



Effects of bushfire stress on birth outcomes: A cohort study of the 2009 Victorian Black Saturday bushfires



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ABSTRACT

Previous studies show that shorter gestation, lower birth-weight and fewer male births can result from maternal exposure to environmental disasters. We examined the 2009 Black Saturday fires in Victoria, Australia using a population cohort method. This study principally finds small but significant increases in pre-term birth ($p=0.04$) and decreases in birth-weight ($p=0.001$) in infants whose mothers were exposed to the fires late in the second trimester or during the third trimester. Because environmental disasters are an increasing threat and poor birth outcomes can have detrimental effects across the lifespan, understanding the relationship between environmental disasters and birth outcomes is important for future disaster policy.

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1. Introduction

Environmental disasters, such as floods and bushfires, create challenges for public health and emergency management practitioners. While some of these challenges (e.g. infection control) are well-recognized, others are less widely recognized, such as the emerging effects of prenatal exposure to environmental disasters. Prenatal exposure to stress from conception onwards has been shown to alter birth outcomes including: increases in the percentage of infants born pre-term (defined as less than 37 weeks gestation) [1], an increase in the percentage of infants born at a low birth-weight (less than 2500 g) [1] and decreases to the secondary sex-ratio (an increase in the number of female infants born compared to male infants born). Although the biological and psychological drivers of these changes are not fully understood at present, stress-related changes to birth outcomes have been observed following exposure to: environmental disasters [2–8]; terrorist attacks [9–11]; wars [12,13]; national economic decline [12,14,15]; severe life stress, such as the death of a partner

or other child [16]; and racism [17]. Thus, as the intensity and frequency of environmental disasters continues to increase, reductions in gestational length and birth-weight may present a significant challenge for public health and disaster policymakers.

Increases in pre-term birth and decreases in birth-weight have been observed following exposure to stress, including stress following environmental disasters [2,3,5,6]. Following a severe ice-storm in Quebec (Canada) and following Hurricane Katrina in New Orleans (US) there were more babies born pre-term to women exposed to the severe weather events, which was attributed to the increased *in utero* stress experienced by the fetus [2,7]. There was also an increase in the number of pre-term births following a major Chilean earthquake; this increase was observed in mothers who gave birth to female children and who were exposed early in gestation [6]. Similar changes were observed following an earthquake in Northridge, California (US) where first trimester earthquake exposure was correlated with an increase in pre-term birth among those women exposed to the earthquake while pregnant [5].

Changes to gestational age and birth-weight appear linked to maternal stress. For example, Inder et al. [18] finds that Corticotrophin-Releasing-Hormone (CRH) is a

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moderate predictor of pre-term birth, explaining about 50% of pre-term deliveries. Further, Wadhwa et al. [19] finds that CRH levels during weeks 28–30 of gestation significantly and negatively predicted gestational length. Maternal levels of stress hormones can account for up to 40% of fetal variation [20–22]. Timing of exposure is also relevant to the potential effect of stress on fetal development. In animal studies, first-trimester stress exposure results in the most significant impacts on offspring [22] and, while more varied, evidence from human studies suggests that first-trimester development is also more susceptible to the effects of prenatal stress, likely due to the rapid rate of growth during this period [22–24].

In terms of changes to secondary sex-ratio, observations showing an association between prenatal stress and the birth of fewer male babies are common [4,10–12,14,15,25–28] and decreased secondary sex-ratio has thus been used as an indicator of population-wide stress [11]. Although other factors (such as the sex of previous births) may influence secondary sex-ratios, the difference observed in the numbers of male to female children born following stressful events may also be due to stress-related pre-conception factors. These include paternal nutrition and sperm motility, both of which may be altered by stress, [4,27] or increased rates of fetal loss (i.e. spontaneous abortion) among male fetuses, which are potentially related to maternal stress [12,25]. There is more limited available evidence in regards to environmental disasters, although the available evidence is consistent with the broader trend, with declines in secondary sex ratio being recorded following the Kobe Earthquake in Japan, the Kerman Earthquake in Iran and a major Chilean Earthquake [4,6,8].

Substantial research shows that pre-term birth and low birth-weight increases the risks of infant mortality and morbidity, and can reduce well-being across the lifespan [22,23,29,30]; while sustained and widespread changes to sex-ratio may also have concerning implications over the long-term [31]. Because of the long-term impacts, any broad-scale causative factor for changes to birth-weight, gestational age or secondary sex ratio presents an issue which merits further investigation. Additionally, exposure to disasters has been linked not only to changed birth outcomes but also to detrimental changes to the neurological and cognitive development of infants exposed *in utero* [32–34], although these findings are not conclusively supported by more recent research [35]. By 2015, up to 375 million people per annum worldwide are predicted to be exposed to an environmental disaster, making their health effects an important field of research [36].

There has been limited investigation of the impact of environmental disasters on birth outcomes. While seven known studies examine changes to gestation length, birth-weight or secondary sex-ratio following an environmental disaster, differences in the nature and extent of these disasters make generalization problematic. Examinations of the 1998 Quebec ice storm [2,3] are possibly the most comparable to the Victorian 2009 Black Saturday fires. Like the Victorian fires, the ice storm occurred in a limited geographic region and thus allowed comparison between affected areas and nearby unaffected areas. Also like the Victorian fires, the ice storm's defined footprint meant that

recovery resources (such as food, shelter and medical assistance) could be imported quickly, from local sources. Auger et al.'s [2] study of this ice storm finds a slight increase in pre-term birth in areas severely affected by the ice storm (but did not examine birth-weight or sex-ratio), while Dancause et al.'s [3] study finds modest increases in pre-term birth and reduced birth-weight where confounding variables were controlled. Other studies that examine changes to birth outcomes following disasters are complicated by impaired access to healthcare (due to the extent of the disaster), which is an important confounding variable [5,6,8]. As the Black Saturday bushfires did not significantly impair access to healthcare, except in the very short-term [37], we were also able to largely exclude this potentially confounding factor.

This study aims to examine changes to gestational age, birth-weight and secondary sex-ratio of babies born in the nine months following the ignition of the 2009 Black Saturday fires. This is the only study identified that examines the effects of wildfires on birth outcomes and is the first to look at the impact of an environmental disaster on the reproductive outcomes of an Australian population. We hypothesize that prenatal stress resulting from exposure to the fires will result in decreases to secondary sex-ratio, gestational age and birth-weight.

2. Methods

Following a prolonged heat wave and widespread minor bushfire ignition during late January and early February 2009, 316 individual bushfires ignited or grew substantially on 7 February 2009, now known as 'Black Saturday'. On that day, high temperatures (peaking at 46.4 °C) and strong winds (up to 120 km per hour) propelled 15 of these fires into large and uncontrollable wildfires [38]. The fifteen principal fires, collectively known as the Black Saturday fires, were located across the Australian state of Victoria. In order of ignition, the fires were located in: Delburn, Bunyip, Kilmore East, Horsham, Coleraine, Pomborneit-Weerite, Churchill, Murrindindi, Redesdale, Narre Warren/Harkaway, Narre Warren/Lynbrook (Coral Drive), Narre Warren/Lynbrook (Golf Club Road), Upper Ferntree Gully, Bendigo and Beechworth-Mudgegonga [38] (see Fig. 1). While some fires were extinguished earlier, the last fires were declared extinguished on 9 March 2009. Combined, the Black Saturday fires burnt for 31 days resulting in 173 deaths and approximately AU\$4 billion in property damage [38]. This loss of life was the greatest resulting from an environmental disaster in Australia since the 19th century and was the ninth highest death toll from a wildfire recorded worldwide [37].

After approval from the Australian National University Human Ethics Research Committee (protocol number 2012/030), data for all registered births in Victoria between 2006 and 2009 were provided by the Victorian State Department of Health through the Victorian Consultative Council on Obstetric and Pediatric Mortality and Morbidity (CCOPMM). The data included gestational age, birth-weight and baby sex. Data provided were non-identifying and categorical (i.e. birth weight data was provided in 500 g increments).

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