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Impacts of High Concentration, Medium Duration Coal Mine Fire Related $PM_{2.5}$ on Cancer Incidence: 5-Year Follow-Up of the Hazelwood Health Study

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ABSTRACT: No studies have investigated the cancer outcomes from high level medium duration coal mine fire fine particulate matter ⩽2.5 μm in diameter ($PM_{2.5}$) exposure. We included 2208 Morwell residents (exposed) and 646 Sale residents (unexposed) who participated in the Hazelwood Health Study Adult Survey. Competing risk regression models were used to evaluate relationships between coal mine fire exposure and cancer incidence, adjusting for known confounders. There were 137 cancers in the exposed and 27 in the unexposed over 14 849 person-years of follow-up. A higher risk of cancer incidence was observed for Morwell participants (HR = 1.67 [95% CI 1.05-2.67]), but no evidence to suggest associations between $PM_{2.5}$ exposure and incidence of all cancers (HR = 1.02 [95% CI 0.91-1.13]), or site-specific cancers. There is no strong evidence that exposure to high concentrations of mine fire-related $PM_{2.5}$ over a prolonged period could explain the higher risk in exposed population in this study.

KEYWORDS: Coal mine fire smoke, fine particulate matter, cancer incidence, data linkage cohort, Hazelwood Health Study

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Introduction

Coal mine fires cause substantial environmental and economic harms, and have been increasingly shown to be associated with adverse effects on human health.[1] However, there are no studies exploring the association between coal mine fire exposure with malignant cancers.[2] Up to 62 compounds with potentially harmful health impacts are found in coal mine fire smoke, including fine particulate matter ⩽2.5 μm in diameter ($PM_{2.5}$)[1] which has been classified as a Group 1 carcinogen to humans.[3] Associations between long-term (years) ambient total $PM_{2.5}$ exposure and cancer risk have been demonstrated in many studies,[4] however the effect of medium-term (weeks to months) exposure at much higher concentration is unknown. The composition of $PM_{2.5}$ from coal mine fires may differ from other sources and have unique health impacts.[5] Five years after the Hazelwood mine fire, which burned for 6 weeks in south-eastern Australia, we investigated the association between this high concentration, medium duration exposure event and cancer incidence.

Methods

Population and study design

The Hazelwood mine fire burned from 9 February 2014 to approximately 31 March 2014 in the Latrobe Valley, a rural area in the State of Victoria, Australia. The Hazelwood Health Study (HHS) (www.hazelwoodhealthstudy.org.au) was commissioned by the Victoria Department of Health and Human Services to investigate the long-term effects of the Hazelwood mine fire.[6] The Adult Survey is one of the streams of research in HHS and the cohort comprised adult residents from the towns of Morwell (located adjacent to the mine and highly exposed) and Sale (60 km away and unexposed).[6] Participants of this study were members of the Adult Survey cohort who consented to linkage with the Victorian Cancer Registry (VCR).

VCR data were obtained for the period 1st January 2008 and 31st December 2019 which comprised demographics, cancer site, International Classification of Disease (ICD) codes, count of tumours and vital status. Death data were obtained from the VCR supplemented with reports by next of kin and Ryerson newspaper index (https://ryersonindex.org) searching. Participants were followed up until 31 December 2019 or date of death, whichever was earlier.

Monash University Human Research Ethics Committee (MUHREC) approved the Hazelwood Adult Survey & Health Record Linkage Study.

Mine-fire related $PM_{2.5}$ exposure

The Commonwealth Scientific and Industrial Research Organisation (CSIRO) modelled temporal and spatial $PM_{2.5}$ concentrations during the mine fire using high-resolution meteorological and dispersion models incorporating local wind data and an appropriate plume rise mechanism.[7] Participants'

Table 1. Participant characteristics at time of interview.

CHARACTERISTIC	MORWELL (N = 2208)	SALE (N = 646)	*P*-VALUE
Mean daily mine-fire related $PM_{2.5}$ exposure (μg/m^3), Mean (SD)	15.3 (11.7)	0.0 (0.3)	
Age at the survey, mean (SD) years	58.1 (16.4)	58.0 (17.4)	.914
0-59	1079 (48.9%)	320 (49.5%)	.765
⩾60	1129 (51.1%)	326 (50.5%)	
Sex			.112
Male	1018 (46.1%)	275 (42.6%)	
Female	1190 (53.9%)	371 (57.4%)	
Marital status			.062
Married	1346 (61.0%)	420 (65.0%)	
Not married	862 (39.0%)	226 (35.0%)	
Education			<.001
Secondary up to year 10	704 (32.1%)	147 (22.9%)	
Secondary year 11-12	435 (19.8%)	106 (16.5%)	
Certificate (trade/apprenticeship/technicians)	759 (34.6%)	266 (41.4%)	
University or other tertiary institute degree	296 (13.5%)	124 (19.3%)	
Missing[a]	14	3	
Employment			<.001
Paid employment (FT, PT, self-employed)	909 (41.5%)	292 (45.3%)	
Other (student/volunteer/home-duties/retired)	1007 (45.9%)	310 (48.1%)	
Unemployed	101 (4.6%)	12 (1.9%)	
Not working due to ill-health	176 (8.0%)	30 (4.7%)	
Missing[a]	15	2	
Occupational exposure[b]			<.001
Not exposed	1244 (56.3%)	407 (63.0%)	
Exposed in coal mine or power station	375 (17.0%)	21 (3.3%)	
Exposed, but not coal mine/station	589 (26.7%)	218 (33.7%)	
Smoking			.033
Never[c]	1070 (48.7%)	345 (53.9%)	
Current smoker	376 (17.1%)	87 (13.6%)	
Former smoker	750 (34.2%)	208 (32.5%)	
Missing[a]	14	6	
Alcohol drinking[d]			
Non-drinker	546 (25.4%)	150 (23.5%)	.011
Low risk	790 (36.8%)	205 (32.2%)	
High risk	810 (37.7%)	282 (44.3%)	
Missing[a]	62	9	

[a]Participants did not answer this question in the questionnaire.
[b]Participants' self-reported job held for at least 6 months which involved breathing a lot of dust, fumes, gas, vapour or mist.
[c]Participants self-reported never smoked or smoked occasionally.
[d]Participants with alcohol use disorders identification test consumption score of 0 indicated a non-drinker, 1 to 3 for men, 1 to 2 for women indicated a low risk drinker and ⩾4 for men, ⩾3 for women indicated a high-risk drinker.

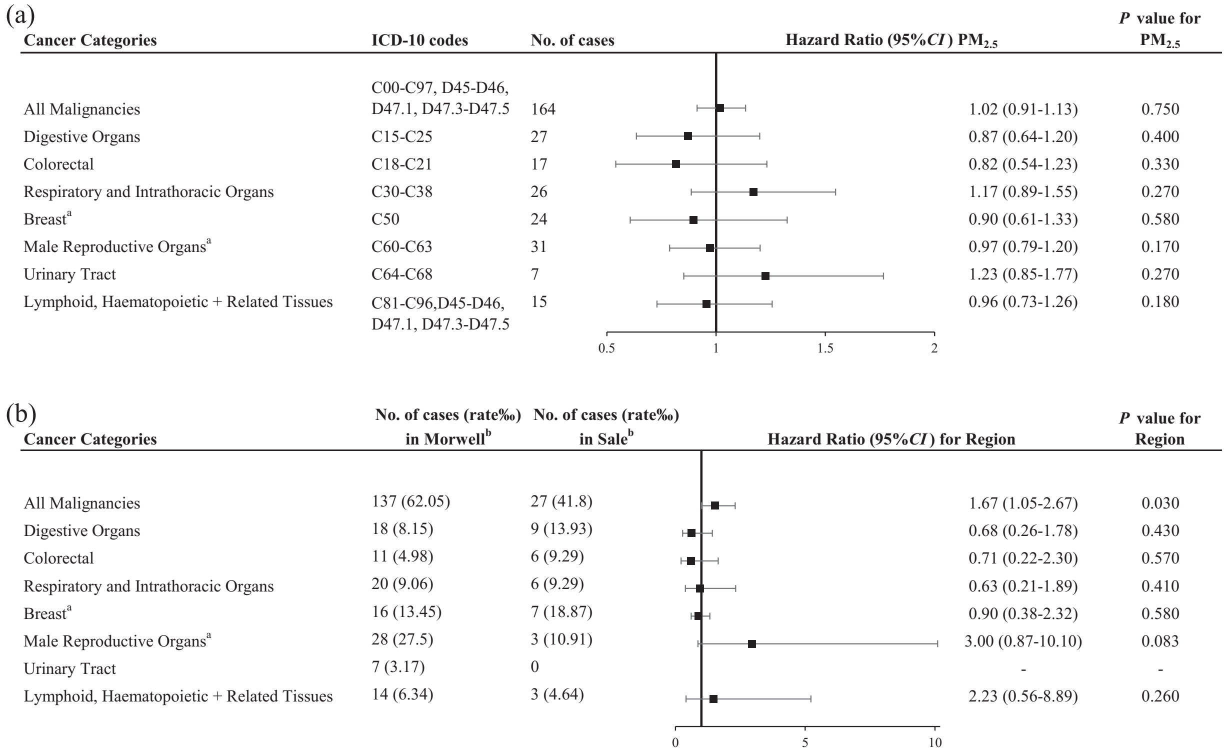

Figure 1. Forest plots showing adjusted Hazard Ratios (HRs with 95% CI) for incidence of all cancers, and site-specific cancers, per 10-μg/m^3 increase in mine-fire related $PM_{2.5}$ exposure for all participants (A) and incidence for participants living in Morwell compared with Sale (B).
Hazard ratios were estimated from competing risk regression model adjusted for sex, age, marital status, education, employment status, smoking and drinking behaviour and occupational exposure.
[a]Analyses for breast cancer were conducted in females only, while analyses for cancers of male reproductive organs, for example, prostate were conducted in males only.
[b]Crude cancer incidence per 1000 (‰) population.

mine-fire related $PM_{2.5}$ exposures were estimated by mapping their detailed time location diaries, collected as a part of Adult Survey, onto the modelled $PM_{2.5}$ data.[6]

Statistical analysis

Subjects diagnosed with a primary malignant cancer (included ICD10: C00-C97, D45-D46, D47.1, D47.3-D47.5) from 6 months after the fire (9 August 2014) were defined as incident cases. Competing risk regression models were developed to quantify the association between region and $PM_{2.5}$ exposures on cancer incidence by calculating hazard ratios (HRs) and 95% confidence intervals (CIs) and controlling for known confounders including age, sex, marital status, education, employment, occupational exposure, smoking and alcohol drinking. Statistical significance was defined as a 2-side P-value $<.05$. R software (V3.4.3, www.R-project.org) was used to perform all data analyses.

Results

There were 164 cancers (137 in the exposed group, 27 in the unexposed group) over 14 849 person-years of follow-up. Risk factors listed in Table 1 were compared between Morwell and Sale. Morwell residents had lower levels of education, employment and risky drinking. For the period 5 years after the fire (9 August 2014-31 December 2019), a higher risk of overall cancer incidence was observed in Morwell compared with Sale (HR = 1.67 [95% CI 1.05-2.67]), after adjustment for known confounders. However increments in mine fire-related $PM_{2.5}$ exposure were not found to be associated with overall cancer incidence (HR = 1.02 [95% CI 0.91-1.13]) or any site-specific cancers during this 5 years period. All urinary tract cancers in the study period were from Morwell and thus not able to estimate an HR (Figure 1).

Discussion

Previous analysis showed that, prior to the mine fire, overall cancer incidence in the Morwell and Sale regions were similar to rural and regional Victoria.[8] We observed an increased incidence of cancer in 5 years of follow-up after the fire in the exposed versus unexposed town, however there was no strong evidence that these cancers were associated with mine fire related $PM_{2.5}$ exposure.

It's possible that homogeneity in $PM_{2.5}$ levels within the exposed participants contributed to the lack of any observed association between increments in $PM_{2.5}$ and cancer incidence. Although there was no effect related to exposure found, the limited number of cases and the long-latency period for many types of cancers likely limited our ability to identify associations. Another possibility for the difference between the 2 townships was related to risk factors that were not measured in the study, for example, diet. For urinary cancers, all cases were from the exposed town, which warrants further investigation using larger population level data to better understand regional differences.

Although no statistically significant association was found with $PM_{2.5}$ 5 years after the exposure, this is to our knowledge the first study to investigate an association between coal mine fire related $PM_{2.5}$ and cancer incidence. Further follow-up is needed to provide more certainty around any effects of the Hazelwood mine fire exposure on cancer incidence.

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Author Contributions

Conception and design: PY, MS, MJA. Development of methodology: PY, YG, MJA. Acquisition of data (provided animals, acquired and managed patients, provided facilities, etc.): CD, DB, JI, ADM. Analysis and interpretation of data: PY, CG, ADM. Writing, review and/or revision of the manuscript: PY, CG, YG, MS, MJA, JI, ADM. Administrative, technical or material support (ie, reporting or organizing data, constructing databases): CG, JI, DB. Study supervision: JI, YG, MS, MJA.

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