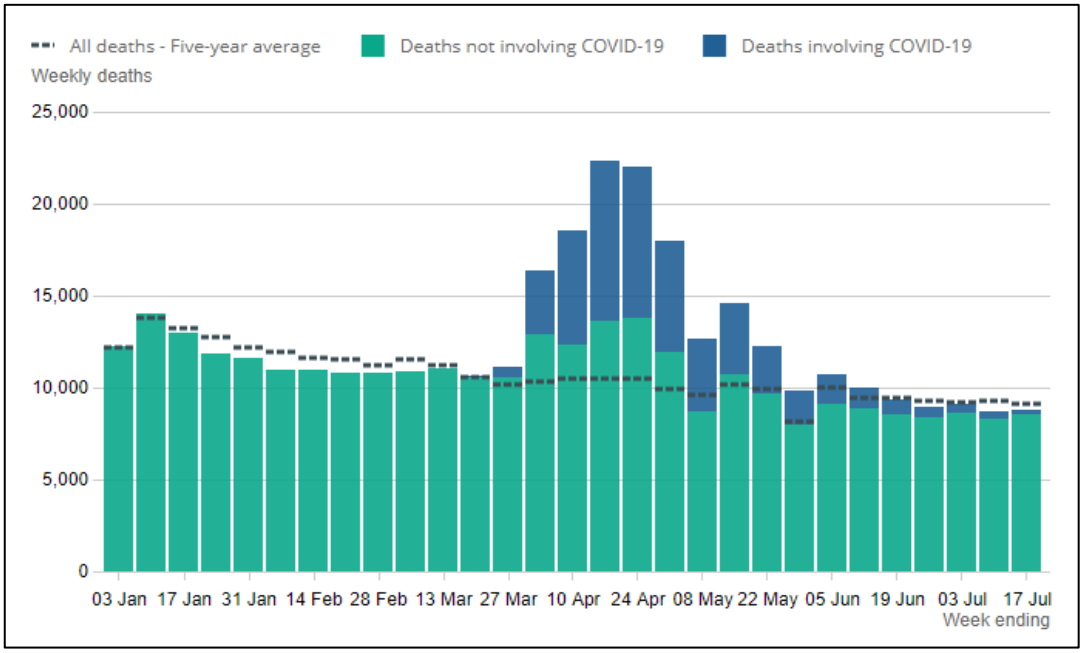
As there is currently no standardisation of methods in calculating excess mortality or an academic analysis of excess mortality at the local authority level in England during the COVID-19 pandemic, this research will add to the body of evidence.

Study Setting

England and the impact of the COVID-19 pandemic

A recent ONS analysis of excess mortality among 21 European countries for the first half of 2020 names England as having the longest continuous period of excess mortality in Europe and the highest number of excess deaths by the end of May.(56) Death registration data from the ONS from 01 January 2020 to 17 July 2020 indicates a total number of 340,267 deaths for England, of which 51,454 (17,8%) are in excess of the five-year average (Figure 1.1).(57) COVID-19 (mentioned anywhere on the death certificate) accounted for 48,692 deaths, which is 14.3% of the total deaths and 95% of the excess deaths.(57) The period of excess mortality in England and Wales can be seen to start from week 13 (week ending 27 March) until week 25 (week ending 19 June).

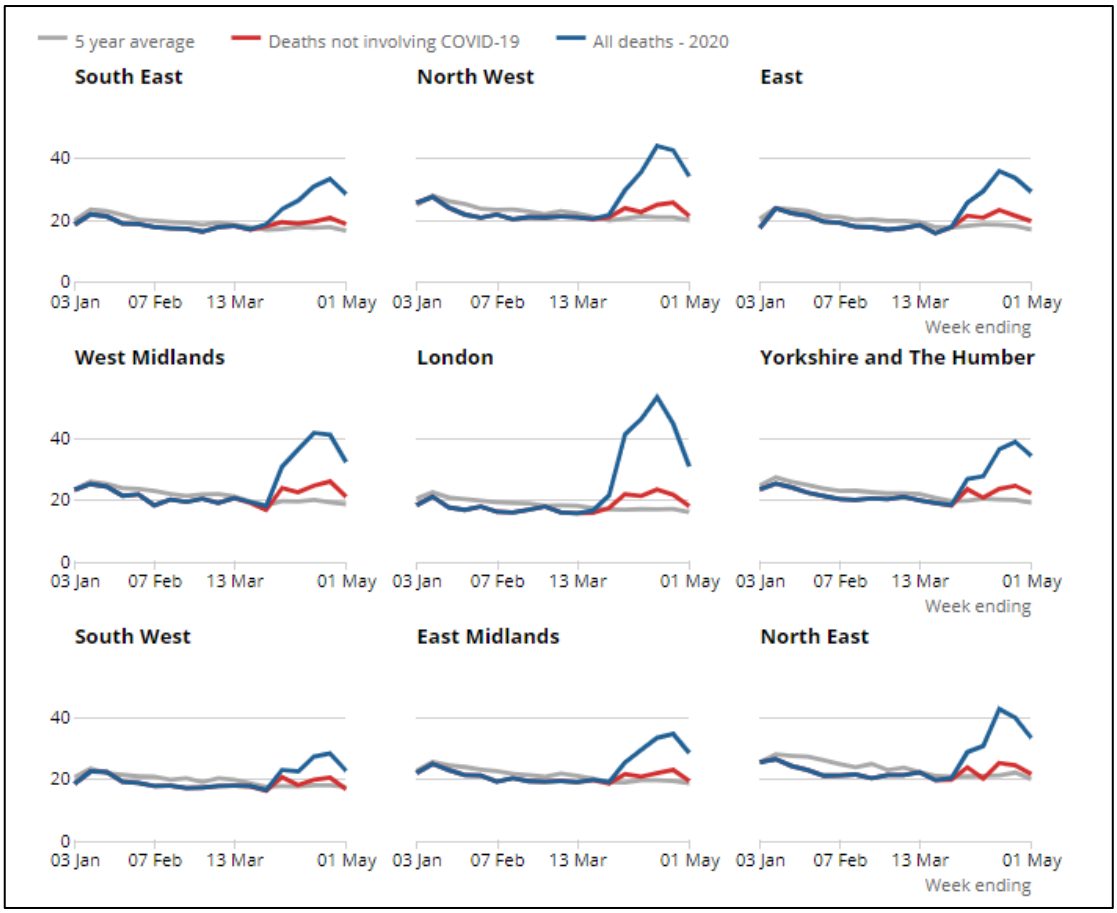
Figure 1.1: Number of Deaths Registered by Week, England and Wales, 28 December 2019 to 17 July 2020



Source: Office for National Statistics Weekly Deaths Bulletin (57)

According to Figure 1.2 from the ONS, all regions across England display a general increase in excess deaths from week 11.(42) London can be seen to have the highest mortality rate for all deaths and excess deaths from week 11. Both London and the West Midlands have the largest differences between all deaths and non-COVID-19 mortality rates, which, according to the ONS, may be attributed to these regions having the largest proportion of Black and Minority Ethnic (BAME) populations.(42) In addition to this, London's high population density and interconnected public transportation are also hypothesised to be contributing factors.(32)

Figure 1.2: Age-Standardised Non-COVID-19 and All-Cause Weekly Mortality Rates and Five-Year Average Mortality Rates for Regions in England and Wales for Weeks 1 to 18 in 2020



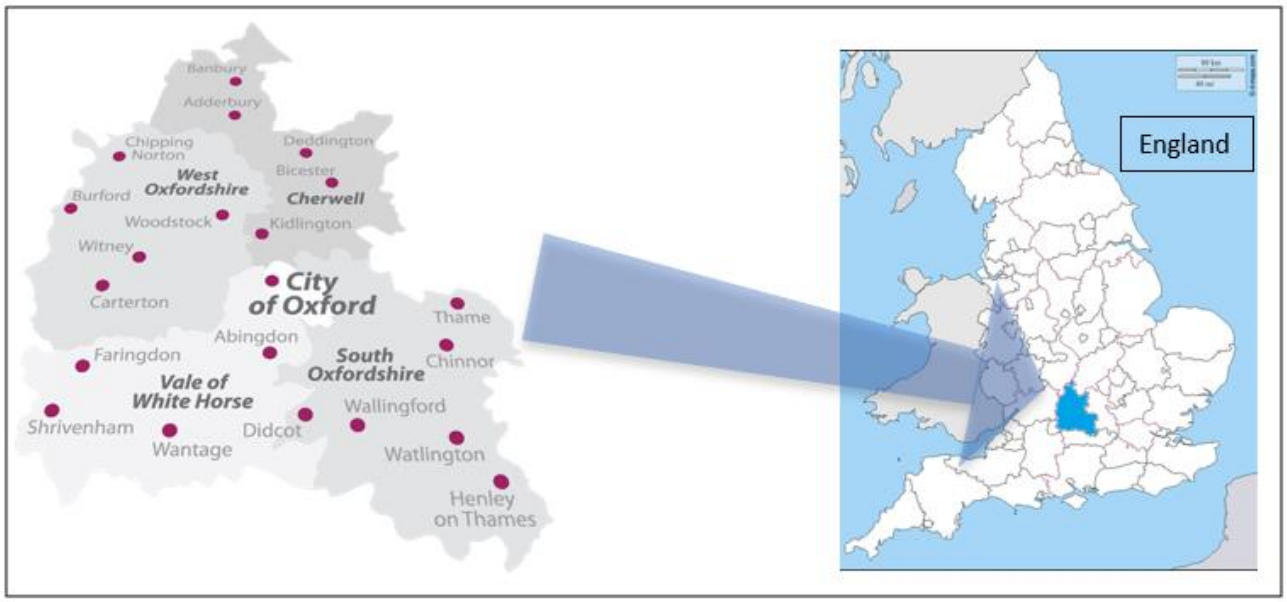
Source: Office for National Statistics-Analysis of Death Registrations not involving COVID-19(42)

Oxfordshire

Oxfordshire, one of the 48 counties in England, is an administrative and historic county located in the South East region.(58) The administrative county is composed of five districts: Cherwell, the City of Oxford (the administrative county capital), South Oxfordshire, Vale of White Horse and West

Oxfordshire (Figure 1.3).(58) In terms of healthcare provision, Oxford University Hospitals Foundation Trust is the largest provider of acute health care services in Oxfordshire, having provided 1.4 million patient contacts during 2018/2019 alone.(59,60)

Figure 1.3: Map of Oxfordshire



Source: Oxford City Guide and D-maps (61,62)

CHAPTER 2
METHODOLOGY

Study Design

This research is based on an applied demographic spatiotemporal analysis of weekly death registration data obtained from the Office for National Statistics for the first 28 weeks of 2020 (week ending 3 January to week ending 10 July 2020) for the 5 districts in Oxfordshire and monthly hospital mortality and attendance for a similar period from Oxford University Hospitals NHS Foundation Trust.

Data collection

Death registration data and population estimates

All death registration data was obtained from the Office for National Statistics (ONS), the largest statistical body in the UK responsible for publishing statistics related to the economy, population and society and national census, adhering to the quality standards of the Code of Practice for Statistics.(63–65) Death registration data captured by the ONS are based on death certifications by medical practitioners or coroners and assigned to a district by the deceased's usual place of residence or place of death if the former is not available.(64) I obtained two datasets - one for 2020 and one for 2015-2019 - for weekly all-cause deaths broken down by place of death and district.(66,67) The 2020 dataset was based on the weekly provisional deaths release for deaths registered up until the week ending 10 July.(66) The ONS defines a week as running from a Saturday to the following Friday.(64) Deaths due to COVID-19 were captured from the 2020 dataset, with the ONS attributing deaths due to COVID-19 where 'COVID-19 or suspected COVID-19 was mentioned anywhere on the death certificate, including in combination with other health conditions.'(34) This was merged to form one workable dataset for the five districts in Oxfordshire consisting of a total of 3,655 death registrations. In order to standardise excess mortality by population size (per capita

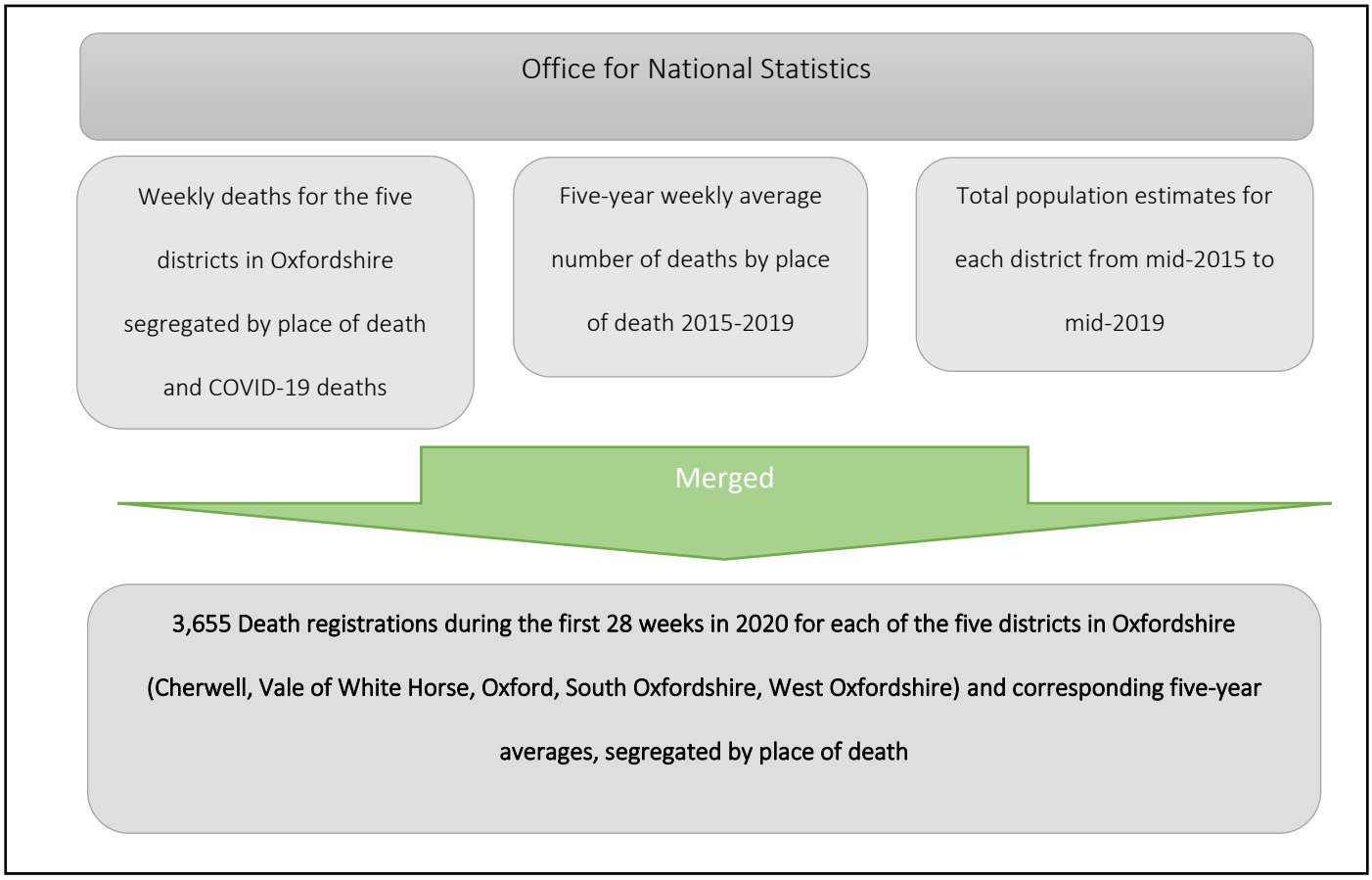
method) and enable more robust district comparisons, mid-year population estimates for 2015-2019 for each district were obtained from the ONS and added to the main dataset.(68) This data collection process is summarized in Figure 2.1 and descriptions of places of death as per the ONS are summarized in Table 2.1.. At each stage of data manipulation, cross-checks were performed with the original ONS datasets to ensure consistency.

Table 2.1: Description of Places of Death used in Death Registrations

Place of death	Description
Home	Private home residence
Care home	Both local authority-owned care homes and privately-owned care homes
Hospice	NHS and private
Hospital	NHS and private
Other communal establishment	Refers to those communal establishments for the care of the sick other than hospitals and hospices
Elsewhere	All places excluded by the above categories and those who were deceased on arrival at hospital

Source: Office for National Statistics- User Guide to Mortality Statistics (64)

Figure 2.1: ONS Data collection flow chart

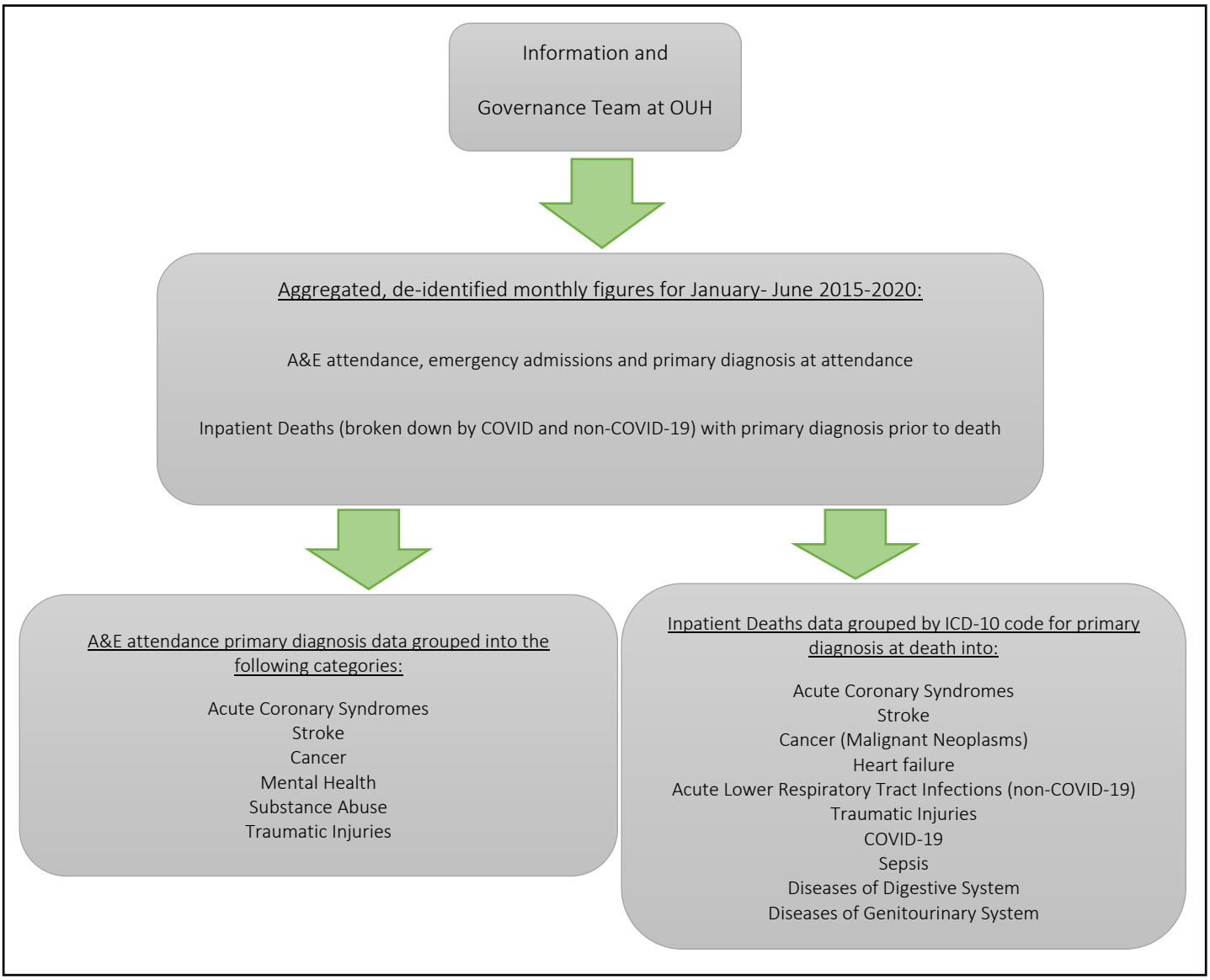


Source: Authors Own

Oxford University Hospitals NHS Foundation Trust

I obtained admission, A&E attendance, admission and mortality data from the Oxford University Hospitals NHS Foundation Trust (OUH) to analyse the impact on hospital utilisation and in-hospital excess mortality during the COVID-19 pandemic and how this may have influenced excess mortality in Oxfordshire. Following approval of a research contract at the Trust, I obtained this data from the Information and Governance team (Figure 2.2).

Figure 2.2: OUH Data collection



Source: Authors Own

Data Analysis

Data management, statistical analysis and data visualisation were computed using Microsoft® Excel® version 2006 and R version 4.0. 2.(69)

Excess Mortality Methodologies

A review of the academic and grey literature was performed to determine the main methodologies used for calculating excess mortality. As there has been a lack of consistency in methods across publications in calculating excess mortality, I chose to explore three different methods in demonstrating the full spectrum of excess mortality in Oxfordshire: excess mortality rates (to account for differences in population size across the districts), raw excess deaths (where population denominators were not quantifiable such as in care homes) and P-Scores (cumulative and weekly). These methods are detailed in Table 2.2 and their strengths and limitations were detailed in Chapter 1, Table 1.1. I looked at week-to-week trends of excess mortality using rates and death counts from week 0 to 28 to demonstrate the time-series evolution of excess deaths across districts. Weeks 12 (week ending 20 March) to week 23 (week ending 5 June) were selected to represent the 'peak pandemic period', based on excess deaths being the highest across Oxfordshire during this period and were used for further analysis in examining the true impact of the pandemic. The 'peak pandemic period' will be referred to as such in further chapters. Calculation of the cumulative P-Score over this peak pandemic period allowed for more robust regional comparisons in comparing the true impact of the pandemic, accounting for the variation in individual weeks.(16) Raw excess death counts were used for comparisons of place of death, since quantifiable population denominators were not available. I used the average of the five-year period from 2015-2019 to estimate 'expected' deaths, which accounted for any short-term increases in deaths in a single year. In the case of assessing excess mortality at the Oxford University Hospitals Trust, an excess mortality rate per 10,000 admissions was calculated.

Table 2.2 : Methodologies Used for Calculating Excess Mortality

Observed number of deaths for time period in 2020 = O_{2020} CI – Confidence Interval

Expected number of deaths for time period based on 2015-2019 historical average= $E_{2015\text{-}2019}$ P – Mid-year population size estimate

Outcome metric	Method	Calculation of 95% confidence intervals	Application to the research
Excess mortality rate **(Excess deaths per 100 000 population)** ***Measures the increase in the absolute risk of dying across the population***	$\frac{O_{2020}}{P_{mid-2019}} - \frac{E_{2015-2019}}{P_{mid-2015-mid-2019\ average}} * 100\,000$ i.e. observed crude death rate -baseline expected crude death rate	Rate difference using 'fmsb' package in R For OUH data, a range of historical expected values was calculated using the 95% confidence interval upper and lower limits	Weekly excess mortality per 100,000 population for each district Monthly excess mortality per 10,000 admissions at Oxford Hospitals University Foundation Trust
P-Score(%) ***Excess deaths as a proportion of expected deaths***	$\frac{O_{2020}-E_{2015-2019}}{E_{2015-2019}}$ x 100%	P-Score ± 1.96 x $\sqrt{\frac{P-Score}{O_{2020}-E_{2015-2019}}}$	Cumulative P-Score calculated for the peak pandemic period (week 12-23) for each district and place of death Weekly P-Score for each district
Raw number of excess deaths	$O_{2020} - E_{2015-2019}$	Not applicable due to data limitations (See section 'Data Limitations')	Weekly excess deaths by District, Place of Death and non-COVID-19 deaths

Source: Authors own drawing on (16,33,70,71)

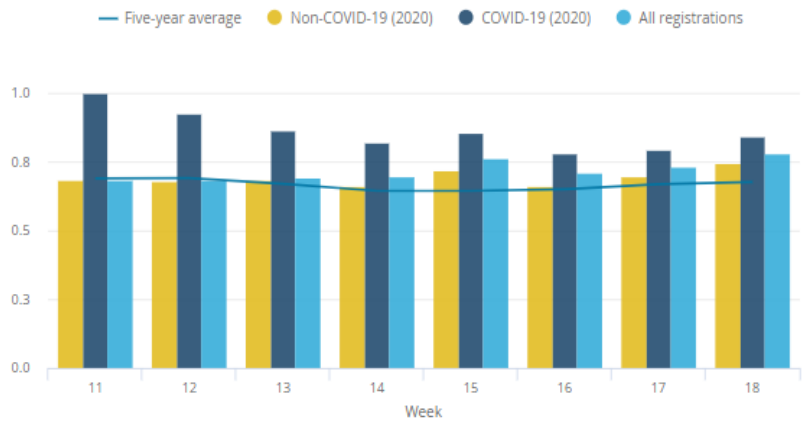
Data limitations

I controlled for population size by using mid-year estimates as weekly fluctuations are generally minimal and weekly population size data was not available. It is usual practice when presenting excess mortality estimates to demonstrate a range of plausible values (confidence interval) for the expected number of deaths based on previous year's averages.(71) This was not possible in my research at the district level due to the only ONS death registration data from 2015-2019 at a local authority level being available as a single five-year average for each week and place of death.(67) In order to compensate for the margin of imprecision, 95% confidence intervals were calculated for the excess mortality rates and P-Scores. A further limitation was that there was no available data for underlying cause of death (other than COVID-19), age and sex for each district at the time of the research, with the ONS usually publishing this data at the required local authority level a few months later. This precluded the calculation of age and sex-standardised excess mortality estimates and further analysis by cause of death.

Both death registration (based on date of registration) and death occurrence (based on the date the death occurred) provisional data were available from the ONS. There is usually an average delay of five days between death occurrence and its registration, but often longer if a post-mortem examination (inquest) by the coroner is required.(64) Since occurrence data is often prone to revisions, only data for death registrations were used to allow for more accurate comparisons.(42) When analysing deaths for the most recent weeks in July however, there may be a proportion of deaths that occurred but were not yet registered.

The introduction of the Coronavirus Act 2020, which became effective from 25 March 2020, allowed for more flexibility in death registrations and exemption from a coroner inquest where death due to COVID-19 was suspected.(72) This included an extension from 14 to 28 days in which the attending doctor could sign the death certificate and allowed for this to be done via video consultation.(72) Such changes may have caused an increase in death registration efficiency for deaths from all causes (including COVID-19) compared to the previous five years and is demonstrated in figure 2.3.(42) However, the ONS notes that it is still too early to assess the full impact of this increased efficiency as most deaths which required a coroner inquest prior to the Act will likely only be registered in the coming months and comparisons of the total number of death registrations will need to be made with the post-pandemic period.(42)

Figure 2.3: The Proportion of Registrations Made Within Seven Days of Death Occurrence, by COVID-19-related Deaths in England and Wales, Weeks 11 to 18 2020



Source: Office for National Statistics (42)

Deaths attributed to COVID-19 are dependent on the judgement of the certifying health professional and can be decided in the absence of testing. In certain cases, this may lead to underdiagnosis of COVID-19 on death certificates, especially where there may have been exacerbation of pre-existing conditions due to COVID-19. Supporting this theory is the fact that a considerable number of death certificates from the first few weeks of the pandemic have been revised to include COVID-19 as the underlying cause of death, which may reflect underdiagnosis of COVID-19 early in the pandemic.(42)

Due to time constraints and the shift in research project to address the COVID-19 pandemic, I was not able to obtain ethical approval to access death certificate data for deaths at OUH. I therefore had to rely on the primary diagnosis at the time of death, which may differ from the actual cause of death. I also had to group these 'causes' of deaths into broader International Classification of Diseases, 10th revision (ICD-10) code categories with assistance and advice from the clinical coding team at OUH, which may have omitted certain conditions depending how they were classified and did not account for comorbidities or secondary diagnoses.

Ethical Considerations

All data for death registration and population demographics were obtained in their aggregated form from national agencies which have made them freely available. All hospital mortality and admission data obtained from the Oxford University Hospitals NHS Foundation Trust was through the Information Governance team and in a de-identified format.

I plan to share the findings of this research with Public Health Oxfordshire officials and engage in a discussion around the broader implications of the findings and how it may contribute to their public health response.

CHAPTER 3
RESULTS

In this chapter, I will present the results of excess mortality in Oxfordshire and its 5 districts, segregated by place of death and deaths due to COVID-19.

Excess Mortality in Oxfordshire and its 5 Districts

A total of 3,655 all-cause deaths were registered in Oxfordshire county for the 28-week period from the week ending 3 January 2020 to the week ending 10 July 2020. The weeks 12 to 23 were chosen to represent the 'peak pandemic period' for comparing excess mortality across the districts as this period accounted for 66% of all deaths due to COVID-19 and the greatest weeks of excess deaths across all districts in Oxfordshire. Of the 3,655 all-cause deaths recorded for the study period (week 1-28), 1878 (51%) occurred during the peak pandemic period, including 642 (34%) excess deaths.

A summary of results for excess deaths and peak pandemic P-Scores by district and place of death as well as totals for Oxfordshire are presented in Table 3.1. Peak pandemic P-Scores for hospice and 'elsewhere' categories were omitted, owing to few deaths occurring in these places.

The peak in overall excess mortality for Oxfordshire occurred in week 16 (week ending 17 April), with an excess mortality rate of 23.9 excess deaths per 100,000 population (95% CI 18.4 - 29.4) (Table 3.2). There were eight continuous weeks (weeks 14 to 22) during which the observed deaths exceeded the expected five-year average in Oxfordshire, although when broken down by the different districts was seen to occur at different times. The weekly trend of excess deaths for each of the five districts is detailed in Figure 3.1.

In drawing comparisons across districts, excess mortality rates and P-Scores were utilised to reflect different ways of representing and understanding excess mortality. The time-trend in excess mortality rates per 100,000 population across the different districts are reflected in Figure 3.2 and a heat map of weekly P-Scores in Figure 3.3.

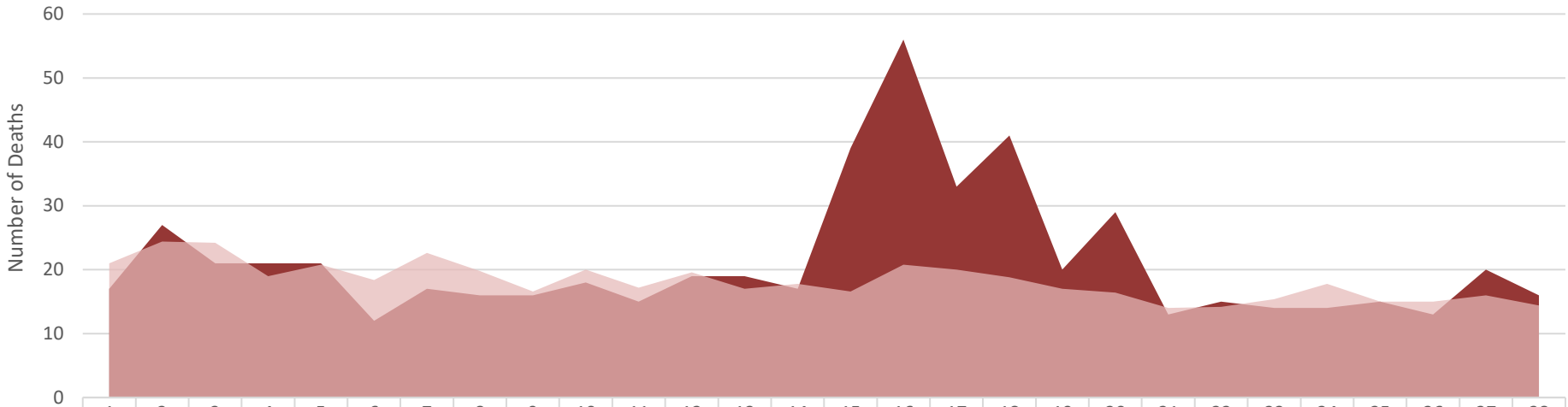
Table 3.1 Summary of Deaths and Cumulative P-Scores by District for the Peak Pandemic Period (Weeks 12 – 23)

District and Place of Death	All-cause deaths 2020	Deaths due to COVID-19 (% of all-cause deaths)	Expected deaths (based on five-year average)	Cumulative P-Score for the peak pandemic period (95% CI)
Oxford	**315**	**70 (22%)**	**208**	**51.4(50.1-52.8)**
Care home	111	26	53	**110.2 (107.5 - 112.9)**
Elsewhere	6	0	3	
Home	88	9	50	**77.4 (74.6 - 80.2)**
Hospice	16	0	17	
Hospital	91	33	85	**7.6 (5.4 - 9.7)**
Other communal establishment	3	2	1	
Cherwell	**428**	**113 (26%)**	**278**	**54.0(52.8-55.1)**
Care home	150	62	70	**113.1 (110.7 - 115.4)**
Elsewhere	7	0	3	
Home	83	4	64	**30.5 (28.0 - 33)**
Hospice	33	1	20	
Hospital	155	46	119	**29.8 (28.0 - 31.6)**
Other communal establishment	0	0	1	
Vale of White Horse	**380**	**120 (32%)**	**236**	**61.0(59.7-62.3)**
Care home	147	58	57	**156.1 (153.5 - 158.7)**
Elsewhere	4	0	5	
Home	82	6	52	**57.7 (55.0 - 60.4)**
Hospice	14	0	16	
Hospital	123	50	102	**20.1 (18.2 - 22.1)**
Other communal establishment	10	6	4	
South Oxfordshire	**393**	**111 (28%)**	**278**	**41.4(40.2-42.5)**
Care home	152	60	74	**106.5 (104.2 - 108.8)**
Elsewhere	7	0	3	
Home	98	3	64	**52.2 (49.7 - 54.6)**
Hospice	9	0	24	
Hospital	125	47	112	**11.6 (9.8 - 13.5)**
Other communal establishment	2	1	0	
West Oxfordshire	**362**	**112 (31%)**	**237**	**52.7(51.5-54.0)**
Care home	173	71	73	**136.3 (134.0 - 138.6)**
Elsewhere	5	1	5	
Home	77	1	56	**36.5 (33.9 - 39.1)**
Hospice	9	0	13	
Hospital	98	39	89	**9.9 (7.8 - 11.9)**
Other communal establishment	0	0	0	
Total for Oxfordshire	**1,878**	**526 (28%)**	**1,236**	**50.6(50.0-51.2)**
Care home	733	277	327	**123.9 (122.8 - 125)**
Elsewhere	29	1	19	
Home	428	23	286	**49.7 (48.5 - 50.8)**
Hospice	81	1	90	
Hospital	592	215	508	**16.6 (15.8 - 17.5)**
Other communal establishment	15	9	6	

Figure 3.1 Excess Deaths by District*

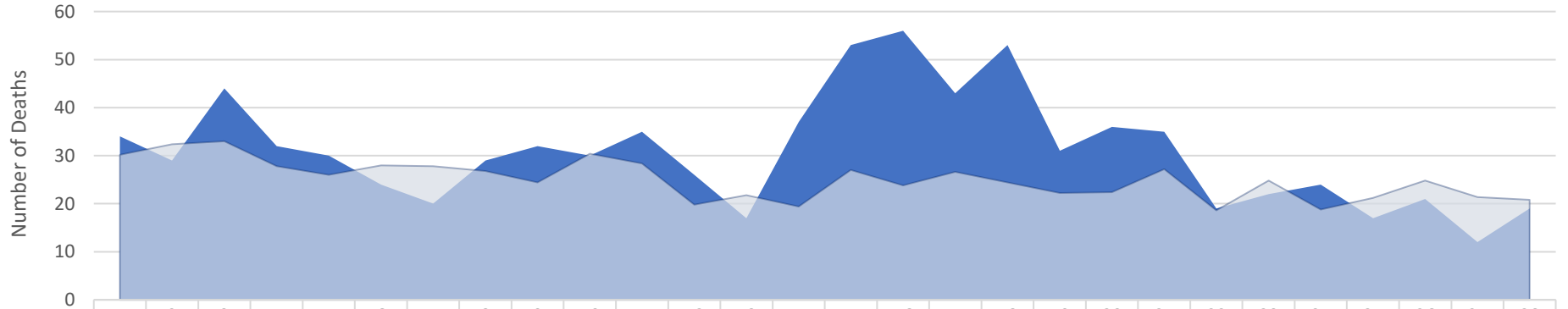
*the excess is represented by the non-overlapping areas

Oxford



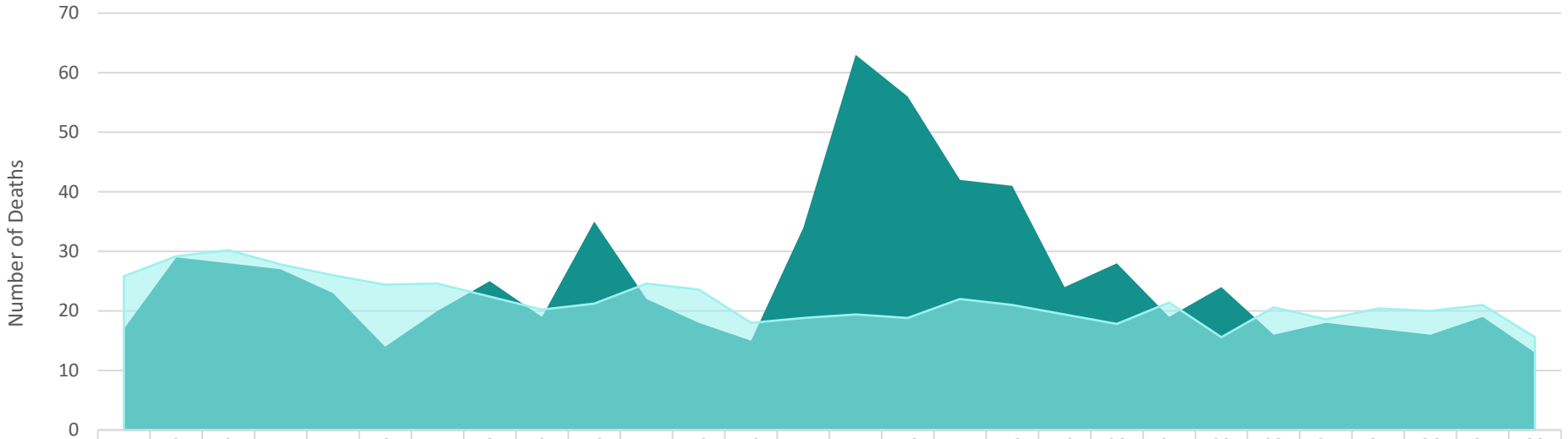
Week	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16	17	18	19	20	21	22	23	24	25	26	27	28
2020 Number of deaths	17	27	21	21	21	12	17	16	16	18	15	19	19	17	39	56	33	41	20	29	13	15	14	14	15	13	20	16
Five-Year Average Number Of Deaths	21	24	24	19	21	18	23	20	17	20	17	20	17	18	17	21	20	19	17	16	14	14	15	18	15	15	16	14
Excess Deaths	-4	3	-3	2	0	-6	-6	-4	-1	-2	-2	-1	2	-1	22	35	13	22	3	13	-1	1	-1	-4	0	-2	4	2

Cherwell



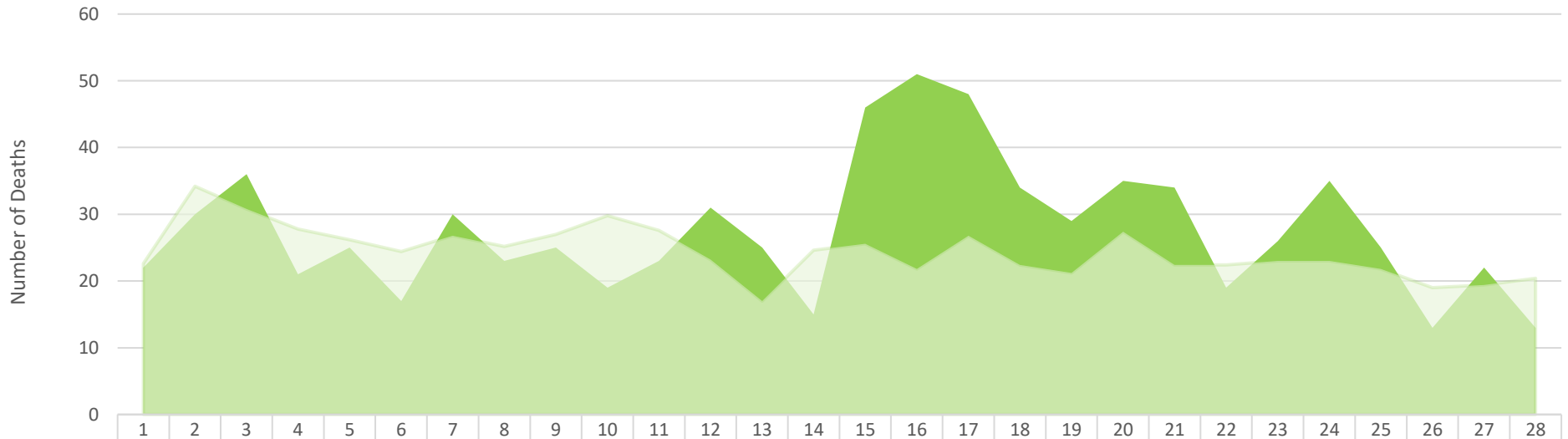
Week	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16	17	18	19	20	21	22	23	24	25	26	27	28
2020 Number of deaths	34	29	44	32	30	24	20	29	32	30	35	26	17	37	53	56	43	53	31	36	35	19	22	24	17	21	12	19
Five-Year Average Number Of Deaths	30	32	33	28	26	28	28	27	24	30	28	20	22	19	27	24	27	24	22	22	27	19	25	19	21	25	21	21
Excess Deaths	4	-3	11	4	4	-4	-8	2	8	0	7	6	-5	18	26	32	16	29	9	14	8	0	-3	5	-4	-4	-9	-2

Vale of White Horse



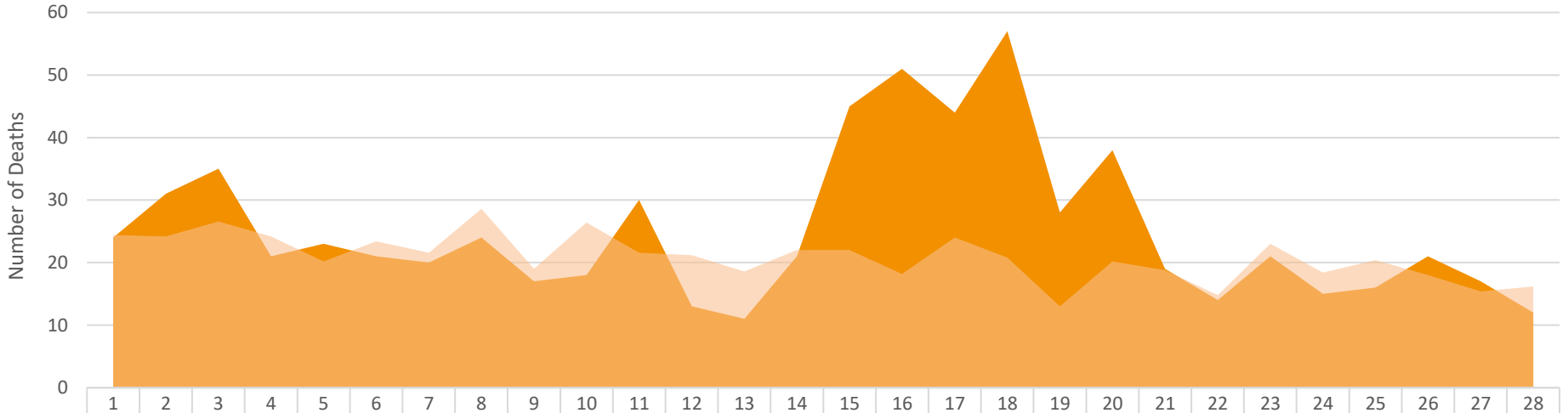
Week	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16	17	18	19	20	21	22	23	24	25	26	27	28
2020 Number of deaths	17	29	28	27	23	14	20	25	19	35	22	18	15	34	63	56	42	41	24	28	19	24	16	18	17	16	19	13
Five-Year Average Number Of Deaths	26	29	30	28	26	24	25	22	20	21	25	24	18	19	19	19	22	21	19	18	21	16	21	19	20	20	21	16
Excess Deaths	-9	0	-2	-1	-3	-10	-5	3	-1	14	-3	-6	-3	15	44	37	20	20	5	10	-2	8	-5	-1	-3	-4	-2	-3

South Oxfordshire



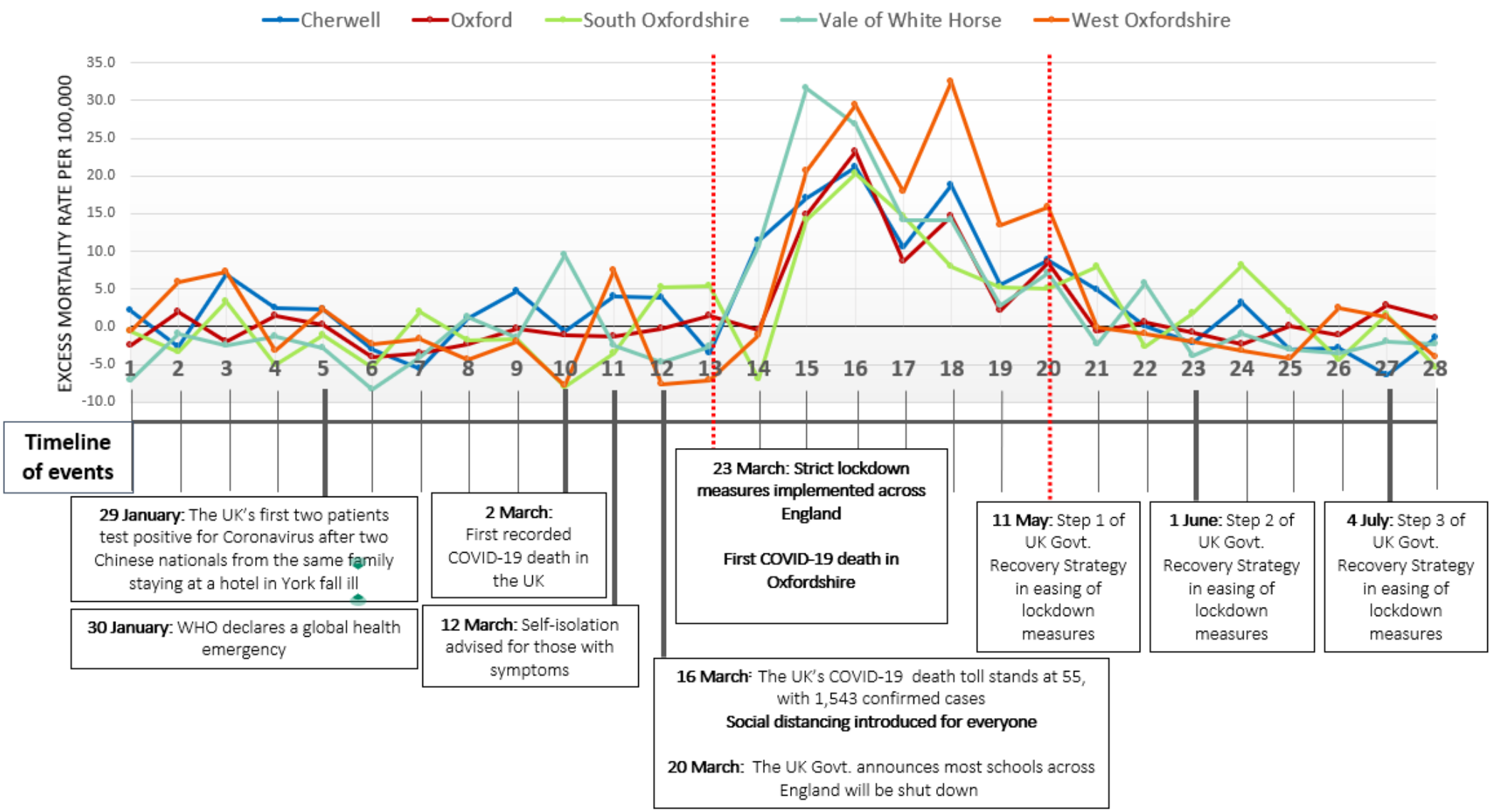
Week	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16	17	18	19	20	21	22	23	24	25	26	27	28
2020 Number of deaths	22	30	36	21	25	17	30	23	25	19	23	31	25	15	46	51	48	34	29	35	34	19	26	35	25	13	22	13
Five-Year Average Number Of Deaths	23	34	31	28	26	24	27	25	27	30	28	23	17	25	26	22	27	22	21	27	22	22	23	23	22	19	19	20
Excess Deaths	-1	-4	5	-7	-1	-7	3	-2	-2	-11	-5	8	8	-10	20	29	21	12	8	8	12	-3	3	12	3	-6	3	-7

West Oxfordshire



Week	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16	17	18	19	20	21	22	23	24	25	26	27	28
2020 Number of deaths	24	31	35	21	23	21	20	24	17	18	30	13	11	21	45	51	44	57	28	38	19	14	21	15	16	21	17	12
Five-Year Average Number Of Deaths	24	24	27	24	20	23	22	29	19	26	22	21	19	22	22	18	24	21	13	20	19	15	23	18	20	18	15	16
Excess Deaths	0	7	8	-3	3	-2	-2	-5	-2	-8	8	-8	-8	-1	23	33	20	36	15	18	0	-1	-2	-3	-4	3	2	-4

Figure 3.2 Weekly Excess Mortality Rate per 100,000 Population in Oxfordshire



Source for timeline events: (73–75)

Figure 3.3 Heat Map of Weekly P-Scores from Week 9 Reflecting Excess Deaths Relative to the Historical Average

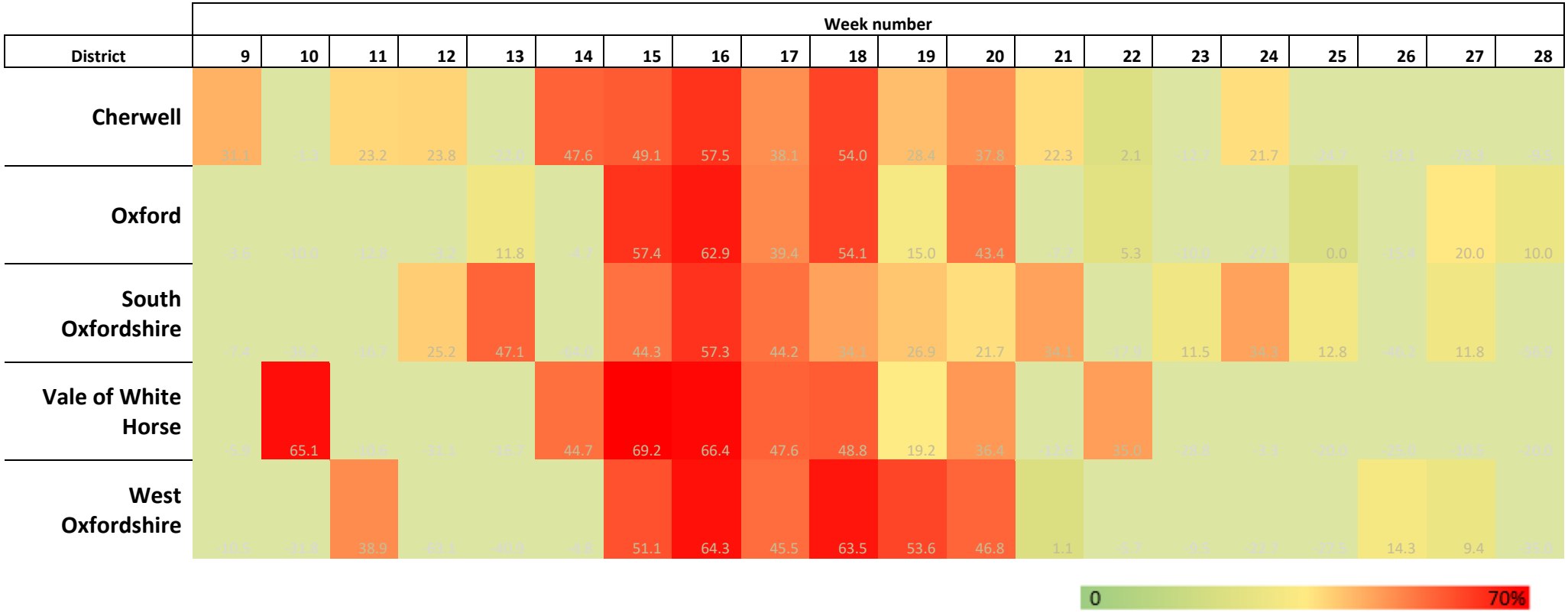


Table 3.2 Excess Mortality Rates per 100,000 Population for Each District with 95% Confidence Interval

Week	Cherwell	Oxford	South Oxfordshire	Vale of White Horse	West Oxfordshire	Oxfordshire
1	2.2 (-8.4 - 12.7)	-2.5 (-10.3 - 5.4)	-0.7 (-9.9 - 8.6)	-7.2 (-16.8 - 2.5)	-0.6 (-13 - 11.8)	-1.7 (-6.1 - 2.7)
2	-2.6 (-12.9 - 7.7)	1.9 (-7.3 - 11.1)	-3.3 (-14.5 - 7.8)	-0.9 (-12.1 - 10.3)	5.9 (-7.3 - 19.1)	0 (-4.9 - 4.8)
3	6.9 (-4.6 - 18.4)	-1.9 (-10.5 - 6.7)	3.3 (-8 - 14.7)	-2.4 (-13.6 - 8.8)	7.3 (-6.6 - 21.3)	2.5 (-2.5 - 7.5)
4	2.5 (-7.7 - 12.6)	1.5 (-6.6 - 9.5)	-5.1 (-14.8 - 4.6)	-1.3 (-12.2 - 9.5)	-3.1 (-15.1 - 8.8)	-0.9 (-5.4 - 3.6)
5	2.4 (-7.5 - 12.2)	0.3 (-8 - 8.6)	-1.1 (-11.1 - 8.8)	-2.9 (-13.2 - 7.4)	2.3 (-9.4 - 14)	0.2 (-4.2 - 4.6)
6	-3.0 (-12.5 - 6.5)	-4.1 (-11.1 - 3)	-5.5 (-14.4 - 3.5)	-8.3 (-17.4 - 0.8)	-2.4 (-14.3 - 9.5)	-4.6 (-8.8 - -0.5)
7	-5.5 (-14.6 - 3.6)	-3.5 (-11.5 - 4.5)	2.0 (-8.5 - 12.4)	-4.0 (-13.9 - 5.8)	-1.7 (-13.2 - 9.8)	-2.6 (-6.9 - 1.7)
8	1.1 (-8.7 - 11)	-2.3 (-10 - 5.3)	-1.8 (-11.5 - 7.8)	1.3 (-8.8 - 11.4)	-4.4 (-17.4 - 8.5)	-1.1 (-5.5 - 3.3)
9	4.8 (-5.1 - 14.6)	-0.3 (-7.6 - 7)	-1.7 (-11.7 - 8.3)	-1.4 (-10.6 - 7.8)	-2.0 (-12.7 - 8.7)	0.1 (-4.1 - 4.3)
10	-0.6 (-10.8 - 9.6)	-1.2 (-9 - 6.7)	-7.9 (-17.6 - 1.8)	9.6 (-1.4 - 20.5)	-7.9 (-19.7 - 4)	-1.4 (-5.9 - 3.1)
11	4.1 (-6.4 - 14.5)	-1.3 (-8.6 - 5.9)	-3.5 (-13.4 - 6.4)	-2.6 (-12.6 - 7.5)	7.4 (-5.4 - 20.2)	0.6 (-3.9 - 5)
12	3.9 (-5 - 12.8)	-0.2 (-8.2 - 7.7)	5.2 (-5 - 15.5)	-4.7 (-14.2 - 4.7)	-7.6 (-18.1 - 2.8)	-0.3 (-4.4 - 3.9)
13	-3.4 (-11.6 - 4.7)	1.4 (-6.2 - 9.1)	5.4 (-3.5 - 14.4)	-2.7 (-11.1 - 5.8)	-7.1 (-16.8 - 2.6)	-1.0 (-4.8 - 2.9)
14	11.5 (1.6 - 21.3)	-0.4 (-7.9 - 7.2)	-7.0 (-15.8 - 1.7)	10.7 (0.1 - 21.3)	-1.1 (-12.8 - 10.6)	2.9 (-1.4 - 7.2)
15	17.0 (5.2 - 28.7)	14.8 (5.3 - 24.4)	14.1 (2.3 - 25.8)	**31.5 (18.3 - 44.7)**	20.6 (6 - 35.1)	19.4 (14 - 24.7)
16	21.1 (9.4 - 32.8)	**23.2 (12 - 34.5)**	**20.3 (8.5 - 32.1)**	26.8 (14.3 - 39.4)	29.5 (14.7 - 44.2)	**23.9 (18.4 - 29.4)**
17	10.6 (-0.4 - 21.5)	8.7 (-0.6 - 18)	14.6 (2.6 - 26.6)	14.1 (2.4 - 25.8)	17.8 (3.2 - 32.5)	12.9 (7.7 - 18)
18	**18.7 (7.2 - 30.2)**	14.7 (4.8 - 24.6)	7.9 (-2.5 - 18.4)	14.1 (2.7 - 25.6)	**32.5 (16.8 - 48.2)**	16.9 (11.7 - 22.1)
19	5.6 (-4 - 15.2)	2.1 (-5.7 - 9.9)	5.3 (-4.6 - 15.1)	2.9 (-6.8 - 12.5)	13.4 (2 - 24.8)	5.5 (1.2 - 9.8)
20	8.8 (-1.2 - 18.8)	8.4 (-0.2 - 17)	5.1 (-5.9 - 16)	7.0 (-2.9 - 16.9)	15.9 (2.3 - 29.4)	8.7 (4.1 - 13.4)
21	4.9 (-5.5 - 15.2)	-0.5 (-7.2 - 6.1)	7.9 (-2.5 - 18.4)	-2.3 (-11.7 - 7)	0 (-11 - 10.9)	2.1 (-2.1 - 6.4)
22	0 (-8 - 8.1)	0.6 (-6.3 - 7.5)	-2.6 (-11.6 - 6.3)	5.8 (-3.4 - 15)	-0.9 (-10.4 - 8.7)	0.6 (-3.2 - 4.4)
23	-2.2 (-11.1 - 6.8)	-0.8 (-7.7 - 6.1)	1.9 (-7.9 - 11.6)	-3.9 (-12.8 - 5)	-2 (-13.9 - 9.8)	-1.3 (-5.4 - 2.8)
24	3.2 (-5.4 - 11.8)	-2.4 (-9.6 - 4.8)	8.2 (-2.4 - 18.8)	-0.9 (-9.8 - 7.9)	-3.3 (-13.6 - 7)	1.2 (-2.9 - 5.2)
25	-3.0 (-11.2 - 5.1)	0.1 (-6.9 - 7.1)	2.0 (-7.5 - 11.5)	-3.0 (-12 - 5.9)	-4.2 (-14.9 - 6.6)	-1.5 (-5.4 - 2.5)
26	-2.8 (-11.7 - 6.1)	-1.2 (-8 - 5.6)	-4.4 (-12.3 - 3.4)	-3.5 (-12.3 - 5.3)	2.5 (-8.6 - 13.6)	-2.0 (-5.9 - 1.8)
27	-6.5 (-14.1 - 1.1)	2.7 (-4.9 - 10.4)	1.6 (-7.3 - 10.6)	-2.0 (-11.3 - 7.3)	1.3 (-8.8 - 11.4)	-0.6 (-4.5 - 3.2)
28	-1.4 (-9.7 - 6.9)	1.2 (-5.9 - 8.2)	-5.4 (-13.5 - 2.6)	-2.3 (-10.2 - 5.5)	-4.0 (-13.4 - 5.5)	-2.2 (-5.9 - 1.4)

Bold figures indicate highest weekly excess mortality rate for that district within the observed period

The elevation in excess mortality reflected in January and early February (weeks 1-5) across all districts may be attributed to the expected excess winter-related mortality seen annually as evidenced by previous ONS excess winter mortality figures.(76) Prior to week 12, weekly excess mortality rates across all districts fluctuated between -8.3 to 9.6 excess deaths per 100,000 population. A surge in excess deaths was seen in Vale of White Horse in week 10, with 14 excess deaths and in West Oxfordshire in week 11 with eight excess deaths (Figures 3.1 and 3.2).

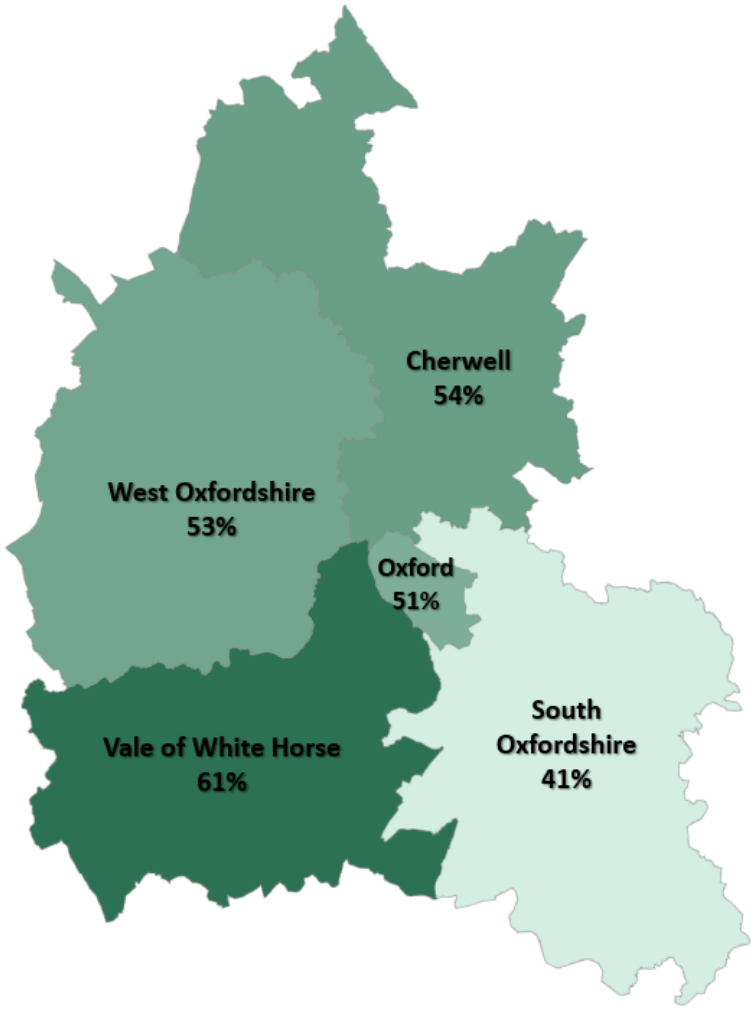
Excess Mortality during the pandemic period:

The weekly P-Score between weeks 15-18 remained consistently above 34% for all districts (Figure 3.3). There was a rapid increase in weekly excess mortality across all districts from weeks 13- 14, with Cherwell, Oxford

and South Oxfordshire reaching their peak by week 16. Excess deaths peaked first in Vale of White Horse in week 15 (31.5 excess deaths per 100,000 population 95% CI 18.3 - 44.7), which was followed by a steady decline back to pre-pandemic levels by week 22. Following a rapid rise in excess deaths from week 14, West Oxfordshire saw the most sustained elevation in excess deaths. Excess deaths in this district reached a peak in week 18 with 32.5 excess deaths per 100,000 population (95% CI 16.8 - 48.2), the highest weekly excess mortality rate seen of all districts during this period and almost double the weekly excess mortality rate compared to Oxfordshire overall for the same week (16.9 excess deaths per 100,000 population 95% CI 11.7 - 22.1).

A P-Score for the cumulative excess mortality between weeks 12-23 were calculated to reflect the impact on excess mortality during the peak pandemic period (Table 3.1, Figure 3.4). By this measure, the highest P-Score during the pandemic period was seen in Vale of White Horse, with the excess mortality being 61% more than the historical baseline (95% CI 59.7-62.3) and the lowest in South Oxfordshire, with 41.4% more excess deaths than the historical baseline (95% CI 40.2-42.5).

Figure 3.4 District Cumulative P-Scores for the Peak Pandemic Period



The Role of COVID-19 in Excess Mortality in Oxfordshire

Deaths due to suspected or confirmed COVID-19 were recorded on death certificates from week 12 (week ending 20 March), with the first COVID-19 death occurring in South Oxfordshire in the hospital setting. While COVID-19 is seen to contribute to a small proportion of total deaths (Figure 3.6), when considered in relation to excess deaths it accounts for the majority of excess deaths across all districts (Figure 3.7). For each district, the peak in weekly COVID-19 deaths (Figure 3.5) coincides with the peak in weekly excess mortality (reflected in figures 3.1 and 3.2). This could reflect the direct impact of COVID-19 infection on excess deaths seen during the pandemic. Figure 3.8 demonstrates the impact of non-COVID-19 deaths in relation to the historical average, indicating that even in the absence of COVID-19 deaths, excess mortality was still seen between weeks 15-20.

Figure 3.5 Weekly Deaths due to COVID-19

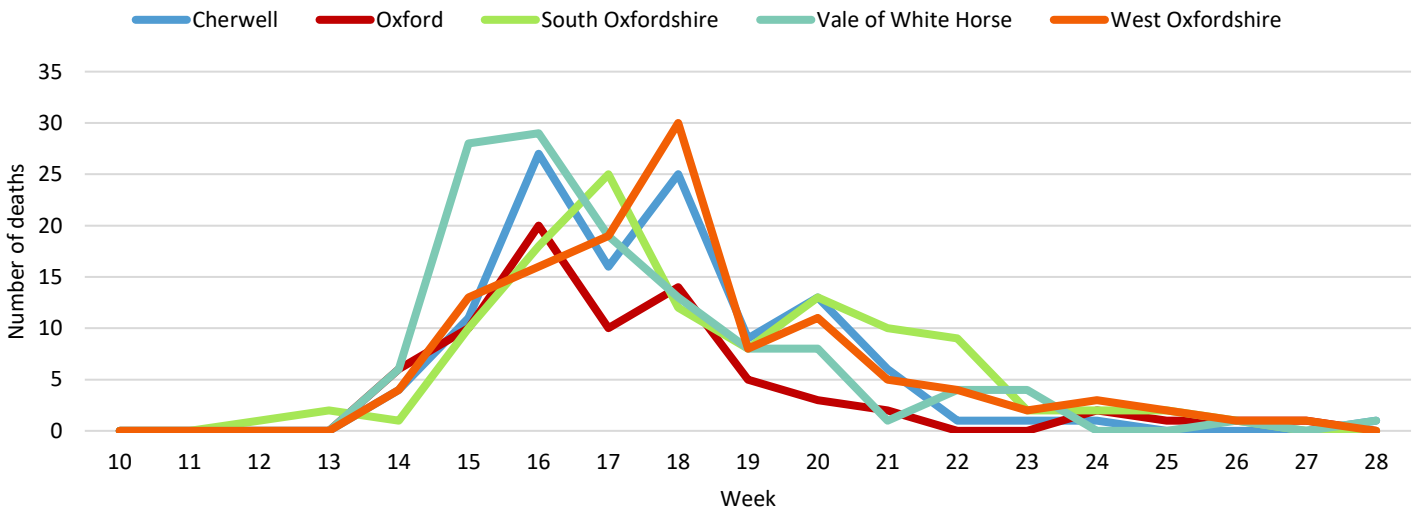


Figure 3.6 Contribution of COVID-19 to Total Deaths During the Peak Pandemic Period

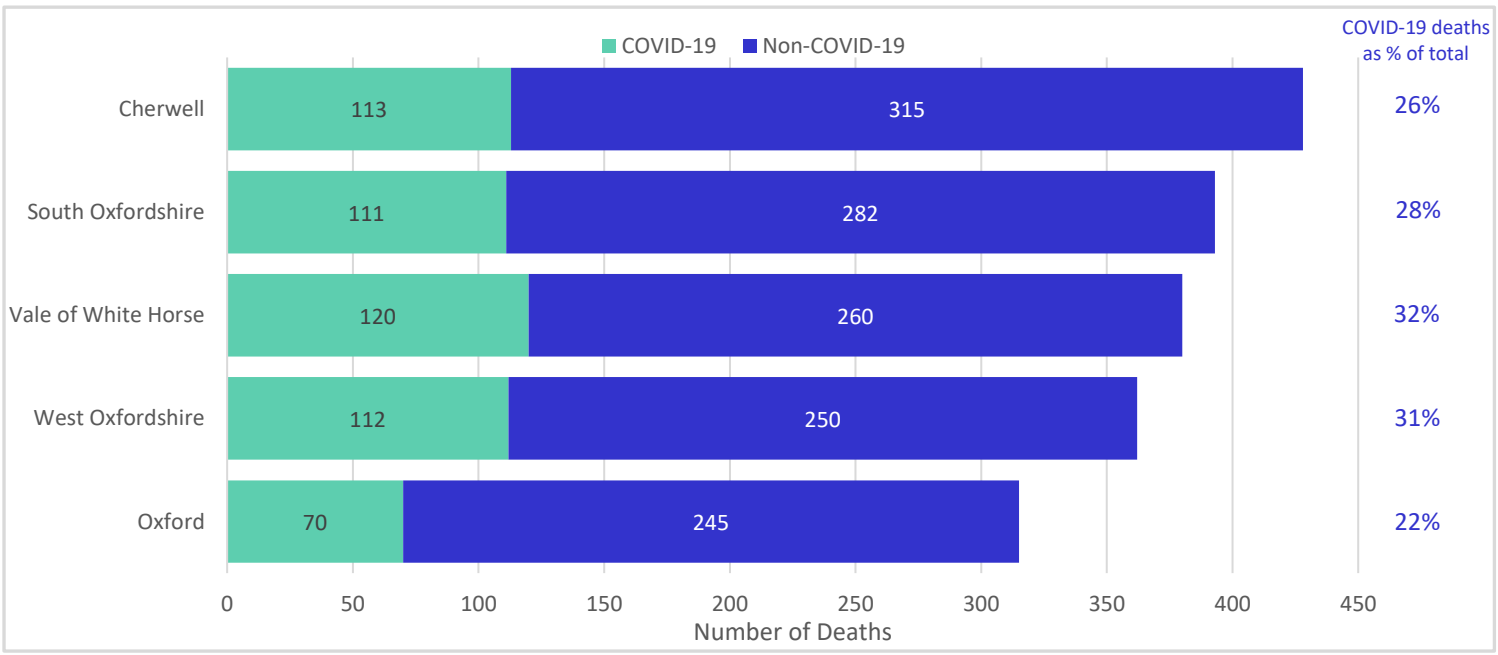


Figure 3.7 Contribution of COVID-19 to Excess Deaths During the Peak Pandemic Period

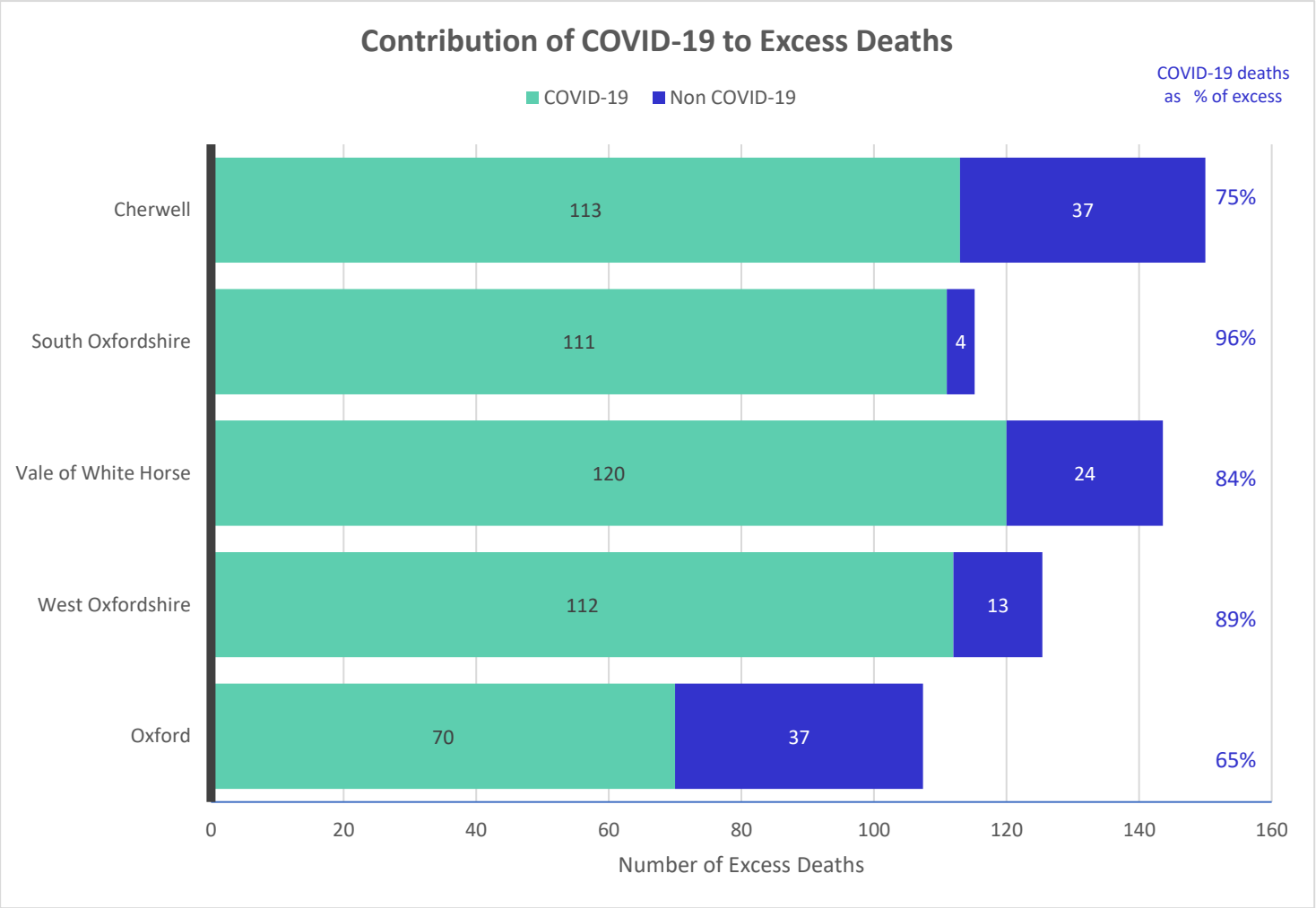
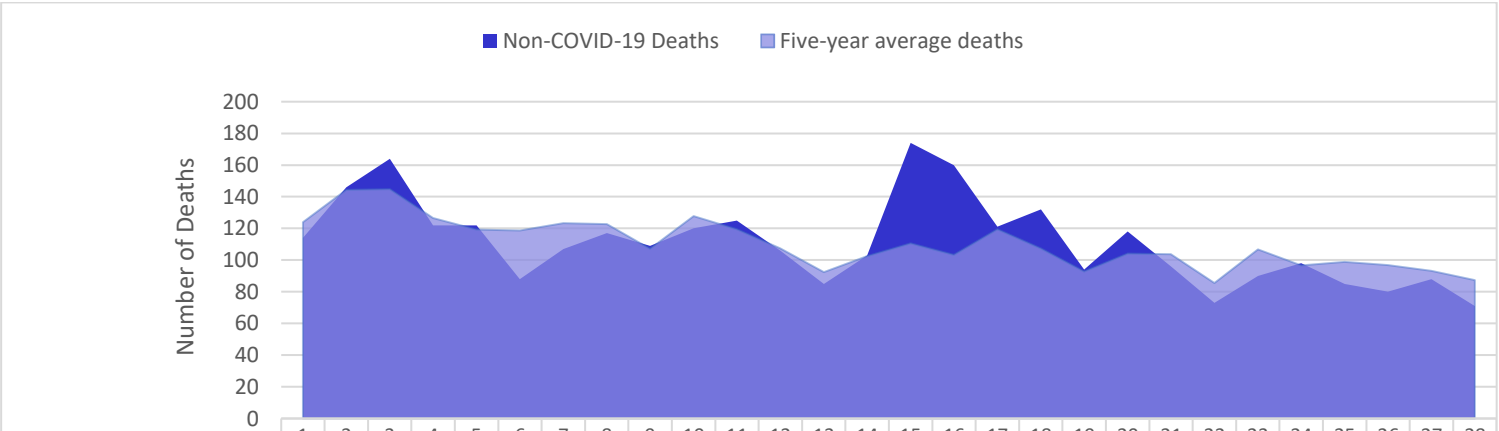


Figure 3.8 Relationship of Weekly Non-COVID-19 Deaths to the Historical Average

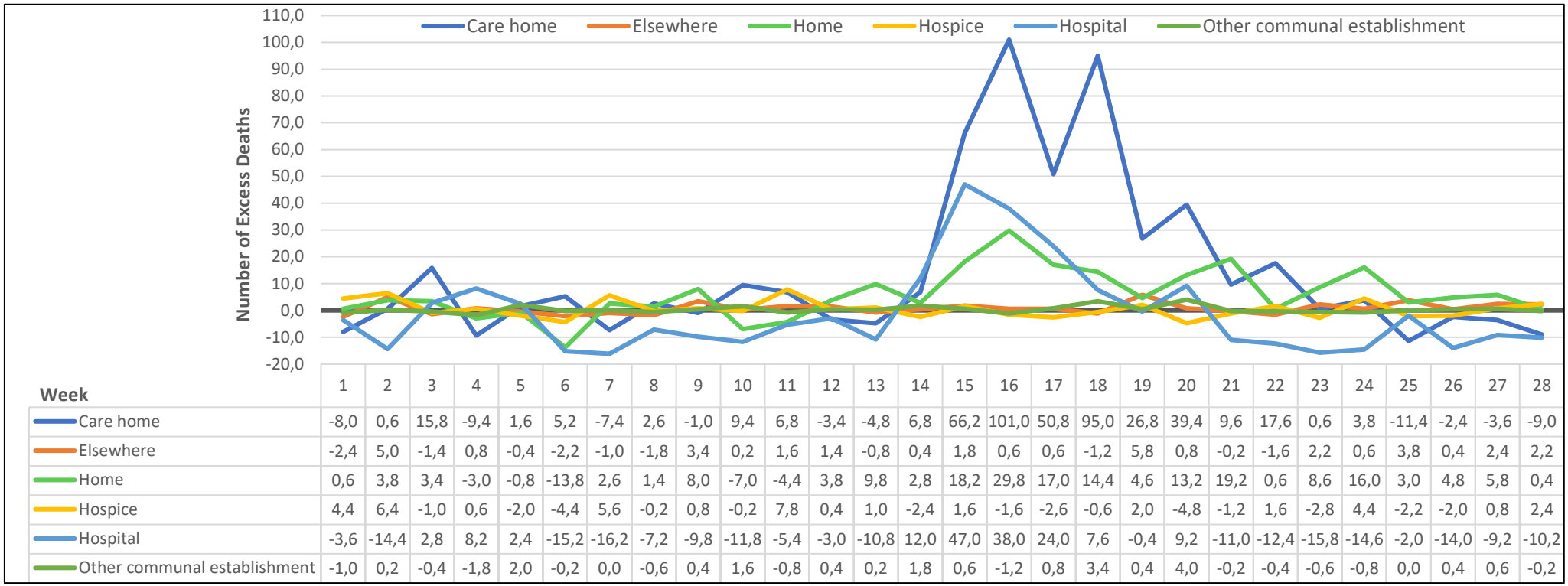


	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16	17	18	19	20	21	22	23	24	25	26	27	28
Non-COVID-19 Deaths	114	146	164	122	122	88	107	117	109	120	125	106	85	103	174	160	121	132	94	118	96	73	90	98	85	80	88	71
Five-year average deaths	124	144	145	127	119	119	123	123	107	128	119	107	92	103	111	103	119	107	93	104	104	86	107	97	99	97	93	87
Excess Deaths	-10	2	19	-5	3	-31	-16	-6	2	-8	6	-1	-7	0	63	57	2	25	1	14	-8	-13	-17	1	-14	-17	-5	-16

Place of Death

The highest number of all-cause deaths across Oxfordshire for the peak pandemic period were seen in care homes, accounting for 39% (n= 733) of all deaths, and hospitals accounting for 32% (n=592) of all deaths (Table 3.1). Weekly excess deaths by place of death are presented in Figure 3.9. The number of excess deaths in care homes rose rapidly from week 14 to reach a peak in week 16 (101 excess deaths) and only recovered to pre-pandemic levels by week 25. Excess deaths in hospitals remained elevated above the historical average from weeks 14 to 19, reaching a peak of 47 deaths in week 15. From week 21 onwards the excess deaths seen in hospitals remained below the historical average, ranging from 2 to 16 deaths below the historical threshold. Deaths occurring in the home setting have continued to see fluctuations above the historical average from week 14 onwards. Hospice deaths, deaths in places classified as 'elsewhere' and deaths in communal establishments saw minimal fluctuations around the historical average for the observed period. The contribution of COVID-19 to total deaths and further segregated by area is presented in Figures 3.11 and 3.12.

Figure 3.9: Weekly Excess Deaths by Place of Death Weeks 1 – 28



Week	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16	17	18	19	20	21	22	23	24	25	26	27	28
Care home	-8,0	0,6	15,8	-9,4	1,6	5,2	-7,4	2,6	-1,0	9,4	6,8	-3,4	-4,8	6,8	66,2	101,0	50,8	95,0	26,8	39,4	9,6	17,6	0,6	3,8	-11,4	-2,4	-3,6	-9,0
Elsewhere	-2,4	5,0	-1,4	0,8	-0,4	-2,2	-1,0	-1,8	3,4	0,2	1,6	1,4	-0,8	0,4	1,8	0,6	0,6	-1,2	5,8	0,8	-0,2	-1,6	2,2	0,6	3,8	0,4	2,4	2,2
Home	0,6	3,8	3,4	-3,0	-0,8	-13,8	2,6	1,4	8,0	-7,0	-4,4	3,8	9,8	2,8	18,2	29,8	17,0	14,4	4,6	13,2	19,2	0,6	8,6	16,0	3,0	4,8	5,8	0,4
Hospice	4,4	6,4	-1,0	0,6	-2,0	-4,4	5,6	-0,2	0,8	-0,2	7,8	0,4	1,0	-2,4	1,6	-1,6	-2,6	-0,6	2,0	-4,8	-1,2	1,6	-2,8	4,4	-2,2	-2,0	0,8	2,4
Hospital	-3,6	-14,4	2,8	8,2	2,4	-15,2	-16,2	-7,2	-9,8	-11,8	-5,4	-3,0	-10,8	12,0	47,0	38,0	24,0	7,6	-0,4	9,2	-11,0	-12,4	-15,8	-14,6	-2,0	-14,0	-9,2	-10,2
Other communal establishment	-1,0	0,2	-0,4	-1,8	2,0	-0,2	0,0	-0,6	0,4	1,6	-0,8	0,4	0,2	1,8	0,6	-1,2	0,8	3,4	0,4	4,0	-0,2	-0,4	-0,6	-0,8	0,0	0,4	0,6	-0,2

Figure 3.10 Contribution of Place of Death to Overall Excess Deaths for the Peak Pandemic Period

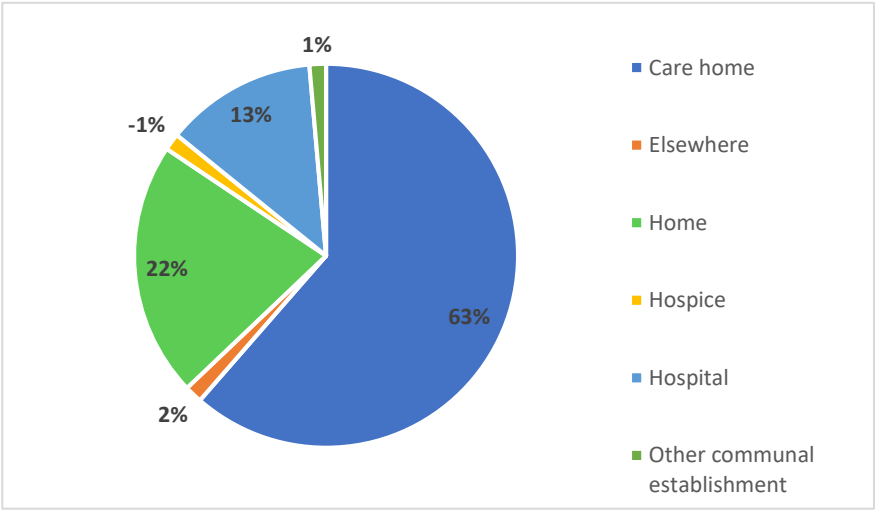
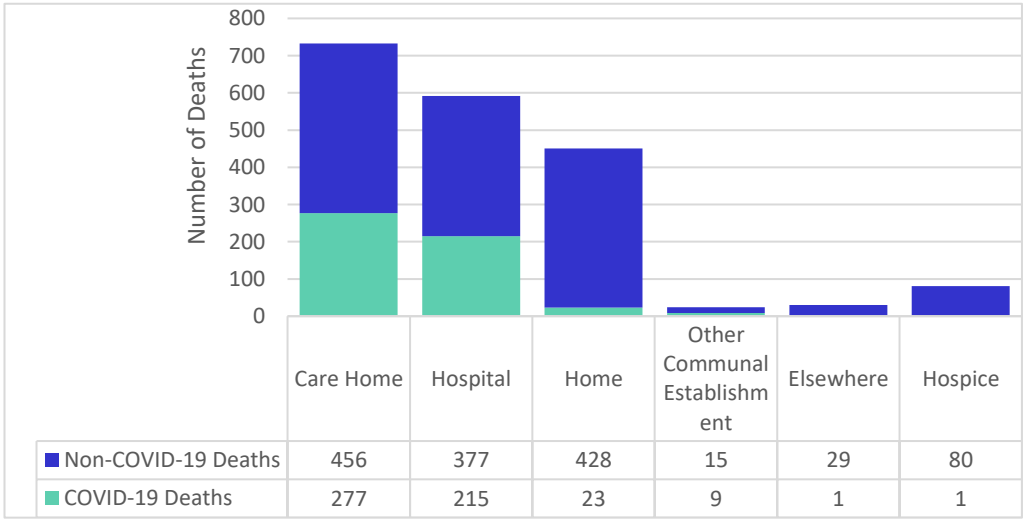
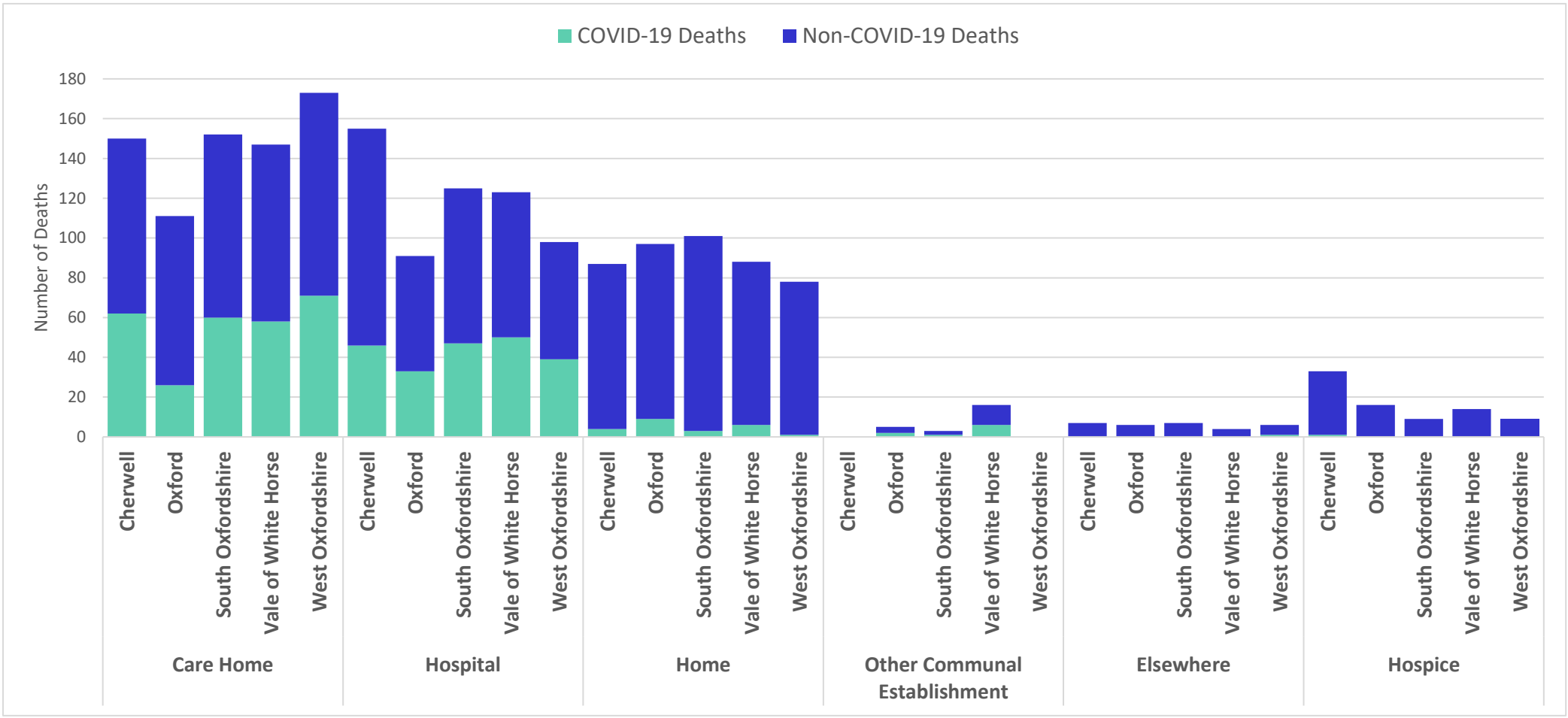


Figure 3.11 Contribution of COVID-19 to Total Deaths by Place of Death for the Peak Pandemic Period



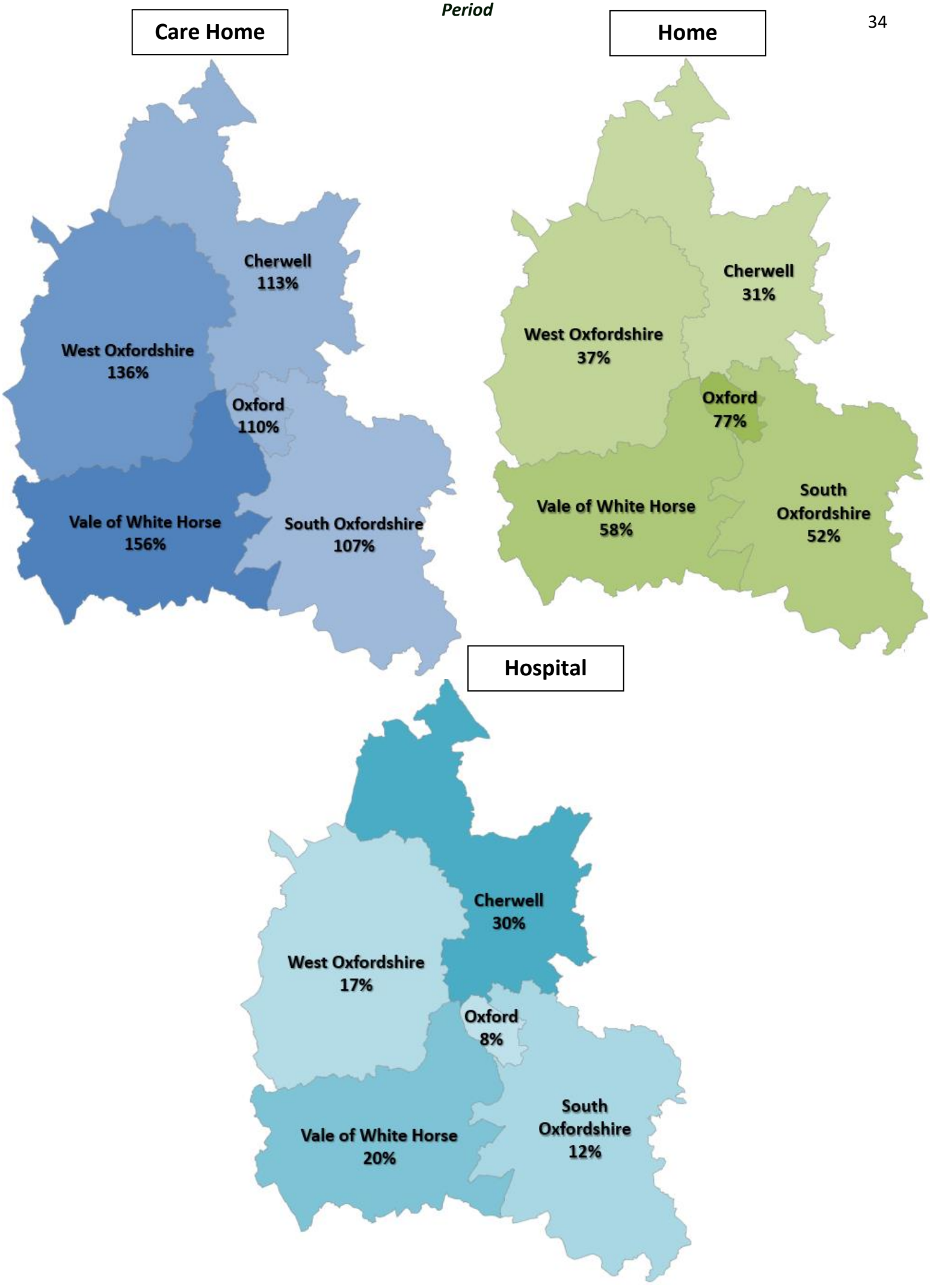
	Care Home	Hospital	Home	Other Communal Establishment	Elsewhere	Hospice
Non-COVID-19 Deaths	456	377	428	15	29	80
COVID-19 Deaths	277	215	23	9	1	1

Figure 3.12 Contribution of COVID-19 to Total Deaths by Area and Place of Death for the Peak Pandemic Period



Further analysis of the place of death (Figure 3.10) show that the majority of excess deaths occurred in care homes (63%) with deaths due to COVID-19 accounting for 61% of deaths (n= 277). Figure 3.13 represents the cumulative P-Scores for deaths occurring in care homes, hospitals and homes in each district. Across all districts in Oxfordshire, the excess mortality in care homes were at least 110% more than the respective historical average, with Vale of White Horse being the worst affected (P-Score 156.1 95% CI 153.5 – 158.7). Oxford was the worst affected in terms of deaths occurring in the home setting, with excess mortality exceeding the historical average by 77.4 % (95% CI 74.6 - 80.2). Deaths occurring in hospital will be evaluated in more detail in Chapter 5.

Figure 3.13: District Cumulative P-Scores by Place of Death for the Peak Pandemic Period



Chapter 4
Discussion

In this study, I sought to describe and critically analyse the excess mortality due to the COVID-19 pandemic in Oxfordshire county and its districts by performing a time-series analysis of excess mortality across the five districts, including the place of death and the contribution of suspected/confirmed COVID-19 as the cause of death. In this chapter, I summarise the main findings from the time-series analysis (Figure 4.1) and interpret this in relation to policy, the indirect effects of the pandemic situation, populations which have been most affected and other mortality measures.

Figure 4.1: Summary of Main Findings

- 3,655 all-cause deaths occurred from weeks 1 to 28 in Oxfordshire, of which 1,878 (51%) occurred during the peak pandemic period (weeks 12-23, 20 March 2020 to 5 June 2020). During this peak pandemic period there were 642 excess deaths of which 526 (82%) were due to COVID-19 (Table 3.1)
- The numbers of COVID-19 deaths were closely aligned with the trajectory of excess mortality over time across all districts, with the peak in COVID-19 deaths for each district following the same trend as excess mortality (Figures 3.1, 3.2 and 3.5)
- Excess mortality across all districts rose rapidly from week 13 onwards, with most districts recovering to the historical average by week 23, except for South Oxfordshire (Figures 3.1 and 3.2)
- Care homes experienced the highest burden of excess deaths for the peak pandemic period (63% of all excess deaths), although COVID-19 as a cause of death only accounted for 38% of total deaths seen in care homes (Figures 3.10 and 3.11)
- For the peak pandemic period, Vale of White Horse experienced the highest excess deaths in Oxfordshire, with excess mortality exceeding the historical threshold by 61% (P-Score 61 95% CI 59.7-62.3) (Table 3.1 and Figure 3.4). The excess mortality seen in Vale of White Horse during this period can be largely attributed to the burden of COVID-19 deaths (84% of excess deaths) and the high number of excess deaths seen its care homes, the worst of all districts in the county (P-Score 156.1 95% CI 153.5 - 158.7) (Figures 3.7 and 3.13)
- Hospitals accounted for 13% of all excess deaths during the pandemic period (Figure 3.10). Excess mortality in this setting occurred over a 4-week period between weeks 14-18 and has fluctuated well-below the historical average since (Figure 3.9)
- All districts except for Oxford saw fluctuations in weekly excess mortality from weeks 9 to 11, prior to the pandemic period, with notable peaks occurring in Vale of White Horse and West Oxfordshire in weeks 11 and 12 and most deaths during these pre-pandemic peaks occurring in care homes (Figures 3.1, 3.2 and 3.9)
- Deaths occurring in the home setting have been greater than the historical average from week 12 onwards and have accounted for 22% of all excess deaths for the pandemic period (Figures 3.9 and 3.10). However, COVID-19 is only mentioned in 5% of these death registrations (n=23) (Figure 3.11)
- Significant excess mortality was still seen between weeks 14-20 even with the exclusion of COVID-19 deaths (Figure 3.8)

Discussion

The trends in excess mortality demonstrated in this research, based on the historical five-year average deaths as the counterfactual, demonstrates the extent of the impact that the COVID-19 pandemic has had both indirectly and directly on deaths. The rapid escalation in excess deaths over weeks 13 to 18 is in stark contrast to the weekly excess mortality rates seen in Oxfordshire prior to the beginning of March.

Policy and timing of deaths

There is evolving evidence that the trajectory of COVID-19 deaths may provide more useful in estimating the effectiveness of non-pharmaceutical interventions, such as lockdown policy measures. Flaxman et. al (77) estimate that the lockdown policies in the UK averted 470,000 deaths as of May 4 2020. However, other modelling estimates suggest that if a lockdown had been instituted up to a week earlier, 20,000 to 30,000 deaths could have been prevented in the UK.(78,79) The trend in weekly excess mortality and COVID-19 mortality observed in Oxfordshire in this study could provide useful insights into understanding this further.

In considering the relationship between deaths and lockdown measures, three factors need to be considered: time from symptom-onset to death, the incubation period of COVID-19 and the delay between death occurrence and registration. A COVID-19 mortality report from Dorigatti et al (80) suggests a mean time from symptom-onset to death of about three weeks, suggesting that the COVID-19 deaths included in this study may have been symptomatic up to three weeks prior to death. Added to this is the incubation period for COVID-19 being between 5 to 14 days.(81) Furthermore, according to the ONS there is a lag of about 5-days on average between death registration and occurrence.(42) Accounting for these three factors suggests that the COVID-19 deaths observed in this study may have occurred up to a week before they were recorded, in individuals who had been infected with COVID-19 up to five weeks before their death. Noting that the peak in COVID-19 deaths occurred in Oxfordshire between weeks 16-18, these may have been individuals who had been infected as early as week 10, three weeks prior to the lockdown. This supports the hypothesis that lockdown measures may

have prevented more deaths had they been instituted earlier. Although highly speculative, these assertions would need to be corroborated with the infection and reproductive rates at the time.

The short-lived surges in weekly excess deaths seen in weeks 9 - 12 occurred mostly in care homes. As cause of death data is not yet available, this could suggest the presence of COVID-19 related deaths prior to the Coronavirus Act being implemented in early March, which regulated COVID-19 being stated as a cause of death certificates, or it may have been due to COVID-19 being underreported due to the delayed response of the UK government's testing strategies. (72,82)

May 11 2020 (week 20) saw the first easing of lockdown measures, with people who were unable to work from home returning to work, unlimited exercise outdoors and allowance of recreation in public spaces and parks.(73) South Oxfordshire saw a second rise in excess deaths from weeks 23-25, which may have been the result of clustering of COVID-19 infections within this district.

The differences in COVID-19 deaths observed between different districts and those with higher rates of excess mortality will need to be examined in further detail for known risk factors of COVID-19 death including age, gender, ethnicity, pre-existing conditions and population density.(83–85) Furthermore, the effects of mortality on areas with lower socio-economic deprivation will need to be fully assessed, especially considering that socioeconomically deprived individuals utilise health and emergency services more frequently than the least deprived and may have been the most adversely affected by reduced healthcare capacity during the pandemic.(86)

The geographical barriers score, a component of the Index of Multiple Deprivation, measures access to services based on road distances to amenities such as a GP surgery or post office.(87) Due its rural nature, most towns in Oxfordshire are below the national average in this score, which may have affected accessibility to healthcare services during the pandemic.(88) The majority of the 407 small towns in Oxfordshire are less disadvantaged than the national average, however, two areas within Oxford (Iffley ward and Northfield Brook ward) are among the most disadvantaged 10% of areas in England.(89) Although my data was limited to the local

authority level, it would be important to assess the impact of the pandemic further looking by examining these rural and most deprived areas.

Contribution of COVID-19 and non-COVID-19 deaths

During the peak pandemic period, 82% of excess deaths were attributed to COVID-19, and the peak in COVID-19 deaths and excess mortality appeared to coincide. This may indicate a strong association between COVID-19 infection and mortality if death registrations at the time are an accurate reflection.

In this study, the indirect mortality effects due to the pandemic situation in Oxfordshire may be evidenced by the elevation in *non-COVID-19* excess deaths relative to the historical average and the 18% of excess deaths that were not caused by COVID-19. These findings are congruent with early evidence on excess mortality for England published by Vandoros.(90) However, most sources agree that comprehensive analysis of non-COVID-19 deaths is premature and should only be performed in a few months to incorporate the longer-term effects of the pandemic and revised death registration data.(42,91) Additionally, since the ONS attributes deaths due to COVID-19 where there was *any* mention of COVID-19 on the death certificate, this may have resulted in less deaths being classified as non-COVID-19 in this study.(34)

Conversely, a possible explanation for the rise in non-COVID-19 excess deaths may be underreporting of COVID-19 deaths, likely due to misdiagnosis or uncertainty where symptoms may have been masked by other conditions such as asthma or diabetes.(42) A number of death registration certificates have been revised in retrospect by certifying practitioners to add COVID-19 as a suspected or confirmed cause of death, which may indicate a degree of uncertainty on the part of certifying practitioners.(42)

During the pandemic, aside from COVID-19-related admissions, the number of patients accessing healthcare, particularly emergency health care services, has reduced drastically worldwide.(92) In this study, hospital mortality was generally well below the historical average apart from the excess deaths observed from weeks 14 to 22 in Oxfordshire. ONS data for England and Wales shows a higher proportion of deaths due to Ischaemic Heart Diseases, Cerebrovascular Diseases and Dementia and Alzheimer disease in care homes, with an overall

reduction in the numbers of deaths due to these causes occurring in hospitals compared to 2019.(93) Additionally, ONS statisticians (93) propose that the increase in excess deaths seen in the home setting, may be linked to the delays in seeking healthcare as an indirect effect of the pandemic situation. Applying this to Oxfordshire, this may be suggested by COVID-19 accounting for only 5% of deaths seen at home during the peak pandemic period, suggesting that deaths due to other causes were occurring in the home setting. The effects of the pandemic on hospital utilisation and mortality is discussed in further detail in the next chapter.

Care Homes

The disproportionate effects of the pandemic on care home excess mortality in Oxfordshire seen in this study is in keeping with data published by Public Health England (PHE) Surveillance.(94) According to PHE, until the week commencing 13 July, 44% of all care homes in England reported confirmed or suspected outbreaks, with Oxfordshire being one of the worst performing authorities in England and the worst in South East England, reporting COVID-19 outbreaks in 75,2% of its 129 care homes.(94) There has been widespread criticism of the handling of the pandemic in Care Homes across England, including the lack of outbreak surveillance and the discharge of potentially infectious patients from hospitals into care homes.(95)

While the NHS adopted a widespread strategy in mid-March of discharging 'medically fit' patients in order to free capacity needed to deal with the pandemic peak, this may have been to the detriment of care home residents.(53) Figures from the National Audit Office indicate that 25,000 patients were discharged from hospitals into care homes between mid-March to mid-April in England, with testing for COVID-19 not being mandatory prior to discharge.(96) This may have contributed to the exponential growth in excess deaths in care homes in Oxfordshire over this period, not only due to COVID-19 infection, but premature discharge from medical care may have played a role in non-COVID-19 deaths as well. Since April 15 2020, the policy has been modified to test all patients being discharged to care homes.(96) In addition to deaths in care homes it would be useful to know the number of deaths of care home residents that took place in hospital in Oxfordshire, since across England 15.5% of hospital deaths were care home residents for the period 2 March to 12 June 2020.(93)

In understanding the true burden of mortality in care homes it is also important to understand the contribution of non-COVID-19 deaths. Underlining the importance of 'indirect' non-COVID-19 deaths is anecdotal evidence from France, where during a care home COVID-19 outbreak, mortality was attributed to multiple confinement-related factors resulting in hypovolaemia rather than COVID-19 itself. Non-COVID-19 factors included: neglect of isolating care home residents by overburdened staff, compromised assistance with food or drink and a lack of physical GP visits.(97) According to my research, almost half of all deaths (n=277) occurring in care homes in Oxfordshire during the pandemic period were not classified as being due to COVID-19, indicating the importance of evaluating these 'indirect' factors.

Adding to the infection burden in care homes, results from the Vivaldi study consisting of 9,081 care homes in England, suggested that infections in staff are a large driver of transmission in care home residents, especially temporary or locum staff, which has supported the Government in its decision to implement an enhanced social care testing strategy of staff in care homes from 3 July 2020.(98,99) The fragmented response from the government during this pandemic with regards to the social care sector has amplified calls for an integrated national health and social care service.(100)

Healthwatch Oxfordshire recently published results of a survey of 123 care homes in Oxfordshire to identify lessons learned from the pandemic experience and areas for improvement.(101) These suggestions include increased support given to care home residents for non-COVID-19 health issues, reviewing pandemic planning protocols, support of allied health services during a pandemic, increased access to Personal Protective Equipment (PPE), creation of a potential staff bank to recruit locum staff and streamlining of information regarding policy changes and epidemiological data to care home management.(101)

Beyond Excess Mortality

Sir David Spiegelhalter's views on mortality have been the subject of much controversy, which speculate that between 5 to 15% of people dying from COVID-19 may have died within a year either way, supported by the fact that COVID-19 mortality risk closely shadows that of the background risk of dying at all ages.(102,103)

These claims are yet to be substantiated on a peer-reviewed platform. Along similar lines, other measures of mortality have been proposed in identifying the true burden of mortality imposed by the COVID-19 pandemic and accounting for life expectancy. One of these are Years of Life lost (YLL), which is based on the age-expectancy of an individual had they not died of COVID-19.(104)

Hanlon et al (105) assessed this in evaluating the YLL measure of COVID-19 deaths in Italy, incorporating the added multimorbidity effects of other pre-existing conditions, and found that YLL was greater than 10 years per person even after adjusting for pre-existing conditions. Bassett et al (106) extended the YLL measure to quantify mortality effects on ethnic minorities aged less than 65 in the USA and found that African Americans and Latino ethnic groups lost significantly more productive years compared to White Americans, despite the affected White American population in the USA being much bigger. Use of YLL may therefore be useful in complimenting and interpreting measures of excess mortality.

Longer-term tracking of excess mortality may reveal a mortality displacement or ‘harvesting’ (seen in previous pandemics and heatwaves), where the most vulnerable populations have died in the first wave of the pandemic, resulting in a decreased population at risk in the coming months and fewer excess deaths.(102) The net effect is unknown to date, but should be analysed in the long-term.

Chapter 5
Excess Mortality and Hospital Utilisation at Oxford University Hospitals NHS Foundation Trust

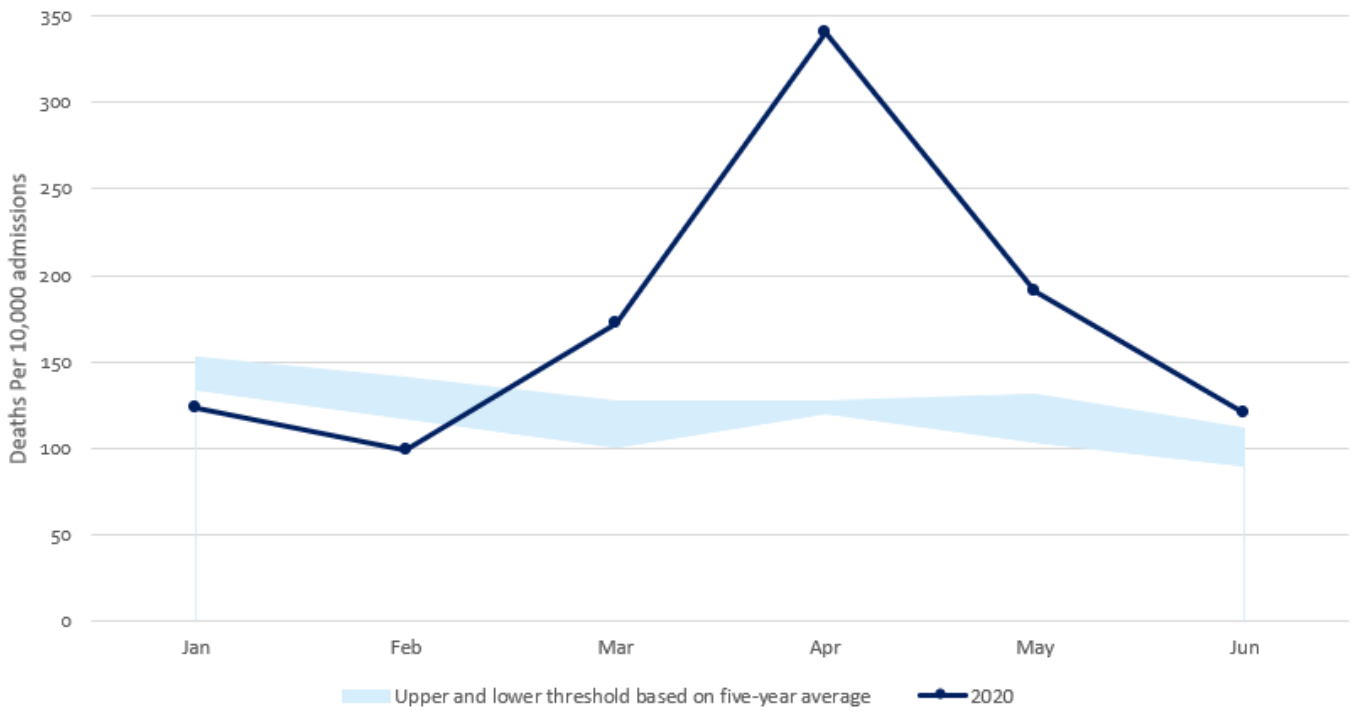
In the previous two chapters, I have described the extent of excess mortality over time in Oxfordshire and its districts using multiple methods and evaluated how excess mortality has differed by place of death and deaths including and excluding COVID-19. In this section I focus on presenting and interpreting the results of excess hospital mortality and hospital utilisation at Oxford University Hospitals NHS Foundation Trust (OUH), the largest provider of acute health care services in Oxfordshire, in order to evaluate the indirect and direct effects of the COVID-19 pandemic situation on this county.

Results of inpatient excess all-cause mortality rates are presented in Table 5.1 and Figure 5.1. For the 6-month period from January to June 2020 there were a total of 1,240 all-cause deaths (Table 5.1). The monthly trend of mortality is represented in the form of an excess mortality rate per 10,000 admissions (Table 5.1, Figure 5.1), indicating mortality rates moving above the expected average from March onwards with a peak in excess mortality rates in April (217 excess deaths per 10,000 admissions).

Table 5.1: Summary of Current and Historical Hospital Mortality and Admissions at OUH

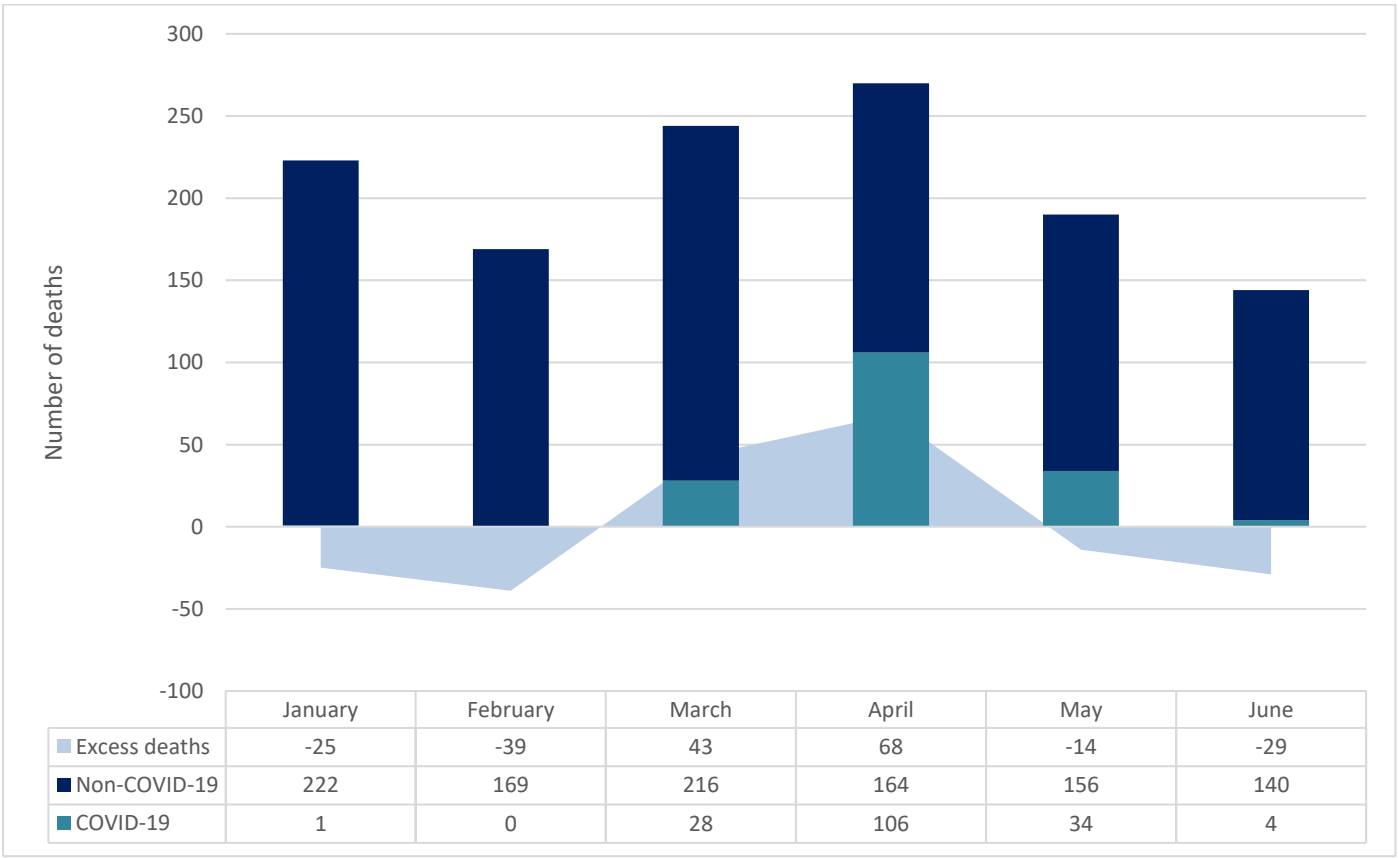
	Historical deaths					2020 deaths	Historical admissions					2020 admissions	Five-year average deaths per 10,000 admissions	Excess deaths per 10,000 admissions
	2015	2016	2017	2018	2019		2015	2016	2017	2018	2019			
Jan	265	219	239	270	247	223	16,960	16,429	17,265	17,598	18,392	18,103	143	-20
Feb	179	203	238	210	211	169	15,783	16,570	15,976	15,846	16,760	17,191	129	-30
Mar	200	221	205	215	164	244	17,862	17,223	18,340	16,964	18,139	14,157	114	59
Apr	199	212	199	197	204	270	15,738	16,748	15,727	16,736	16,808	7,931	124	217
May	221	228	196	172	201	190	16,416	17,583	17,850	17,897	17,626	9,980	117	74
Jun	182	170	144	170	197	144	17,260	17,158	17,690	16,826	16,940	12,190	101	17

Figure 5.1 Oxford University Hospitals Monthly Deaths per 10,000 Admissions Compared to the Forecasted Upper and Lower Limits (95% CI) of the Historical Average



Assessment of the contribution of COVID-19 to overall excess deaths (Figure 5.2) indicates that the number of deaths due to COVID-19 were highest in April (106 deaths), which coincides with the highest excess mortality rate for the same month as well.

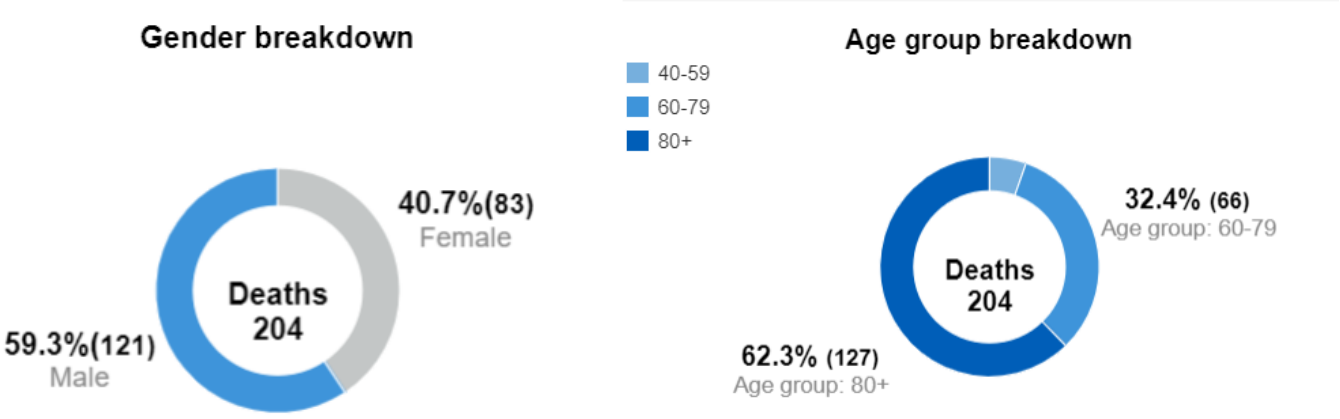
Figure 5.2 Contribution of COVID-19 to Monthly Deaths and Excess Deaths at OUH



	January	February	March	April	May	June
Excess deaths	-25	-39	43	68	-14	-29
Non-COVID-19	222	169	216	164	156	140
COVID-19	1	0	28	106	34	4

The following results for a breakdown of age and gender for the 204 COVID-19 deaths occurring in hospitals in Oxfordshire as of 28 July 2020 were obtained from the NHS COVID-19 Mortality Dashboard and Analytics Hub (Figure 5.3).(107) This data provides preliminary evidence that mortality due to COVID-19 is increased in older age groups and males as seen in other settings.

Figure 5.3 Age and Gender Breakdown of COVID-19 Hospital Deaths Occurring in Oxfordshire



Source: NHS COVID-19 Mortality Dashboard and Analytics Hub(107)

A&E attendance and emergency admissions

There was a marked decrease in A&E attendance between March to June compared to the previous 5 years, with a reduction in A&E attendance by roughly half in April (Figure 5.4, Table 5.2). Emergency admissions data was only captured by OUH from 2016 onwards. The monthly trends are demonstrated in Figures 5.4 and 5.5.

Table 5.2 Change in A&E attendance and Admissions Compared to Historical Averages

	% change in A&E attendance from 2015-2019 average for the same month	*% change in Emergency admissions from 2016-2019 average for the same month*
January	***11***	***15***
February	***13***	***15***
March	***-20***	***-13***
April	***-46***	***-39***
May	***-26***	***-19***
June	***-19***	***-5***

Figure 5.4 Monthly A&E Attendance at OUH from January to June 2015-2019

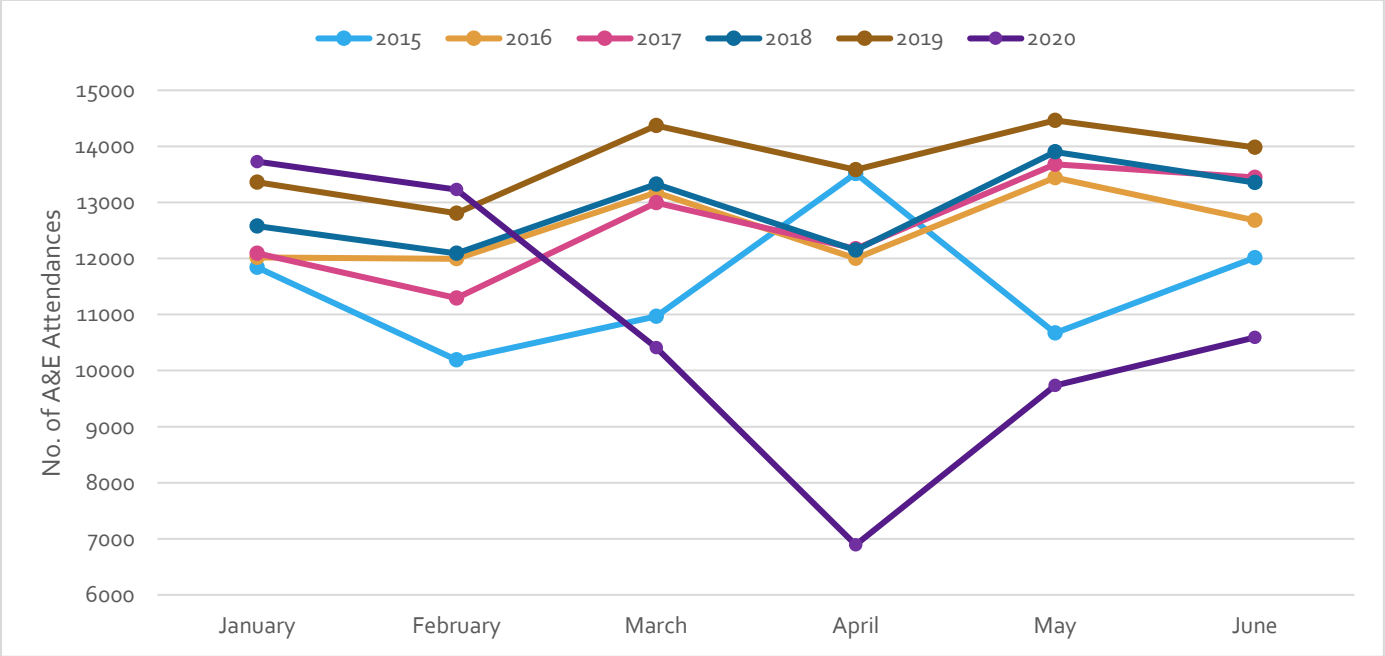


Figure 5.5 Monthly Emergency admissions at OUH from January to June 2015-2020

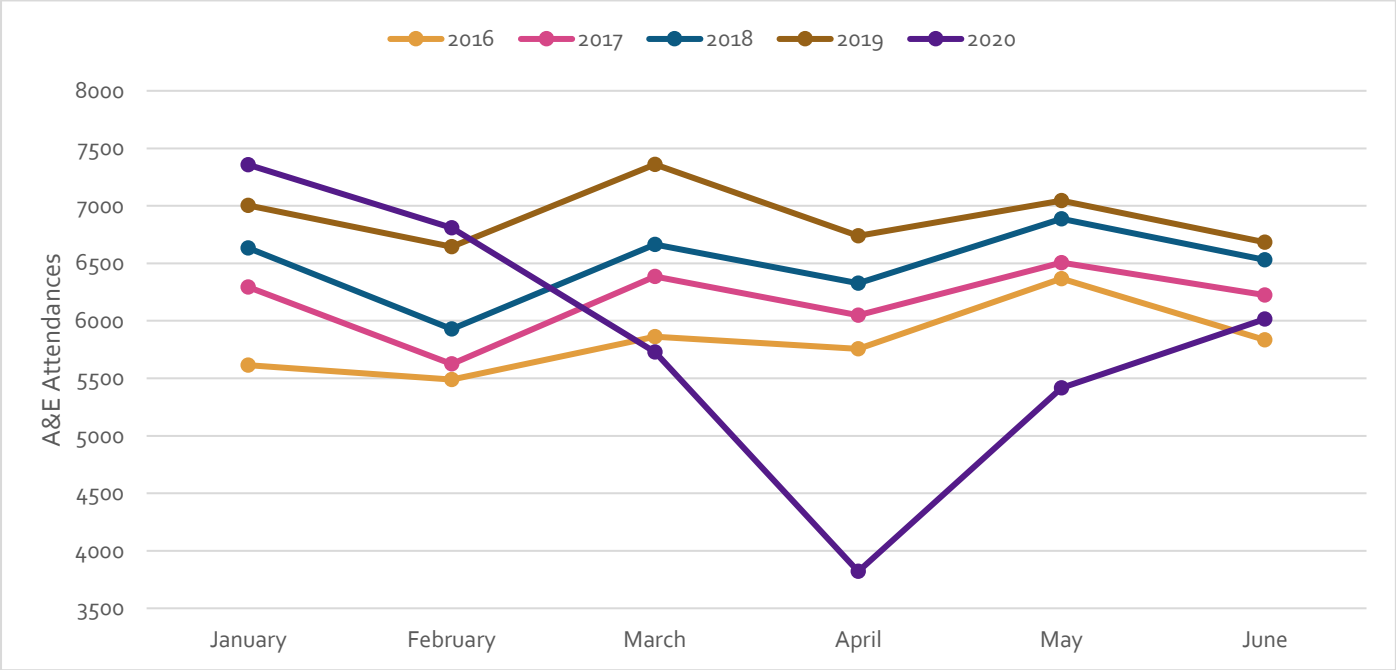
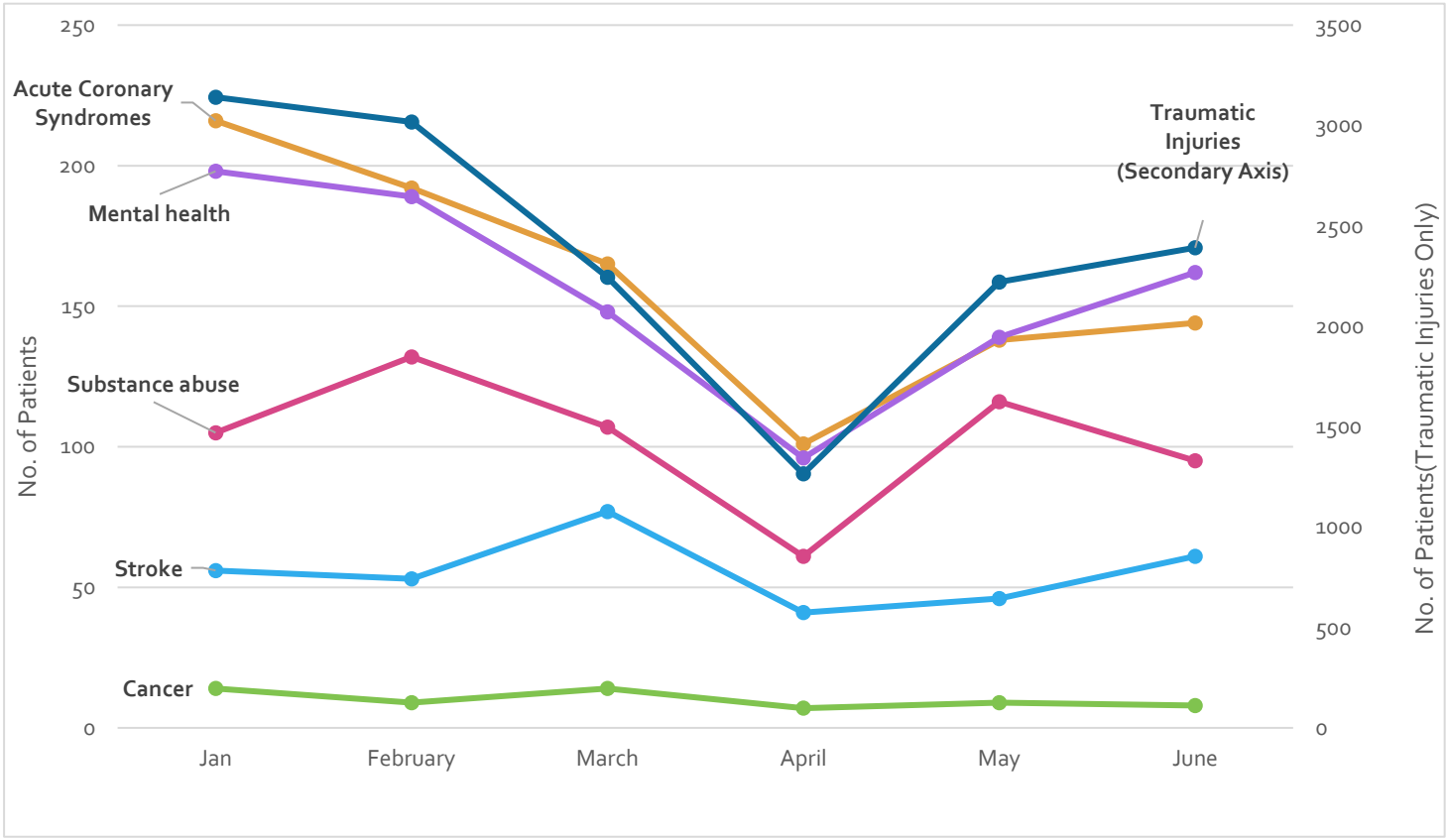


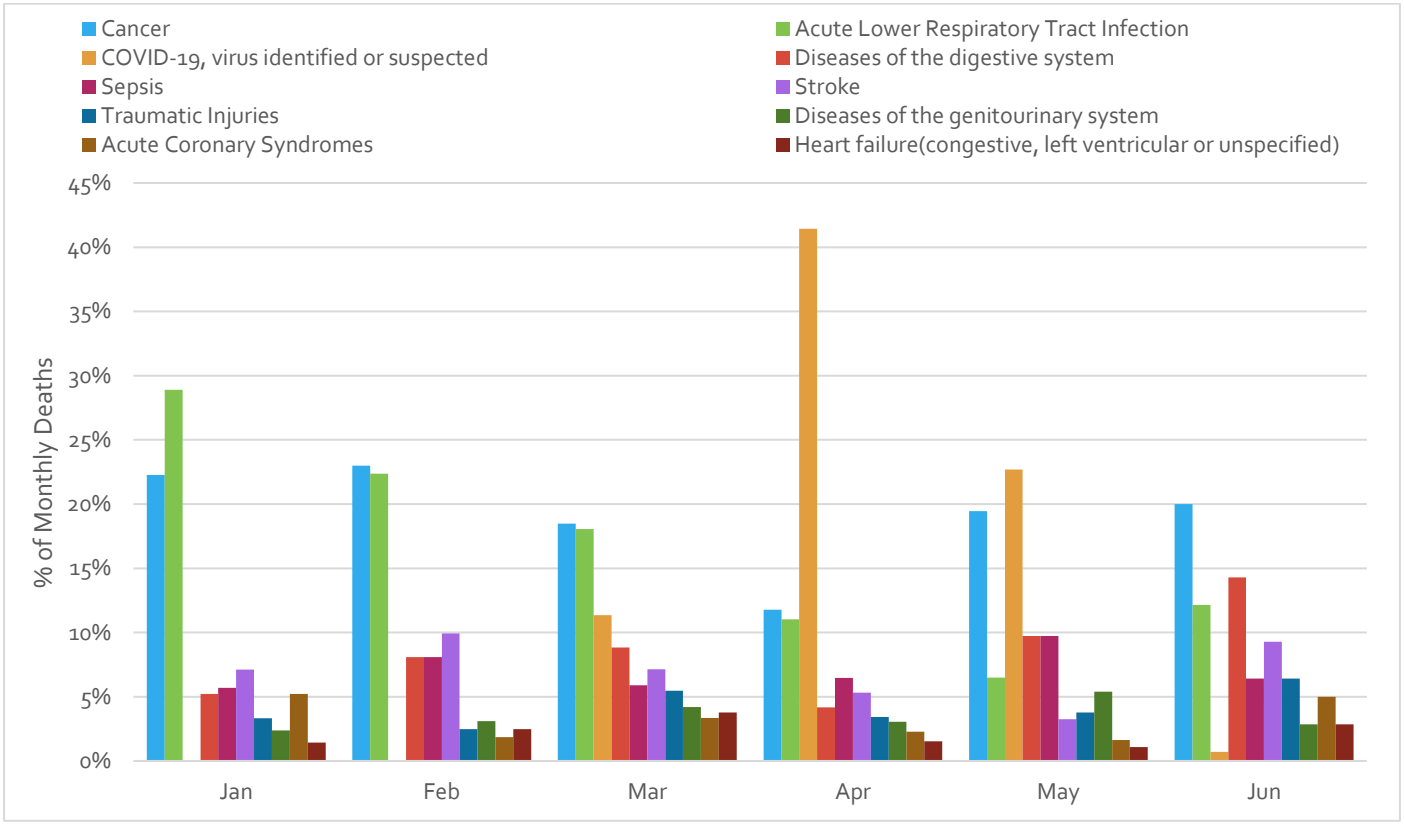
Figure 5.6 represents monthly A&E attendances for specific conditions at OUH, using the patient's primary diagnosis in A&E as the reason for attendance. Patients presenting to A&E due to mental health reasons, traumatic injuries, acute coronary syndromes (ACS) and substance abuse saw a steady decline from February to April, while patients presenting with cancer and stroke symptoms saw minimal fluctuations over the 6 months.

Figure 5.6 Conditions presenting to OUH A&E from January to June 2020



Main causes of inpatient excess deaths

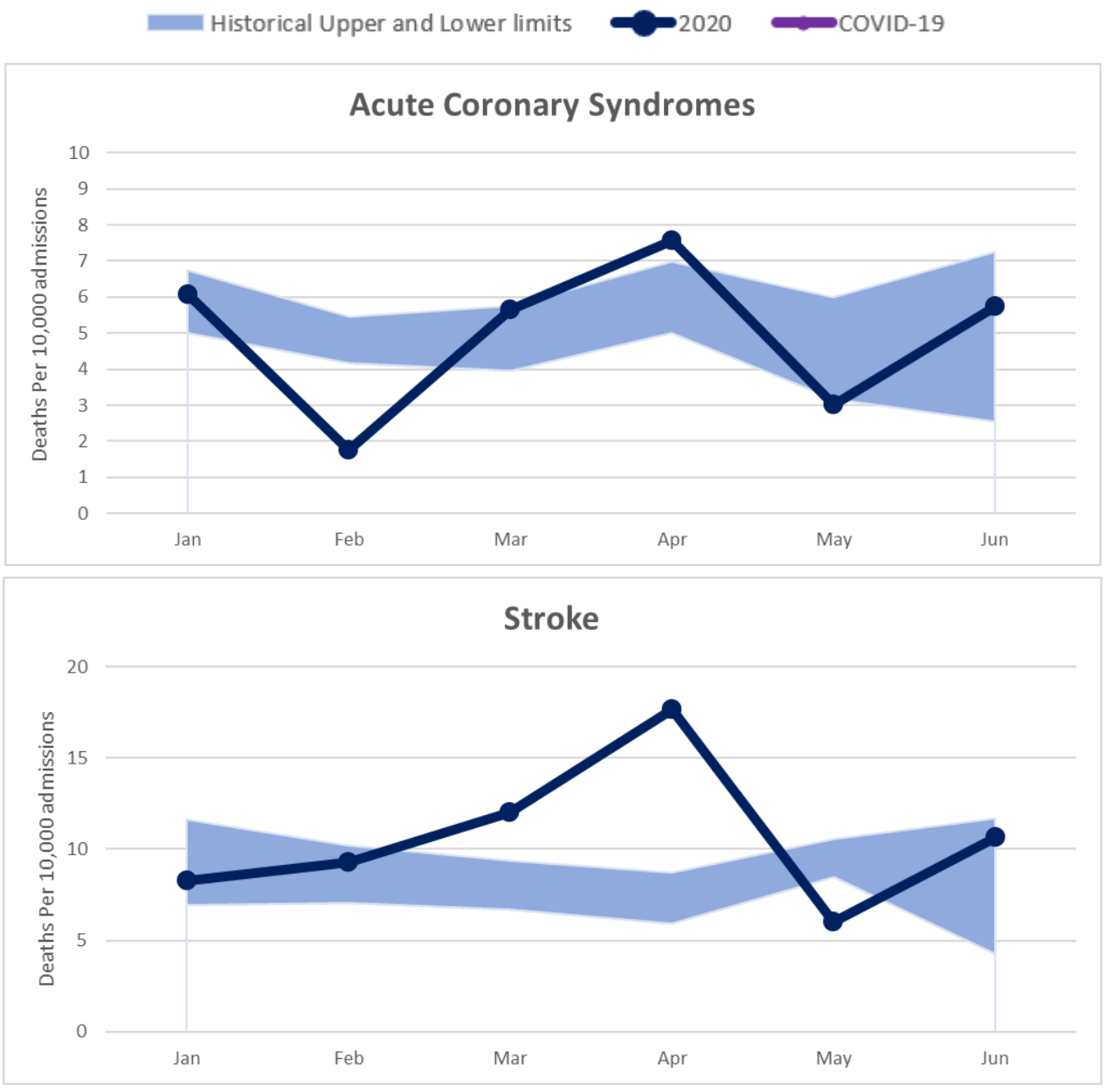
Figure 5.7: Top Ten Causes of Monthly Deaths for Patients who Died from January to June 2020 Shown as a Percentage of Total Monthly Deaths

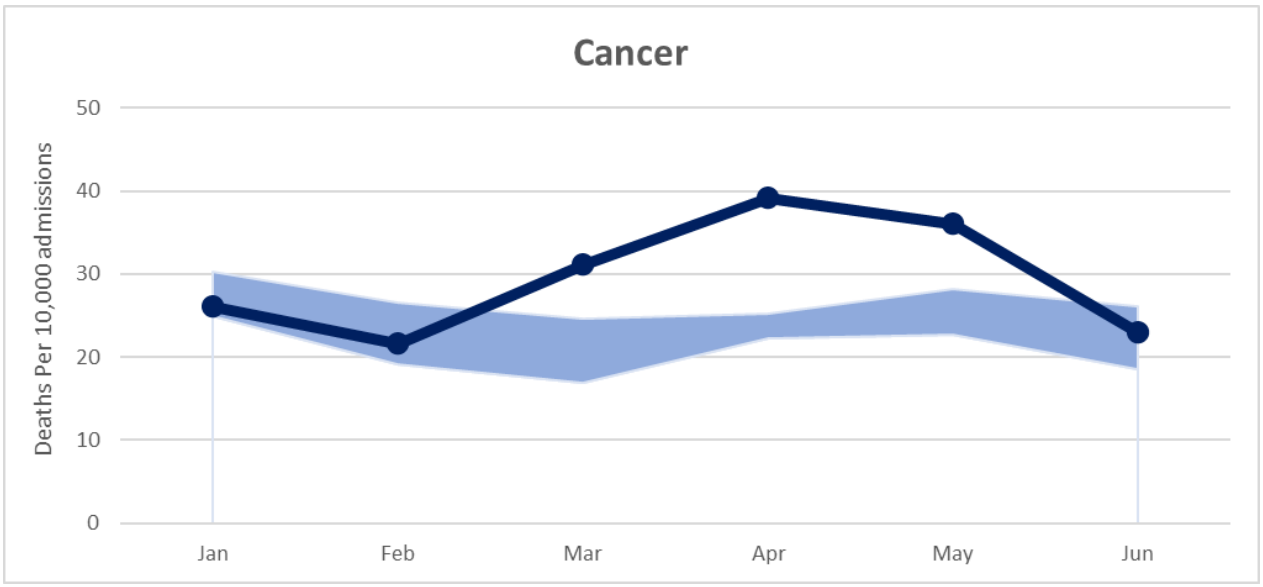


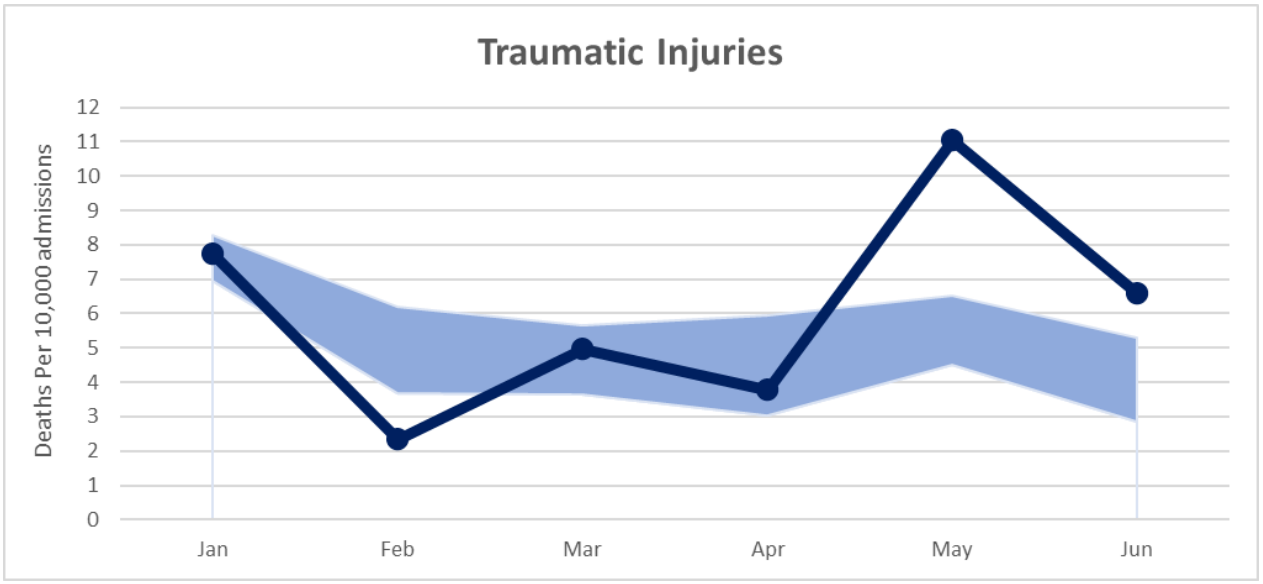
A review of inpatient deaths from January to June 2020 and their primary diagnoses at death (Figure 5.7) demonstrates a peak in deaths due to COVID-19 in April with a reciprocal decrease in deaths due to non-COVID-19 acute lower respiratory tract infections (LRTI) in April and May.

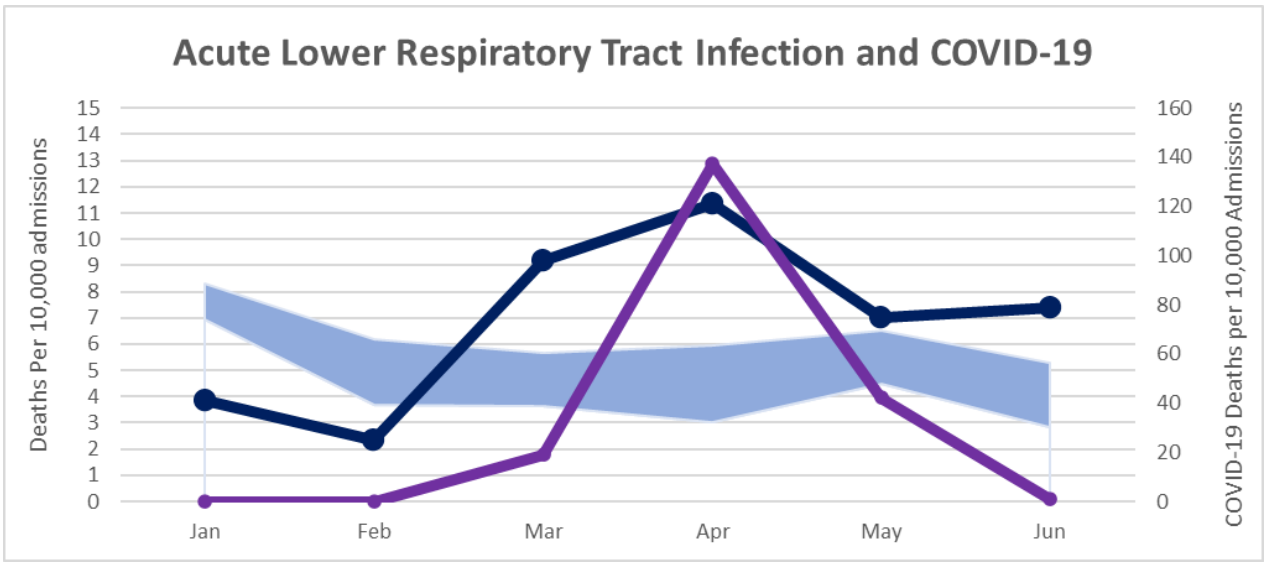
Computation of cause-specific excess deaths per 10,000 admissions compared to the five-year historical average (with 95% CI used to represent the range around the average) are presented in Figure 5.8 for deaths due to traumatic injuries, stroke, ACS, acute LRTI, COVID-19 and cancer.

Figure 5.8 Cause-specific Inpatient Deaths per 10,000 Admissions Compared to the Five-Year Historical Average









There is a decrease in deaths due to ACS during February and a small number of excess deaths seen in April. There is also a large increase in deaths above the historical average due to stroke in March and April. Excess mortality due to traumatic injuries is seen in May and June. In 2020, these traumatic injuries mainly

included traumatic head injuries and lower limb fractures. Excess deaths due to Acute LRTI are below the expected values during January and February, are seen to peak in April and remain above the expected values until June. At the same time, deaths due to COVID-19 (secondary axis) far exceed deaths due to acute LRTI from March to May. Eighteen percent of acute LRTI deaths stated aspiration pneumonia as the primary diagnosis. While using the primary diagnosis at death to estimate the excess mortality provides useful insights, these results may differ considerably when using cause of death information directly from the deceased's death certificate, which was not a feasible option at the time of research due to ethical and time considerations.

Discussion

According to the Public Health England Emergency Department Syndromic Surveillance System (EDSSS) A&E attendance dropped by 25% in the first week of lockdown (week 13 - week ending 23 March) compared to the previous week.(108) The same phenomenon has been observed at OUH, with dramatic reductions in A&E attendances in March and April that have not yet fully recovered to pre-pandemic levels (Table 5.2, Figure 5.4). Such changes in emergency care utilization due to the pandemic situation may have resulted in collateral damage in the form of excess deaths due to treatable emergency conditions and delays in seeking care.

The root cause of excess deaths in the acute hospital setting can be viewed as two-fold: due to behavioural factors in delaying access to health care and delays in receiving diagnosis and treatment within health facilities.(109,110) In terms of behavioural factors, hospitals are known to be avoided due to fear of contracting the virus and not wanting to overwhelm hospital capacity.(109) In England, the panic and fear surrounding COVID-19 was widespread in the media from late February as the virus overwhelmed Italy, with a focus in media headlines in the following weeks being on the NHS frontline role in freeing up capacity in a bid to prepare for the worst case scenario.(111) In terms of delays encountered once in the hospital, these can be attributed to overwhelmed emergency service resources and staff during the pandemic peaks and the added time taken in following strict infection control measures.(110)

Reductions in accessing emergency care have been well-documented for cases of ACS and stroke in China, Spain, Austria, Italy and the USA.(112–116) The largest wide-scale study of ACS cases presenting to A&E across England, found that admissions for ACS dropped by 40% for the month of March compared to a similar period in 2019, and by the end of May returned to 16% less than 2019 levels.(117) A similar trend is observed at OUH, with ACS presentations to A&E dropping in April to less than half of January figures, with a slow recovery back to pre-pandemic levels from May onwards (Figure 5.6).

The widespread closure of health facilities and the postponement of routine outpatient appointments, cancer and other chronic disease treatments may have contributed to a large number of indirect deaths during the pandemic period and is expected to have unintended long-term consequences (21,40) There is limited evidence to support this from an ONS analysis of non-COVID-19 deaths until 1 May in England and Wales, which shows that deaths due to both cancer and renal failure had reduced in hospital and started to increase in the home setting and 'elsewhere' category.(42)

The excess inpatient mortality seen in patients with stroke (March to April), cancer (March to May) and ACS (April) compared to historical averages may be indicative of patients suffering from these conditions seeking healthcare later in more advanced stages of illness and/or the end-result of reduced outpatient care. To fully assess this claim, cause of death on death certification would be required as well as secondary diagnoses. If these conditions truly present less during these months, one may expect to see an increase in non-COVID-19 deaths outside of hospital for the relevant months, which is suggested in the increase in non-COVID-19 excess deaths seen in the home setting in Oxfordshire, represented in figures 3.9 and 3.12 in chapter 3. Furthermore, it would be useful to corroborate the A&E utilisation data with the ambulance service callouts and calls to NHS 111.

There are a multitude of indirect consequences on mortality and morbidity because of the pandemic that are difficult to quantify. The strict lockdown period from 23 March 2020 resulted in less motor vehicles on roads and strict social distancing, which meant halting educational activities, introduction of remote working and disruption to most physical labour occupations. As a result, cases of injuries were reduced, with a regional trauma centre in the UK seeing a 53% reduction in orthopaedic trauma admissions during

the first two weeks of the lockdown compared to the same period in 2019.(118) The same phenomenon is observed in traumatic injuries presenting to A&E at OUH, with less than half of these cases presenting to A&E than in January or February 2020 (Figure 5.6).

However, owing to the increased time at home, the number of 'DIY' injuries increased as well as mental health issues such as stress, anxiety, and depression throughout the UK.(119–121) The National Domestic Abuse Helpline saw calls increase 49% higher than average three weeks into lockdown, and the Counting Dead Women Project recorded 16 domestic-violence related deaths within the first three weeks of the UK lockdown as compared to previous year's averages of two deaths per week.(122,123) This has been part of a universal phenomenon in which domestic abuse hotlines and emergency calls have increased exponentially during the lockdown periods for respective countries, with the United Nations naming it a 'Shadow Pandemic'.(124)

According to the ONS, deaths due to suicide, drugs or violence take longer to be registered and for this reason may not be reflected in short-term excess death counts.(42) In these cases, hospital data may provide a useful tool in assessing the burden of excess mortality attributable to these conditions. However, it was not possible to accurately describe mortality due to substance abuse, violence, or mental health in this research due to secondary diagnosis and death certificate data not being available.

While the study results are only for the time period until June 2020, the true impact of the pandemic and its contribution to excess mortality will only reveal itself in future months as patients who were previously reluctant to seek health care or had procedures and appointments postponed now start to re-enter the healthcare system. Conditions where death registrations may require coroner referral (such as suicides) take longer to be registered and will only be reflected in future death registration data. Consequently, these estimates will need to be reviewed after a longer period to understand the full impact of the pandemic on excess mortality and specific conditions.

Chapter 6
Conclusion

Strengths and Contributions of the Study

To my knowledge, this is the first study examining excess mortality at the county and local authority level in England. In addition, it is one of the few studies to corroborate this data with local hospital trends in utilisation and mortality. The majority of excess mortality research in England to date has been at the national level and focused on drawing national comparisons or in forecasting deaths as opposed to the retrospective analysis done in this research. (24,37) Another strength of this research is the length of the time period over which excess mortality was observed; very few international studies have assessed weekly excess mortality trends over the 6 month period at a local authority level to assess the mid-term impact of the COVID-19 pandemic.

While most excess mortality research published in the past has been statistically complex and challenging to reproduce, this study presents the simplest and accessible methodology for assessing excess mortality through the use of vital registry data during a pandemic. These methods are applicable to all settings, including crisis and low-resourced contexts where vital registry data may be limited. The limitations in the availability of death registry data encountered at the county or district level in England during the pandemic bear some similarities to the limitations of deaths data encountered in less-resourced contexts as reported by my colleagues. However, this study demonstrates that both excess mortality rates (using crude mortality rates) and P-Scores can be reliably computed with mid-year population estimates and monthly or weekly deaths data.

By examining excess mortality across areas and their contributory factors, this type of research and analysis has the potential to provide policy and decision-makers with a succinct snapshot of the true toll of a pandemic. Both the excess mortality rate and P-Score methods provide easy to understand measures, although P-Scores are more useful for drawing comparisons between areas and lend to more impactful visualisations. Following on from this research, it would be interesting to draw comparisons between

different regions in England, accounting for the differences in demographic factors such as population density and the effects of differences in regional and local policies.

This study was able to quantify the excess mortality for the first wave of the pandemic, identify the worst-off areas and provide a comprehensive break down by place of death. In doing so, the disproportionate effect of the pandemic on care home mortality was quantified, which is important to understand so that areas for improvement by local stakeholders can be identified and actioned for the future. While I did not intend to evaluate the direct effects of lockdown or policy measures on the burden of infection or excess mortality in Oxfordshire, the trends over time may suggest a relationship between the peak of excess deaths and the timing of individuals being infected. This provides useful insights for any further research carried out in the area and could be used in conjunction with surveillance mechanisms to identify areas at high risk.

Limitations and Challenges

There are several limitations which require consideration. Firstly, despite significant efforts at obtaining more granular data, I was only able to obtain a single dataset of five-year weekly death averages for each district for the period 2015-2019. Not having the data available by year precluded the calculation of a historical range of expected deaths, as is custom with most other excess mortality studies. Furthermore, I was not able to include cause of death, age, or sex, as this data is not yet available. Stratification of 2020 deaths by age and sex would have allowed for age-standardised mortality rates to be calculated. This may have the implication that excess mortality rates presented in this research are likely to have been overestimated in districts with older population structures compared to those with younger age structures. In order to understand the full spectrum of impact of the pandemic on care homes it would have been useful to know care home population estimates for each district, however, after multiple enquiries, it was found that this data does not exist.

Regarding OUH deaths data, I used the ICD-10 code of the primary diagnosis at death to attribute cause of death (due to reasons explained in Chapter 3), which may differ from the cause of death stated on the

death certificate. I grouped these ICD-10 codes into broader categories to enable further analysis and in doing so may have excluded a small number of deaths which were not included in the ICD coding scheme. Secondly the A&E attendance data used for this analysis is limited in that the diagnosis in A&E, made at the discretion of the treating clinician, may not be reflective of the patient's final diagnosis. Moreover, there may be overlap between certain conditions such as those contributing to both mental health and substance abuse issues.

The ONS death registration data used for the primary analysis were from weekly provisional datasets released 11 days after the week ends. These were subject to weekly revision, depending on health care practitioners revising their cause of death and results from post-mortem examinations for deaths referred to the coroner. To ensure that the most up-to-date dataset was used, I constantly cross-checked and revised my dataset until the latest possible release prior to dissertation submission – the week ending 10 July 2020. Since there is an average 5-day lag from death occurrence to death registration noted by the ONS, the results for week 28 (the last week in my dataset) are to be interpreted with the caveat that this may not include all deaths for this week and that across all time periods, deaths referred to the coroner may not yet be reflected.(42)

I had intended to include data on demographic factors across the districts and examine their relationship to excess mortality. However, the last census data available was from 2011 and data on the other variables lacked the granularity to perform further statistical analyses. Furthermore, I attempted a negative binomial regression to quantify the differences in mortality rates between different districts and time periods, although I have not included this in my formal analysis. I have attached a summary of this data in Appendix A.

Summary

By critically analysing the time-trend in excess mortality in Oxfordshire and its districts during the unprecedented COVID-19 pandemic period, this study showed that 642 excess deaths occurred during the peak pandemic period (weeks 12-23), with 82% of these deaths being due to suspected or confirmed COVID-19. Vale of White Horse experienced the highest excess mortality of all districts in Oxfordshire as well as the highest excess mortality in care homes. Care homes accounted for the largest proportion (62%) of all excess deaths during the pandemic period, providing evidence of a neglected social care sector during the pandemic. While the number of COVID-19 deaths were closely related to the peaks in excess mortality seen across the districts, the contribution of non-COVID-19 deaths to overall mortality was also evident.

In addition, an analysis of A&E attendance and in-hospital mortality data revealed that while in-hospital excess mortality remained elevated from March to June, there has been a substantial decrease in A&E attendances for the same months to below the five-year average. This points towards the fact that deaths may be occurring more outside the hospital setting.

This research contributes to the growing evidence on the usefulness of the excess mortality measure in demonstrating the full impact of the COVID-19 pandemic and in demonstrating its usefulness and accessibility for both decision-makers and lay-people. The findings further the understanding of the true scale of the COVID-19 pandemic for a county in England, that extends beyond just the impact from COVID-19 infection alone and offers valuable insights in preparing for a second wave and what might be expected in the healthcare setting as the long-term consequences of the pandemic.

Expansion of the research accounting for demographic factors and age-standardisation will allow for enhanced understanding of the differences in excess mortality between districts. While this study provides a snapshot of excess mortality for the first 28 weeks of 2020, the net effect of pandemic measures and mortality displacement will need to be fully analysed over a longer period as the ONS vital registry data is revised.

Appendix

In this section I include supplementary analyses which I started during the course of my research but were not sufficiently informative to include within the main content.

Assessing the influence of population size, area of death and time across the districts in Oxfordshire using a multivariate regression model

A Poisson regression model was selected to model for the effects of time and area and on mortality rates, accounting for population size. Univariable and multivariable analyses were performed, yielding crude and adjusted mortality rate ratios.

Selection of model:

A Poisson regression was chosen as opposed to logistic regression to account for the differences in population size across districts. Overdispersion of data was confirmed using the 'dispersiontest' function from the AER package in R (125), which eliminated use of the standard poisson model. Two options for modelling the overdispersed count data were Quasipoisson or negative binomial regression. A goodness of fit chi-squared test (using the residual deviance) were calculated for each of these models. Based on these results, a negative binomial model was chosen (Table A.1).

Table A.1: Results of Goodness of Fit Testing

	Residual Deviance	Residual Degrees of Freedom	P-value	AIC
Negative Binomial	106.69	109	0.38	859.56
Quasipoisson	587.12	103	<0.001	N/A(126)

Selection of variables:

Selection of predictor variables were performed by a stepwise method of likelihood ratio tests, dependent on how they improved the log likelihood of the model, using the existing ONS death registration dataset. Likelihood ratio testing for 'Week' provided significant evidence for a quadratic exposure effect and was

therefore included in the model. Likelihood ratio testing provided significant evidence against including the interactions between area and Time-period in the model.

A negative binomial regression model was selected to model for the effects of time, area and on mortality rates, accounting for population size for the peak pandemic period (weeks 12-23). Univariable and multivariable analyses were performed, yielding crude and adjusted mortality rate ratios. The results are presented in Table A.2.

Table A.2 Univariable and multivariable analysis to assess the effects of time period, area and week on mortality rates

** p<0.01 ***p<0.001

	Mortality rate ratio(MRR)	
	Crude MRR (95% CI)	Adjusted MRR (95% CI)
Area		
Oxford	**1,00(REF)**	**1,00(REF)**
Cherwell	1,27(1.08-1,50)**	1,25(1.08-1,45)**
South Oxfordshire	1,28(1.09-1,51)**	1,27(1.09-1.47)**
Vale of White Horse	1,26(1.07-1,48)**	1,23(1,06-1,43)**
West Oxfordshire	1,55(1,31-1.82)***	1,53(1,32-1,77)***
Time period		
2015-2019	**1,00(REF)**	**1,00(REF)**
2020	1,39(1.26-1,54)***	1,36(1,24-1.49)***
Week		
Week(linear)	1.06(1.03-1.09)***	1.05(1.02-1.08)***
Week(quadratic)	0.998(0.997-0.999)***	0.998(0.997-0.999)***

Mortality rates were 36% higher in 2020 in Oxfordshire compared to previous 5 years (Adjusted MRR 1,36 CI 1,24-1.49 p<0.001). Among the five districts, mortality rates in Cherwell, South Oxfordshire, Vale of White Horse and West Oxfordshire were all higher than Oxford City, with West Oxfordshire having a 55% higher mortality rate compared to Oxford City (Adjusted MRR 1,53 CI 1,32-1,77 $p < 0.001$). The 95% Confidence Intervals for each district are mostly overlapping, suggesting that they have similar increased risk compared to Oxford City. The influence of increasing week in both the univariable and multivariable analyses indicated a small decrease in mortality as the weeks progressed and were statistically significant (0.998 CI 0.997-0.999) $p < 0.001$). Likelihood ratio testing provided significant evidence against including the interactions between area and time-period in the model as well as population density.

Influence of Demographic Factors

I would have liked to include variables for black and ethnic minority (BAME) populations, income deprivation scores and population density as these have been identified as potential risk factors for COVID-19 severity. In addition, because I was not able to obtain death registration data stratified by age, I collected data on the median age and the total population over the age of 65 for each district. However, the granular data for each of these variables was not available for the purposes of further statistical analysis and correlation tests with existing data were low. I have summarised the data on some of these variables in table A.3 along with the P-Scores from my research.

Table A.3 Demographic factors

	Mid- 2019 Population density (people per km^2)	Median age	% Total population over age 65	% BAME of total population	P-Score for pandemic period (95% CI)
Oxford	256	29	13	22.3	**51.4 (50.1-52.8)**
Cherwell	3314	41	18	7.8	**54.0 (52.8-55.1)**
Vale of White Horse	209	44	20	5.1	**61.0 (59.7-62.3)**
South Oxfordshire	235	43	21	3.9	**41.4 (40.2-42.5)**
West Oxfordshire	155	48	22	3.2	**52.7 (51.5-54)**

Source: (127,128)

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