Hazelwood
HEALTH STUDY

The Latrobe Early Life Follow-up (ELF) Cohort Study Volume 1

Description of the cohort and preliminary assessment of possible associations between mine fire emissions and parent-reported perinatal outcomes

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UNIVERSITY of TASMANIA
MENZIES
Institute for Medical Research

Authors

Shannon Melody

Marita Dalton

Martine Dennekamp

Amanda Wheeler

Shyamali Dharmage

Karen Wills

Melanie Reeves

Jane Ford

Tierney O'Sullivan

Grant Williamson

Alison Venn

Christine Roberts

Fay Johnston

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Caveat

This report presents a preliminary analysis which has not been submitted to independent peer review. Subsequent scientific manuscripts which undergo independent peer review may vary in their findings or interpretation.

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Abbreviations

95% CI	95 percent confidence interval
CATI	Computer Assisted Telephone Interview
CAWI	Computer Assisted Web Interview
CSIRO	Commonwealth Scientific and Industrial Organisation
HRF	Hunter Research Foundation
IQR	Interquartile range
Latrobe ELF Study	Latrobe Early Life Follow-Up Study: The child health and development stream of the Hazelwood Health Study
LBWAT	Low Birth Weight at Term
LCC	Latrobe City Council
LGA	Large for Gestational Age
$PM_{2.5}$	Particulate matter with an aerodynamic diameter less than 2.5 micrometres
RR	Relative Risk
SGA	Small for Gestational Age

Executive Summary

This is the first report of preliminary findings from the Latrobe Early Life Follow-up (ELF) Study, which aims to understand the impacts of exposure to smoke from the 2014 Hazelwood coal mine fire on young children and children born to women who were pregnant during the smoke episode. The ELF Study has three components: (i) studying an identified cohort of children from the Latrobe Valley, (ii) an analysis of de-identified state-wide perinatal data, and (iii) an anonymised data-linkage cohort study of children born in the Latrobe Valley. This report presents some initial results from the identified cohort study. Specifically we present the first findings from the survey completed by the parents or carers of participating children when they enrolled in the study, focussing on birth related outcomes. More results from the survey will be presented in later reports.

Children born from 1 March 2012 until 31 December 2015, whose primary residential address was in the Latrobe City local government area were eligible to enrol in the study. The cohort was designed to have a balance of numbers by the timing of exposure (prenatal exposure, infant exposure, and a comparison group conceived after the fire, with no exposure) and magnitude of smoke exposure (residents of Morwell, which was closest to the fire and had greater smoke exposure, vs residents from the rest of the Latrobe Valley). Recruitment targets were exceeded overall (110% of target) with 548 children enrolled. The approximate balance across exposure groups was achieved with 199 whose mothers were pregnant during the fire, 190 who were aged up to 2 years at the time of the fire, and 159 who were conceived after the fire. All except two children were Australian born. About half (48%) were female, and 31 (6%) identified as Aboriginal and/or Torres Strait Islander.

The mean daily concentration of particulate matter with an aerodynamic diameter less than 2.5 micrometres ($PM_{2.5}$) directly attributable to the mine fire was the primary exposure evaluated in this study. The average and peak daily $PM_{2.5}$ for the 51-day period from 9 February 2014 to 31 March 2014, at a spatial resolution of 1x1 km, was derived from an atmospheric transport model. The exposure of pregnant mothers to mine fire smoke was estimated from modelled outputs for their residential addresses during pregnancy. For mothers in Morwell, the average daily smoke-derived $PM_{2.5}$ during this period was 18.4 $\mu g/m^3$ (range 5.4 - 56.1 $\mu g/m^3$), and the average 24-hour peak was 266.7 $\mu g/m^3$ (range 95.1 – 991.3 $\mu g/m^3$). The exposure was much lower for mothers from the rest of the Latrobe valley. Their average daily smoke-derived $PM_{2.5}$ was 2.2 $\mu g/m^3$ (range 0.1 - 17.4 $\mu g/m^3$), and the average 24-hour peak was 79.9 µg/m3 (range 5.1 – 617.0 $\mu g/m^3$). Exposure to $PM_{2.5}$ from mine fire smoke during pregnancy for the mothers of children born before or conceived after the fire was zero.

Most mothers (81%) were aged between 20 to 34 years at the time of the birth of their child, 13% were 35 years or older, while 4% were 19 years or younger. More than half (60%) had a post-secondary qualification. Stress during pregnancy was reported as being experienced 'sometimes' by 47% of mothers and 'most of the time' by 17% of mothers. Approximately 8% reported consuming alcohol in the first half of pregnancy and 4% during the second half, while smoking at any stage was reported by 18%. The majority of parents reported increased stress in response to the mine fire (74% of mothers and 59% of fathers) and those living closest to the fire reported greater stress in response to the event, than those living further away.

Of the ELF study cohort of children, 70% were born by vaginal delivery. The mean gestational age was 39.2 weeks with 9% born before 37 weeks of gestation. The mean birthweight of children born at term was 3406 grams (standard deviation 636.8 grams).

After adjusting for the influence of known risk factors for adverse perinatal outcomes, no associations were observed between maternal exposure to the average or peak $PM_{2.5}$ from the mine fire and preterm birth, birth weight at term, or being small or large for gestational age (Table 1).

Table 1. Summary of associations between exposure to poor air quality from the Hazelwood coal mine fire and birth outcomes

	Adjusted RR^ (95%CI) per unit increase in average maternal $PM_{2.5}$ exposure	**Adjusted RR^ (95%CI) per 10 unit increase in peak maternal $PM_{2.5}$ exposure**
Preterm birth	1.00 (0.97 to 1.04)	0.99 (0.97 to 1.02)
Low birth weight at term	0.99 (0.96 to 1.03)	0.99 (0.97 to 1.02)
Small for gestational age	0.95 (0.90 to 1.01)	0.97 (0.94 to 1.004)
Large for gestational age	1.01 (0.99 to 1.04)	1.00 (0.99 to 1.02)

^Adjusted for child Aboriginality, maternal age, maternal education, maternal smoking in pregnancy and maternal alcohol consumption in pregnancy

We did not observe an association between stress specifically related to the mine fire and adverse perinatal outcomes. However, a number of well-recognised risk factors, including smoking in pregnancy, general stress in pregnancy and lower maternal education, were independently associated with some adverse birth outcomes evaluated in the study cohort.

In summary, these preliminary analyses did not demonstrate an association between maternal exposure to mine fire smoke and adverse birth outcomes. Further studies of perinatal outcomes are planned. These will include an evaluation of birth outcomes in this cohort using improved personal exposure estimates based on more detailed location data than residence during the mine fire, and a separate analysis of de-identified perinatal data for all children in the Latrobe Valley.

1. Introduction

The Hazelwood open cut coal mine is located adjacent to the town of Morwell in the Latrobe Valley of Victoria. In 2014, during a period of bushfire activity in the surrounding vegetation, the coal deposit caught fire and burned for almost six weeks. During this period the fire produced some of the most extreme concentrations of fine particulate matter ($PM_{2.5}$), affecting populated regions, ever measured in Australia (1). As there were few precedents upon which to base public health protection messages or to assess adverse health effects, the Victorian Department of Health and Human Services commissioned the Hazelwood Health Study to identify any medium or long term health impacts among residents of the affected communities, and to inform policy and planning in the event of future similar events.

The Latrobe ELF Study forms one stream of the Hazelwood Health Study. It aims to understand the impact of the mine fire smoke exposure during pregnancy or infancy on perinatal outcomes and the subsequent health and development of children in the Latrobe Valley.

Specifically, the Latrobe ELF Study aims to:

1. Compare perinatal outcomes, particularly foetal growth and maturity, of those exposed, and not exposed, to smoke from the Hazelwood coal mine fire.
2. Compare the frequency of parental reports of minor illnesses in infants over a three-year period of those exposed, and not exposed, to smoke from the Hazelwood coal mine fire.
3. Follow and compare the development of respiratory and cardiovascular function in children exposed, and not exposed, to smoke from the Hazelwood coal mine fire.
4. Assess long-term indicators of health and development through data extraction and data linkage studies comparing those exposed, and not exposed, to smoke from the Hazelwood mine fire.

To achieve these aims, three sub-studies have been established:

1. An **identified cohort** of children who have been enrolled by his/her parents to participate in the study.
2. **A state-wide de-identified data extraction** of perinatal data from the Victorian Perinatal Data Collection.
3. **A long-term anonymised data linkage study** of all children born in the Latrobe Valley.

The purpose of the identified cohort study (sub-study 1) is to gather detailed information from parents about specific clinical outcomes in their children, and possible confounding factors that are not available from data extraction studies. Such confounding factors include maternal stress, smoking and alcohol consumption in pregnancy. The parallel data extraction and anonymised linkage studies (sub-studies 2 and 3) will evaluate the complete cohort of children born in the Latrobe Valley. These anonymous data analyses have the advantages of greater statistical power due to the larger sample size, and they avoid the limitations of recruitment bias, recall bias, or loss to follow-up. However, it is not possible to obtain detailed social, clinical and environmental information from data sets collected for administrative purposes.

This is the first report of results from the Latrobe ELF Study. It focuses on recruitment and initial results from the identified cohort study (sub-study 1) in relation to aim 1, perinatal outcomes. Further perinatal outcomes will be reported following analysis of the state-wide perinatal data extraction once those data become available.

Investigation of perinatal outcomes is important because of the relative paucity of evidence relating to air quality and birth outcomes, especially in the context of severe smoke events from

landscape and ground fires such as peat or coal fires. Smoke generated from coal combustion includes a range of pollutants that are known to be harmful to human health, including particulate matter, carbon monoxide, polyaromatic hydrocarbons, benzene and others. There is very little evidence about the specific impact of coal mine fire smoke events on human health (2). The health impacts of similar exposures, such as severe smoke events from wildfires, have been investigated in relation to cardiovascular and respiratory outcomes. In relation to perinatal outcomes, there is a small but growing body of evidence demonstrating that maternal exposure to indoor and ambient air pollution is associated with preterm birth and growth restriction (3-5). However, very few studies have explored the impact of severe smoke events on perinatal outcomes and none have specifically investigated coal mine fire smoke events (6, 7).

Pregnancy outcomes are determined by the ability of the fetus to thrive, which in turn is influenced by a host of genetic, social and environmental factors. The developing fetus is sensitive to a range of internal and external influences that can potentially have lifelong effects on health. Infants who are born preterm or growth restricted are at increased risk of a number of poor health outcomes in the immediate neonatal period as well as throughout the life course (8, 9). As such, efforts to optimise the perinatal period are of key importance in improving individual and population health.

2. Methods

The study was approved by the Tasmanian Health and Medical Human Research Ethics Committee (reference H14875 and H15033). Additional approval was received from the Human Research Ethics Committees of Monash University, Monash Health, the University of Melbourne, the University of Sydney and Edith Cowan University.

2.1 Study design

The Latrobe ELF Study is a prospective cohort study that collected cross-sectional data through a comprehensive baseline survey at study enrolment. Children born from 1 March 2012 until 31 December 2015, whose primary residential address was in the Latrobe City local government area at the time of the mine fire (or in pregnancy if conceived post-fire) were eligible to enrol in the study.

This time period included infants who were aged up to 2 years or whose mothers were pregnant at the time of the fire, and a comparison group of children from the same location who were conceived after the fire. Sampling from the wider Latrobe Valley, rather than the town of Morwell alone, was conducted to ensure an adequate sized population base to sample from and to enable assessment of a gradient of exposure to smoke from the mine fire on health outcomes. The identified cohort was therefore designed to have a balance of numbers by the timing of exposure (prenatal, infant, and pre-conception exposure group) and magnitude of smoke exposure (Morwell, which was closest to the fire, versus the rest of the Latrobe Valley). An overall target sample size of 500 children was determined from reviewing comparable studies of environmental exposures and health outcomes to identify the expected size of important health effects, and consideration of the expected loss to follow-up over the course of the study.

The recruitment by target timing of exposure and location within the Latrobe Valley is shown in Table 2.

Table 2. Recruitment targets for the identified cohort of Latrobe Early Life Follow-Up Study

Group		Residential address	Date of Birth	Description	Target recruitment number
	**Early childhood exposure**	Morwell	1 March 2012 – 9 Feb 2014	Aged less than two years old at the start of the fire	84
		Rest of Latrobe Valley (excluding Morwell)			84
	**In utero exposure**	Morwell	10 Feb 2014 – 31 Dec 2014	Mothers who were pregnant during the fire	83
		Rest of Latrobe Valley (excluding Morwell)			83
	**No exposure**	Morwell	1 Jan 2015 – 31 Dec 2015	Conceived after the fire	83
		Rest of Latrobe Valley (excluding Morwell)			83
TOTAL					**500**

2.2 Exposure assessment

The mean daily concentration of particulate matter with an aerodynamic diameter less than 2.5 micrometres ($PM_{2.5}$) directly attributable to the mine fire was the primary exposure metric used in this study.

The average and peak daily $PM_{2.5}$ concentrations for the 51-day period from 9 February 2014 to 31 March 2014 were determined using a chemical transport model. Collaborators at the Commonwealth Scientific and Industrial Organisation (CSIRO) Oceans & Atmosphere Flagship developed a high resolution exposure model to determine exposure estimates of $PM_{2.5}$ at an hourly time step and 1x1 km spatial resolution. The full model included background $PM_{2.5}$ from natural sources, vehicular and power station emissions, landscape fires and the mine fire. See http://hazelwoodhealthstudy.org.au/study-findings/study-reports/ for the full report. The difference between the model run with and without emissions from the mine fire was used to determine the concentration of $PM_{2.5}$ specific to the mine fire. Although the fire was declared safe on 26 March 2014, small amounts of smoke emissions continued into the following week, which is why the exposure modelling was continued until 31 March 2014. In the analyses presented here, the exposure for each participating child was assigned according to the residence of his/her mother during pregnancy. At the time of preparing this report, more precise exposure estimates based on daily activity patterns during the mine fire period were not available. Those will be important to consider in future analyses because many people left the smoke affected area for

one or more days during the study. The exposure estimates determined by the model were completed prior to the analysis of birth outcomes.

We compared perinatal health outcomes using the following two smoke exposure measures:

- **Average $PM_{2.5}$ exposure:** The average of the daily $PM_{2.5}$ concentrations over the 51-day exposure period.
- **Peak $PM_{2.5}$ exposure:** The maximum daily $PM_{2.5}$ concentration during the 51-day exposure period.

2.3 Recruitment

2.3.1 Establishing a nominal roll

The Latrobe City Council's (LCC) Maternal Child Health Service routinely collects contact details of families with children aged from birth to six years of age for the purposes of providing maternal and child health care. The council generated a nominal roll of potentially eligible participants (i.e. children born 1 March 2012 to 31 December 2015) known to their service. This roll was forwarded to Births, Deaths and Marriages Victoria for matching against death records, to avoid the study team contacting families of any deceased children. The LCC then contacted all potential families to inform them about the study and provided those families with an opportunity to opt-out before their contact details were passed on to the study team for recruitment. A final file containing contact details for 3 444 children was passed on to ELF Study researchers in February 2016.

2.3.2 Recruitment strategy

After review of the nominal roll by ELF Study researchers and removal of duplicate or ineligible records, a total population of 3 371 individuals was available to be approached for participation. To achieve the recruitment targets by age and locality, stratified random sampling across six groups was conducted (Table 2). Only one child per family was invited to join the study, except for cases of twins or where the parents/guardians requested that siblings also be enrolled.

Recruitment was conducted in a staggered approach as follows:

1. Invitation packages were mailed to a random selection of potential participants by study strata. These included the study information sheet, consent form and instructions on how to complete the baseline survey, and a unique log-in to enable completion of the baseline survey online. Invitees were given a two-week period to contact the study team to opt-out.
2. The Hunter Research Foundation (HRF) contacted eligible families, who had not opted out or previously completed an online survey, to invite them to participate and complete the baseline survey by telephone.
3. The process was repeated every two weeks, with recruitment rates across each strata closely monitored.
4. For those who did not opt out and were not contactable by phone, the study team conducted a round of door knocking to invite study participation.

2.3.3 Indirect contact methods

In addition to the direct contact methods described above, a number of activities were conducted to enhance community awareness of the study's activities and to encourage participation. These activities included:

- Regular updates to the Hazelwood Health Study webpage **www.hazelwoodhealthstudy.org.au/**
- Coverage by local television news.
- Distribution of Latrobe ELF Study postcards at local health services and childcare centres (Figure 1).
- Attendance at community events facilitated by the Hazelwood Health Study.
- Establishment of a dedicated 1800 phone number and email address for public enquiries.
- Hosting a stall at the Latrobe Valley Health and Wellbeing Expo in November 2015.

Figure 1. Latrobe Early Life Follow-up Recruitment postcard distributed throughout the Latrobe Valley community

2.4 Data collection

2.4.1 The Latrobe ELF Study Baseline Survey

The Latrobe ELF Study Baseline Survey was a detailed survey completed by parents/guardians of eligible participants upon enrolment in the Latrobe ELF Study. Parents and/or guardians of the eligible children were given the option of completing the survey by computer assisted telephone interview (CATI), online by Computer Assisted Web Interview (CAWI), or in person, depending on his/her preference. The survey was divided into the following sections:

Section A – Details about the person completing the survey: this section assessed study eligibility and gathered sociodemographic details on the person completing the survey, his/her

smoking status and his/her relationship to the study child. Sociodemographic details included age, gender, residential address, country of birth, highest level of educational attainment and employment status.

Section B – The study child and his/her family: this section explored sociodemographic details of the study child, his/her family and the smoking status of family members. The survey captured sociodemographic details for all family members (as per section A), including family members in other homes if the child lived in more than one home on a regular basis.

Section C – Child's health: this section explored the study child's birth details, self-reported perinatal outcomes, breastfeeding status, health problems, medication use, childcare attendance, number of siblings and history of atopy (allergic illness) in siblings.

Section D – Child's residential history: this section gathered details on the house that the child had lived in and the house(s) that the study child's mother lived in whilst pregnant. Housing details included year the house was built, material of the roof, heating and cooling used in the home, floor coverings and incense use. This data will be used in assessing exposure to air pollution.

Section E – Child's residence during the fire: this section determined the whereabouts of the study child (or study child's mother if pregnant) during the mine fire period. This section captured location information on a 12-hourly time scale by capturing daily and nightly whereabouts. The survey questions focused on exceptions to his/her usual locations during the day and the evening over the course of the fire. Coupled with modelling from CSIRO collaborators, this section is key in assigning individual exposure to the mine fire.

Section F – Information about the biological parents: this final section captured information about medical comorbidities of the biological mother and father and risk factors such as smoking, smoking during pregnancy, alcohol consumption, general stress in pregnancy and the effect of the mine fire on stress.

2.4.2 Data quality

A number of measures were used to maximise data quality collected from the Latrobe ELF Baseline Survey.

- Use of validated questions: Where possible, the survey utilised questions that had been previously utilised in large-scale cohort studies, national datasets or validated in the literature. This included questions relating to sociodemographic characteristics, tobacco smoking and alcohol consumption in pregnancy, breastfeeding history and history of atopy.
- Where possible, questions were written to align with wording of questions in the adult survey to enable comparison of findings between study streams.
- Piloting: components of the survey were piloted as part of the Latrobe Infant Health Study (n = 22). Additionally, the survey was piloted in Hobart and with a subset of Latrobe ELF Study participants (n = 12) prior to final endorsement and use. Piloting of the survey ensured the survey was user-friendly, easy to understand, complete and did not generate ambiguous results.
- Training: HRF staff who were contracted to conduct the CATI were provided training that outlined the background of the study and the rationale for each question in the survey.

2.4.3 The Exit Survey

Eligible individuals who declined to participant in the full Latrobe ELF Study Baseline Survey were invited to complete a brief exit survey. This consisted of six short questions about sociodemographic characteristics, parental education, parental smoking status and family medical history. This exit survey aimed to assess selection bias by determining whether families who declined full participation differed systematically from those who participated.

2.5 Data entry and cleaning

Data completed as either a CAWI or a CATI were downloaded from a secure server located at HRF in Excel spreadsheet format. It was then uploaded to a Microsoft SQL™ Server database and accessed using Microsoft Access™. Paper completed surveys were entered by hand onto a specially prepared Excel spreadsheet and imported into the Microsoft SQL™ Server tables.

In the process of data cleaning, a number of validation checks on the Latrobe ELF Study Baseline Survey were performed. For example:

- Date of birth was validated against other sources, such as the LCC nominal roll and also upon attendance at the subsequent cardiovascular and respiratory clinics.
- Birthweights were assessed against a validated population-based study of birthweights by gestational age and gender. If recorded birthweight was unusually high or low for gestation, the parent/guardian of the study child was contacted over the phone, or in clinic, to validate the birthweight.
- Free-text responses in the Survey, that fit into already listed response categories, were reclassified.

2.6 Statistical analysis

2.6.1 Data preparation

Survey responses were dichotomous ('yes' or 'no'), categorical ('not stressed at all,' 'somewhat stressed' etc.) or continuous (age in months, birthweight in grams etc.). For reporting purposes, some categories were combined. For example, parental education categories were collapsed into two categories: year 12 and below and post-secondary qualifications.

For perinatal outcomes, the following standard definitions were used (10):

- Term delivery: birth between 37and 42 completed weeks gestation
- Preterm birth: birth at less than 37 completed weeks
- Low birth weight at term (LBWAT): birthweight less than 2500 grams at term
- Small for gestational age (SGA): a birthweight $<10^{th}$ percentile for gestational age
- Large for gestational age (LGA): a birthweight $>90^{th}$ percentile for gestational age

Birthweight percentiles were defined using a peer-reviewed Australian population-based study of birthweight by gestational age (11). Comparisons between SGA/LGA and non-SGA/LGA infants were against 'appropriately grown' infants ($\geq 10^{th}$ to $\leq 90^{th}$ centile).

The proportion of missing data was generally low (see Table 4). Missing data was handled using multiple imputation by chained equations. Given the low proportion of missing data, five imputed

datasets were considered adequate. Regression models were then fitted (as per 2.7.2) using the imputed data.

2.6.2 Data analysis

Basic descriptive statistics were used to describe the baseline sociodemographic characteristics of the study participants and their families. Full participants were compared with those who completed the exit survey (n = 42). Differences between participant groups and the exit survey sample were determined using Pearson's chi-squared tests (χ^2) for categorical measures.

The associations between mine fire smoke exposure (average and peak maternal $PM_{2.5}$ exposure) and continuous outcomes (e.g. birthweight in grams, gestational maturity in weeks) were assessed using multivariable linear regression. Residual diagnostics were used to assess model assumptions and transformed if required. Choice of transformation was guided by Box Cox transformation. Akaike information criteria (AIC) were used to inform model selection.

The associations between mine fire smoke exposure (average and peak maternal $PM_{2.5}$ exposure) and binary ('yes'/'no') birth outcomes were determined using multivariable log-binomial regression.

The mean daily concentration of particulate matter with an aerodynamic diameter less than 2.5 micrometres ($PM_{2.5}$) directly attributable to the mine fire was the primary exposure metric used. The exposure metric for each participating child was assigned according to the residence of his/her mother during pregnancy.

Twin pregnancies were excluded from the analysis, as they were not comparable to singleton pregnancies for the perinatal outcomes of interest.

Choice of covariates to include in the adjusted analyses involved identification of potential covariates through review of comparable studies in the peer-reviewed literature. All covariates were also assessed for evidence of interaction. The following covariates were included in the models: child Aboriginality, maternal age ($\leq$19 and $\geq$35 years old vs. 20 to 34 years old), maternal education, smoking in pregnancy and alcohol consumption in pregnancy.

Results are reported per single unit increases for average $PM_{2.5}$ exposure. As the range of peak $PM_{2.5}$ exposure values across the cohort was large, results are reported per 10 units increase in peak $PM_{2.5}$. All statistical analyses were conducted in the statistical software program R (version 3.4.0) (12).

3. Results

3.1 Recruitment, data collection and completeness

3.1.1 Recruitment

At the conclusion of the active recruitment period, 548 children were recruited into the Latrobe ELF Study; 190 were children during the fire, 199 were *in utero* during the fire and 159 were conceived after the fire. Among the early childhood exposure and maternal exposure group, 150 resided in Morwell (39%) and 222 resided in other parts of the Latrobe Valley (57%). Recruitment targets were exceeded overall (110% of target) and the desired balance across exposure groups was achieved. Just under a third (32%) of those who were contactable were recruited into the study. Recruitment outcomes by timing of exposure (prenatal exposure, infant exposure, not exposed) are shown in Table 3 below. The geographical distribution of participants is demonstrated in Figure 2.

Table 3. Recruitment results of the Latrobe Early Life Follow-up Study categorised by study group

Study Group	Residential address*	Number completed survey	Percent of recruitment target
Early childhood exposure	Morwell	90	108
 (aged less than 2 years at the time of the fire)	Latrobe Valley (other)	83	100
	Outside the Latrobe Valley	17	NA
	Total	**190**	**114**
In utero exposure	Morwell	60	72
 (mother pregnant at the time of the fire)	Latrobe Valley (other)	139	167
	Total	**199**	**120**
No exposure	Morwell	51	61
 (conceived after the fire)	Latrobe Valley (other)	98	118
	Outside the Latrobe Valley	10	NA
	Total	**159**	**96**

*Pregnancy address is presented

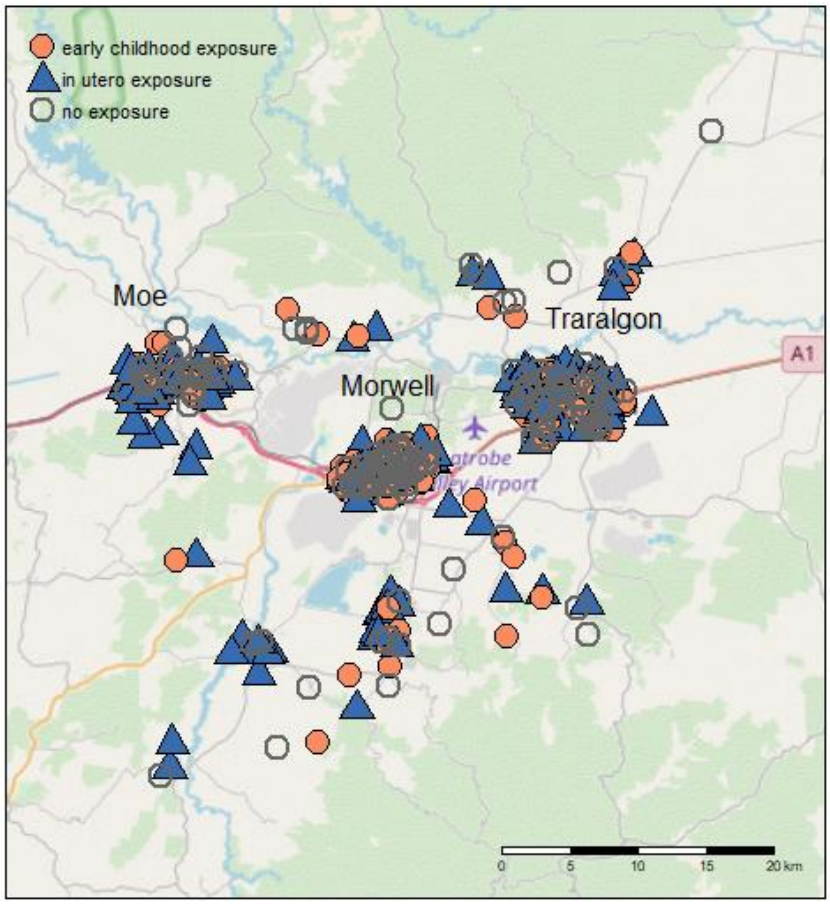


Figure 2. Map of the Latrobe Valley showing the approximate residential location of mothers during the fire and pregnancy by exposure category (note: fire location displayed for early childhood exposure and *in utero* exposure groups. Pregnancy location displayed for those conceived post-fire. Locations have been randomly plotted within an area of 4 square km).

3.1.2 Mode of survey completion

Two-thirds (66%) of participants completed the survey via CATI when contacted by HRF, while almost a third (31%) of participants chose to complete the baseline survey online (CAWI). Just 3% of surveys were completed in paper format.

3.1.3 Data completeness

Table 4 shows the proportion of missing data across data fields. The majority of fields were completed in full, with the exception of information pertaining to the second parent/guardian. Whilst multiple imputation by chained equations was used to cope with missing data in the analyses, it did not meaningfully alter the results.

Table 4. Summary of data completeness of the Latrobe Early Life Follow-up Study Baseline Survey

Data field	Number and proportion of responses where data were missing N (%)
Child sociodemographic details	
Date of birth	0 (0)
Gender	0 (0)
Country of birth	0 (0)
Language spoken at home	0 (0)
Identification as Aboriginal and/or Torres Strait Islander	1 (0.2)
Duration of breastfeeding	4 (0.7)
Biological siblings	3 (0.5)
Maternal-specific details	
Maternal age	10 (1.8)
Residence in pregnancy	1 (0.2)
Stress in pregnancy	12 (2.2)
Impact of coal mine fire on stress	13 (2.4)
Smoking status in pregnancy	13 (2.4)
Alcohol consumption in early pregnancy	12 (2.2)
Alcohol consumption in late pregnancy	12 (2.2)
Parent/guardian 1 sociodemographic details	
Highest level of educational attainment	0 (0)
Employment status	4 (0.7)
Smoking status	0 (0)
Parent/guardian 2 sociodemographic details	
Highest level of educational attainment	120 (21.9)
Employment status	122 (22.3)
Impact of coal mine fire on stress	45 (8.2)
Smoking status	119 (21.7)
Perinatal outcomes	
Birth weight	22 (4.0)
Gestational maturity	3 (0.5)
Method of birth	5 (0.9)
Location of birth	4 (0.7)

3.2 Characteristics of study participants and families

3.2.1 Sociodemographic characteristics of the study children

The Latrobe ELF Study children were approximately equal in gender distribution across maternal residence area. Six percent of participants identified as Aboriginal and/or Torres Strait Islander. The vast majority were born in Australia and lived in homes where English was the primary spoken language (Table 5).

3.2.2 Sociodemographic characteristics of the parent/guardian of the study child

Sociodemographic characteristics of the parents and/or guardians of study children are presented in Table 6. A large proportion of parent/guardian 1 were not in paid employment (44%). This is not surprising as many were likely to be engaged in home duties.

Table 5. Sociodemographic characteristics of the Latrobe Early Life Follow-up Study participants

	Maternal residence in pregnancy			
	Morwell	**Latrobe Valley (other)**	**Outside of the Latrobe Valley**	**All participants**
	N = 201	**N = 320**	**N = 27**	**N = 548**
	N (%)	**N (%)**	**N (%)**	**N (%)**
Child's gender				
Male	95 (47.3)	176 (55.0)	13 (48.1)	284 (51.8)
Female	106 (53.7)	144 (45.0)	14 (51.9)	264 (48.2)
Unsure	0 (0)	0 (0)	0 (0)	0 (0)
Not stated	0 (0)	0 (0)	0 (0)	0 (0)
Child's country of birth				
Australia	201 (100.0)	319 (99.7)	26 (96.3)	546 (99.6)
Other	0 (0)	1 (0.3)	1 (3.7)	2 (0.4)
Unsure	0 (0)	0 (0)	0 (0)	0 (0)
Not stated	0 (0)	0 (0)	0 (0)	0 (0)
Child's Aboriginality				
Aboriginal and/or Torres Strait Islander	17 (8.5)	7 (2.2)	7 (25.9)	31 (5.7)
Non-Aboriginal	182 (90.5)	312 (97.5)	20 (74.1)	515 (94.0)
Unsure	1 (0.5)	1 (0.3)	0 (0)	2 (0.3)
Not stated	1 (0.5)	0 (0)	0 (0)	0 (0)
Language spoken in child's home				
English	199 (99.0)	317 (99.1)	27 (100.0)	543 (99.1)
Other	1 (0.5)	2 (0.6)	0 (0)	3 (0.5)
Unsure	1 (0.5)	1 (0.3)	0 (0)	2 (0.4)
Not stated	0 (0)	0 (0)	0 (0)	0 (0)
Child has biological siblings				
Yes	142 (70.6)	208 (65.0)	19 (70.4)	369 (67.4)
No	58 (28.9)	110 (34.4)	8 (29.6)	176 (32.1)
Unsure	0 (0)	0 (0)	0 (0)	0 (0)
Not stated	1 (0.5)	2 (0.6)	0 (0)	3 (0.5)

Table 6. Sociodemographic characteristics of the Latrobe Early Life Follow-up Study parents and guardians compared with all adults in the Latrobe Valley

	Maternal residence in pregnancy				
	Morwell	**Latrobe Valley (rest)**	**Outside of the Latrobe Valley**	**All participants**	**All Latrobe Valley**
	N = 201	**N = 320**	**N = 27**	**N = 548**	
	N (%)	**N (%)**	**N (%)**	**N (%)**	**N (%)**
Highest level of education – Parent/guardian 1					**All adults[a]**
Year 12 or below	107 (53.2)	103 (32.2)	12 (44.4)	222 (40.5)	31 450 (56.8)
Post-secondary	94 (46.8)	217 (67.8)	15 (55.6)	326 (59.5)	18 951 (34.2)
Unsure	0 (0)	0 (0)	0 (0)	0 (0)	N/A
Not stated	0 (0)	0 (0)	0 (0)	0 (0)	5 000 (9.0)
Highest level of education – Parent/guardian 2					**All adults[a]**
Year 12 or below	60 (29.9)	94 (29.4)	6 (22.2)	160 (29.2)	31 450 (56.8)
Post-secondary	71 (35.3)	174 (54.4)	12 (44.4)	257 (46.9)	18 951 (34.2)
Unsure	7 (3.5)	4 (1.2)	0 (0)	11 (2.0)	N/A
Not stated	63 (31.3)	48 (15.0)	9 (33.3)	120 (21.9)	5 000 (9.0)
Paid employment status – Parent/guardian 1					**All adults[a]**
In paid employment	87 (43.3)	206 (64.4)	10 (37.0)	303 (55.3)	49 111 (84.4)
Not in paid employment	113 (56.2)	111 (34.7)	17 (63.0)	241 (44.0)	4 288 (7.4)
Unsure	0 (0)	0 (0)	0 (0)	0 (0)	N/A
Not stated	1 (0.5)	3 (0.9)	0 (0)	4 (0.7)	4 761 (8.2)
Paid employment status – Parent/guardian 2					**All adults[a]**
In paid employment	104 (51.7)	248 (77.5)	12 (44.4)	364 (66.4)	49 111 (84.4)
Not in paid employment	32 (15.9)	24 (7.5)	6 (22.2)	62 (11.3)	4 288 (7.4)
Unsure	0 (0)	0 (0)	0 (0)	0 (0)	N/A
Not stated	65 (32.4)	48 (15.0)	9 (33.3)	122 (22.3)	4 761 (8.2)
Smoking status – Parent/guardian 1					**All adults[b]**
Current smoker	60 (29.9)	38 (11.9)	17 (63.0)	115 (21.0)	(19.8)
Ex- or never smoked	141 (70.1)	282 (88.1)	10 (37.0)	433 (79.0)	(79.3)
Unsure	0 (0)	0 (0)	0 (0)	0 (0)	N/A
Not stated	0 (0)	0 (0)	0 (0)	0 (0)	(0)
Smoking status – Parent/guardian 2					**All adults[b]**
Current smoker	40 (19.9)	37 (11.6)	3 (11.1)	80 (14.6)	(19.8)
Ex- or never smoked	97 (48.3)	237 (74.1)	15 (55.6)	349 (63.7)	(79.3)
Unsure	0 (0)	0 (0)	0 (0)	0 (0)	N/A
Not stated	64 (31.9)	46 (14.3)	9 (33.3)	119 (21.7)	(0)

[a] data from 2011 Census
[b] data from the 2011-12 Victorian Population Health Survey

3.2.3 Exit survey

The Latrobe ELF Study Baseline Survey participants were compared with 42 individuals who declined to participate in the full survey, but completed a short exit survey. Latrobe ELF Study survey participants were comparable with those who completed the exit survey in respect to study child gender. Study participants were not comparable in reference to the primary guardian's level of education or smoking status. Parents/guardians in the Latrobe ELF Study were more likely to have obtained a higher level of education and more likely to be a current smoker than those completing the exit survey (Table 7). Due to the small number of those who completed the exit survey (n = 42) and the relatively high proportion of 'not stated' responses in this group, the utility of these comparisons is limited. Additionally, those who completed the exit survey may not be representative of all study non-responders and those who declined to complete the exit survey.

Table 7. Latrobe Early Life Follow-up Study participants compared with those who completed the exit survey

	Baseline survey participants N = 548	**Exit survey N = 42**	**χ^2 p value**
	N (%)	**N (%)**	
Gender			
Male	284 (51.8)	23 (54.8)	0.72
Female	264 (48.2)	19 (45.2)	
Unsure	0 (0)	0 (0)	
Not stated	0 (0)	0 (0)	
Highest level of education of child's primary caregiver			
Year 12 or below	222 (40.5)	16 (38.1)	<0.0001
Post-secondary school qualification	326 (59.5)	22 (52.4)	
Unsure	0 (0)	0 (0)	
Not stated	0 (0)	4 (9.5)	
Smoking status of child's primary caregiver			
Current smoker	115 (21.0)	4 (9.5)	<0.0001
Non-smoker	433 (79.0)	36 (85.7)	
Unsure	0 (0)	0 (0)	
Not stated	0 (0)	2 (4.8)	

3.3 Maternal-specific characteristics

3.3.1 Maternal age

The majority of mothers were aged between 20 to 34 years old (81%; n = 442) (Table 8).

Table 8. Age of mothers of the Latrobe Early Life Follow-up Study participants

	Maternal residence in pregnancy			
	Morwell	**Latrobe Valley (rest)**	**Outside of the Latrobe Valley**	**All participants**
	N = 201	**N = 320**	**N = 27**	**N = 548**
Maternal age (years)	**N (%)**	**N (%)**	**N (%)**	**N (%)**
19 or younger	11 (5.5)	8 (2.5)	4 (14.8)	23 (4.2)
20 to 34	158 (78.6)	263 (82.2)	21 (77.8)	442 (80.7)
35 or older	29 (14.4)	42 (13.1)	2 (7.4)	73 (13.3)
Unsure	0 (0)	0 (0)	0 (0)	0 (0)
Not stated	3 (1.5)	7 (2.2)	0 (0)	10 (1.8)

3.3.2 Smoking status in pregnancy

Just under one-fifth of mothers reported smoking whilst pregnant (n = 99; 18%) (Table 9). This is notably higher than the national prevalence of smoking in pregnancy of 11% (13). A larger proportion of mothers living in Morwell were current smokers compared with mothers living outside of Morwell ($\chi 2 = 19.47$, df = 2, $p < 0.0001$).

Table 9. Maternal smoking status while pregnant

	Maternal residence in pregnancy			
	Morwell	**Latrobe Valley (rest)**	**Outside of the Latrobe Valley**	**All participants**
	N = 201	**N = 320**	**N = 27**	**N = 548**
Maternal smoking status in pregnancy	**N (%)**	**N (%)**	**N (%)**	**N (%)**
Smoker	55 (27.3)	38 (11.9)	6 (22.2)	99 (18.0)
Non-smoker	139 (69.2)	276 (86.3)	21 (77.8)	436 (79.6)
Unsure	0 (0)	0 (0)	0 (0)	0 (0)
Not stated	7 (3.5)	6 (1.8)	0 (0)	13 (2.4)

The majority of mothers who smoked during pregnancy reported smoking nine or less cigarettes per day (n = 76; 77% in early pregnancy and n = 58; 59% in late pregnancy). Women residing in Morwell reported smoking fewer cigarettes per day in pregnancy compared with women residing in the rest of the Latrobe Valley (Early pregnancy $\chi 2 = 24.53$, df = 6, $p < 0.001$; late pregnancy $\chi 2 = 31.58$, df = 10, $p < 0.001$) (Table 10).

Table 10. Quantity of cigarettes smoked per day in pregnancy

	Maternal residence in pregnancy			
	Morwell	**Latrobe Valley (rest)**	**Outside of the Latrobe Valley**	**All smoking participants**
	N = 55	**N = 38**	**N = 6**	**N = 99**
	N (%)	**N (%)**	**N (%)**	**N (%)**
Number smoked in first 20 weeks of pregnancy				
9 or less per day	46 (83.6)	26 (68.4)	4 (66.7)	76 (76.8)
10 or more per day	6 (10.9)	10 (26.3)	1 (16.7)	17 (17.2)
Unsure	3 (5.5)	2 (5.3)	1 (16.7)	6 (6.0)
Declined to answer	0 (0)	0 (0)	0 (0)	0 (0)
Number smoked in last 20 weeks of pregnancy				
Quit smoking late pregnancy	8 (14.5)	12 (31.6)	0 (0)	20 (20.2)
9 or less per day	35 (63.6)	19 (50.0)	4 (66.7)	58 (58.6)
10 or more per day	6 (10.9)	7 (18.4)	1 (16.7)	14 (14.2)
Unsure	3 (5.5)	0 (0)	1 (16.7)	4 (4.0)
Declined to answer	3 (5.5)	0 (0)	0 (0)	3 (3.0)

3.3.3 Alcohol consumption in pregnancy

Approximately 8% (n = 41) of women reported consuming alcohol in early pregnancy (<20 weeks of gestation) and an even smaller proportion (4%; n = 20) reported alcohol consumption in late pregnancy (>20 weeks of gestation) (Table 11).

Table 11. Alcohol consumption in pregnancy

	Maternal residence in pregnancy			
	Morwell	**Latrobe Valley (rest)**	**Outside of the Latrobe Valley**	**All participants**
	N= 201	**N = 320**	**N = 27**	**N = 548**
	N (%)	**N (%)**	**N (%)**	**N (%)**
Alcohol consumption in the first 20 weeks of pregnancy				
No alcohol in early pregnancy	178 (88.5)	292 (91.3)	22 (81.5)	492 (89.8)
Alcohol in early pregnancy	15 (7.5)	21 (6.6)	5 (18.5)	41 (7.5)
Unsure	1 (0.50)	2 (0.6)	0 (0)	3 (0.5)
Declined to answer	0 (0)	0 (0)	0 (0)	0 (0)
Not stated	7 (3.5)	5 (1.5)	0 (0)	12 (2.2)
Alcohol consumption in the last 20 weeks of pregnancy				
No alcohol in late pregnancy	187 (93.0)	302 (94.4)	25 (92.6)	514 (93.8)
Alcohol in late pregnancy	5 (2.5)	13 (4.0)	2 (7.40)	20 (3.6)
Unsure	2 (1.0)	0 (0)	0 (0)	2 (0.4)
Declined to answer	0 (0)	0 (0)	0 (0)	0 (0)
Not stated	7 (3.5)	5 (1.6)	0	12 (2.2)

3.3.4 Stress during pregnancy

There were varying levels of general stress reported by mothers during pregnancy. However, differences in reported stress levels did not significantly vary by residential location in pregnancy ($\chi 2 = 11.47$, df = 8, p = 0.16) (Table 12).

Table 12. Reported maternal stress levels during pregnancy

	Maternal residence in pregnancy			
	Morwell	**Latrobe Valley (rest)**	**Outside of the Latrobe Valley**	**All participants**
Reported maternal stress in pregnancy	**N = 201** **N (%)**	**N = 320** **N (%)**	**N = 27** **N (%)**	**N = 548** **N (%)**
Not stressed at all	19 (9.4)	28 (8.8)	1 (3.7)	48 (8.8)
Hardly ever stressed	44 (21.9)	84 (26.2)	5 (18.5)	133 (24.3)
Sometimes stressed	91 (45.3)	156 (48.8)	11 (40.7)	258 (47.1)
Stressed often/nearly all of the time	39 (19.4)	45 (14.0)	10 (37.1)	94 (17.1)
Unsure	1 (0.5)	2 (0.6)	0 (0)	3 (0.5)
Not stated	7 (3.5)	5 (1.6)	0 (0)	12 (2.2)

3.3.5 Breastfeeding history

Approximately one-eighth of study children were never breastfed (n = 72; 13%) (Table 13). Compared to the national average, this represents a much greater proportion of study children who never received breastmilk (13.1% v. 4.1%), but a similar proportion of study children breastfed over 6 months of age (44.7% vs. 42.2%) (14).

Table 13. Status and duration of breastfeeding

Breastfeeding status	**All participants** **N = 548** **N (%)**
Never breastfed	72 (13.1)
Breastfed up to 6 months of age	222 (40.5)
Breastfed over 6 months of age	245 (44.8)
Unsure	5 (0.9)
Not stated	4 (0.7)

3.4 Impacts of the Hazelwood coal mine fire

3.4.1 Impact of the mine fire on the air quality of mothers during pregnancy

Mothers of 199 participants were pregnant at the time of the fire. This group made up over one-third (36%) of the full Latrobe ELF cohort. Among this group maternal exposure to $PM_{2.5}$ from the mine fire smoke emissions was much greater for Morwell residents than those living in the rest of the Latrobe Valley (1) (Table 14). Average and peak maternal $PM_{2.5}$ exposures were highly correlated (Figure 3).

Table 14. Average and peak maternal exposure to coal mine fire smoke $PM_{2.5}$ for participants whose mothers were pregnant during the coal mine fire (N = 199)

	Maternal residence during the coal mine fire		
	**Morwell** **N = 60**	**Latrobe Valley (rest)** **N = 139**	**All maternal exposures** **N = 199**
Average $PM_{2.5}$ exposure µg/m³			
Mean	18.4	2.2	7.1
Median	14.0	2.0	2.7
Range	5.4 – 56.1	0.1 – 17.4	0.1 – 56.1
Interquartile Range	7.2 – 20.9	1.5 - 2.8	1.8 - 7.1
Peak $PM_{2.5}$ exposure µg/m³			
Mean	133.3	40.0	68.1
Median	96.5	33.5	40.0
Range	47.6 – 495.7	2.6 – 308.5	2.6 – 495.7
Interquartile Range	61.4 – 160.3	23.0 – 41.4	25.6 – 86.1

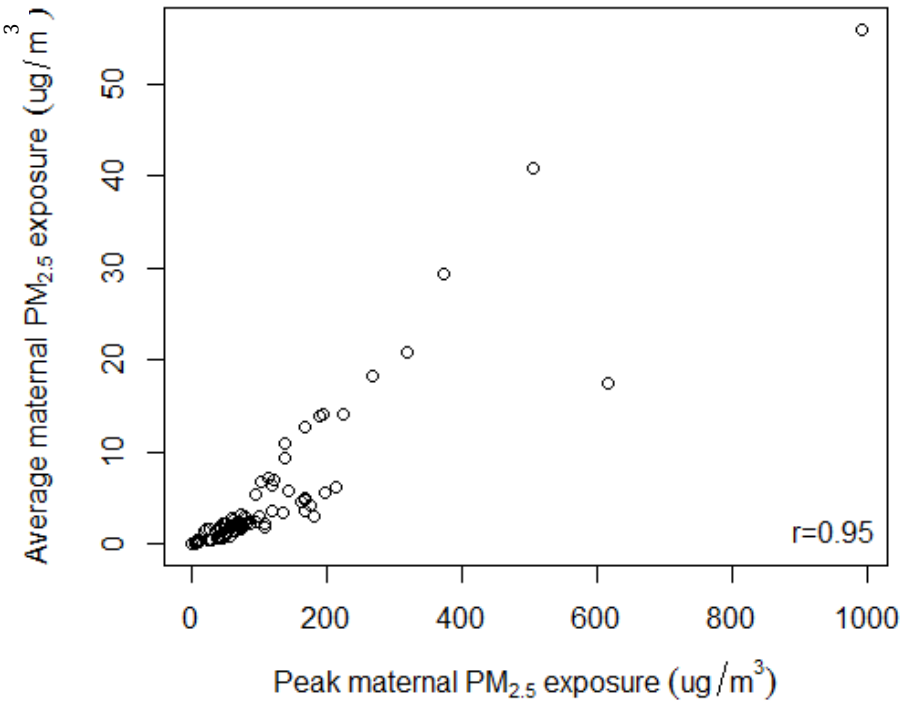


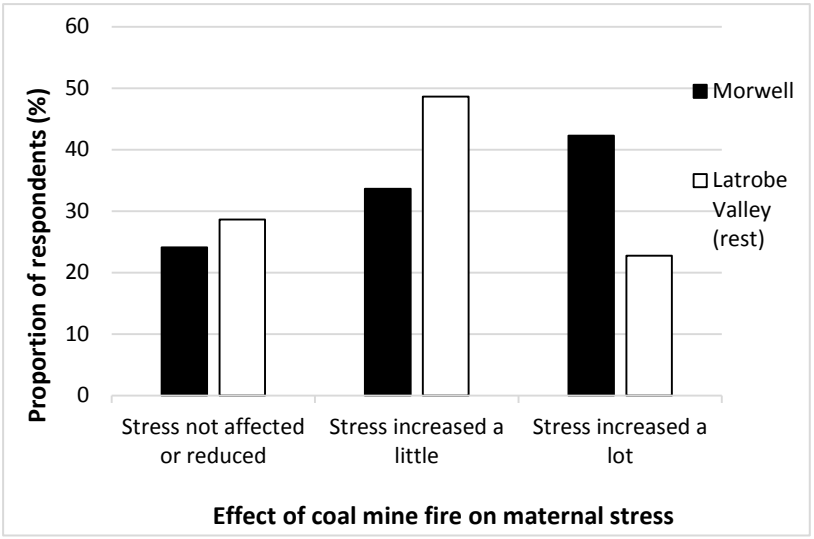
Figure 3. Relationship between average maternal $PM_{2.5}$ exposure and peak $PM_{2.5}$ exposure during the coal mine fire for the Latrobe Early Life Follow-up Study participants

3.4.2 Impact of the mine fire on parental stress

A greater proportion of mothers reported increased stress in response to the mine fire compared to fathers (74% of mothers and 59% of fathers; $\chi 2 = 33.96$, df = 2, p <0.0001). Those who were residing in Morwell during the mine fire reported significantly greater stress in association with the event, compared to those living in other parts of the Latrobe Valley (maternal stress $\chi 2 = 33.96$, df = 2 p<0.0001; paternal stress $\chi 2 = 36.47$, df = 2, p <0.0001) (Figure 4).

A larger proportion of parents of participants aged 0 to 2 years during the fire reported that their 'stress was increased a lot' compared with those who were pregnant during the fire, or parents of participating children who were conceived after the fire ($\chi 2 = 34.32$, df = 10, p <0.001) (Figure 5). The impact of the mine fire on stress among fathers was not significantly different across the three participant groups ($\chi 2 = 15.29$, df = 10, p = 0.080).

a)



b)

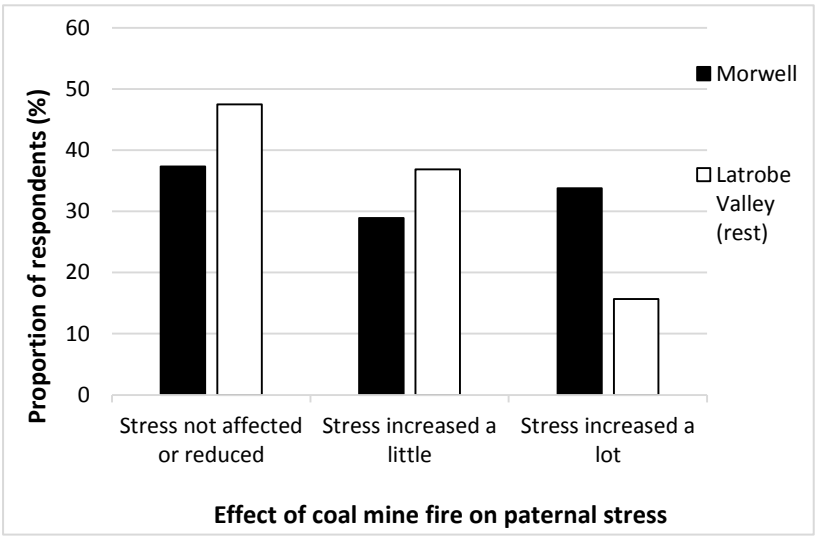
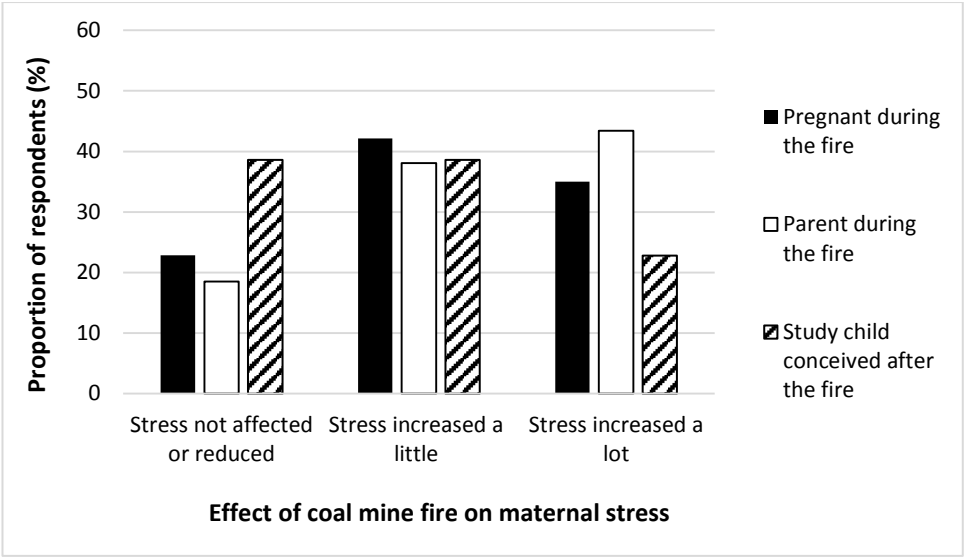


Figure 4. Impact of the coal mine fire on stress as reported by mothers (a) and fathers (b) by residential location at the time of the fire

a)



b)

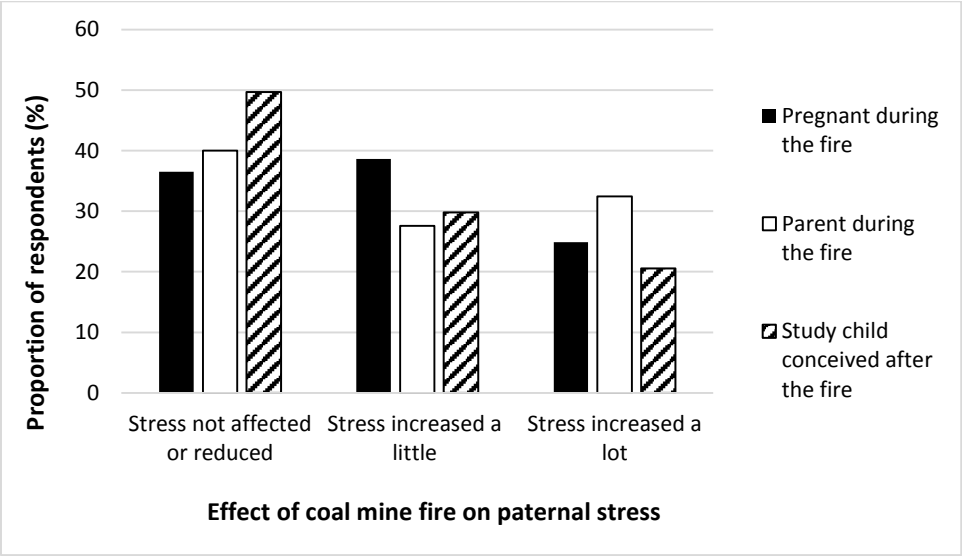


Figure 5. Impact of the coal mine fire on reported stress by mothers (a) and fathers (b) by parental status at the time of the fire

3.5 Perinatal outcomes

3.5.1 Method of birth

Seventy percent of the study cohort were born by vaginal delivery (n = 380) and 30% were born by Caesarean section (n = 162) (Table 15). These rates are similar to those observed in Victoria: in 2015 67% of women had a vaginal birth and 33% had a caesarean section (10). Data on whether caesarean sections were elective or non-elective were not collected. A total of six twin pairs were recruited into the study. Twin pregnancies were excluded from the following analyses.

Table 15. Method of birth by exposure group

	In utero* during fire – Morwell	***In utero* during fire - Latrobe Valley (rest)***	**Not *in utero* during fire***	**All participants***
				
	N = 60	**N = 137**	**N = 345**	**N = 542**
	N (%)	**N (%)**	**N (%)**	**N (%)**
Vaginal delivery	41 (68.3)	94 (68.6)	245 (71.0)	380 (70.1)
Caesarean section	19 (31.7)	43 (31.4)	100 (29.0)	162 (29.9)

*Excluding twin pregnancies

3.5.2 Gestational age

The mean gestational age of Latrobe ELF study participants was 39.2 weeks (Table 16).

Table 16. Gestational age (completed weeks) at birth by exposure group

	In utero* during fire – Morwell	***In utero* during fire - Latrobe Valley (rest)***	**Not *in utero* during fire***	**All participants***
				
	N = 60	**N = 137**	**N = 345**	**N = 542**
Mean	39.2	39.1	39.3	39.2
Median	40.0	39.0	40.0	40.0
Range	35.0 to 42.0	30.0 to 42.0	32.0 to 43.0	30.0 to 43.0
Interquartile Range	38.75 to 40.0	38.0 to 40.0	38.0 to 41.0	38.0 to 41.0

*Excluding twin pregnancies

Maternal risk factors and gestational age

In single variable analyses, there were no observed associations between maternal smoking or alcohol consumption in pregnancy, maternal age, maternal education, stress in pregnancy or stress response to the mine fire and reduced gestational maturity at birth.

Maternal coal mine fire $PM_{2.5}$ exposure and gestational age

There was no observed association between maternal exposure to $PM_{2.5}$ from the mine fire and gestational age at birth (β= -3.24 days; 95%CI -13.85 to 10.85 days; p = 0.81). There was also no association between peak maternal $PM_{2.5}$ exposure and gestational age (β= -2.75 days; 95%CI -8.95 to 6.79 days; p = 0.79).

3.5.3 Preterm birth

Preterm birth is defined as birth at less than 37 completed weeks. Amongst the study cohort, 9% of infants were born preterm (n = 48), slightly higher than the Victorian average of 8.4% of births (10). Data on whether preterm births were spontaneous or medically indicated (iatrogenic) were not collected (Table 17).

Table 17. Preterm birth (less than 37 weeks) by exposure group

	In utero* during fire – Morwell	***In utero* during fire - Latrobe Valley (rest)***	**Not *in utero* during fire***	**All participants***
				
	N = 60	**N = 137**	**N = 345**	**N = 542**
	N (%)	**N (%)**	**N (%)**	**N (%)**
Preterm birth	7 (11.7)	13 (9.5)	28 (8.1)	48 (8.9)
Term birth	53 (88.3)	124 (90.5)	317 (91.9)	494 (91.1)

*Excluding twin pregnancies

Maternal risk factors and preterm birth

Mothers with a lower level of educational attainment and higher reported levels of stress in pregnancy were more likely to experience preterm birth (lower educational attainment RR 1.64; 95% CI 0.99 – 2.72; p = 0.054; higher levels of stress in pregnancy RR 2.83; 95%CI 1.67 – 4.66; p <0.0001). Smoking and alcohol consumption in pregnancy, maternal age and stress response to the mine fire were not independently associated with preterm birth.

Maternal coal mine fire $PM_{2.5}$ exposure and preterm birth

The prevalence of preterm birth by study group is described in Table 17. There was no association between average maternal $PM_{2.5}$ exposure from the mine fire and preterm birth (adjusted RR 1.00; 95%CI 0.97 - 1.04; p = 0.98). Similarly, there was no association between peak maternal $PM_{2.5}$ exposure and preterm birth (adjusted RR 0.99; 95%CI 0.97 - 1.02; p = 0.91).

3.5.4 Birthweight

The mean birthweight amongst the study cohort born at term was 3406 grams (g) (median 3 459 g; IQR 3 033 to 3 799 g) (Table 18).

Table 18. Birthweight (grams) of study participants by exposure group

	In utero* during fire - Morwell 	***In utero* during fire - Latrobe Valley (rest)*** 	**Not *in utero* during fire*** 	**All participants***
Mean	3428	3467	3364	3406
Median	3430	3500	3430	3459
Range	1673 to 4350	1200 to 5330	1417 to 5642	1200 to 5642
Interquartile Range	3164 to 3933	3118 to 3879	2977 to 3770	3033 to 3799

*Excluding twin pregnancies

Maternal risk factors for changes in birthweight

Smoking in pregnancy and general stress in pregnancy were independently associated with significant changes in birthweight. The birthweight of infants born to women who smoked in pregnancy was -181.90 grams less compared to non-smoking mothers (95%CI -29.53 to -323.1 grams; p = 0.016). Infants born to mothers with greater general stress during the pregnancy were -180.47 grams lighter compared to mothers with lower stress levels in pregnancy (95%CI – 38.95 to -322.0 grams; p = 0.013). There was no independent association between maternal alcohol consumption in pregnancy, maternal education, maternal age or stress response to the mine fire (in those pregnant at the time of the fire) and birthweight.

Maternal coal mine fire $PM_{2.5}$ exposure and birthweight

Every unit increase in average maternal $PM_{2.5}$ exposure was associated with weak evidence of marginal increases in birthweight (β= 5.92 grams; 95%CI -1.47 to 13.32 grams; p = 0.11). Similarly, 10 unit increases in peak maternal $PM_{2.5}$ exposure was also associated with weak evidence of increases in birthweight (β= 4.1 grams; 95%CI -0.61 to 8.81 grams; p = 0.088).

3.5.5 Low birth weight at term

Low birth weight at term (LBWAT) is defined as a birthweight less than 2500 grams at term (gestational age greater than 37 completed weeks). In the ELF cohort, 3% of infants (n = 15) were born as LBWAT (excluding twin pregnancies).

Maternal risk factors and low birth weight at term

Greater stress in pregnancy was associated with increased risk of LBWAT (RR 2.55; 95%CI 1.60 – 3.93; p= <0.0001). Lower maternal educational attainment was associated with weak evidence of increased risk of LBWAT(RR 1.47; 95%CI 0.95 – 2.28; p = 0.084). Smoking and alcohol consumption in pregnancy, maternal age and stress response to the mine fire were not associated with LBWAT.

Maternal coal mine fire $PM_{2.5}$ exposure and low birth weight at term

There was no association between average maternal $PM_{2.5}$ exposure attributable to the mine fire and LBWAT (adjusted RR 0.99; 95%CI 0.96 to 1.03; p = 0.68). Similarly, peak maternal $PM_{2.5}$ exposure was not associated with LBWAT (adjusted RR 0.99; 95%CI 0.97 - 1.02; p = 0.50).

3.5.6 Small for gestational age

Small for gestational age (SGA) is defined as a birthweight <10th percentile for gestational age. Among the study cohort, 76 infants (14%) were born SGA (excluding twin pregnancies).

Maternal risk factors and small for gestational age

Smoking in pregnancy was associated with a 64% increased risk of having a SGA infant (RR 1.64; 95%CI 1.04 – 2.49; p = 0.024). Similarly, 'higher risk' maternal age ($\leq$19 years and $\geq$ 35 years) was associated with a 65% increased likelihood of having a SGA infant (RR 1.65; 95%CI 1.02 – 2.65; p = 0.039). Lower maternal education, maternal alcohol consumption, general stress in pregnancy and stress response to the mine fire were not associated with SGA in this cohort.

Maternal coal mine fire $PM_{2.5}$ exposure and small for gestational age

Average maternal $PM_{2.5}$ exposure attributable to the mine fire was not significantly associated with the likelihood of SGA (adjusted RR 0.95; 95%CI 0.90 - 1.01; p = 0.11). Similarly, peak $PM_{2.5}$ exposure was not significantly associated with SGA (adjusted RR 0.97; 95%CI 0.94 - 1.01; p = 0.09).

3.5.7 Large for gestational age

Large for gestational age (LGA) is defined as birthweight >90th percentile for gestational age. Among the study cohort, 12% (n = 67) were born as LGA (excluding twin pregnancies).

Maternal risk factors and large for gestational age

Smoking and alcohol consumption in pregnancy, maternal age, maternal education, stress in pregnancy and stress response to the mine fire were not significantly associated with the likelihood of LGA.

Maternal coal mine fire $PM_{2.5}$ exposure and large for gestational age

Average maternal $PM_{2.5}$ exposure attributable to the mine fire was not associated with LGA (adjusted RR 1.01; 95%CI 0.99 - 1.04; p = 0.23). Similarly, peak maternal $PM_{2.5}$ exposure was not associated with LGA (adjusted RR 1.00; 95%CI 0.99 - 1.02; p = 0.28).

Table 1. Summary of associations between exposure to poor air quality from the Hazelwood coal mine fire and birth outcomes

	Adjusted RR^ (95%CI) per unit increase in average maternal $PM_{2.5}$ exposure	**Adjusted RR^ (95%CI) per 10 unit increase in peak maternal $PM_{2.5}$ exposure**
Preterm birth	1.00 (0.97 to 1.04)	0.99 (0.97 to 1.02)
Low birth weight at term	0.99 (0.96 to 1.03)	0.99 (0.97 to 1.02)
Small for gestational age	0.95 (0.90 to 1.01)	0.97 (0.94 to 1.004)
Large for gestational age	1.01 (0.99 to 1.04)	1.00 (0.99 to 1.02)

^Adjusted for child Aboriginality, maternal age, maternal education, maternal smoking in pregnancy and maternal alcohol consumption in pregnancy

4. Discussion

This first report from the Latrobe ELF Study describes the preliminary findings from the Baseline Survey of the identified cohort study. A total of 548 children participated in the survey, exceeding recruitment targets. Completeness of data was high for the majority of data fields, with the exception of details pertaining to the other parent/guardian. The study cohort is representative of the wider Latrobe Valley in terms of child gender. Children born in a country other than Australia and who spoke a language other than English were underrepresented in the study sample compared with the general population, however this was consistent with eligibility being based on residence of pregnant women and young children in the Latrobe Valley. Children who were identified as Aboriginal and/or Torres Strait Islander were overrepresented in the study sample compared with the wider Latrobe Valley. Study families tended to have obtained a higher level of education than the general Latrobe Valley population, a phenomenon common to study participants in general (15).

The Hazelwood coal mine fire affected families differently. The impact of the fire on stress among mothers and fathers was significantly greater for those living in Morwell compared to those residing in the rest of the Latrobe Valley. For mothers, the impact of the fire on stress was greatest if they were already a parent, compared to those who were pregnant or those who had conceived the study child after the mine fire.

There was no evidence that average and peak maternal $PM_{2.5}$ exposure attributable to the mine fire was associated with adverse perinatal outcomes, including preterm birth, LBWAT, SGA and LGA. The evidence base outlining the adverse impacts of maternal exposure to ambient $PM_{2.5}$ in pregnancy on perinatal outcomes is quite well developed (3, 4). However, those specifically exploring severe smoke events are very limited. A study exploring the impact of a wildfire event during pregnancy on birthweight found marginal reductions in birth weight in association with exposure to the fire during the first and second trimesters (7). A study exploring the impact of sharp increases in particulate matter exposure resulting from the Puyehue volcano eruptions in Chile in 2011 found significant associations between maternal exposure and increased likelihood of preterm birth, but not consistent associations with birth weight or LBWAT (16). To date, ours is the first study to explore the impact of a severe mine fire smoke event on perinatal outcomes.

Consistent with the existing evidence, traditionally recognised risk factors for adverse perinatal outcomes such as smoking in pregnancy, socioeconomic disadvantage (as measured by highest level of educational attainment) and stress in pregnancy were associated with adverse perinatal outcomes in the Latrobe ELF Study cohort. Risk factors for adverse perinatal outcomes, including smoking in pregnancy, were more prevalent in the ELF Study cohort compared to the wider Australian population (13). Consistent with the literature, we found that greater levels of stress in pregnancy had deleterious effects on birthweight (8, 17-19). The magnitude of the effect of general prenatal stress was similar to that of smoking on birthweight, which has also been reported elsewhere (20).

Stress in pregnancy may result from a number of sources, including social stressors, life events, work-related stress, anxiety and/or depression and stress in response to a disaster. The biological pathway by which maternal stress is thought to affect the fetus is through the hypothalamus-pituitary-adrenal axis, particularly by affecting the release of adrenocorticotropic-releasing hormone, corticotrophin-releasing hormone, prostaglandins, cortisol, catecholamine and oxytocin ('stress hormones'). It has been proposed that the mechanism by which the stress hormones affect the developing fetus is through reduced uteroplacental blood flow,

transplacental transport of maternal stress hormones and secretion of placental corticotrophin-releasing hormone to the fetus (20).

Strengths of this study include the recruitment of participants in excess of our initial target. Additionally, the comprehensive data gathered through the baseline survey allowed analyses to adjust for a number of important confounding variables. These covariates are not often available through routinely collected administrative datasets. Additionally, in this cohort the exposure preceded the outcome, which strengthens our ability to assess causality. There are a number of limitations in these analyses, which will be addressed in future work. Some aspects of the survey are yet to be analysed, namely housing characteristics and family medical history. Housing characteristics are relevant in considering exposure to smoke, as features such as roof materials and air conditioning affect indoor air quality during a severe smoke event. The current analyses did not have information about gestational diabetes or body mass index that can affect perinatal outcomes. Data on selected maternal conditions and obstetric complications will become available to the study team with the planned anonymous data extractions from the Victorian Perinatal Data Collection. This data extraction will provide the study team with a complete cohort of children born in the Latrobe Valley.

Additionally, more detailed individual assessment of exposure is currently underway by the study team. Combining details obtained from section E of the survey about the specific whereabouts of the study child (or mother if pregnant during the fire) with the CSIRO model, the study team will be able to assign an individual exposure metric that captures mobility within and outside of the Latrobe Valley during the fire. In the results currently presented, exposure was assigned based only on pregnancy residence. Although this exposure assignment is a validated method, it does not account for whether families moved out of the Latrobe Valley for extended periods during the fire, and therefore may misclassify exposure (21).

In summary, a number of well-recognised risk factors including smoking in pregnancy, stress in pregnancy and lower maternal educational attainment were observed in the study cohort for some birth outcomes. However, these preliminary findings demonstrate no association between exposure to mine fire smoke and adverse birth outcomes. Further studies of perinatal outcomes are planned. These will include evaluation of birth outcomes in this cohort using improved personal exposure estimates, and separate analyses of de-identified perinatal data for all children in the Latrobe Valley.

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Document History

Version Number	Date	Contact	Brief description
1.0	16 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	Title change. Resubmitted to DHHS.
1.2	13 August 2018	Hazelwood Health Study Senior Project Manager	Caveat added to page 2. Typographical errors corrected in Tables 3 & 14