A mass shooting at Port Arthur, Tasmania, Australia: a study of its impact on early pregnancy losses using a conception time-based methodology

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STUDY QUESTION: Does an acute calamity in a community cause early miscarriage and is this association the same for male and female fetuses?

SUMMARY ANSWER: Estimated losses of 29.5% of first trimester pregnancies in the affected region could be associated with an acute calamity, with no statistically significant difference in estimated losses by fetal sex.

WHAT IS KNOWN ALREADY: There are very few studies on the impact of a calamity on early pregnancy loss and its differential effects on male and female fetuses. A decline in the human sex ratio at birth associated with the events of 9/11 in New York has been documented.

STUDY DESIGN, SIZE, DURATION: This is a retrospective descriptive study of birth register data in Tasmania, Australia, from 1991 to 1997, covering the period in which the calamity occurred. The register contains data on all pregnancies that proceeded to ≥20 weeks gestation. The conception date was calculated by subtracting gestational age from birth date. We estimated that 40,318 pregnancies were conceived in the period 1991–1996 inclusive. These were aggregated to 4-weekly blocks classified by region and sex.

PARTICIPANTS/MATERIALS, SETTING, METHODS: The acute calamity was at Port Arthur, Tasmania, Australia. On 28 April 1996, a gunman opened fire on visitors and staff in a tourist cafe. A very stressful 20 h period, ended with 35 people dead and 22 injured. A negative binomial regression model was used to assess the association between this calamity and pregnancy loss. This loss is evidenced by a shortfall in the registration of pregnancies that were in their first trimester at the time of the calamity.

MAIN RESULTS AND THE ROLE OF CHANCE: We estimated a shortfall of 29.5% or 229 registered pregnancies among those in the first trimester at the time of the calamity (P < 0.001), in the region surrounding the calamity site. There was no sex effect in this shortfall (P = 0.911). There was no corresponding shortfall in other parts of Tasmania (P = 0.349).

LIMITATIONS, REASONS FOR CAUTION: The study is descriptive and cannot produce causal inferences. These first trimester miscarriages are estimated statistically and it is understood that gestational age is an estimate. The use of maternal residential postcodes at birth as a surrogate for geographic area or space assumes that the mother has not moved into the postcode area after the calamity and before the reporting of a birth.

WIDER IMPLICATIONS OF THE FINDINGS: The results of this study suggest that calamities bring about significant pregnancy loss affecting both sexes. The methodology presented of inferring conception date from birth date and using this for analysis, provides a more accurate assessment of first trimester pregnancy losses than raw birth data or sex ratio at birth.

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TRIAL REGISTRATION NUMBER: This was not a clinical trial.

Key words: miscarriage / stress / pregnancy / acute calamity / first trimester / conception based / acute / sex ratio
Introduction

Maternal stress and anxiety in pregnancy has been shown to be associated with adverse outcomes such as preterm birth and infants with lower birthweights (Austin and Leader, 2000). This, in turn, has adverse implications for fetal neurodevelopment and infant outcomes. Women who experienced major life events such as the death of a family member are at 1.4–1.8 times greater risk of preterm birth, with strongest effects when events occur early in pregnancy (Austin et al., 2005a,b; Schetter and Tanner, 2012).

Previous studies of natural disasters such as earthquakes and hurricanes have shown that there is an increase in the number of preterm births and low birthweight infants (Simeona, 2009). The greater the disaster, the greater the impact on the outcome (Glyn et al., 2001). The earlier that mothers are affected in the second trimester of pregnancy, the greater the negative impact on preterm deliveries. The duration of exposure as well as the severity of the event affect the chances of suboptimal pregnancy outcomes.

A study of floods in a village in Southern Poland in 1997 (Neuberg et al., 1998) reported an increased incidence of spontaneous abortion. Both that study and a study of the flooding of the Red River in North Dakota in 1997 (Tong et al., 2011) showed an increase in preterm birth and low birthweight infants, although there was no increase in the number of small for gestational age infants in the North Dakota sample. Xiong et al. (2008) found that birth outcomes among the survivors of Hurricane Katrina depended on maternal exposure to the disaster with depressed birthweight being the key result. A study on women who were pregnant during a major ice storm in Quebec, Canada, found that their children had poorer intellectual and language functioning at 2 years of age (King and Laplante, 2005).

Camacho (2007) used the explosion of land mines in Colombia to test the effects of increased exposure to terrorist attacks on pregnancy outcomes. That study found that the incidence of land mine explosions in close proximity to the mothers during pregnancy was a significant predictor of low birthweight infants and preterm deliveries. The effects were especially pronounced, if maternal stress occurred in the first and last trimesters.

Elevated levels of the stress hormones corticotrophin-releasing hormones (CRH) have been associated with poor regulation of stress and increased fear behaviour in infants (Davis et al., 2005; Weinstock, 2005). Austin et al. (2005a,b) showed that stressed and anxious mothers were more likely to have infants whose temperament was classified as difficult.

A study by Catalano and Hartig (2001) on very low birthweight using Swedish data found an association with ‘communal bereavement’. Another study by Bruckner et al. (2010) suggests that variations in the fetal death sex ratio show evidence of ‘communal bereavement’. Acute calamities such as 9/11 have an extended reach well beyond emergency workers and witnesses.

A number of calamity studies have analysed the human sex ratio at birth in survivors of these events. Catalano et al. (2005) examined variations in the sex ratio at birth in a Californian population after 9/11. A second study examined the same variations in New York (Catalano et al., 2006). A decline in the human sex ratio at birth was reported.

The methodology of using a sex ratio to determine possible pregnancy loss carries the assumption that male fetuses are more vulnerable than female fetuses and leads to differential losses of males. The only interpretation open to these studies is that in the aftermath (up to 9 months later) of severely traumatic events, more males were lost than females, hence the variation in the human sex ratio at birth.

Summary

There are little data on the impact of calamity on early pregnancy loss. The standard practice of recording pregnancies that survive beyond 20 weeks does not allow for estimating earlier pregnancy losses. Among the many causes of miscarriage, the effects of exogenous calamities on a pregnant population before the beginning of the mandatory reporting period are not well understood.

Study objective

The objective of this study was to use hospital data in the NPDC (National Perinatal Data Collection) to establish whether there were pregnancy losses as a result of a calamity.

To answer this question, we have developed a conception time-based methodology, which we believe enables us to determine whether an acute calamity can be associated with pregnancy losses before the beginning of the mandatory reporting period.

Materials and Methods

Ethics approval was obtained from the Department of Health and Human Services, Tasmania, as well as from the Australian Institute of Health and Welfare, Canberra, and The University of New South Wales Ethics Committee, Sydney, New South Wales, Australia.

Tasmanian birth data were collected for the period 1991–1997 (both years inclusively) comprising 40,788 births. The data were obtained from the NPDC, an all Australian States and Territories’ collection of hospital birth data which includes all births over 20 weeks gestation or weighing more than 400 g.

Gestational age in Australia is defined as the duration of pregnancy in completed weeks calculated from the date of the women’s last menstrual period and her baby’s date of birth. If the dates are not known then the gestational age of the pregnancy is determined by a first trimester ultrasound examination.

The birth data set for this study has the following variables for each birth: birth date, gestational age in weeks, maternal residential postcode and sex. We transform these data to a conception time-based data set by calculating the conception date for each birth as the birth date minus gestational age plus 2 weeks. Gestational age is a mandatory reporting item in the NPDC collection. It is, of its nature, an estimate.

The three variables in the conception time-based model which are used in the statistical modelling are estimated conception date, maternal residential postcode and sex. The result is a form of simulation, which we refer to as conception time-based methodology.

We estimated that 40,318 pregnancies were conceived in the years 1991–1996 inclusively (Table I). The difference between pregnancies (40,788) and conceptions (40,318) occurs because pregnancies in the 1991–1997 study period were conceived before 1991. Similarly, many pregnancies ending after 1996 were conceived within the study period.

Assuming the calamity effect was most severe at and around the site of the calamity in the south eastern corner of Tasmania, maternal residential postcode was used as a geographic variable for division of the state into two regions, southern and northern (Fig. 1 postcode map). Pregnancies were aggregated into disjoint 4-week blocks of conception time and classified by region and sex. The 12-week period 6 February to 28 April 1996 was taken as the calamity period, i.e. pregnancies conceived during that period were in their first trimester at the time of the calamity.
The acute calamity

On 28 April 1996, an armed gunman entered the Broad Arrow cafe in the well-known tourist venue at Port Arthur on the Tasman Peninsula in Tasmania, Australia (Fig. 1). He immediately killed 12 people in the space of 15 s (Cox, 1996). In the following hours, he killed a total of 35 people and injured 22. Many of the dead and wounded were local residents. The wounded, some seriously, were immediately evacuated to Hobart hospitals. By nightfall, the gunman was still at large. That night police closed the venue and peninsula (Fig. 1) and imposed a lockdown over the whole peninsula. Tourists (both domestic and international), paramedics, residents, and so on, were evacuated to Hobart. In a direct line, it is ~50 km from Hobart to Port Arthur.

Table 1  Estimated calendar month-specific number of conceptions for all Tasmania for the years 1991–1996.

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emergency workers and venue staff, trapped by these security precautions, spent the night in cramped conditions with furniture pushed against doors and windows of the many buildings at the venue (Scott, 1997). Many of the emergency staff were from Hobart and environs (shaded area in Fig. 1).

The Tasman Peninsula is very narrow at its’ northern extremity and a simple blockade was sufficient to keep the gunman and unfortunately everyone else within the peninsula area. The gunman was arrested the following morning. The shock from these serial murders was widely publicized and conveyed throughout the world. We use this incident as the calamitous event.

Statistical analyses
We assessed the potential effect of the calamity on pregnancies within their first trimester at the time of the calamity. The number of pregnancies in 4-week blocks of conception time, classified by region and sex, was the dependent variable in a multivariate regression model. The predictors were secular trend (linear) annual cyclic trend (a cosine term), region, sex and a binary variable indicating if the conception time corresponded to a pregnancy within its first trimester at the time of the calamity. (A sine term was originally included, but, as it was not statistically significant, it was excluded from the model.) Interaction terms were used to assess the effects of calamity and sex within region. As a Poisson response distribution provided an inadequate fit to the data, a negative binomial regression model was used.

In regression modelling, the negative binomial response distribution is parameterized in terms of its mean and a dispersion parameter, and a log-linear model is specified on the mean (McCullagh and Nelder, 1989).

The Akaike information criterion (Lindsey and Jones, 1996) was used for model selection and quantile residuals (Dunn and Smyth, 1996) for assessment of model fit.

The statistical language R (version 3.1.2) (RCoreTeam, 2014) was used for analysis. A significance level of 5% was used for statistical testing.

Results
Figure 2 shows the number of pregnancies conceived (4-weekly totals) over the study period, with northern and southern regions indicated, as well as the calamity period. In the southern region, the registration of pregnancies that were in the first trimester during the calamity period exhibit an apparent shortfall.

The negative binomial regression model for pregnancies by conception time (Table II) shows a statistically significant effect of calamity in the southern region ($P < 0.001$), after correction for linear secular trend ($P < 0.001$), annual cyclic seasonality ($P < 0.001$), region ($P < 0.001$) and sex ($P < 0.001$). There was no significant effect of the calamity in the northern region ($P = 0.349$).

A three-way interaction between calamity, region and sex was not significant ($P = 0.911$), meaning that the effect of the calamity in the southern region was not significantly different for males and females. (As this effect was not significant, it was omitted from the final model and is not shown in Table II.)

The incidence rate ratio (IRR) for calamity in the southern region is 0.705. This is a multiplier on the expected number of registered pregnancies and means that, the number of first trimester pregnancies at the time of the calamity that proceeded to 20 weeks is reduced by 29.5%. This represents an expected shortfall of 229 pregnancies. When the (12 weeks) calamity period was broken down into three 4-week blocks, there were no significant differences in the effect of the calamity between the first, second and third blocks ($P = 0.471$). The IRR for sex (female) is 0.933, implying a sex ratio of 107 males to 100 females (Fig. 2).

Discussion
We have demonstrated a substantial loss of first trimester pregnancies at the time of the calamity, in the region of the calamity. The current practice of mandatory recording of all births that occur after 20 weeks gestation does not allow for the reporting of first trimester pregnancy losses. Our methodology allows for the estimation of shortfalls in pregnancies proceeding to 20 weeks, by taking individual recorded births and using their estimated gestational age to calculate conception date.

We suggest that the shortfall of 229 first-trimester pregnancies were miscarriages as a result of calamity from maternal stress and anxiety. Causes for the shortfall could be: (i) miscarriage as a result of calamity induced stress, (ii) infertility prior to the calamity (and therefore not caused by it), or (iii) terminations of pregnancy. There are no reasons or evidence to suggest that (ii) or (iii) have any validity.
As Popper (1959) points out, the closeness of time (immediate 12 weeks before the calamity) and space (the area immediately around the calamity site) strengthen the case that the observed association is causal. Trusted (1979), while endorsing Popper’s maxim, added statistical significance to argue for causation. The size of the shortfall suggests that the calamity effect was not limited to victims and eye witnesses.

There was no significant sex effect in the shortfall. Male and female fetuses were affected to the same extent. Our methodology produces an estimate of total estimated pregnancy loss, thus differing from methodologies which focus on the human sex ratio at birth (Catalano et al., 2005, 2006). The latter exclude any estimate of female fetal loss, with an underlying assumption of male fetal vulnerability and female fetal robustness.

In later studies, hypothesis that populations without firsthand knowledge of people involved in a calamity or are some geographical distance from a calamity nevertheless show signs of distress (Bruckner et al., 2010). Intimacy is not the only factor when communicating grief.

It is significant to note that while the Tasman Peninsula is sparsely populated, Hobart and environs has a population of nearly 200 000 people. This calamity affected directly; hospital staff, doctors, paramedics, police officers, forensic staff, fire fighters and everyone who entered the Broad Arrow Café that afternoon after the gunman had left (Scott, 1997).

The pathophysiological mechanism of how stress may cause early pregnancy loss has been explored by a number of studies. Nepomnaschy et al. (2006) showed that women with increased levels of urinary cortisol levels in the first 3 weeks after conception were more likely to miscarry. In a further publication, Nepomnaschy et al. (2007) explored the endocrine and immunological effects of stress in reproduction.

Women with increased levels of cortisol tend to have lower level of progesterone which in turn is associated with an increased miscarriage rate. James (2015) suggested that stress induced higher levels of adrenal androgens which were an important factor in early miscarriages. Wainstock et al. (2013) showed women exposed to repeated rocket attacks were at an increased risk of miscarrying.

The medical and epidemiological literature suggests that the increased production of neuropeptide CRH during periods of anxiety plays a role in initiating labour. Women with elevated blood levels of CRH in the second trimester or early third trimester are at a higher risk of preterm deliveries (Wadhwa et al., 1998; Hobel et al., 1999; McLean et al., 1999; Holzman et al., 2001; Hobel et al., 2008; Chen et al., 2010).

Neuroendocrine studies have demonstrated that the acute response to stress is associated with a rise in cortisol secretion from the adrenal gland. If the stressor becomes chronic, the hypothalamic–pituitary–adrenal (HPA) axis may be abnormally reset and chronically raised CRH and cortisol levels can ensue (Austin et al., 2005b).

Mancuso et al. (2004) showed that maternal stress measured at 28–30 weeks of gestation correlated significantly with maternal CRH levels measured at the same time. Women who had higher levels of measurable CRH at both 18–20 and 28–30 weeks delivered earlier than women with lower CRH levels. Kalantaridou et al. (2010) questioned whether it was the raised level of CRH that led to preterm birth or whether the raised level was a consequence of the underlying pathophysiology.

It appears that antenatal fetal exposure to small amounts of stress may be necessary for normal infant development. In some cases, earlier maturity of the fetal HPA axis can be protective and produce some beneficial effects. For example, preterm infants whose mothers developed choriamnionitis had a decreased requirement for respiratory support in the first week of post-natal life (Watterberg et al., 1997).

What is not known at present is the level of maternal stress, in terms of both amount and duration that may become harmful to the fetus and consequently the child in the longer term.

Limitations of the study

This methodology allows for estimating pregnancy losses that occurred before the mandatory reporting period. As such losses are not reported, we can only offer an estimate based on gestational age and time to ovulation as noted in the next paragraph.

Calculation of conception date was based on the assumption that the last menstrual period for each maternal case was 2 weeks before implantation.

We acknowledge that some women may have irregular or longer cycles and that reporting of the last menstrual cycle may not be accurate in all cases.

The use of maternal residential postcodes as a surrogate for geographic area or space assumes that the mother has not moved into the postcode area after the calamity and before the reporting of a birth.

Summary and conclusion

In conclusion, we record the following findings:

(i) We have developed a statistical model which estimates excess first trimester pregnancy losses at the time of an acute calamity. This conception time-based methodology illuminates an area of pregnancy loss not previously identified. Routinely, collected birth data only records birth losses after 20 weeks gestation.

(ii) A statistically significant shortfall in first trimester pregnancies was estimated in the geographic region of the calamity at the time of the calamity. The size of the shortfall suggests that the effect of the calamity was not limited to victims and eye witnesses.

(iii) No sex effect was observed in the shortfall.

This study is the first to estimate excess first trimester pregnancy losses after an acute calamity. This model establishes a conception-based methodology which can be utilized to estimate excess pregnancy losses within a geographical location, by time and sex.

Authors’ roles

R.G.D. conceived original idea and study design, conducted literature review, performed data and statistical analysis, and drafted and edited this paper. J.D. provided statistical guidance, examined the efficacy of the original idea, data selection and transformation from birth to conception, extraction and analysis, editing this manuscript and provided the postcode Tasmania map. G.Z.H. performed the data analysis and critically reviewed and edited the manuscript. L.R.L. reviewed and drafted and edited the relevant literature, provided data analysis and critically reviewed the manuscript, tables and figures.

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Conflict of interest

None declared.

References


Cox CJ. R vs Bryant Sentencing Comments. Supreme Court of Tasmania, Hobart, 1996.


James WH. Hypothesis: high levels of maternal adrenal androgens are a major cause of miscarriage and other forms of reproductive suboptimality. J Theor Biol 2015;364:316–320.