Hazelinks

Medicare Benefits Schedule and Pharmaceutical Benefits Scheme data: Time Series Analyses

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Abbreviations and key terms

ACE	Angiotensin Converting Enzyme
ATC	Anatomical Therapeutic Chemical classification
CSIRO	Commonwealth Scientific and Industrial Research Organisation
DHS	Commonwealth Department of Human Services
EREC	External Request Evaluation Committee
GLM	Generalised linear model
GP	General Practitioner
MBS	Medicare Benefits Schedule
Mine fire period	The 30-day period from 9 February to 10 March 2014 when the modelled daily $PM_{2.5}$ concentration, averaged across the Latrobe Valley SA3 area, exceeded 1µg/m^3
PBS	Pharmaceutical Benefits Scheme
$PM_{2.5}$	Particulate matter with an aerodynamic diameter of 2.5 micrometres (thousandths of a millimetre) or less
PM_{10}	Particulate matter with an aerodynamic diameter of 10 micrometres (thousandths of a millimetre) or less
RR	Relative Risk
SA	Statistical area level
95% CI	95% Confidence Interval

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1. Executive Summary

From 9 February 2014, smoke and ash from a fire in the Morwell open cut brown coal mine adjacent to the Hazelwood power station covered parts of the Latrobe Valley, eastern Victoria, for up to 6 weeks. In response, the Hazelwood Health Study was established in order to monitor any long-term health effects of that smoke event. This report describes analyses undertaken by the Hazelwood Health Study's Hazelinks Stream, examining whether mine fire-related air pollutants were associated with increased use of health services and medications for cardiovascular diseases, respiratory diseases and mental health/psychiatric conditions in the Latrobe Valley area during the mine fire period. The analyses utilised daily concentrations of mine fire-related air particulate matter smaller than 2.5 thousandths of a millimetre in diameter ($PM_{2.5}$) modelled by the Commonwealth Scientific and Industrial Research Organisation (CSIRO) Oceans & Atmosphere. For this report, the "mine fire period" was defined as the 30-day period from 9 February to 10 March 2004.

Daily counts of health service visits were derived from Medicare Benefits Schedule (MBS) data for the period July 2012 to June 2016, based on date of service for general practice (GP) consultations and date of referral for specialist attendances, diagnostic procedures, investigations and diagnostic imaging services. Daily counts of prescription medications dispensed by pharmacies were derived from Pharmaceutical Benefits Scheme (PBS) data for the period January 2013 to December 2016. Time series statistical models were used to assess the associations between daily mine fire-related $PM_{2.5}$ and health service use or medications dispensed, after controlling for seasonality, long-term temporal trends, day of the week, maximum ambient temperature and public holidays.

The analyses showed clear evidence that mine fire-related $PM_{2.5}$ was significantly associated with increased medical service utilisation. Specifically, increased short and long GP consultations were observed after a lag of 4-5 days exposure. Increased respiratory service visits were observed after a lag of 7 days exposure and increased mental health/psychiatric consultations were observed after a lag of 15 days exposure. There was no increase observed in cardiovascular service visits. Further, mine fire-related $PM_{2.5}$ was significantly associated with increased dispensing of all examined medication types (cardiovascular, respiratory and mental health) after a lag of 3 days exposure.

During the mine fire period, and for each 10 μg/m^3 increase in mine fire-related $PM_{2.5}$, the estimated percentage increases in health service visits were 37% for visits by men to respiratory services, 32% for visits by men to mental health services, 10% for visits by men and women combined for short GP consultations and 17% for visits by men and women combined for long GP consultations. During the mine fire period, there were 3,274 short or long GP consultations and 159 respiratory service visits attributable to mine fire-related $PM_{2.5}$ exposure in the Latrobe Valley. Correspondingly, the attributable fractions were 4% and 8% respectively.

During the mine fire period, and for each 10 $\mu g/m^3$ increase in mine fire-related $PM_{2.5}$, the estimated percentage increases in medications dispensed for men and women combined were 25% for respiratory medications, 12% for mental health medications and 10% for cardiovascular medications. Among medications dispensed during the mine fire period, there were 2,093 cardiovascular, 890 respiratory and 1,053 mental health medications attributable to mine fire-related $PM_{2.5}$ exposure. Correspondingly, the attributable fractions were 5%, 11% and 6% respectively.

This study should be helpful to develop and implement effective and timelier adaptive strategies to mitigate cardiovascular, respiratory and mental health risks due to possible future coal mine fire derived air pollution exposure in the community.

2. Introduction

On 9 February 2014, the Morwell open cut brown coal mine adjacent to the Hazelwood power station in the Latrobe Valley, eastern Victoria, caught fire resulting in nearby areas being covered in plumes of smoke and ash over a six-week period. Subsequently, a Monash University-led consortium of researchers was contracted by the Victorian Department of Health and Human Services to undertake the Hazelwood Health Study (HHS; https://hazelwoodhealthstudy.org.au). The Study is a comprehensive program of research investigating the long-term health and wellbeing of Latrobe Valley residents following exposure to the smoke from the Hazelwood mine fire.

The Hazelinks Stream of the Hazelwood Health Study aims to use administrative health data sets to investigate short, medium and long-term health outcomes in the Latrobe Valley region. This report draws upon data routinely collected by the Australian Government on health services utilisation and dispensing of prescription pharmaceuticals.

3. Background

The adverse effect of air pollution on health has long been appreciated and, due to improved methods of monitoring and measurement, has become a more active research area in the last twenty years. Extensive clinical, epidemiological and toxicological studies have provided evidence of relationships between exposure to ambient air pollutants and human health (Brunekreef and Holgate, 2002, Beelen et al., 2014). The short-term effects of air pollution have mainly been demonstrated by increases in respiratory (Haikerwal et al., 2016) and cardiovascular-related morbidity (Haikerwal et al., 2015) and mortality (Dennekamp et al., 2010, Strickland et al., 2010, Faustini et al., 2012, Milojevic et al., 2014, Pope et al., 2006). There is also a growing body of research investigating the relationship between air pollution and adverse mental health outcomes such as depression and suicide (Lim et al., 2012, Szyszkowicz et al., 2010).

Large, destructive coal mine fires such as the Hazelwood mine fire are often beyond human control, despite technologically advanced fire-fighting services and the resources allocated to fire control. Pollutants generated by coal combustion are similar to those generated from domestic solid fuel combustion and outdoor biomass fires (Melody and Johnston, 2015). Pollutants may be broadly categorised as gases, particles with a median aerodynamic diameter less than 10µm or 2.5µm (PM_{10} or $PM_{2.5}$), volatile organic compounds and trace elements. Many of these are known to be deleterious to human health. The immediate impact of coal mine fires can be devastating, with loss of life, livelihood and infrastructure at the fire fronts. However, to date there is limited evidence on the impacts of smoke from coal mine fires on health outcomes.

4. Aim and objectives

The aim of the analyses was to examine whether the Hazelwood coal mine fire-related $PM_{2.5}$ was related to increased use of health services and medications dispensed for respiratory diseases, cardiovascular diseases and mental health conditions.

5. Human Research Ethics Committee and other approvals

The Monash University Human Research Ethics Committee (MUHREC) approved the Hazelwood Adult Survey & Health Record Linkage Study in 2015 for a five-year period (MUHREC project number 6066) and again in 2020 (MUHREC project number 25680). The application was also approved by the Commonwealth Department of Human Services (DHS) External Request Evaluation Committee (EREC). MBS and PBS data were initially requested to be aggregated at the Statistical Area (SA) 1 level, for each of the 38 SA1s contained within the Morwell SA2 boundary. However due to privacy considerations DHS released the data at the aggregated SA3 level for the Latrobe Valley as a whole. The Commonwealth DHS holds 4.5 years of data, therefore the earliest data available for extraction were from 1 July 2012.

6. Methods

6.1. Datasets

Data on health service use

Data on health service use were collected from the Medicare Benefits Schedule (MBS) database held by the Commonwealth DHS. The dataset contained de-identified information on patient health care utilisation for GPs, medical specialists, diagnostic procedures, investigations and diagnostic imaging services. The dataset only included claim records for services that qualified for Medicare benefits and for which a claim had been processed.

Data for all ages were analysed from the MBS database for the period 1 July 2012 – 30 June 2016, based on date of service for GP consultations and date of referral for specialist attendances, diagnostic procedures, investigations and diagnostic imaging services. These dates of analyses were selected to reflect the distinction between primary medical services (GP consultations) and secondary medical services requiring a GP referral. This distinction was made because it may be possible that primary medical service utilisation is more responsive to short term changes in air quality than secondary services.

Residents should have been able to consult GPs relatively quickly and therefore the date of service may reflect short term health responses to air quality. In comparison, there is often a waiting period to access secondary services and therefore the date of referral rather than the date of service should better reflect possible short-term health responses to changes in air quality. MBS data were broken down into category, group, subgroup and item number for each unit record (category being the broadest description, and item number the most specific). The MBS data request was restricted to specific categories/groups/subgroups that were relevant to the study research questions (e.g. Category: Professional Attendances, Group: GP Mental Health treatment).

Data on medication dispensing

Data on medication dispensing were obtained from the Pharmaceutical Benefits Scheme (PBS) database also held by the Commonwealth DHS. This dataset contained de-identified information on prescription medicines dispensed to patients at a Government subsidised price, where the cost of the medication was greater than the patient contribution and therefore the pharmacist supplying the medication required reimbursement for the remaining cost. Since 2012, PBS data also included prescription medications where the cost of the medication was covered by the patient, so the pharmacist did not require reimbursement. The PBS dataset only contained information on prescription medicines where the prescription had been processed (i.e. the prescription had been filled by the pharmacist).

Data for all ages were analysed from the PBS database for the period 1 January 2013 - 31 December 2016, based on date of supply. The PBS data were broken down using the Anatomical Therapeutic Chemical (ATC) Classification System (WHOCC, 2011). As the study aimed to identify changes in medication use for respiratory, cardiovascular and mental health conditions during and after the mine fire, only records relating to these categories of medications were requested (e.g. Group name: Cardiovascular System).

Data on air pollution and definition of the 'mine fire period'

The CSIRO Oceans & Atmosphere provided modelled exposure fields for $PM_{2.5}$ ranging from 100-500 m resolution near the fire to 3-9 km resolution further away from the fire. The 24-hourly average $PM_{2.5}$ concentrations were calculated for the Latrobe Valley SA3 area. Further details of the modelling approach can be found in CSIRO's report (Emmerson et al., 2016) and journal paper (Luhar et al., 2020).

The Hazelwood coal mine fire is generally considered to have burned for about six weeks from 9 February to 31 March 2004. However, for this report the *mine fire period* was defined as the period when the modelled daily $PM_{2.5}$ concentration, averaged across the Latrobe Valley SA3 area, exceeded 1µg/m^3. This corresponded to the period 9 February to10 March 2014 (30 days). After 10 March 2014, daily average $PM_{2.5}$ concentrations attributable to the coal mine fire fell below 1µg/m^3. The median modelled daily average $PM_{2.5}$ concentration attributable to the coal mine fire during the 30-day analysis period for the Latrobe Valley area was 5.2 µg/m^3 and the interquartile range was 0.1 – 31.2 µg/m^3.

Data on ambient maximum temperature

As ambient temperature can have significant impacts on health (Guo et al., 2014, Guo et al., 2017), we controlled for temperature when we assessed associations between air pollution and health outcomes. Daily maximum temperatures were collected from the Australian Bureau of Meteorology (http://www.bom.gov.au/climate/data-services/station-data.shtml).

Data on geographical boundaries

The geographical boundary used for the analyses was defined using the Australian Statistical Geography Standard 2011 classification SA3 spatial unit. The Latrobe Valley SA3 area incorporated five SA2 regions: Morwell, Churchill, Moe - Newborough, Traralgon and Yallourn North - Glengarry. Figure 1 shows a map of the Latrobe Valley SA3 geographical area, and the corresponding SA2 areas, included in the analysis.

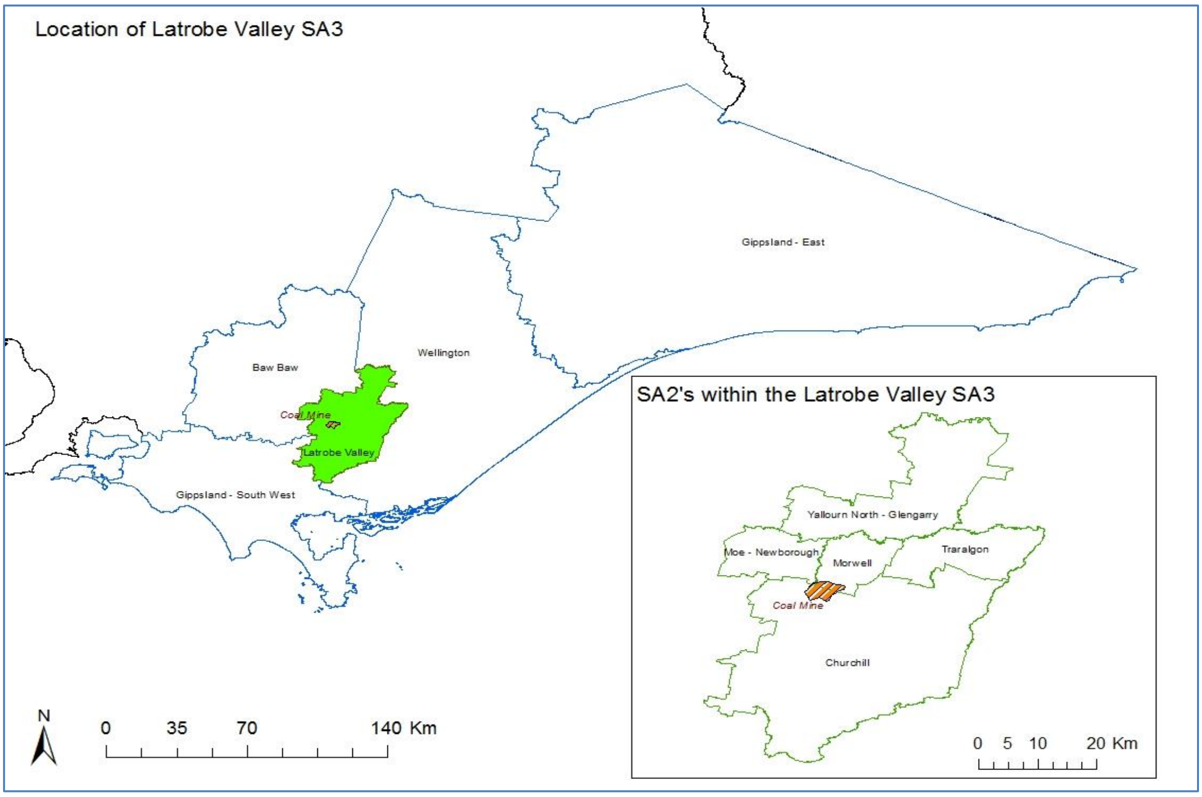

Figure 1 Geographical location of the Latrobe Valley SA3 area

6.2. Definition of outcomes

Health service data

The health service data were reviewed by a panel of researchers and clinicians (see acknowledgments) and Service types considered relevant for the hypothesis were included in the analysis. For the purpose of the analyses, all item numbers that were considered relevant were grouped into one of five categories: short GP consultations, long GP consultations, cardiovascular services, respiratory services and mental health/psychiatric consultations.

Short GP consultations were defined as consultations lasting less than 20 minutes and incorporated standard consultations (Item 23) and long GP consultations were defined as consultations lasting 20 minutes or more. Cardiovascular and respiratory service groups incorporated their respective specialist/consultant consultations and diagnostic and imaging tests. Mental health consultations incorporated GP mental health and specialist/consultant mental health consultations. A small number of service types were not considered relevant and were excluded, for example Subgroup: Cardiovascular, Item Number: Blood Dye test. Supplementary Table 1 (Appendix 1) presents the full list of item numbers by health service group included in the analyses.

Dispensed medication data

The PBS medication classifications were also reviewed by a panel of researchers and clinicians and medications considered relevant for the hypothesis were included in the analyses. The ATC grouping was used in analyses. Cardiovascular medications included cardiac glycosides, anti-arrhythmics, nitrates, antihypertensives, diuretics, beta blockers, calcium channel blockers, ACE inhibitors, angiotensin antagonists and lipid modifying agents. Respiratory medications included systemic and inhaled glucocorticoids, beta agonists, anticholinergics, combination inhalers, xanthines, leukotriene antagonists and cough suppressants. Medications for mental health conditions included psycholeptics such as phenothiazines, haloperidol, indoles, thioxanthenes, benzodiazepines, benzamides and other antipsychotics; antidepressants such as monoamine oxidase (MAO) inhibitors, serotonin reuptake inhibitors, other antidepressants; and stimulants including dexamphetamine and methylphenidate. A small number of medications not considered relevant were excluded, for example analgesics and anti-Parkinsonian drugs. Supplementary Tables 2-4 (Appendix 1) present the full medication classifications and examples of medications in each class that were used in the analyses.

6.3. Statistical analyses

Descriptive analysis

The results of the analyses for both health service use and medication dispensing were investigated using multiple techniques. Weekly time series counts of service use and medication dispensing plotted over the duration of their respective analyses' periods provided a high level of insight regarding the potential time dependent patterns within the data. As our aim was to assess the short-term associations between air pollution and health outcomes, plotting the raw data would help us to understand if there were long-term trends and/or seasonality. In addition, daily time series counts of service use and medication dispensing were compared across two comparison time periods to ascertain whether utilisation varied during the 30-day mine fire period, compared to the 30 days immediately pre and post the fire, and compared to the same dates as the 30-day mine fire period but one-year pre and post the fire.

Time series regression

Time-series analyses relating daily air pollutant data to health outcomes (e.g. medical service use and pharmaceutical dispensing) are frequently used to assess the short-term health effects of air pollution (Bhaskaran et al., 2013). The method allows for adjustment of an outcome-exposure relationship by confounders stable over time, and examines the outcomes in a population repeatedly over the days in a specific time period under varying daily exposure conditions.

We used time series regression to examine the associations between daily mine-fire-related $PM_{2.5}$, health service use and dispensing of medications. Initial exploratory analyses of the time series data plots confirmed the presence of seasonality, trend and effects of public holidays (e.g. Christmas). A generalized linear model (GLM) with Poisson regression was used to model the impacts of air pollution on the outcomes: health service use and medication dispensing. In the GLM structure, the modelled daily fire-generated $PM_{2.5}$ was included alongside potential confounders including seasonality, long-term trend, day of the week, maximum ambient temperature and public holidays. Additional details relating to the parameters used in the statistical model may be found in Appendix 2.

Total health service use and medication dispensing records during the fire period for the MBS item codes and PBS ATC codes listed in Supplementary Tables 1 to 4 (Appendix 1), were first examined in preliminary analyses. The results of these analyses indicated that the number of records were too few for many of the specific conditions to yield reliable statistical inference. Hence the subsequent time series analyses were performed using larger condition groups: all respiratory diseases, all cardiovascular diseases and all mental health conditions.

The dose response relationships between a 10 $\mu g/m^3$ increase in fire-related $PM_{2.5}$ and health service utilisation and medication dispensing were examined to determine whether there were increases in the risk of utilisation and dispensing as fire-related $PM_{2.5}$ concentrations increased.

Cumulative relative risks (RR) over a lag period per 10 $\mu g/m^3$ increase in fire-related $PM_{2.5}$ were also calculated with their associated 95% confidence intervals (CIs) for each service type and medication type. Cumulative RR could be interpreted as the sum of lag effects associated with air pollution exposure over the specified lag days. Estimated cumulative RRs greater than 1 indicated elevated risks for service use associated with mine fire-generated $PM_{2.5}$. The 95% CI indicated the uncertainty of the cumulative RR value as an estimate of the true underlying association between the air pollutant and the health outcome. Smaller p-values indicated stronger evidence of a true underlying association (with the threshold of $p<0.05$ commonly referred to as statistically significant). However, it must be borne in mind that p-values and the width of the confidence interval were dependent on not just the size of the estimated cumulative RR, but also on the number of occurrences of the health outcome being analysed.

Attributable counts and fractions were also calculated. Attributable counts indicated the number of service visits or medications dispensed that occurred in the Latrobe Valley as a result of population exposure to fire-related $PM_{2.5}$ emissions. Attributable fractions were the percentage change in service visits or medications dispensed, attributable to fire-related $PM_{2.5}$ emissions.

7. Results

7.1. MBS health service usage

Total counts of health service use for the Latrobe Valley for both the entire period analysed and the fire period are summarised in Table 1. Short GP consultations accounted for the majority (76%) of health services used during the fire period. Median daily health service use counts for the 2014 fire period and the equivalent 30-day period one year earlier are summarised in Table 2. During the 2014 fire period the median daily health service visits were 1,982 for all long and short GP consultations, 140 for all mental health consultations, 96 for all cardiovascular services and 44 for all respiratory services. All four service types had marginally elevated utilisation compared to the equivalent 30-day period one year prior to the fires.

Table 1 Total number of MBS health service visits by service type for the Latrobe Valley

Health service type	Analysis period July 2012 June 2016	Mine fire period 9 Feb 2014 - 10 March 2014
	No. of records	No. of records
Short GP consultations	1,932,076	38,446
Long GP consultations	258,401	5,327
All Long & Short GP consultations	2,190,477	43,773
Mental Health- GP consultations	52,964	1,176
Mental Health- Specialist consultations	93,418	2,219
All Mental Health consultations	146,382	3,395
Cardiovascular specialist consultations	25,938	466
Cardiovascular diagnostic & imaging tests	86,267	1,859
All Cardiovascular service visits	112,205	2,325
Respiratory specialist consultations	16,906	370
Respiratory diagnostic & imaging tests	39,729	793
All Respiratory service visits	56,635	1,163
All above service types combined	2,505,699	50,656

Table 2 Median number of daily health service visits by service type for the Latrobe Valley

Health service type	1 Year pre fire 9 Feb 2013 - 10 March 2013		Mine fire period 9 Feb 2014 - 10 March 2014	
	Median	**Interquartile Range**	**Median**	**Interquartile Range**
Short GP consultations	1,704	272-1,816	1,720	273-1,869
Long GP consultations	209	21-230	240	30-267
All Long & Short GP consultations	1,922	292-2,049	1,982	304-2,139
Mental Health- GP consultations	53	5-58	48	10-58
Mental Health- Specialist consultations	74	10-106	86	15-118
All Mental Health consultations	130	13-166	140	19-173
Cardiovascular specialist consultations	18	6-37	12	5-24
Cardiovascular diagnostic & imaging tests	74	17-87	78	9-93
All Cardiovascular service visits	92	21-119	96	15-120
Respiratory specialist consultations	8	0-17	14	0-21
Respiratory diagnostic & imaging tests	30	6-35	30	7-40
All Respiratory service visits	40	7-57	44	10-58
All above service types combined	2,240	323-2,321	2,318	354-2,456

The weekly time series graphs for health service use were used to visualise the sequences of data and detect underlying seasonality and trends (Figure 2). There was some evidence of a trend of increased utilisation across the four-year analysis period and the annual fluctuations within each calendar year reflected troughs in utilisation during public holiday periods. There were apparent increases in health service use during the mine fire compared to pre-fire periods and continuing increases following the fire.

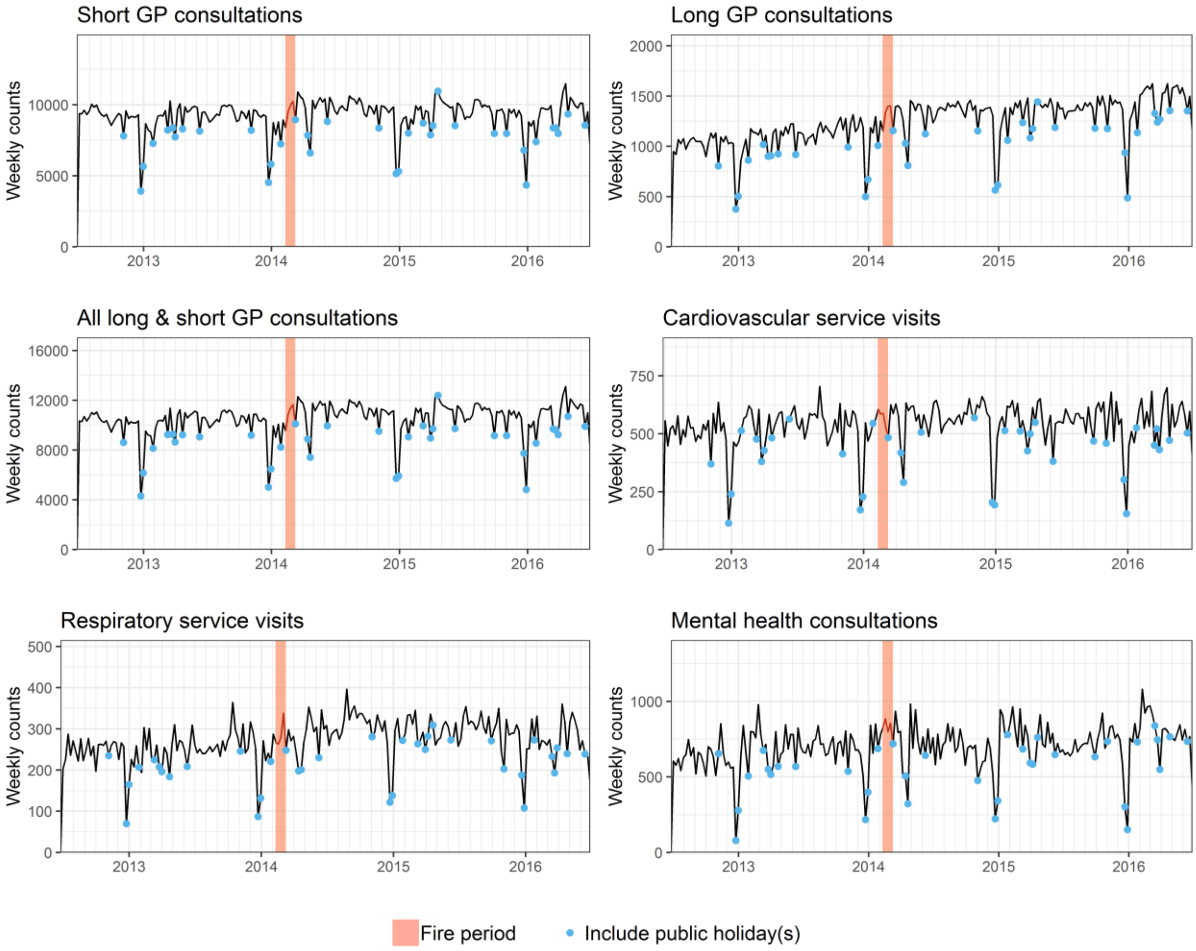

Figure 2 Time series plots of weekly medical service utilisation counts in the Latrobe Valley for the period July 2012 to 30 June 2016.

Note: The red shading indicates the 30-day fire period and blue dots indicate weeks which include public holidays.

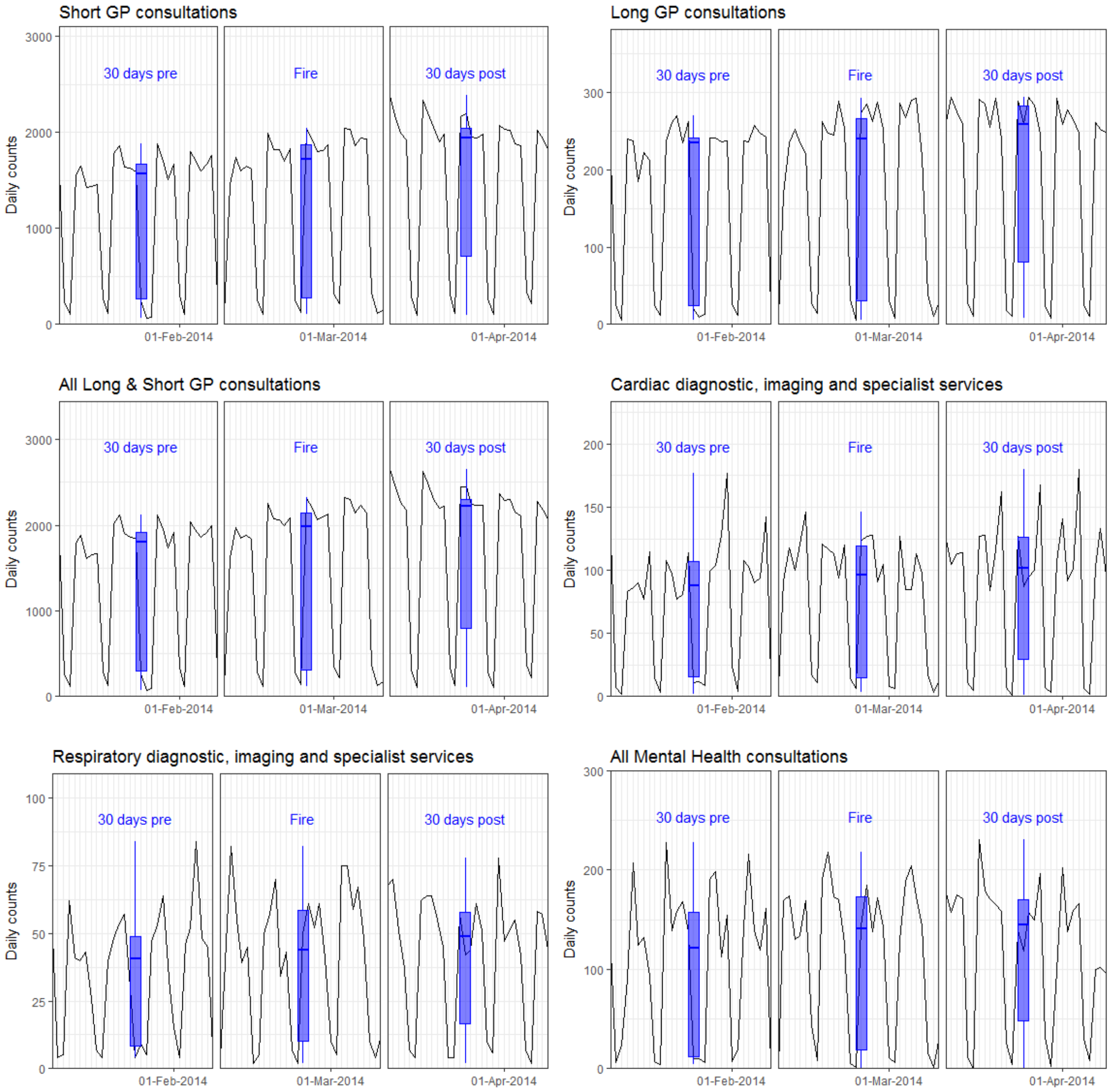

Figure 3 Time series plots of daily medical service utilisation counts in the Latrobe Valley for the 30 days during the fire, the 30 days before the fire, and the 30 days after the fire.

Note: The blue bar is the boxplot of the distribution of daily counts; the box indicates the distribution lying within the 25th and 75th percentiles, the blue line indicates the median, and whiskers indicate the lowest and highest values.

Figure 3 compares the 30-day fire period to 30 days pre and post the fire, and Figure 4 compares the 30 day fire period to the same 30 day periods one year pre and post the fire. Descriptive investigation of the health service use data for short and long GP consultations, all cardiovascular services, all respiratory services and all mental health consultations, indicated a rise in service use during the mine fire period compared with the 30 days pre-fire, and a further rise during the 30 days post the fire (Figure 3).

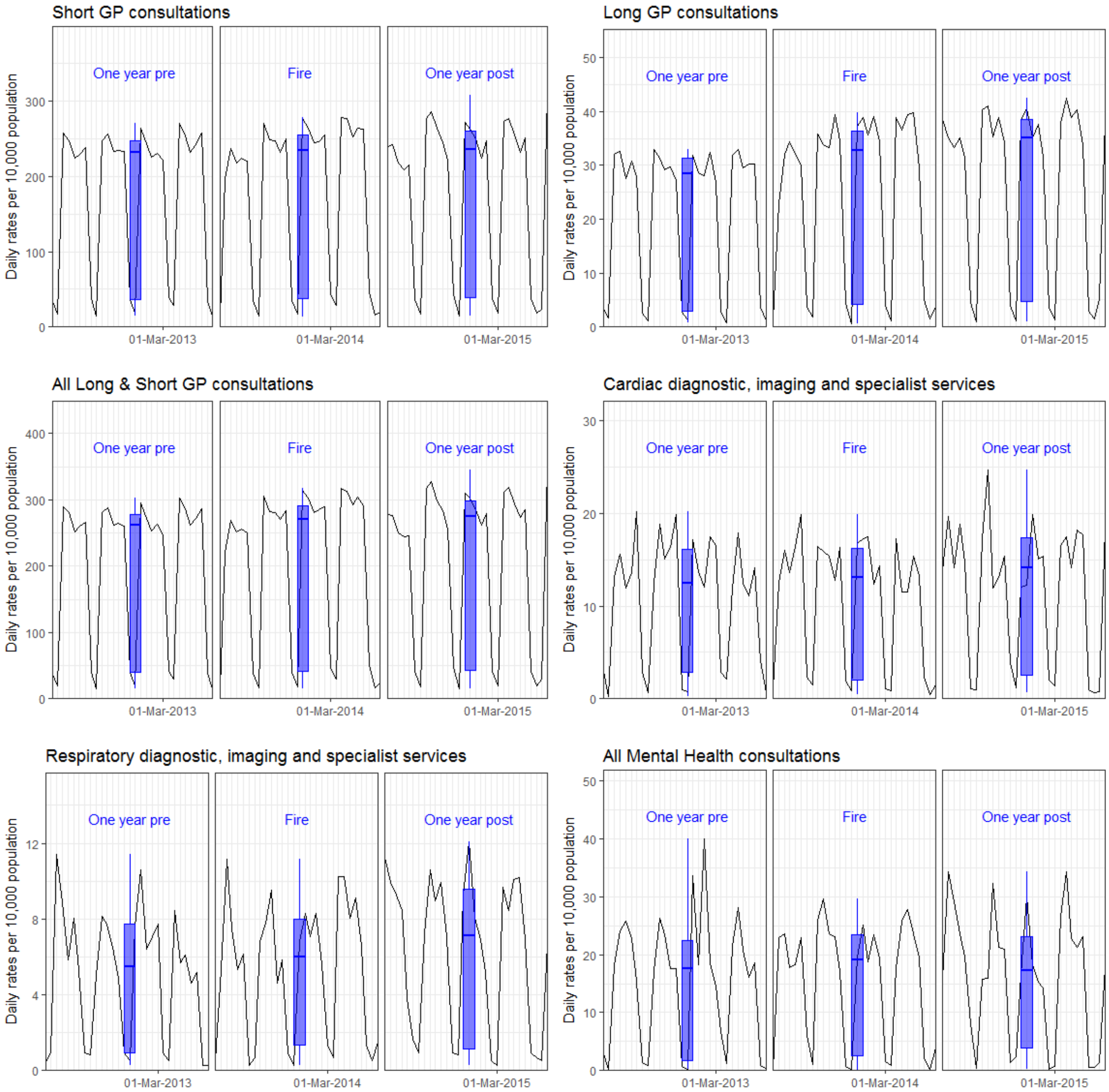

Figure 4 Time series plots of daily medical service utilisation counts (given as rate per 10,000 population) in the Latrobe Valley for the 30 days during the fire and the same 30-day period one year before the fire and one year after the fire.

Note: Blue bar is the boxplot of distribution of daily rates per 10,000 where the box indicates the distribution lying within the 25th and 75th percentiles, the blue line indicates the median, and whiskers the lowest and highest values.

Initial investigations of the health service use data for short-GP consultations indicated a relatively constant trend for the same 30 day period, when one year prior to the fire, the year of the fire and the year post the fire were compared (Figure 4). Visits for long GP consultations, and visits to all cardiovascular services and all respiratory services appeared to increase during the fire period compared to one year earlier,and increase further one year post the fire. Health service use for all mental health consultations appeared to increase during the year of the fire compared to one year prior, before returning to pre fire levels one year later (Figure 4).

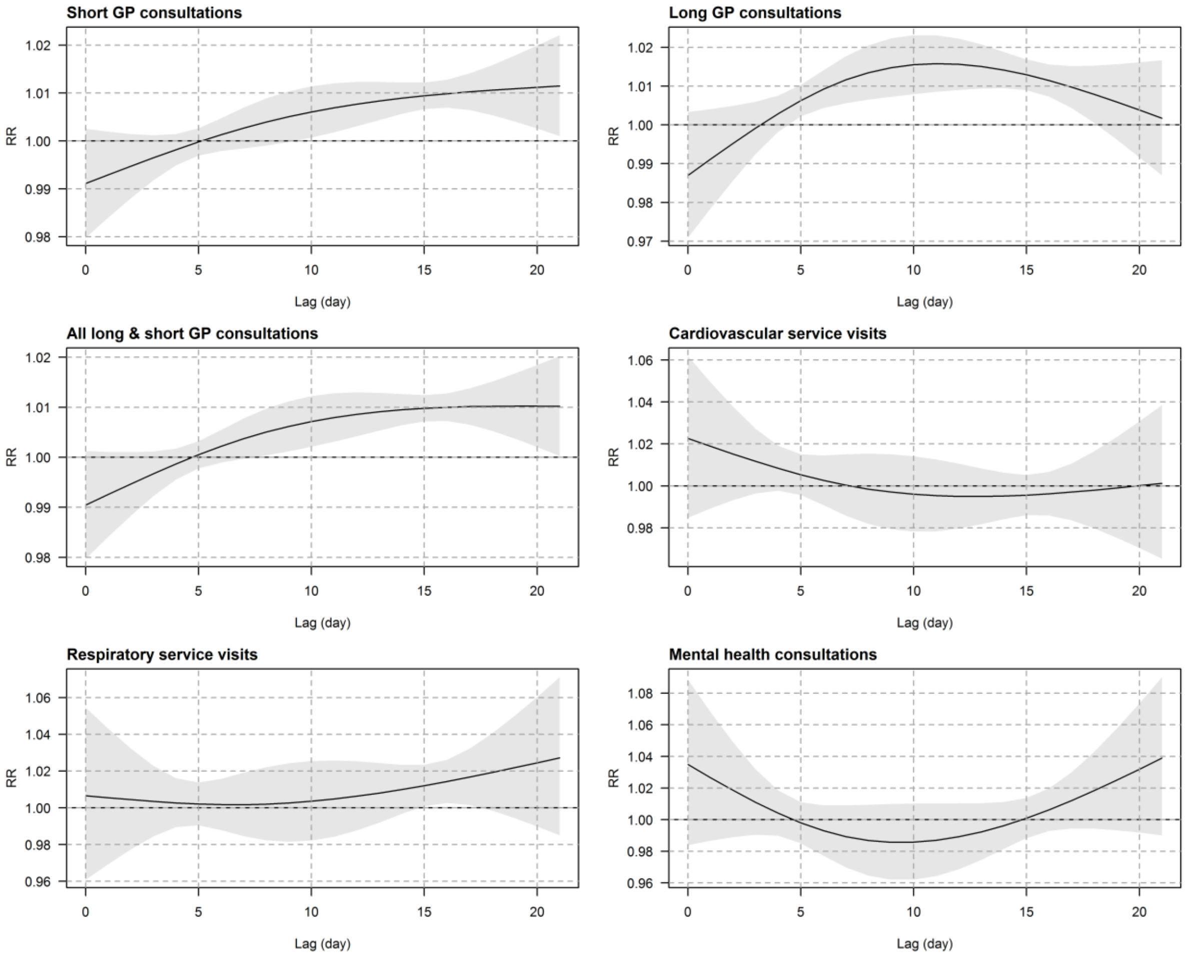

Figure 5 Exposure response relationships between 10 µg/m3 increases in mine fire-related $PM_{2.5}$ and health service use, at lags of 0-21 days after controlling for seasonality, public holidays, day of the week, long-term temporal trends and daily maximum ambient temperature.

Modelling of the lag structure for the dose response associations between mine fire-related $PM_{2.5}$ and health service use are shown in Figure 5. The association between mine fire-related $PM_{2.5}$ and short and long GP consultations demonstrated a lag of 5 and 4 days respectively, before the observed RR was greater than one. RRs continued to increase for short GP consultations and peaked after 11 lag days for long consultations. For respiratory health service visits, the corresponding RR was above one at lag 0, before declining marginally, then progressively increasing after 7 lag days. For mental health consultations the lag structure modelling indicated the dose response RR was above one at lag 0, fell below one for lag days 5-15, then rose above one and continued to increase. No dose response association between mine fire-related $PM_{2.5}$ and health service use was observed for cardiovascular service visits. Sensitivity analyses (not tabulated) suggested the results were not sensitive to changes in the degrees of freedom or number of lag days chosen for lags of air pollution, the degrees of freedom for dose-response and lag-response relationships of temperature and the degrees of freedom for the non-linear effect of day of the year.

Table 3 The association between a 10 μg/m³ increase in mine fire-related $PM_{2.5}$ and GP consultations in the Latrobe Valley.

Health service type	Service visit count	% of total GP & specialist count	Daily median count	Cumulative RR*	95% CI	p-value	p-value for difference^
Short GP consultations	**38,446**	**75%**	**1,720**	**1.10**	**1.06 - 1.15**	**<0.001**	
Sex							
Female	22,602	45%	1,019	1.09	1.05 - 1.14	<0.001	Reference
Male	15,844	31%	698	1.10	1.05 - 1.15	<0.001	0.792
Age (years)							
<20	6,442	13%	281	1.18	1.10 - 1.28	<0.001	Reference
20 - 34	7,297	14%	318	1.03	0.98 - 1.08	0.260	0.003
35 - 49	6,635	13%	297	1.13	1.07 - 1.20	<0.001	0.362
50 - 64	8,059	16%	363	1.09	1.03 - 1.15	0.002	0.080
65+	10,013	20%	442	1.08	1.00 - 1.17	0.037	0.099
Long GP consultations	**5,327**	**11%**	**240**	**1.17**	**1.11 - 1.24**	**<0.001**	
Sex							
Female	3,415	7%	146	1.20	1.12 - 1.29	<0.001	Reference
Male	1,912	4%	85	1.11	1.02 - 1.21	0.020	0.143
Age (years)							
<20	565	1%	22	1.41	1.19 - 1.68	<0.001	Reference
20 - 34	1,014	2%	44	1.14	1.02 - 1.28	0.025	0.044
35 - 49	1,032	2%	46	1.20	1.07 - 1.35	0.002	0.138
50 - 64	1,208	2%	55	1.13	1.01 - 1.25	0.029	0.030
65+	1,508	3%	70	1.12	1.01 - 1.24	0.027	0.023
All long and short GP consultations	**43,773**	**86%**	**1,982**	**1.11**	**1.07 - 1.15**	**<0.001**	
Sex							
Female	26,017	51%	1,188	1.11	1.06 - 1.15	<0.001	Reference
Male	17,756	35%	786	1.10	1.06 - 1.15	<0.001	0.920
Age (years)							
<20	7,007	14%	303	1.20	1.11 - 1.29	<0.001	Reference
20 - 34	8,311	16%	366	1.04	0.99 - 1.09	0.111	0.002
35 - 49	7,667	15%	343	1.14	1.08 - 1.20	<0.001	0.296
50 - 64	9,267	18%	419	1.09	1.04 - 1.15	<0.001	0.049
65+	11,521	23%	518	1.09	1.01 - 1.16	0.018	0.062

*Cumulative RR over a 21 lag day period adjusting for seasonality, public holidays, day of the week, long-term trend and daily maximum ambient temperature.

^Univariate random-effects meta-regression p-values.

Table 4 The association between a 10 µg/m³ increase in mine fire-related $PM_{2.5}$ and specialist/consultant health service visits in the Latrobe Valley

Health service type	Service visit count	% of total GP & specialist count	Daily median count	Cumulative RR*	95% CI	p-value	p-value for difference^
Cardiovascular service visits	**2,325**	**5%**	**96**	**1.04**	**0.91 - 1.20**	**0.540**	
Sex							
Female	1,124	2%	49	0.99	0.82 - 1.18	0.884	Reference
Male	1,201	2%	47	1.09	0.91 - 1.32	0.340	0.433
Age (years)							
<20	83	0%	2	0.87	0.49 - 1.57	0.651	Reference
20 - 34	182	0%	6.5	1.19	0.83 - 1.69	0.343	0.381
35 - 49	244	0%	8.5	0.97	0.73 - 1.29	0.838	0.751
50 - 64	690	1%	28.5	1.19	0.95 - 1.49	0.139	0.339
65+	1,126	2%	45	0.97	0.79 - 1.19	0.756	0.748
Respiratory service visits	**1,163**	**2%**	**44**	**1.22**	**1.04 - 1.43**	**0.015**	
Sex							
Female	530	1%	21	1.05	0.83 - 1.34	0.688	Reference
Male	633	1%	21	1.37	1.11 - 1.69	0.003	0.101
Age (years)							
<20	50	0%	2	1.15	0.64 - 2.08	0.643	Reference
20 - 34	117	0%	3	2.08	1.38 - 3.14	<0.001	0.108
35 - 49	188	0%	6	1.58	1.12 - 2.24	0.010	0.363
50 - 64	317	1%	11	1.10	0.82 - 1.47	0.512	0.899
65+	491	1%	19	1.06	0.82 - 1.36	0.676	0.795
Mental health consultations	**3,395**	**7%**	**140**	**1.14**	**0.95 - 1.36**	**0.170**	
Sex							
Female	2,103	4%	87	1.03	0.81 - 1.31	0.787	Reference
Male	1,292	3%	50	1.32	1.02 - 1.72	0.035	0.170
Age (years)							
<20	630	1%	19	1.35	0.93 - 1.95	0.110	Reference
20 - 34	971	2%	35	1.01	0.74 - 1.37	0.963	0.232
35 - 49	844	2%	32	1.15	0.82 - 1.63	0.410	0.541
50 - 64	699	1%	26	0.97	0.61 - 1.52	0.878	0.260
65+	251	0%	7	1.50	0.83 - 2.70	0.181	0.775
Total GP & specialist service visit count	**50,656**						

*Cumulative RR over a 21 lag day period adjusting for seasonality, public holidays, day of the week, long-term trend and daily maximum ambient temperature.
^Univariate random-effects meta-regression p-values.

Table 3 shows the dose response association between a 10 µg/m^3 increase in mine fire-related $PM_{2.5}$ and GP consultations. Analyses of the overall population showed a 10% increase in short GP consultations (RR 1.10; 95% CI 1.06 to 1.15; p<0.001) and a 17% increase in long consultations (RR 1.17; 95% CI 1.11 to 1.24; p<0.001) per 10 µg/m^3 increase in fire-related $PM_{2.5}$. Stratification by sex found the RRs for short GP consultations to be similar in both sexes and, for long GP consultations, stronger in women than in men. Age stratification shown in Figure 6 demonstrates increased risk for short GP consultations in four of the five age groups and increased risk for long GP consultations in all age groups. For both long and short GP consultations the strongest associations were observed in those aged 0-19 and 35-49 years.

Table 4 shows the associations between a 10 µg/m^3 increase in mine fire-related $PM_{2.5}$ and specialist/consultant health service visits. For respiratory services, the analyses of the overall population showed a 22% increase in respiratory service use (RR 1.22; 95% CI 1.04 to 1.43; p=0.015) per 10 µg/m^3 increase in fire-related $PM_{2.5}$. Stratification by sex showed that the increase was observed in men (RR 1.37; 95% CI 1.11 to 1.69; p=0.003) and not in women. In Figure 6, stratification by age revealed that increases in respiratory service use were predominantly amongst those aged 20-34 and 35-49 years, and not in the younger or older age groups.

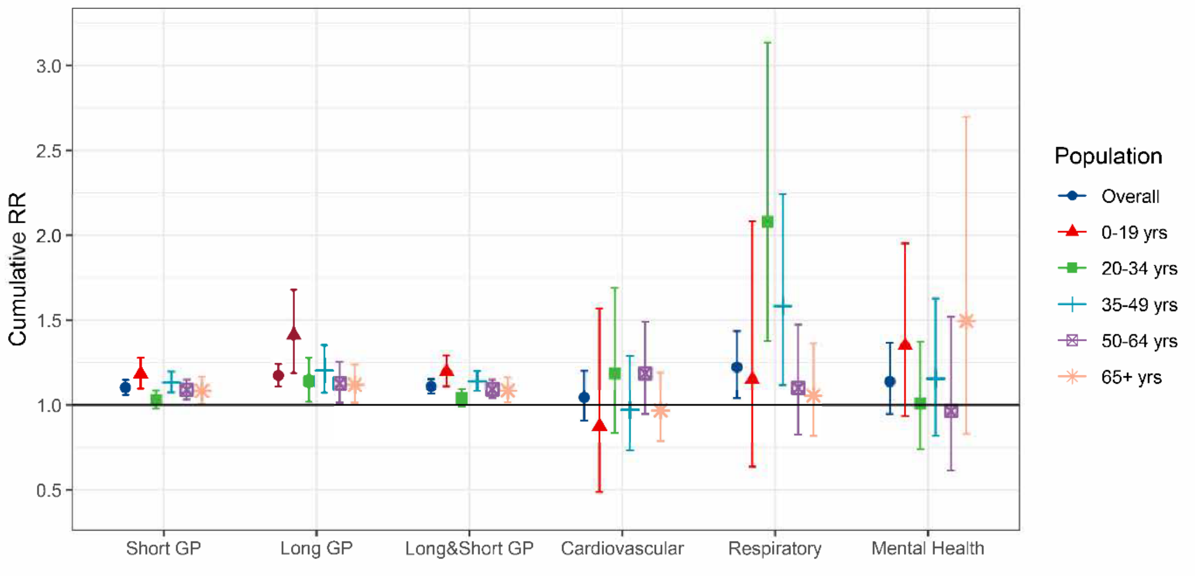

Figure 6. Overall and age stratified cumulative 21 day RR and 95% CIs for medical service utilisation per 10 µg/m^3 increase in mine fire-related fine $PM_{2.5}$.

Note: RRs are adjusted for seasonality, public holidays, day of the week, long-term trend and daily maximum ambient temperature.

No associations were observed for mental health consultations in the overall population, whilst stratification by sex showed an increased risk in men (RR 1.32; 95% CI 1.02 to 1.72; p=0.035) but not in women (Table 4). Age stratification indicated no associations for mental health consultations (Figure 6).

No dose response associations were observed for visits to cardiovascular services (Table 4, Figure 6).

Table 5 Attributable fraction and attributable counts for lag 21 days of health service use due to coal mine fire-related $PM_{2.5}$ in the Latrobe Valley SA3, during period of the coal mine fire

Health service type	Mean attributable fraction (95% CI)	Total attributable counts (95% CI)
Short GP consultations	4% (2%, 5%)	2,721 (1626, 3789)
Long GP consultations	6% (4%, 8%)	599 (392, 799)
All Long & Short GP consultations	4% (3%, 6%)	3,274 (2099, 4421)
All Cardiovascular service visits	2% (-4%, 7%)	72 (-165, 289)
All Respiratory service visits	8% (2%, 13%)	159 (32, 274)
All Mental Health consultations	5% (-2%, 12%)	301 (-137, 692)

The attributable fractions and attributable counts for health service utilisation due to mine fire-related $PM_{2.5}$ concentrations are presented in Table 5. There were 3,274 short and long GP consultations and 159 respiratory service visits during the 30 day mine fire period, which were attributable to mine fire-related $PM_{2.5}$ in the Latrobe Valley. Correspondingly, the attributable fractions were 4% for short and long GP consultations and 8% for respiratory services.

7.2. PBS medication dispensing

Total counts of medications dispensed for the Latrobe Valley for the entire period analysed and the mine fire period are summarised in Table 6. Median daily medication dispensing during the 2014 mine fire period and the equivalent period one year earlier are summarised in Table 7. During the 2014 mine fire period, the median numbers dispensed daily were 1,256 cardiovascular medications, 239 respiratory medications and 558 for mental health medications. This represented a slight increase in respiratory and mental health medications being dispensed on a daily basis, and a slight reduction in cardiovascular medications, compared to the equivalent 30-day period one year prior to the fire.

Table 6 Numbers of medications dispensed by medication type in the Latrobe Valley SA3

Medication type	Analysis Period Jan 2013 - June 2016	Mine Fire Period 9 Feb 2014 - 10 March 2014
	No. of records	No. of records
Cardiovascular	1,617,221	30,593
Respiratory	305,377	6,066
Mental Health	703,271	13,354
All above medications	**2,625,869**	50,013

Table 7 Median of medications dispensed daily by medication type for the Latrobe Valley SA3

Medication type	1 Year pre fire 9 Feb 2013 - 10 March 2013		Mine Fire Period 9 Feb 2014 - 10 March 2014	
	Median	**Interquartile Range**	**Median**	**Interquartile Range**
Cardiovascular	1,301	674-1,404	1,256	620-1,384
Respiratory	199	88-218	239	128-273
Mental Health	528	252-605	558	258-598
All above medications	**2,044**	**1,008-2,216**	**2,111**	**1,020-2,249**

As with health service utilisation, the initial investigation into medication dispensing (Figure 7) appeared to indicate an increased trend in dispensing across the four-year analysis period and annual fluctuations within each calendar year, which were reflected in peaks pre-Christmas and troughs during public holiday periods. This meant we had to allow for seasonality and public holidays when assessing potential associations between daily air pollution and medication dispensing. Variations in medication dispensing are hard to visually detect in Figure 7, hence subsequent figures are presented that compare the 30-day fire period to the 30 days pre and post the fire (Figure 8) and the same 30-day period one year pre and post the fire (Figure 9).

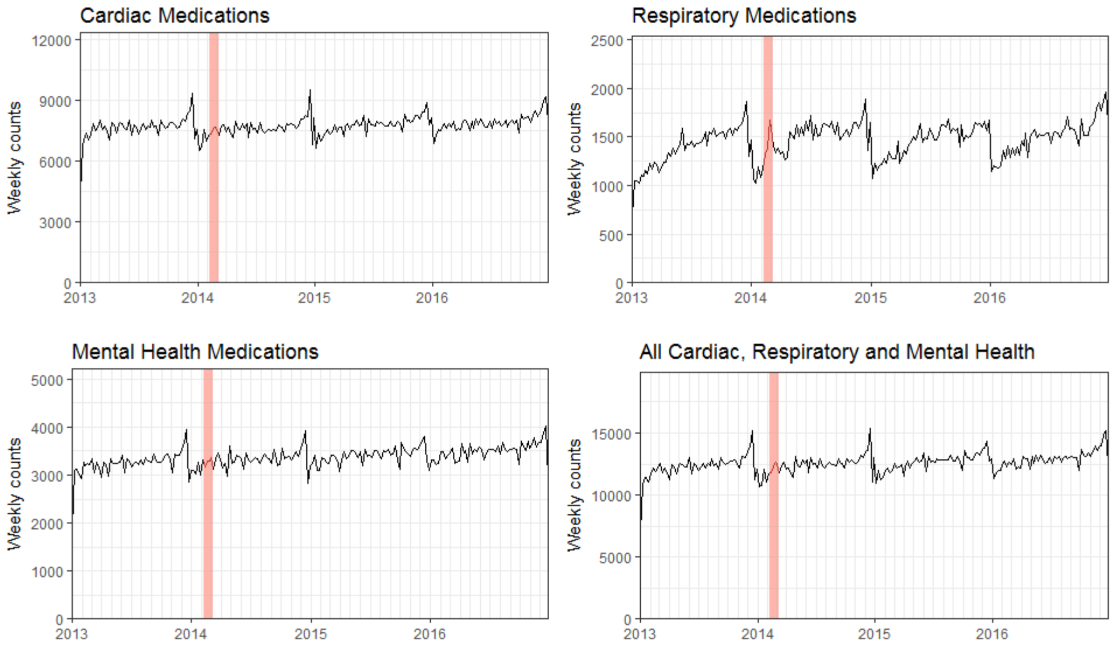

Figure 7 Time series plots for PBS medications dispensed in the Latrobe Valley, 1 Jan 2013 to 31 Dec 2016.

Note: The red bar indicates the fire period.

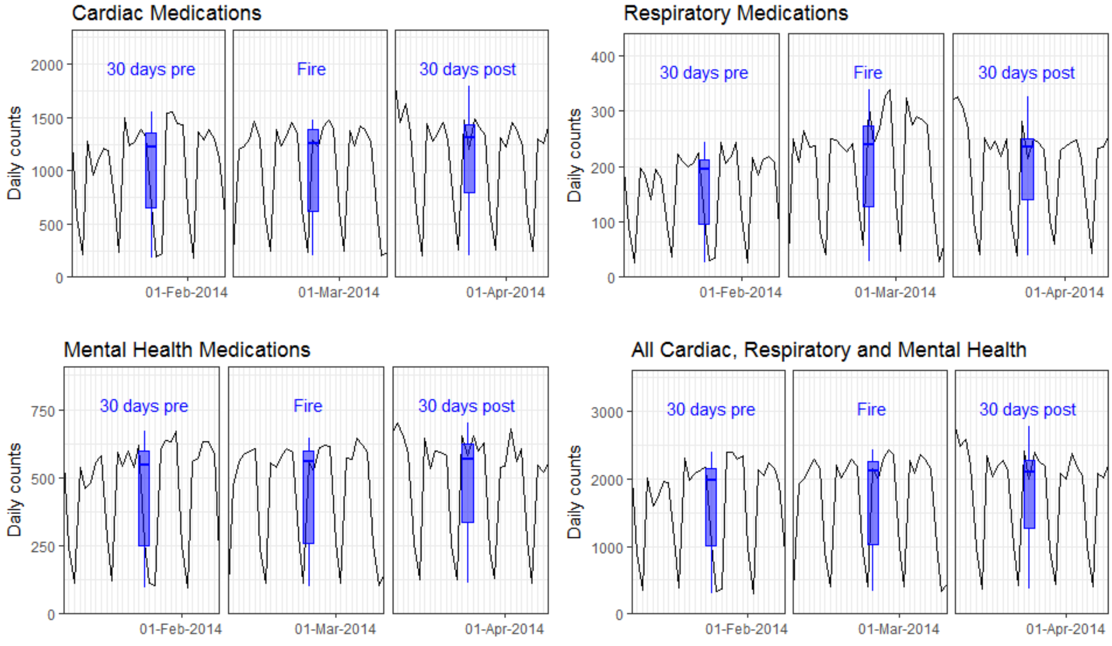

Figure 8 Time series plots of daily medications dispensed in the Latrobe Valley for the 30 days during the fire, 30 days before the fire and 30 days after the fire.

Note: The blue bar is the boxplot of the distribution of daily counts; the box indicates the distribution lying within the 25th and 75th percentiles, the blue line indicates the median, and whiskers the lowest and highest values.

As seen in Figure 8, the raw data indicated that cardiovascular medication dispensing stayed relatively stable during the fire period compared to the 30 days prior and then increased slightly in the 30 days post the fire. Respiratory medication dispensing appeared to increase during the fire period compared to the 30-day pre-fire period, then slightly declined after the fire but remained above pre-fire levels. Dispensing of medications for mental health conditions increased very slightly during the fire compared to 30 days pre-fire and continued to increase slightly after the fire.

As seen in Figure 9, initial investigation of cardiovascular medication dispensing indicated a slight downward trend for the same 30 day period when one year prior to the fire, the year of the fire and the year following the fire were compared. Respiratory medication dispensing appeared to increase in the fire year and then declined the following year but remained above pre-fire levels. Dispensing of medications for mental health conditions appeared to increase in the fire year and then remain stable at the higher level one year later.

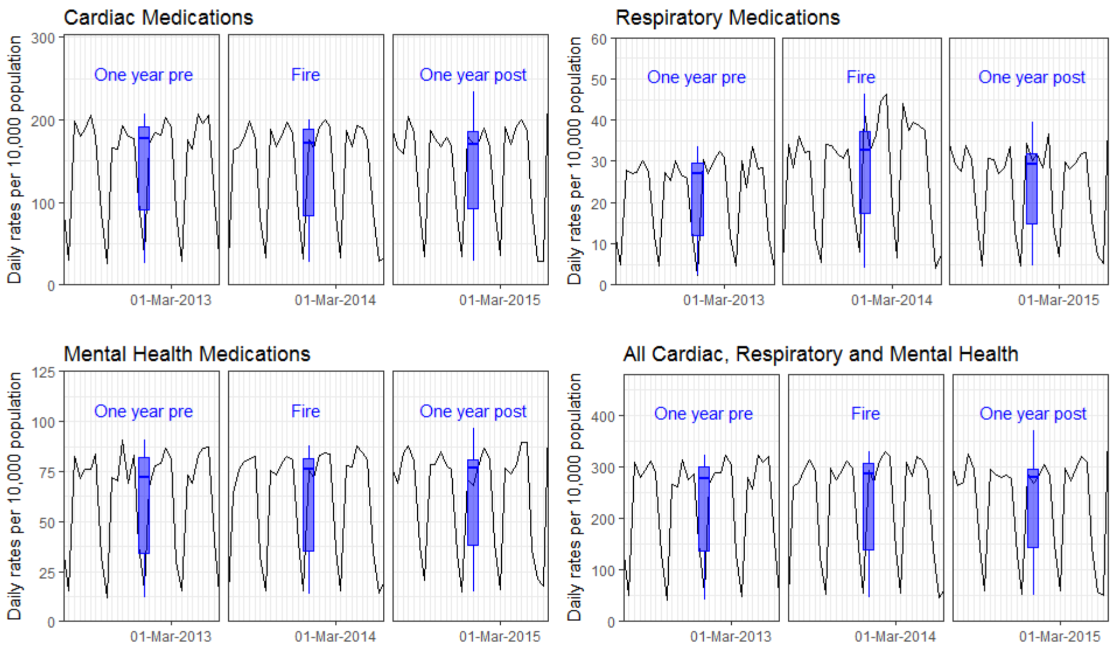

Figure 9 Time series plots of daily PBS medication dispensing in the Latrobe Valley for the 30 days during the fire and the same 30-day period one year before the fire and one year after the fire.

Note: Blue bar is the boxplot of distribution of daily rates per 10,000 where the box indicates the distribution lying within the 25th and 75th percentiles, the blue line indicates the median, and whiskers the lowest and highest values.

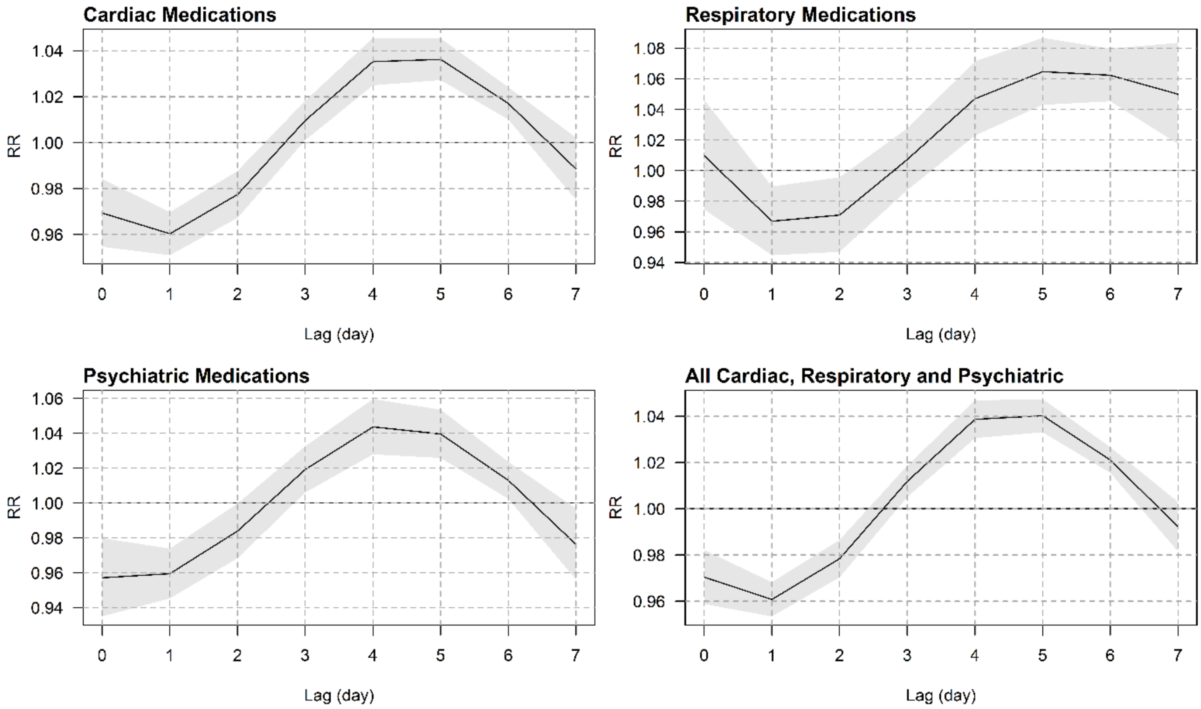

Figure 10 Modelling of the lag structure. Exposure response relationships between medication dispensing and a 10 µg/m3 increase in fire-related $PM_{2.5}$ at lags of 0-7 days.

Note: Analyses control for seasonality, holidays, day of the week, long-term temporal trends and daily maximum temperatures.

The lag relationships between exposure and outcomes are plotted in Figure 10. Associations between exposure to mine fire-related $PM_{2.5}$ and different types of dispensed medications were found after three days of exposure. Those associations lasted an additional three days for dispensed cardiovascular and psychiatric medications (lag effect between three and six days), and four days for respiratory medications (lag effect between three and seven days). Therefore, these lags were used when calculating the risk estimates.

Table 8 Cumulative RR of daily PBS medication dispensing associated with 10 μg/m³ increases in fire-related $PM_{2.5}$

Medication Types†	Cumulative RR*	95% CI	p-value	p-value for difference^
Cardiovascular	**1.10**	**1.07 - 1.13**	**<0.001**	
Sex				
Female	1.12	1.08 - 1.16	<0.001	Reference
Male	1.08	1.05 - 1.12	<0.001	<0.001
Age (years)				
<20	0.77	0.52 - 1.15	0.200	Reference
20 - 34	1.19	0.90 - 1.56	0.216	0.076
35 - 49	1.02	0.93 - 1.12	0.667	0.176
50 - 64	1.10	1.05 - 1.15	<0.001	0.080
65+	1.11	1.08 - 1.15	<0.001	0.071
Respiratory	**1.25**	**1.19 - 1.32**	**<0.001**	
Sex				
Female	1.29	1.20 - 1.38	<0.001	Reference
Male	1.21	1.12 - 1.31	<0.001	0.052
Age (years)				
<20	1.42	1.22 - 1.65	<0.001	Reference
20 - 34	1.62	1.34 - 1.96	<0.001	0.284
35 - 49	1.34	1.17 - 1.55	<0.001	0.582
50 - 64	1.19	1.07 - 1.33	0.007	0.062
65+	1.15	1.06 - 1.25	0.001	0.016
Mental Health	**1.12**	**1.08 - 1.16**	**<0.001**	
Sex				
Female	1.11	1.06 - 1.17	<0.001	Reference
Male	1.14	1.07 - 1.21	<0.001	<0.001
Age (years)				
<20	1.14	0.95 - 1.35	0.154	Reference
20 - 34	1.10	1.00 - 1.21	0.056	0.724
35 - 49	1.11	1.03 - 1.20	0.002	0.784
50 - 64	1.16	1.07 - 1.24	<0.001	0.857
65+	1.10	1.02 - 1.19	0.010	0.712

*Cumulative RR over lag period adjusting for seasonality, public holidays, long term trend, day of the week and daily maximum ambient temperature and their associated 95% confidence intervals (CI).
^Univariate random-effects meta-regression p-values.
† Cardiovascular and mental health medications lag 3-6 days and respiratory medications lag 3-7 days

As shown in Table 8 each 10 μg/m^3 increase in fire-related $PM_{2.5}$ was associated with an estimated 25% increase (RR 1.25; 95% CI 1.19 to 1.32) in the dispensing of respiratory medications, a 10% increase (RR 1.10; 95% CI 1.07 to 1.13) in the dispensing of cardiovascular medications and a 12% increase (RR 1.12; 95% CI 1.08 to 1.16) in the dispensing of mental health/psychiatric medications, over the applicable lag period. Gender stratification indicated both males and females had an increased risk of medications dispensed for the three health conditions. Females had the strongest cumulative RRs for respiratory (29% increase) and cardiovascular medications (12% increase) and males had the strongest cumulative RR for psychiatric medications (14% increase). Age stratification indicated there was an increased cumulative RR of medication dispensing for respiratory medications for all age groups, particularly those aged under 35 years. Those in the older age groups had an increased cumulative RR for cardiovascular and psychiatric medications.

Table 9 Attributable fractions and attributable counts for lag 3-7 days of PBS medication dispensing due to mine fire-related $PM_{2.5}$ in the Latrobe Valley SA3, during the period of the coal mine fire.

Medication type	Mean attributable fraction (95% CI)	Total attributable counts (95% CI)
Cardiovascular	5% (4%, 6%)	2,093 (1,571, 2602)
Respiratory	11% (9%, 14%)	890 (700, 1072)
Mental Health	6% (4%, 8%)	1,053 (712, 1382)
All above medications	**6% (5%, 7%)**	**3,840 (3,182, 4485)**

Note: Cardiovascular and mental health medications lag 3-6 days and respiratory medications lag 3-7 days.

The fractions and counts for dispensing of respiratory medications, cardiovascular medications and mental health medications attributable to mine fire-related $PM_{2.5}$ during the mine fire period are presented in Table 9. There were 2,093 prescriptions dispensed during the 30 day mine fire period for cardiovascular medications, 890 for respiratory medications and 1,053 for mental health medications attributable to mine fire-related $PM_{2.5}$ in the Latrobe Valley. Correspondingly, the attributable fractions for dispensed medications were 5% for cardiovascular, 11% for respiratory and 6% for mental health medications.

8. Discussion

8.1. Summary of main findings

This is the first study to examine the impacts of the 2014 Hazelwood coal mine fire on Commonwealth reimbursed health service use and medication dispensing. To the best of our knowledge this is also the first study anywhere to investigate the association between coalmine fire smoke exposure, health service use and dispensing of medications. Our time series analyses showed that the Hazelwood coal mine fire-related $PM_{2.5}$ was significantly associated with estimated increases in the utilisation of short and long GP consultations, respiratory service visits and mental health consultations, and with increased dispensing of respiratory, cardiovascular and mental health medications.

Descriptive analyses

Descriptive analysis of the raw data indicated that the rates of health service utilisation for all service types (short and long GP visits, respiratory, cardiovascular and mental health services) increased during the mine fire period in comparison to the period 30 days prior to the fire, and continued to increase in the 30 days following the fire. In addition, it was observed that the number of dispensed respiratory medications increased during the fire compared to 30 days before the fire, then slightly declined after the fire but remained above pre-fire levels. Cardiovascular medication dispensing appeared relatively stable during the fire period compared to the 30 days prior and then increased slightly in the 30 days after. Dispensing of mental health medications increased very slightly during the fire compared to 30 days pre-fire and continued to increase slightly after the fire. However, care should be taken when interpreting these results as they simply compare the raw data without any statistical correction for confounders or measurement error.

Time series analyses

After statistically adjusting for long-term trend, seasonality, temperature, day of the week and public holidays, for each 10 $\mu g/m^3$ increase in mine fire-related $PM_{2.5}$ the most notable estimated percentage increases in health service visits were: 37% for visits by men to respiratory services, 32% for visits by men to mental health services, 10% for visits by men and women combined for short GP consultations and 17% for visits by men and women combined for long GP consultations. Stratification by age group indicated that the dose response association between $PM_{2.5}$ and respiratory service visits was highest in 20-34 year-old participants. There was no evidence of a dose response relationship between mine fire $PM_{2.5}$ and visits to cardiovascular services.

Modelling of the lag structure indicated that the associations between $PM_{2.5}$ and increased short and long GP consultations appeared after a lag of 4-5 days. Increased respiratory health service visits predominantly appeared after 7 lag days whilst increased mental health consultations predominantly appeared after 15 lag days.

During the mine fire period, there were 3,274 short or long GP consultations and 159 respiratory service visits attributable to mine fire-related $PM_{2.5}$ exposure in the Latrobe Valley. Correspondingly, the attributable fractions were 4% and 8% respectively. Dose response relationships between mine fire-related $PM_{2.5}$ and the dispensing of medications were also observed. For each 10 $\mu g/m^3$ increase in mine fire-related $PM_{2.5}$ the estimated percentage increases in medications dispensed for men and women combined were 25% for respiratory medications, 12% for mental health medications and 10% for cardiovascular medications. Increased dispensing of respiratory medications was observed for all age groups, but was highest for those aged between 20 and 34 years. Increased dispensing of psychiatric medications was observed amongst those aged 35 and older, and increased dispensing of cardiovascular medications was observed amongst those aged 50 years or older.

Modelling of the lag structure indicated that the associations between $PM_{2.5}$ and increased dispensing of medications appeared after three days of exposure. These associations lasted an additional three days for dispensed cardiovascular and psychiatric medications and four days for respiratory medications. Therefore, these lags were used when calculating the risk estimates. There were 2,093 cardiovascular medications, 890 respiratory medications and 1,053 mental health medications, attributable to mine fire-related $PM_{2.5}$ exposure during the mine fire period. Correspondingly, the attributable fractions were 5%, 11%, and 6%, respectively.

8.2. Relationship to previous published work

There have been no previously published studies on the associations between coal mine fire-related $PM_{2.5}$ concentrations and health service utilisation or medication dispensing against which our findings can be compared. However, our findings are consistent with epidemiological bushfire studies that have typically reported positive associations between bushfire-related $PM_{2.5}$ exposure and respiratory morbidity (Haikerwal et al., 2016). In four Canadian based studies, positive associations were found between wildfire $PM_{2.5}$ and increased dispensing of the bronchodilator salbutamol (Elliott et al., 2013; Yao et al., 2013; Yao et al., 2016; Yuchi et al., 2016). In three of those studies a positive association was also found between wildfire $PM_{2.5}$ and increased respiratory physician visits (Yao et al., 2013; Yao et al., 2016; Yuchi et al., 2016). In two additional Canadian studies, a positive association between PM_{10} and increased respiratory physician visits was found

(Henderson et al., 2011; Moore et al., 2006). In August 2006 a wave of wildfires affected 83,000 hectares in the north-west of Spain. A study comparing unexposed with exposed municipalities in the region reported evidence of increased dispensing of medications for obstructive airways disease in the exposed municipalities (Caamano-Isorna et al., 2011).

Similar to our study, others have not found consistent associations between bushfire $PM_{2.5}$ and cardiovascular outcomes. In a Canadian study, evidence was found for increased dispensing of fast-acting nitro-glycerine (a common medication for angina) and cardiovascular physician visits, when the analysis was limited to extreme fire days. However, no association was found for either cardiovascular health indicator when the entire fire season was analysed (Yao et al., 2016). In another Canadian study, a largely null association was found between bushfire PM_{10} and cardiovascular physician visits, however a small positive association was found for those aged 40-50 years and over 80 years (Henderson et al., 2011). In an earlier Canadian study, no association was found between bushfire PM_{10} and cardiovascular physician visits (Moore et al., 2006).

The relationships between Hazelwood mine fire-related $PM_{2.5}$ and estimated increases in mental health-related health service utilisation and medications in the Latrobe Valley, are consistent with research showing increased psychiatric morbidity following Australia's devastating Ash Wednesday fires (McFarlane et al., 1997). In Caamano-Isorna's Spanish study, increased dispensing of anxiolytics-hypnotics was observed in wildfire-exposed municipalities. (Caamano-Isorna et al., 2011). However, both of the above-mentioned studies involved widespread bushfires (more than 180 fires in Australia and more than 1000 in Spain) that led to massive destruction of land, property and, in Australia, loss of human lives. For those studies, it was likely that the psychiatric response to the events included the trauma of having lives and livelihoods directly threatened. The Hazelwood mine fire event was unique in that the flames themselves did not directly threaten the lives, homes or livestock in nearby communities. Nonetheless, the duration and intensity of the smoke exposure was distressing, with the Hazelwood Health Study's Adult Survey showing $PM_{2.5}$ to be associated with increased self-reported post-traumatic symptoms more than 2 ½ years after the mine fire. (Maybery et al., 2020). In contrast to our finding of an association between $PM_{2.5}$ and increased mental health consultations, one of the above Canadian studies found no association between bushfire PM_{10} and mental health physician visits (Moore et al., 2006).

It should be noted that most bushfires are much shorter in duration than the Hazelwood mine fire event, with smoke dissipating in days. Therefore, our analyses have contributed new findings to the literature.

8.3. Strengths & weaknesses

These Hazelinks analyses have several strengths:

- This research provides the first known report of health services use and medication dispensing after a prolonged brown coal open cut mine fire event, thereby providing direct evidence regarding the impact of prolonged coal mine fire smoke on human health.
- This study had access to two very complete government administrative health datasets (MBS and PBS) from which to source health service utilisation and medication dispensing data.
- The use of a distributed nonlinear lag model to examine the potential delayed effects has been helpful to understand which days of exposure were associated with estimated increases in health service use and medication dispensing. A major benefit of using these statistical models is that they are able to account for the delayed and nonlinear effects of ambient maximum temperature and pollutants to provide cumulative risk estimates for health outcomes along with lag specific ones. We were able to identify a lagged impact of $PM_{2.5}$ across a number of days and establish where the significant lagged effects lay. The flexibility of this type of modelling technique lies in the ability to set the number of degrees of freedom, number of lags and type of smooth spline used.
- The analyses controlled for the potential confounding effects of maximum daily ambient temperature, long-term trend, public holidays, day of the week and seasonality.
- The use of a high spatial resolution air exposure model allowed $PM_{2.5}$ smoke concentrations, attributable to the coal mine fire, to be estimated for geographic areas where air quality monitor measurements were not available.

However, these analyses also have some limitations:

- This study design was semi-ecological and, therefore, it was not possible to explore effect modification or confounding at an individual level.
- Our analyses only investigated the impact of coal mine fire-related $PM_{2.5}$ and did not include other criteria pollutants such as carbon monoxide, ozone, nitrogen dioxide, sulphur dioxide. However, the levels of those other pollutants were lower than National Environment Protection Measures. Focusing on one measure, rather than the cumulative impact of

multiple (mostly lower level) exposures, might underestimate the health risks in relation to the coal mine fire smoke.

- The use of modelled $PM_{2.5}$ concentration levels in lieu of individual level measurements may have introduced exposure misclassification. This would bias effect estimates towards the null, reducing the likelihood of detecting an association. Additionally, the exposure analysis was conducted at a relatively coarse spatial resolution. This was because health utilisation and medication dispensing data were only provided at the aggregated SA3 level due to privacy concerns. Aggregating concentration estimates over large areas also has the potential to introduce exposure misclassification, biasing the effect estimates towards the null. The potential for such misclassification can be seen in Figure 11 which compares modelled $PM_{2.5}$ concentrations attributable to the coal mine fire at different levels of aggregation. The comparison indicates that concentrations experienced in the Morwell SA2 area (red line) were considerably higher than the Latrobe Valley average concentration values (black line) used in the analyses and therefore any potential health effects may have been underestimated for Morwell residents.

- The datasets used in these analyses were collected for administrative billing purposes and therefore presented some limitations. One limitation relates to the fact that MBS service coding may not be standardised across all health services, as it is dependent on the treating physician or practice staff. A further limitation is the fact that the dispensing of medications does not necessarily reflect disease exacerbation nor actual medication consumption. PBS data is also limited in that it does not include all medications. For example, salbutamol inhalers are available over the counter at pharmacies, without any PBS subsidy. The MBS dataset only includes claim records for services that qualified for Medicare benefits and for which a claim had been processed. The PBS dataset only contained information on prescription medicines where the prescription had been processed (i.e. the prescription had been filled by the pharmacist). Both the MBS and PBS exclude some allied health and complementary medicine services.

- It was not possible to sub-divide short and long GP consultations into specific health categories. GP data in the MBS did not specify health information and therefore had to be analysed at group level.

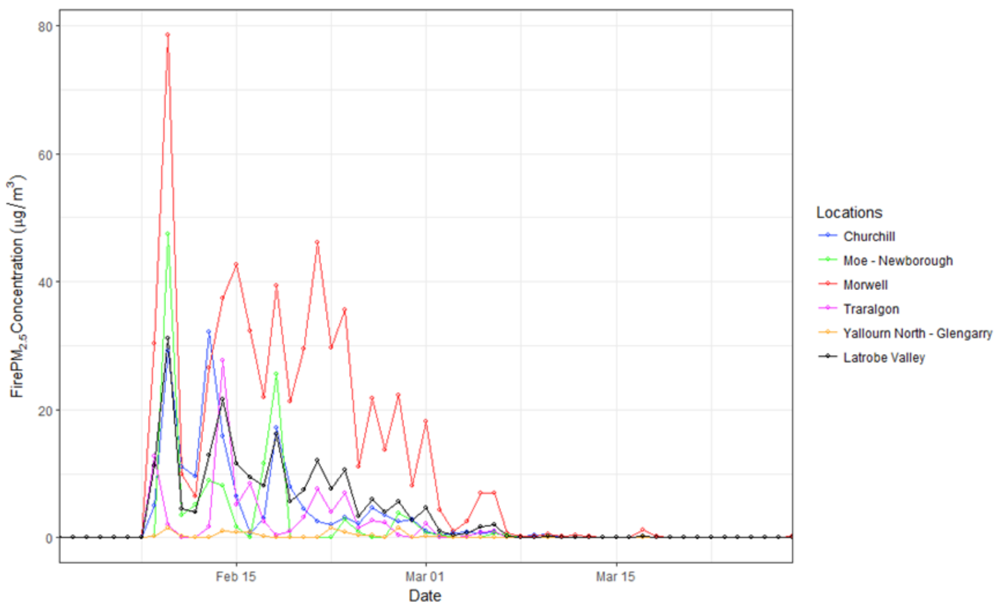

Figure 11 Daily average modelled $PM_{2.5}$ concentrations attributable to the mine fire aggregated at different spatial scales: the SA2 areas within the Latrobe Valley and the Latrobe Valley SA3

8.4. Conclusion

This analysis shows clear evidence that coal mine fire-related $PM_{2.5}$ was significantly associated with estimated increases in the utilisation of respiratory health services, short and long GP visits and mental health consultations. There is also clear evidence of an association between increasing $PM_{2.5}$ and the dispensing of all medication types examined (respiratory, cardiovascular and mental health). This contributes to filling the knowledge gap which currently exists regarding the health impact of open cut brown coal mine fire smoke exposure. Such robust evidence-based research is important to improve health impact assessment of at-risk groups, and to improve targeted health advice and emergency health services. This study should be helpful to develop and implement effective and more timely adaptive strategies to mitigate cardiovascular, respiratory and mental health risks due to possible future coal mine fire derived air pollution exposures in the community.

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Appendix 1: Supplementary Tables

Supplementary Table 1: MBS health service use by service type included in the analysis

Health service type	
Group	**Item Numbers**
Short GP consultations	
A1 General Practitioner	3, 4, 20, 23, 24, 35
A2 Other non-referred	52, 53, 58,59, 92, 93
A11 After Hours	597, 598,5 99,600
A21 Medical Practitioner (Emergency Physician) attendances	501, 503
A22 GP after-hours attendances to which no other item applies	5000, 5003, 5010, 5020, 5023, 5028
A23 Other non-referred after-hours attendances to which no other item applies	5200, 5203, 5223, 5260, 5263
Long GP consultations	
A1 General Practitioner	36, 37, 43, 44, 47, 51
A2 Other non-referred	54, 57, 60, 65, 95, 96
A5 Prolonged	160, 161, 162, 163, 164
A21 Medical Practitioner (Emergency Physician) attendances	507, 511, 515, 520
A22 GP after-hours attendances to which no other item applies	5040, 5043, 5049, 5060, 5063, 5067
A23 Other non-referred after-hours attendances to which no other item applies	5207, 5208, 5227, 5265, 5267
GP Mental Health consultations	
A20 GP Mental Health Treatment	2700, 2701, 2712, 2713, 2715, 2717, 2721, 2725
Specialist Mental Health consultations	
A8 Consultant Psychiatrist	288, 289, 291, 293, 296, 297, 299, 300, 302, 304, 306, 308, 310, 319, 320, 322, 324, 326, 328, 330, 332, 334, 336, 338, 342, 346, 348, 350, 352, 355, 356, 357, 359, 361, 367, 369
M6 Psychological Therapy Services	80000, 80005, 80010, 80015, 80020
M7 Focussed Psychological Strategies	80100, 80105, 80110, 80115, 80120, 80125, 80135, 80140, 80145, 80150, 80155, 80160, 80165,80170
Cardiovascular specialist consultations	
A4 Consultant Physician (other than Psychiatry) Where Provider Derived Specialty Description = "CP-CARDIOLOGY"	110, 112, 116, 119, 132, 133

Cardiovascular diagnostic & imaging tests	
D1 Miscellaneous Diagnostic Procedures and Investigations	11602, 11610, 11611, 11612, 11700, 11701, 11702, 11708, 11709, 11710, 11711, 11712, 11713, 11718, 11719, 11721, 11722, 11724, 11725, 11727
I1 Ultrasound (Echocardiography)	55113, 55114, 55115, 55116, 55117, 55118, 55130, 55135, 55224, 55227, 55233, 55238, 55244, 55246, 55248, 55252, 55274, 55276, 55278, 55280, 55282, 55284, 55292, 55294, 55296,
I3 Diagnostic Radiology	59903, 59912, 59925, 59970, 59972, 59973, 60000, 60003, 60006, 60009, 60012, 60018, 60021, 60024, 60027, 60030, 60033, 60039, 60042, 60045, 60048, 60051, 60054, 60057, 60060, 60063, 60066, 60069, 60072, 60075, 60078
T1 Miscellaneous Therapeutic Procedures	13400
Respiratory specialist consultations	
A4 Consultant Physician (other than Psychiatry) Where Provider Derived Specialty Description = "CP-THORAC-MED"	110, 112, 116, 119, 132, 133
Respiratory diagnostic & imaging tests	
D1 Miscellaneous Diagnostic Procedures and Investigations (Lung function tests)	11503, 11506, 11512
I3 Diagnostic Radiology	58503

Supplementary Table 2: Cardiovascular system medication classifications included in the analyses

NAME2	NAME4	ATC	DRUG_NAME
Cardiac Therapy		**C01**	
	Digitalis Glycosides	C01AA05	Digoxin
	Antiarrhythmics, Class IA	C01BA03	Disopyramide
	Antiarrhythmics, Class IB	C01BB01	Lignocaine Hydrochloride
	Antiarrhythmics, Class IC	C01BC04	Flecainide Acetate
	Antiarrhythmics, Class III	C01BD01	Amiodarone Hydrochloride
	Adrenergic & Dopaminergic Agents	C01CA24	Adrenaline
	Organic Nitrates	C01DA02	Glyceryl Trinitrate
	Organic Nitrates	C01DA08	Isosorbide Dinitrate
	Organic Nitrates	C01DA14	Isosorbide Mononitrate
	Other Vasodilators used in Cardiac Diseases	C01DX16	Nicorandil
Antihypertensives		**C02**	
	Methyldopa	C02AB01	Methyldopa
	Imidazoline Receptor Agonists	C02AC01	Clonidine
	Imidazoline Receptor Agonists	C02AC05	Moxonidine
	Alpha-Adrenoreceptor Antagonists	C02CA01	Prazosin Hydrochloride
	Hydrazinophthalazine Derivatives	C02DB02	Hydralazine Hydrochloride
	Pyrimidine Derivatives	C02DC01	Minoxidil
	Other antihypertensives	C02KX01	Bosentan
	Other antihypertensives	C02KX02	Ambrisentan
	Other antihypertensives	C02KX04	Macitentan
Diuretics		**C03**	
	Thiazides, Plain	C03AA03	Hydrochlorothiazide
	Sulfonamides, Plain	C03BA04	Chlorthalidone
	Sulfonamides, plain	C03BA11	Indapamide
	Sulfonamides, Plain	C03CA01	Frusemide
	Aryloxyacetic Acid Derivatives	C03CC01	Ethacrynic acid
	Aldosterone Antagonists	C03DA01	Spironolactone
	Aldosterone Antagonists	C03DA04	Eplerenone
	Low-ceiling Diuretics & Potassium-Sparing Agents	C03EA01	Hydrochlorothiazide with Triamterene
	Low-ceiling Diuretics & Potassium-Sparing Agents	C03EA01	Hydrochlorothiazide with Amiloride Hydrochloride
Beta Blocking Agents		**C07**	
	Beta Blocking Agents, Non-selective	C07AA02	Oxprenolol Hydrochloride
	Beta Blocking Agents, Non-selective	C07AA03	Pindolol
	Beta Beta Blocking Agents, Non-selective	C07AA05	Propranolol Hydrochloride
	Beta Blocking Agents, Non-selective	C07AA07	Sotalol Hydrochloride
	Beta Blocking Agents, Selective	C07AB02	Metoprolol Tartrate
	Beta Blocking Agents, Selective	C07AB02	Metoprolol Succinate

	Beta Blocking Agents, Selective	C07AB03	Atenolol
	Beta Blocking Agents, Selective	C07AB07	Bisoprolol
	Beta Blocking Agents, Selective	C07AB12	Nebivolol
	Alpha & Beta Blocking Agents	C07AG01	Labetalol Hydrochloride
	Alpha & Beta Blocking Agents	C07AG02	Carvedilol
Calcium Channel Blockers		**C08**	
	Dihydropyridine Derivatives	C08CA01	Amlodipine
	Dihydropyridine Derivatives	C08CA02	Felodipine
	Dihydropyridine Derivatives	C08CA05	Nifedipine
	Dihydropyridine Derivatives	C08CA13	Lercanipidine
	Phenylalkylamine Derivatives	C08DA01	Verapamil Hydrochloride
	Benzothiazepine Derivatives	C08DB01	Diltiazem Hydrochloride
Agents Acting on the Renin-Angiotensin System		**C09**	
	Ace Inhibitors, Plain	C09AA01	Captopril
	Ace Inhibitors, Plain	C09AA02	Enalapril Maleate
	Ace Inhibitors, Plain	C09AA03	Lisinopril
	Ace Inhibitors, Plain	C09AA04	Perindopril
	Ace Inhibitors, Plain	C09AA05	Ramipril
	Ace Inhibitors, Plain	C09AA06	Quinapril
	Ace Inhibitors, Plain	C09AA09	Fosinopril
	Ace Inhibitors, Plain	C09AA10	Trandolapril
	Ace Inhibitors & Diuretics	C09BA02	Enalapril with Hydrochlorothiazide
	Ace Inhibitors & Diuretics	C09BA04	Perindopril with Indapamide
	Ace Inhibitors & Diuretics	C09BA06	Quinapril with Hydrochlorothiazide
	Ace Inhibitors & Diuretics	C09BA09	Fosinopril with Hydrochlorothiazide
	Ace Inhibitors & Calcium Channel Blockers	C09BB02	Enalapril & Lercanidipine
	Ace Inhibitors & Calcium Channel Blockers	C09BB04	Perindopril & Amlodipine
	Ace Inhibitors & Calcium Channel Blockers	C09BB05	Ramipril & Felodipine
	Ace Inhibitors & Calcium Channel Blockers	C09BB10	Trandolapril & Verapamil
	Angiotensin II Antagonists, Plain	C09CA01	Losartan
	Angiotensin II Antagonists, Plain	C09CA02	Eprosartan
	Angiotensin II Antagonists, Plain	C09CA03	Valsartan
	Angiotensin II Antagonists, Plain	C09CA04	Irbesartan
	Angiotensin II Antagonists, Plain	C09CA06	Candesartan
	Angiotensin II Antagonists, Plain	C09CA07	Telmisartan
	Angiotensin II Antagonists, Plain	C09CA08	Olmesartan Medoxomil
	Angiotensin II Antagonists & Diuretics	C09DA02	Eprosartan with Hydrochlorothiazide

	Angiotensin II Antagonists & Diuretics	C09DA03	Valsartan with Hydrochlorothiazide
	Angiotensin II Antagonists & Diuretics	C09DA04	Irbesartan with Hydrochlorothiazide
	Angiotensin II Antagonists & Diuretics	C09DA06	Candesartan with Hydrochlorothiazide
	Angiotensin II Antagonists & Diuretics	C09DA07	Telmisartan with Hydrochlorothiazide
	Angiotensin II Antagonists & Calcium Channel Blockers	C09DB01	Amlodipine & Valsartan
	Angiotensin II Antagonists & Calcium Channel Blockers	C09DB02	Olmesartan with Amlodipine
	Angiotensin II Antagonists & Calcium Channel Blockers	C09DB04	Telmisartan & Amlodipine
	Angiotensin II Antagonists, Other Combinations	C09DX01	Amlodipine with Valsartan & Hydrochlorothiazide
	Angiotensin II Antagonists, Other Combinations	C09DX03	Olmesartan with Amlodipine & Hydrochlorothiazide
Lipid Modifying Agents		**C10**	
	HMG COA Reductase Inhibitors	C10AA01	Simvastatin
	HMG COA Reductase Inhibitors	C10AA03	Pravastatin
	HMG COA Reductase Inhibitors	C10AA04	Fluvastatin
	HMG COA Reductase Inhibitors	C10AA05	Atorvastatin
	HMG COA Reductase Inhibitors	C10AA07	Rosuvastatin
	Fibrates	C10AB04	Gemfibrozil
	Fibrates	C10AB05	Fenofibrate
	Bile Acid Sequestrants	C10AC01	Colestyramine
	Bile Acid Sequestrants	C10AC02	Colestipol Hydrochloride
	Other Lipid Modifying Agents	C10AX09	Ezetimibe
	HMG COA Reductase Inhibitors In Combination with Other Lipid Modifying AG	C10BA02	Simvastatin & Ezetimibe
	HMG COA Reductase Inhibitors In Combination with Other Lipid Modifying AG	C10BA05	Atorvastatin & Ezetimibe
	HMG COA Reductase Inhibitors In Combination with Other Lipid Modifying AG	C10BA05	Ezetimibe with Atorvastatin
	HMG COA Reductase Inhibitors In Combination with Other Lipid Modifying AG	C10BA06	Ezetimibe & Rosuvastatin
	HMG COA Reductase Inhibitors, Other Combinations	C10BX03	Atorvastatin & Amlodipine

Supplementary Table 3: Respiratory system medication classifications included in the analyses

NAME2	NAME4	ATC	DRUG_NAME
CORTICOSTEROIDS FOR SYSTEMIC USE		H02	
	GLUCOCORTICOIDS	H02AB01	BETAMETHASONE
	GLUCOCORTICOIDS	H02AB02	DEXAMETHASONE
	GLUCOCORTICOIDS	H02AB04	METHYLPREDNISOLONE
	GLUCOCORTICOIDS	H02AB06	PREDNISOLONE
	GLUCOCORTICOIDS	H02AB07	PREDNISONE
	GLUCOCORTICOIDS	H02AB08	TRIAMCINOLONE
	GLUCOCORTICOIDS	H02AB09	HYDROCORTISONE
	GLUCOCORTICOIDS	H02AB10	CORTISONE
DRUGS FOR OBSTRUCTIVE AIRWAY DISEASES		R03	
	SELECTIVE BETA-2-ADRENORECEPTOR AGONISTS	R03AC02	SALBUTAMOL
	SELECTIVE BETA-2-ADRENORECEPTOR AGONISTS	R03AC03	TERBUTALINE
	SELECTIVE BETA-2-ADRENORECEPTOR AGONISTS	R03AC12	SALMETEROL
	SELECTIVE BETA-2-ADRENORECEPTOR AGONISTS	R03AC13	EFORMOTEROL
	SELECTIVE BETA-2-ADRENORECEPTOR AGONISTS	R03AC18	INDACATEROL
	ADRENERGICS IN COMBINATION WITH CORTICOSTEROIDS	R03AK06	SALMETEROL & FLUTICASONE
	ADRENERGICS IN COMBINATION WITH CORTICOSTEROIDS	R03AK07	EFORMOTEROL with BUDESONIDE
	ADRENERGICS IN COMBINATION WITH CORTICOSTEROIDS	R03AK10	FLUTICASONE with VILANTEROL
	ADRENERGICS IN COMBINATION WITH CORTICOSTEROIDS	R03AK11	FLUTICASONE with EFORMOTEROL
	ADRENERGICS IN COMBINATION WITH ANTICHOLINERGICS	R03AL03	UMECLIDINIUM with VILANTEROL
	ADRENERGICS IN COMBINATION WITH ANTICHOLINERGICS	R03AL04	INDACATEROL with GLYCOPYRRONIUM
	ADRENERGICS IN COMBINATION WITH ANTICHOLINERGICS	R03AL05	ACLIDINIUM with EFORMOTEROL
	ADRENERGICS IN COMBINATION WITH ANTICHOLINERGICS	R03AL06	TIOTROPIUM with OLODATEROL
	INHALED GLUCOCORTICOIDS	R03BA01	BECLOMETHASONE DIPROPIONATE
	INHALED GLUCOCORTICOIDS	R03BA02	BUDESONIDE
	INHALED GLUCOCORTICOIDS	R03BA05	FLUTICASONE
	INHALED GLUCOCORTICOIDS	R03BA08	CICLESONIDE
	ANTICHOLINERGICS	R03BB01	IPRATROPIUM
	ANTICHOLINERGICS	R03BB04	TIOTROPIUM
	ANTICHOLINERGICS	R03BB05	ACLIDINIUM
	ANTICHOLINERGICS	R03BB06	GLYCOPYRRONIUM
	ANTICHOLINERGICS	R03BB07	UMECLIDINIUM
	XANTHINES	R03DA04	THEOPHYLLINE
	LEUKOTRIENE RECEPTOR ANTAGONISTS	R03DC03	MONTELUKAST
COUGH AND COLD PREPARATIONS		R05	
	COUGH SUPPRESSANTS	R05DA04	CODEINE
	COUGH SUPPRESSANTS	R05DA08	PHOLCODINE

Supplementary Table 4: Mental Health/psychiatric medication classifications included in the analyses

NAME2	NAME4	ATC	DRUG_NAME
PSYCHOLEPTICS		**N05**	
	PHENOTHIAZINES WITH ALIPHATIC SIDE-CHAIN	N05AA01	CHLORPROMAZINE HYDROCHLORIDE
	PHENOTHIAZINES WITH PIPERAZINE STRUCTURE	N05AB02	FLUPHENAZINE DECANOATE
	PHENOTHIAZINES WITH PIPERAZINE STRUCTURE	N05AB04	PROCHLORPERAZINE
	PHENOTHIAZINES WITH PIPERAZINE STRUCTURE	N05AB06	TRIFLUOPERAZINE HYDROCHLORIDE
	PHENOTHIAZINES WITH PIPERIDINE STRUCTURE	N05AC01	PERICYAZINE
	BUTYROPHENONE DERIVATIVES	N05AD01	HALOPERIDOL
	INDOLE DERIVATIVES	N05AE04	ZIPRASIDONE
	INDOLE DERIVATIVES	N05AE05	LURASIDONE
	THIOXANTHENE DERIVATIVES	N05AF01	FLUPENTHIXOL
	THIOXANTHENE DERIVATIVES	N05AF05	ZUCLOPENTHIXOL
	DIAZEPINES, OXAZEPINES, THIAZEPINES & OXEPINES	N05AH02	CLOZAPINE
	DIAZEPINES, OXAZEPINES, THIAZEPINES & OXEPINES	N05AH03	OLANZAPINE
	DIAZEPINES, OXAZEPINES, THIAZEPINES & OXEPINES	N05AH05	ASENAPINE
	BENZAMIDES	N05AL05	AMISULPRIDE
	OTHER ANTIPSYCHOTICS	N05AX08	RISPERIDONE
	OTHER ANTIPSYCHOTICS	N05AX12	ARIPIPRAZOLE
	OTHER ANTIPSYCHOTICS	N05AX13	PALIPERIDONE
	BENZODIAZEPINE DERIVATIVES	N05BA01	DIAZEPAM
	BENZODIAZEPINE DERIVATIVES	N05BA04	OXAZEPAM
	BENZODIAZEPINE DERIVATIVES	N05BA08	BROMAZEPAM
	BENZODIAZEPINE DERIVATIVES	N05BA12	ALPRAZOLAM
	BENZODIAZEPINE DERIVATIVES	N05CD02	NITRAZEPAM
	BENZODIAZEPINE DERIVATIVES	N05CD03	FLUNITRAZEPAM
	BENZODIAZEPINE DERIVATIVES	N05CD07	TEMAZEPAM
	BENZODIAZEPINE DERIVATIVES	N05CD08	MIDAZOLAM
	BENZODIAZEPINE RELATED DRUGS	N05CF01	ZOPICLONE
PSYCHOANALEPTICS		**N06**	
	NON-SELECTIVE MONOAMINE REUPTAKE INHIBITORS	N06AA02	IMIPRAMINE
	NON-SELECTIVE MONOAMINE REUPTAKE INHIBITORS	N06AA04	CLOMIPRAMINE HYDROCHLORIDE
	NON-SELECTIVE MONOAMINE REUPTAKE INHIBITORS	N06AA09	AMITRIPTYLINE HYDROCHLORIDE
	NON-SELECTIVE MONOAMINE REUPTAKE INHIBITORS	N06AA10	NORTRIPTYLINE HYDROCHLORIDE
	NON-SELECTIVE MONOAMINE REUPTAKE INHIBITORS	N06AA12	DOXEPIN
	NON-SELECTIVE MONOAMINE REUPTAKE INHIBITORS	N06AA16	DOTHIEPIN
	SELECTIVE SEROTONIN REUPTAKE INHIBITORS	N06AB03	FLUOXETINE HYDROCHLORIDE
	SELECTIVE SEROTONIN REUPTAKE INHIBITORS	N06AB04	CITALOPRAM
	SELECTIVE SEROTONIN REUPTAKE INHIBITORS	N06AB05	PAROXETINE
	SELECTIVE SEROTONIN REUPTAKE INHIBITORS	N06AB06	SERTRALINE
	SELECTIVE SEROTONIN REUPTAKE INHIBITORS	N06AB08	FLUVOXAMINE
	SELECTIVE SEROTONIN REUPTAKE INHIBITORS	N06AB10	ESCITALOPRAM
	MONOAMINE OXIDASE INHIBITORS, NON-SELECTIVE	N06AF03	PHENELZINE SULPHATE
	MONOAMINE OXIDASE INHIBITORS, NON-SELECTIVE	N06AF04	TRANYLCYPROMINE SULPHATE
	MONOAMINE OXIDASE A INHIBITORS	N06AG02	MOCLOBEMIDE
	OTHER ANTIDEPRESSANTS	N06AX03	MIANSERIN HYDROCHLORIDE
	OTHER ANTIDEPRESSANTS	N06AX11	MIRTAZAPINE

OTHER ANTIDEPRESSANTS	N06AX12	BUPROPION
OTHER ANTIDEPRESSANTS	N06AX16	VENLAFAXINE
OTHER ANTIDEPRESSANTS	N06AX18	REBOXETINE
OTHER ANTIDEPRESSANTS	N06AX21	DULOXETINE
OTHER ANTIDEPRESSANTS	N06AX23	DESVENLAFAXINE
CENTRALLY ACTING SYMPATHOMIMETICS	N06BA02	DEXAMPHETAMINE SULPHATE
CENTRALLY ACTING SYMPATHOMIMETICS	N06BA04	METHYLPHENIDATE
CENTRALLY ACTING SYMPATHOMIMETICS	N06BA07	MODAFINIL
CENTRALLY ACTING SYMPATHOMIMETICS	N06BA09	ATOMOXETINE
CENTRALLY ACTING SYMPATHOMIMETICS	N06BA12	LISDEXAMFETAMINE

Appendix 2: Parameters used in the time series analysis models

In the GLM structure, the modelled daily fire-generated $PM_{2.5}$ was included alongside potential confounders including seasonality, long-term trend, day of the week, maximum ambient temperature and public holidays (Buckingham-Jeffery et al., 2017). A natural cubic spline of time with 7 degrees of freedom per year was employed to control for seasonality and long-term trend, which allowed for a complex non-linear pattern of outcome rates over time. A variable was used to control for day of the week. A distributed lag non-linear structure was applied to allow for flexible relationships between health outcomes and lag effect of daily fire-generated $PM_{2.5}$. The effect of $PM_{2.5}$ was assumed linear and the lagged effect up to 7 days with a natural cubic spline set with knots at day 2 which means 3 degrees of freedom for the lag. The effect of ambient maximum temperature was assumed nonlinear with a natural cubic spline with 3 degrees of freedom and the lagged effect up to 21 days with a natural cubic spline set with 3 degrees of freedom for the lag.

Most of the data cleaning and variable transformation, and all of the analyses were conducted using the statistical analysis software package R (version 3.4.1: R Development Core Team 2017). Generalized linear models were implemented using R function “glm” and distributed lag non-linear structures using R package “dlnm” (Gasparrini, 2011). Stata Version 15 (StataCorp, College Station, TX) was used for additional data manipulation and data management.

Document History

Version Number	Date	Contact	Brief description
1.0	20 November 2017	Hazelwood Health Study Senior Project Manager	Submitted to DHHS for approval for public release
1.1	19 December 2017	Hazelwood Health Study Senior Project Manager	Minor corrections at p 2 and p 12
1.2	19 February 2018	Hazelinks Coordinator	Corrections made in response to feedback from Commonwealth Department of Human Services at p 10
1.3	20 March 2018	Hazelinks Coordinator	Corrections made in response to feedback from EREC at p 11 and p 33. Dates of PBS analysis period corrected throughout the report.
1.4	13 August 2018	Hazelwood Health Study Senior Project Manager	Caveat added to page 2
2.0	3 September 2020	Hazelwood Health Study Senior Project Manager	Data analysis reviewed at the time of writing journal articles. Revised, per reviewed findings incorporated retrospectively into this report. Caveat removed from page 2.