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Complete List of Authors:	McInerney, Carol; The University of Sydney Northern Clinical School, Women and Babies Research; New South Wales Ministry of Health, NSW Biostatistics Training Program Ibiebele, Ibinabo; The University of Sydney Northern Clinical School, Women and Babies Research; Northern Sydney Local Health District, Kolling Institute Ford, Jane; The University of Sydney Northern Clinical School, Women and Babies Research; Northern Sydney Local Health District, Kolling Institute Randall, Deborah; The University of Sydney Northern Clinical School, Women and Babies Research; Northern Sydney Local Health District, Kolling Institute Morris, Jonathan; The University of Sydney Northern Clinical School, Women and Babies Research; Royal North Shore Hospital, Obstetrics and Gynaecology Meharg, David; The University of Sydney Faculty of Health Sciences; The University of Sydney Poche Centre for Indigenous Health Mitchell, Jo ; New South Wales Ministry of Health, Centre for Population Health Milat, Andrew; New South Wales Ministry of Health, Centre for Epidemiology and Evidence Torvaldsen, Siranda; The University of Sydney Northern Clinical School, Women and Babies Research; University of New South Wales School of Public Health and Community Medicine
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Benefits of not smoking during pregnancy for Australian Aboriginal and Torres Strait Islander women and their babies: a retrospective cohort study using linked data

Carol McInerney[1,2]
Biostatistician cmci0455@uni.sydney.edu.au

Ibinabo Ibiebele[1,3]
Research Fellow ibinabo.ibiebele@sydney.edu.au

Jane Ford[1,3]
Principal Research Fellow jane.ford@sydney.edu.au

Deborah Randall[1,3]
Senior Research Fellow deborah.randall@sydney.edu.au

Jonathan Morris[1,4]
Professor of Obstetrics and Gynaecology jonathan.morris@sydney.edu.au

David Meharg[5,6]
Research Associate david.meharg@sydney.edu.au

Jo Mitchell[7]
Executive Director jo.mitchell@health.nsw.gov.au

Andrew Milat[8]
Director andrew.milat@health.nsw.gov.au

Siranda Torvaldsen[1,9]
Corresponding author
Principal Research Fellow siranda.torvaldsen@sydney.edu.au

[1] The University of Sydney Northern Clinical School, Women and Babies Research, St Leonards, New South Wales, Australia
[2] NSW Biostatistics Training Program, NSW Ministry of Health, Australia
[3] Northern Sydney Local Health District, Kolling Institute, New South Wales, Australia
[4] Department of Obstetrics and Gynaecology, Royal North Shore Hospital, Australia
[5] The University of Sydney, Faculty of Health Sciences, Sydney, New South Wales, Australia.
[6] Poche Centre for Indigenous Health, The University of Sydney, Sydney, New South Wales, Australia.
[7] Centre for Population Health, NSW Ministry of Health, Sydney, Australia
[8] Centre for Epidemiology and Evidence, NSW Ministry of Health, Sydney, Australia
[9] School of Public Health and Community Medicine, UNSW Sydney, Australia

Abstract

Objectives

To provide relevant evidence for targeted smoking cessation policy, the aim of this study was to compare pregnancy outcomes of Aboriginal mothers who reported *not* smoking during pregnancy with Aboriginal mothers who reported smoking during pregnancy.

Design

Population based retrospective cohort study using linked data.

Setting

New South Wales, the most populated Australian state.

Population

18,154 singleton babies born to 13,477 Aboriginal mothers between 2010–2014 were identified from routinely collected New South Wales datasets. Aboriginality was determined from birth records and from four linked datasets through an Enhanced Reporting of Aboriginality algorithm.

Exposure

Not smoking at any time during pregnancy.

Main outcome measures

Unadjusted and adjusted relative risks and 95% confidence intervals from modified Poisson regression were used to examine associations between not smoking during pregnancy and maternal and perinatal outcomes including severe morbidity, inter-hospital transfer, perinatal death, preterm birth and small-for-gestational age.

Results

Compared to women who smoked during pregnancy (n=8,919), those who did not smoke (n=9,235) had a lower risk of being transferred to another hospital (aRR=0.76, 95%CI 0.66–0.89). Compared with babies born to mothers who smoked during pregnancy, babies born to non-smoking mothers had a lower risk of all adverse perinatal outcomes including perinatal death (aRR=0.58, 95%CI 0.44–0.76), preterm birth (aRR=0.58, 95%CI 0.53–0.64) and being born small-for-gestational age (aRR=0.35, 95%CI 0.32–0.39).

Conclusions

Babies born to women who did not smoke during pregnancy had a lower risk of all adverse perinatal outcomes. Rates of adverse outcomes among Aboriginal non-smokers were similar to those among the general population. These results highlight why effective smoking cessation programs are so urgently required for this population.

Article summary

Strengths and limitations of this study

- The first study to examine the association between *not* smoking in pregnancy and pregnancy outcomes among Aboriginal women
- A large population-based cohort study using whole-of-population linked data
- No data on alcohol consumption nor history and heaviness of smoking were available

Introduction

In 2008 the Australian federal, state and territory governments committed to reducing the national adult daily smoking rate by 2018, including halving the Aboriginal adult smoking rate.(1) Although smoking rates have substantially declined over this time, they remain high among pregnant Aboriginal women. In 2016, 41% of all pregnant Aboriginal women reported smoking at some time during their pregnancy compared to just 7% of non-Aboriginal women.(2) Smoking during pregnancy is the 'most important preventable risk factor for maternal and infant health'(3), thus smoking cessation for pregnant Aboriginal women remains a key priority for New South Wales (NSW) Health.(4) For the purposes of this study, Aboriginal and/or Torres Strait Islander people were considered together in one group. The reason for this was the small proportion of Torres Strait Islander people living in NSW (an estimated 2.6% of all females of Aboriginal and/or Torres Strait Islander descent(5))and that some people were recorded as both. We respectfully use the term Aboriginal as Aboriginal people are the original inhabitants of NSW.(6)

Australia's anti-tobacco campaigns and smoking cessation strategies are among the most comprehensive in the world, and there is growing evidence that programs specifically targeted to Aboriginal Australians are more effective.(7) There have been several campaigns to promote smoking cessation among pregnant Aboriginal mothers with varying efficacy.(8) To date these have been grounded in evidence from a general population.

Although the benefits of not smoking during pregnancy are well established (9-13), no previous studies have demonstrated associations between not smoking in pregnancy and positive pregnancy outcomes *among* Aboriginal women. This study aims to compare pregnancy outcomes of mothers who reported not smoking during pregnancy with those who reported any smoking during pregnancy from the Aboriginal population of NSW. Findings from this study will provide the most relevant evidence to date for pregnant Aboriginal women.

Methods

Study population and data sources

The study population consisted of all singleton babies born to Aboriginal women residing in NSW between 1 January 2010 and 31 December 2014 and their mothers. This population-based retrospective cohort study used linked data from routinely collected NSW datasets. The study population was identified from all records in the NSW Perinatal Data Collection ('birth data') for the period 1 January 2010 to 31 December 2014. All births in the population, including births at NSW public and private hospitals and home births are recorded in the birth data. This surveillance system includes all live births and stillbirths of at least 400 grams birthweight or at least 20 weeks gestation.(14)

All deaths within NSW are registered in the Registry of Births, Deaths and Marriages and fact of death was retrieved from these data between 1 January 2010 and 31 December 2015. Public and private hospital admission records were drawn from the NSW Admitted Patient Data Collection ('hospital data') for admissions from 1 September 2009 to 31 December 2014. An additional 4 months of hospital data

were retrieved prior to the start of the study period to allow for admissions to hospital for births early in 2010. Diagnoses coded in the hospital data are applied according to the International Classification of Diseases, Australian Modification (ICD-10-AM). Records within and across all datasets were probabilistically linked using personal identifiers by the NSW Centre for Health Record Linkage with an estimated false linkage rate of less than 5 per 1,000 records.(15) Hospital birth records were those where the birth was recorded to have occurred between the mother's admission and discharge dates using the linked birth data. It's estimated that 96% of records from the birth data link to the mother's and infant's hospital records from the birth.(16)

Aboriginal women were defined as those who were recorded as Australian Aboriginal in the birth data or who were assigned Aboriginal status according to the Enhanced Reporting of Aboriginality (ERA) algorithm.

Enhanced Reporting of Aboriginality (ERA)

It is widely acknowledged that Aboriginal status is under-recorded on routinely collected health datasets nationwide.(17) Enhancement of reporting of Aboriginal people using linked records creates a statistical construct that results in improved information about Aboriginal people. It does not define a person as being Aboriginal, nor does it replace efforts to improve the overall quality of recording Aboriginal status at the point of care.

Information surrounding individuals' Aboriginal status was pooled via linkage of the birth data, NSW Registry of Births, Deaths and Marriages birth registrations, hospital data and the NSW Emergency Department Data Collection. Using this information, a weight of evidence surrounding a woman's Aboriginal status was determined by a multistage median algorithm.(18) Since multiple datasets were used and some women had multiple records in each of these datasets, the algorithm initially assigned a separate status for each woman and dataset. Aboriginal or Torres Strait Islander status was assigned to a mother if: one or two linked records were available and at least one reported her as Aboriginal; three or more linked records were available and at least two reported her as Aboriginal. A comparable algorithm using dataset-specific statuses instead of records was used to determine the inclusion of each woman in the study population.

The enhanced reporting of Aboriginality is a technique used by many research groups.(19-21) Although this combination of datasets and algorithm has not been used before, similar methods have been found to minimise the risk of incorrect inclusion while capturing more women than simply relying on a single record.(22) Details on the algorithm, the data used and the mothers identified through the ERA have been described in more detail elsewhere.

Exposure

The exposure of interest for this study was not smoking at any time during pregnancy. Mothers who reported not smoking during pregnancy will henceforth be referred to as non-smokers and those who reported any smoking during pregnancy are referred to as smokers. To increase ascertainment, birth data and mother's hospital birth record(s) were used to assign smoking status. If the birth data indicated that a mother smoked at any time during her pregnancy and/or recorded her as a current smoker within the hospital birth record(s) (according to the ICD-10-AM diagnosis codes Z72.0 and F17) then she was

considered to be a smoker. The sensitivity and specificity of current smoking from the most recent separation in the hospital data is estimated to be 58.5% and 98.4% respectively.(23) Where a mother had multiple hospital records associated with the birth and those records contradicted each other according to smoking status, her smoking status defaulted to that recorded in the birth data.

Outcomes

Maternal outcomes were identified using the birth data and the mother's hospital birth record and included three binary outcomes: severe maternal morbidity, inter-hospital transfer and breastfeeding. Severe maternal morbidity was defined using a validated composite indicator that captures a broad range of diagnoses and procedures such as cardiac arrest, renal failure or assisted ventilation.(24) Mothers requiring inter-hospital transfer were defined as those with at least one record with a mode of separation indicating transfer or where multiple hospitalisation records were present with differing hospital codes. Breastfeeding included any breastfeeding at the time of mother's discharge from hospital.

Perinatal outcomes, including birth outcomes and those occurring within the first 28 days of life for the baby were retrieved from the birth data and the baby's linked hospital and birth registration records. These included perinatal death (stillbirth and neonatal death), preterm birth (<37 completed weeks of gestation), and small for gestational age (birth weight <3rd and/or 10th percentile for sex and age (25)). Admissions to a special care nursery (SCN) or neonatal intensive care unit (NICU) were assessed among an eligible population of babies born in a hospital classified as level 3 or above (NSW Ministry of Health's *Guide to the Role Delineation of Hospitals*) or a private hospital. Severe neonatal morbidity, measured according to a validated composite indicator (26), was assessed among all live births.

Covariates

Maternal age and parity were reported according to the birth data. The mother's chronic conditions, hypertension and diabetes information were obtained from the birth data and the hospital birth record(s). We used the broad category of any hypertension rather than the specific categories of chronic hypertension, pregnancy hypertension, preeclampsia and eclampsia, as there is known misclassification among types of hypertension (27). The NSW ranking of the Australian Bureau of Statistics (ABS) 2011 Socio-Economic Index for Areas (SEIFA) Index of Relative Socio-Economic Disadvantage (IRSD) and the 2011 Remoteness Areas were used to assess the mother's relative socio-economic status and access to services respectively. Where available, the mother's 2011 Statistical Local Area (SLA) according to her birth data was used to assign these measures. Otherwise, and for all babies born in 2010, the mother's 2010 SLA was used. Hospital type is an indicator of the size of a hospital and its location (urban or regional)(28) and was assigned using the hospital code recorded in the birth data.

Statistical analyses

The study population was described using frequencies and percentages by potential confounders and the mother's smoking status. Summary statistics were calculated by mother's smoking status to investigate the associations between smoking during pregnancy and maternal and child outcomes. To estimate the unadjusted and adjusted relative risk of binary outcomes while accounting for the correlation within the data (some mothers had more than one baby during the study period), an extension to the modified Poisson regression (29) was used with an unstructured correlation matrix.

Those observations where data were missing for an outcome were excluded from analysis for that outcome. SAS for Windows 9.4 (SAS Institute, Cary, NC, USA) was used for all data manipulation and analysis.

Patient and public involvement

An Aboriginal advisory committee was consulted prior to submission of the study proposal to ethics committees and throughout the process. The committee provided guidance on presentation and interpretation of results. It was of particular importance to members of the committee that the results were framed positively, ie the *benefits* of not smoking, rather than the risks of smoking. It was also important to committee members that all comparisons were among Aboriginal women and that Aboriginal women were not compared with non-Aboriginal women. There are plans to develop culturally appropriate educational material based on the results of this research and in collaboration with Aboriginal Health Workers and others involved in the care of Aboriginal women who are pregnant or may be planning a pregnancy.

Results

Following exclusion of duplicates (n=76), a total of 487,388 babies were born to 379,116 mothers in NSW and were assessed for inclusion in this study. Records for 16,904 babies born to 12,720 mothers who were recorded as Aboriginal in the birth data were available for analysis. An additional 1,921 babies born to 1,624 mothers were identified as eligible for inclusion in the study using the ERA. Of the total 18,825 babies, 557 were from a multiple birth and 114 were born to mothers who were not residents of NSW. These babies did not meet the eligibility criteria and were excluded. Thus the final study population consisted of 18,154 singleton babies born to 13,477 Aboriginal mothers. **Error! Reference source not found.** outlines the flow of participants in this study.

Among the study population, 9,235 (51%) babies were born to non-smoking mothers and 8,919 (49%) were born to smoking mothers (

Table 1). Ascertainment of smoking information was increased by using both the birth and hospital data and only two percent of all linked records had contradictory smoking statuses from these data sources. For comparison, when smoking status was assigned only according to that reported on the birth data, 52% of babies were born to non-smoking mothers and 48% were born to smoking mothers.

Mothers who reported not smoking at any time during their pregnancy were generally less disadvantaged than their smoking counterparts; approximately 8.1% of non-smoking mothers were in the highest SEIFA quintile, compared to just 4.1% of smoking mothers. Non-smoking mothers were older, lived in less remote regions and had fewer previous pregnancies than smoking mothers. The number of non-smoking mothers with hypertension (1,106) was almost double that of smoking mothers (578) and slightly more non-smoking mothers had diabetes (Table 1).

The majority (70%) of mothers only had one baby during the study period however a substantial number had multiple: 25% had two, 4.4% had three and 0.4% had four. For 564 (4%) mothers, their smoking status changed between births, 6,814 (53%) mothers reported not smoking in all births during the study period and 6,099 (47%) consistently reported smoking. For the mothers whose smoking status changed, 47% changed from smoking to non-smoking and 48% changed from non-smoking to smoking in all subsequent pregnancies.

More mothers who did not smoke were breastfeeding their babies at the time of discharge from hospital: 75% of non-smoking mothers reported any breastfeeding compared to 62% of smoking mothers (Table 2). The rate of inter-hospital transfer was lower in the non-smoking group at 3.7% compared with the smoking group (5.1%), with an adjusted relative risk of RR=0.76 (95% CI 0.66, 0.89).

Adverse perinatal outcomes occurred less frequently among babies born to non-smoking mothers (Table 3). Perinatal deaths were rare in both populations however the rate was lower in the non-smoking group with perinatal death occurring in 1.0% of babies born to non-smoking mothers, compared to 1.8% in smoking mothers. Also, severe neonatal morbidity and admission to SCN or NICU was less frequent in babies born to non-smoking mothers when compared to those born to smoking mothers.

Overall, the gestational age of babies from the non-smoking group was closer to term than those from the smoking group; more babies born to non-smoking mothers (66%) were born between 39 and 41 weeks than those born to smoking mothers (55%). Preterm birth was considerably less frequent among babies born to mothers who did not smoke during pregnancy; 8.2% of births to non-smoking mothers were preterm compared to 14% from smoking mothers. Similarly, babies born to non-smoking mothers were less often small for gestational age, with 2.0% and 7.3% of these babies having a birthweight below the 3rd and 10th percentiles respectively compared to 7.0% and 20% of babies of smoking mothers. All relative risks were less than 1, suggesting a reduced risk of all adverse outcomes among babies born to non-smoking mothers when compared to those born to smoking mothers. Of note were the relative risks for preterm birth (RR=0.58 95% CI 0.53, 0.64), small-for-gestational age (<10^{th} percentile; RR=0.35 95% CI 0.32, 0.39) and perinatal death (RR=0.58 95% CI 0.44, 0.76).

Discussion

This study of a recent population of pregnant Aboriginal women clearly demonstrates improved pregnancy outcomes among Aboriginal mothers who reported not smoking during pregnancy when compared to Aboriginal mothers who reported smoking during pregnancy. Benefits of not smoking were found for both maternal and perinatal outcomes. Mothers who did not smoke during pregnancy were 16% more likely to breastfeed their baby than their smoking counterparts. These results align with the literature from a general Australian population, where the odds of breastfeeding for smoking mothers are 0.8 times that of non-smoking mothers.(30) We also found non-smoking mothers had a 24% lower risk of being transferred to another hospital during the birth admission than smoking mothers of similar demographics. This means they are less likely to be away from their family and country during this challenging time. Although a slightly lower risk of severe maternal morbidity was found in the non-smoking group, there was not sufficient evidence to suggest a true difference existed as the confidence interval included 1 (RR=0.92, 95% CI 0.77–1.11). Among babies born to mothers of a similar age, with similar pre-existing conditions (any diabetes or hypertension), parity and socio-economic status, those with a non-smoking mother had a 42% less risk of perinatal death and preterm birth, 65% less risk of being small-for-gestational age (<10th percentile), 30% less risk of severe neonatal morbidity, and 33% less risk of being admitted to a SCN or NICU than those born to a mother who smoked at any time during her pregnancy.

The reductions in adverse outcomes for babies born to non-smoking mothers were statistically and clinically significant and remained so even after adjustment. Despite some rates being marginally higher, overall very little difference exists between the rates of adverse perinatal outcomes among the non-smoking Aboriginal mothers in this study and the general NSW population.(14) Some commonly included variables such as preterm birth or growth restrictions were not adjusted for as particular care was taken to avoid adjusting for variables on the causal pathway.

As expected, and similar to findings from other studies, (31) mothers from the non-smoking group were less disadvantaged, older, resided in less remote regions and had fewer previous pregnancies than those from the smoking group. Diabetes and hypertension were more prevalent among non-smoking mothers than smoking mothers. The small difference in prevalence of diabetes (8.7% vs 6.5%) could be due to the non-smoking group being slightly older than the smoking group. However the prevalence of hypertension in non-smoking mothers was almost double that of smoking mothers (12% vs 6.5%). Whilst this finding may surprise some, it is consistent with findings from previous studies (32-35). A systematic review of 48 studies concluded that smoking during pregnancy reduces the risk of preeclampsia by up to 50% and that there is a dose-response relationship (33). Similar results have been reported when the outcome includes gestational hypertension as well as preeclampsia, and the protective effect appears to continue even after women quit smoking later in pregnancy (35). This protective effect may be mediated via the biological effects of carbon monoxide that is formed during smoking (34). However, when preeclampsia does occur, the outcomes are much worse for babies whose mothers smoked (32). Although preeclampsia is associated with adverse pregnancy outcomes, and smoking reduces the incidence of preeclampsia, the net effect of smoking is still a worsening of pregnancy outcomes and there are dose-dependent increases in perinatal deaths and SGA babies among mothers who smoke

(32). Hence these findings in no way indicate any benefit to mothers or babies if the mother smokes during pregnancy.

As well as being a national health priority in Australia, reducing smoking during pregnancy is a key performance indicator in the annual service agreements between the NSW Ministry of Health and Local Health Districts.(36) As part of this commitment, the Quit for New Life program was established in 2013 with the aim to support women having an Aboriginal baby to quit smoking. The program was integrated into Aboriginal Maternal and Infant Health Services and has supported over 2,500 pregnant women, 950 postnatal women and 1,650 cohabitants in their quit attempt.(37) However, further efforts including health professional training, expansion to other maternal health services and community programs, and improved data collection and reporting are required to reduce the prevalence of smoking in pregnancy in this population.

Health professionals have a critical role in communicating the benefits of not smoking during pregnancy found in this study. However some practitioners perceive intervention to be ineffective and thus may not raise this issue with their patients.(38) The highly relevant evidence from this study may increase the salience of the issue and provide further motivation for health professionals to consistently ask and advise about smoking.

While the health impacts of smoking on maternal and child health are well known (9-13), this study provides local information that can be used to further engage Australian health professionals and community members on the benefits of not smoking. Building on the strength and resilience of Aboriginal people is an important foundation for efforts to reduce smoking among this population.(39) Using local evidence on the *benefits* of not smoking during pregnancy has the potential to re-frame health messages for women, their families and communities and to mobilise community action to achieve better health outcomes.

Strengths and limitations

This is the first study we are aware of that examines associations between smoking in pregnancy and adverse pregnancy outcomes exclusively among Aboriginal and/or Torres Strait Islander women. This was a large population-based study. Using data linkage, we were able to capture more women through the ERA, further increasing our sample size. Despite the unavailability of information surrounding some potential confounders our findings were consistent with those among other populations from the literature (9-13). Limited data on the heaviness of smoking during pregnancy meant that potential dose effects could not be calculated. However, new data around quitting in pregnancy is available from 2016 onward so there is potential for future work to examine this phenomenon further. Similarly, no information was available on the mother's history of smoking or alcohol consumption and so effects from longer term smoking and potential confounding from alcohol consumption could not be accounted for. A lack of data surrounding history and heaviness of smoking means that the treatment effects estimated in this study are likely to be biased toward the null and thus underestimate the true benefits of not smoking in pregnancy.

Conclusions

Babies born to Aboriginal mothers who did not smoke during pregnancy were at a significantly reduced risk of all adverse perinatal outcomes compared to those born to smoking mothers of similar demographics. Rates of these adverse outcomes among Aboriginal women who did not smoke were very similar to those among the general NSW population.

These results reinforce the importance of targeted smoking cessation policy for Aboriginal women. Barriers to smoking cessation in this population are complex and it is vital that this evidence is provided concurrently with sufficient support to enable Aboriginal women to quit smoking. Distributing this information in isolation runs the risk of furthering shame and stress experienced by pregnant women and may discourage them from seeking further help, highlighting the importance of systematic approaches to encourage and support Aboriginal women to quit smoking.

What is already known on this topic

- Despite a significant decline in smoking among the general Australian population, smoking rates remain high among pregnant Aboriginal women.
- Growing evidence suggests targeted smoking cessation policy is more effective among Aboriginal Australians.
- Although the benefits of not smoking during pregnancy are well established, no previous studies have demonstrated associations between not smoking in pregnancy and positive pregnancy outcomes *among* Aboriginal women.

What this study adds

- Babies born to Aboriginal mothers who did not smoke during pregnancy were at a significantly reduced risk of all adverse perinatal outcomes compared to those born to smoking mothers of similar demographics.

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Footnotes

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Contributors

JMitchell and AM had the initial idea for this study. ST wrote the study proposal and was responsible for the ethics application. CM undertook all analyses, with guidance from ST, II and DR, and drafted the manuscript. JF, JMorris, JMitchell, AM and ST all contributed to the design of the study and, with DM, the interpretation of the results. All authors commented on drafts and read and approved the final manuscript. The corresponding author attests that all listed authors meet authorship criteria and that no others meeting the criteria have been omitted. CM is the guarantor.

Statement of Conflicts of Interest

All authors have completed the ICMJE uniform disclosure form at www.icmje.org/coi_disclosure.pdf and declare: CM and ST's salaries came from a Prevention Research Support Program grant from the NSW Ministry of Health, no other relationships or activities that could appear to have influenced the submitted work.

Role of the Funding Source

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Ethics approval

Ethics approval for this study was given by the Aboriginal Health and Medical Research Council of New South Wales, Australia (HREC reference number: 1326/17) and was exempt from informed consent requirements as there was no contact with the study population and the authors only had access to de-identified data.

Transparency statement

The lead author affirms that the manuscript is an honest, accurate, and transparent account of the study being reported; that no important aspects of the study have been omitted; and that any discrepancies from the study as planned have been explained.

Data sharing

No additional data are available.

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Table 1 Demographics at the time of birth of all Aboriginal or Torres Strait Islander mothers who gave birth to at least one singleton baby in NSW between 2010 and 2014 reported for all births and by smoking status during pregnancy.

	All births		Non-smoking		Smoking	
	N = 18,154		N_{ns} = 9,235 (51%)		N_s = 8,919 (49%)	
Year (Baby's DOB)	**n**	**%**	**n**	**%**	**n**	**%**
2010	3,487	19	1,740	50*	1,747	50*
2011	3,380	19	1,638	48*	1,742	52*
2012	3,680	20	1,833	50*	1,847	50*
2013	3,716	20	1,944	52*	1,772	48*
2014	3,891	21	2,080	53*	1,811	47*
Maternal age						
Under 20	3,214	18	1,568	17	1,646	19
20–24	6,014	33	2,983	32	3,031	34
25–29	4,608	25	2,381	26	2,227	25
30–34	2,729	15	1,455	16	1,274	14
35 and over	1,589	8.8	848	9.2	741	8.3
Total	18,154	100	9,235	100	8,919	100
Parity						
0	6,259	35	3,720	40	2,539	29
1	4,709	26	2,589	28	2,120	24
2	3,107	17	1,490	16	1,617	18
3+	4,072	22	1,431	16	2,641	30
Total	18,147	100	9,230	100	8,917	100
SEIFA IRSD quintiles**						
1st – most disadvantaged	4,827	27	2,131	23	2,696	30
2nd	3,674	20	1,887	21	1,787	20
3rd	5,375	30	2,806	31	2,569	29
4th	3,068	17	1,617	18	1,451	16
5th – least disadvantaged	1,115	6.2	748	8.1	367	4.1
Total	18,059	100	9,189	100	8,870	100
Remoteness area						
Major cities	4,193	23	2,246	24	1,947	22
Inner regional	6,147	34	3,310	36	2,837	32
Outer regional	6,097	34	2,966	32	3,131	35
Remote	1,027	5.7	421	4.6	606	6.8
Very remote	595	3.3	245	2.7	350	4.0
Total	18,059	100	9,188	100	8,871	100
Hospital level						
Tertiary	4,099	23	2,108	23	1,991	22
Small and medium urban	308	1.7	178	1.8	130	1.5
Large urban	2,895	16	1,607	9	1,288	14

Small regional	3,441	19	1,519	16	1,922	22
Medium regional	3,042	17	1,550	17	1,492	17
Large regional	3,897	21	1,896	21	2,001	22
Private	336	1.7	323	3.2	13	0.2
Other	136	0.7	54	0.6	82	0.9
Total	18,154	100	9,235	100	8,919	100
Chronic conditions^						
Yes	343	1.9	147	1.6	196	2.2
Total	18,154	100	9,235	100	8,919	100
Any hypertension						
Yes	1,684	9.3	1,106	12	578	6.5
Total	18,154	100	9,235	100	8,919	100
Any diabetes						
Yes	1,413	7.8	804	8.7	609	6.5
Total	18,154	100	9,235	100	8,919	100

* Percentage of all births within each year.
**Socio-Economic Index for Areas – Index of Relative Socio-Economic Disadvantage (SEIFA IRSD). When ranking areas within NSW in order of their relative disadvantage, the lowest 20% (most disadvantaged) fall in the 1st quintile and the highest 20% (least disadvantaged) fall in 5th quartile.
^Chronic conditions encompasses renal, cardiac, thyroid, asthma, psychiatric, and other autoimmune conditions(40).

Table 2 Frequencies of maternal outcomes at the time of birth of all Aboriginal mothers by smoking status during pregnancy.

	All births		Non-smoking		Smoking		Unadjusted	Adjusted
	N = 18,154		N_{ns} = 9,235		N_s = 8,919			
Severe maternal morbidity	**n**	**%**	**n**	**%**	**n**	**%**	**RR (95% CI)**	**RR (95% CI)**
Yes	523	2.9	257	2.8	266	3.0	0.94 (0.79, 1.12)	0.92* (0.77, 1.11)
Inter-hospital transfer								
Yes	793	4.4	337	3.7	456	5.1	0.73 (0.63, 0.84)	0.76** (0.66, 0.89)
Breastfeeding on discharge^								
Yes	12,500	69	6,970	75	5,530	62	1.19 (1.16, 1.21)	1.16* (1.14, 1.19)

*adjusted for maternal age, any hypertension, any diabetes, parity and socio-economic status (SEIFA).
** adjusted for maternal age, any hypertension, any diabetes, parity and remoteness area.
^ Refers to a baby receiving any breast milk at the time of mother's discharge from hospital.

Table 3 Frequencies of perinatal outcomes among all babies born to Aboriginal or Torres Strait Islander mothers by maternal smoking status.

	NSW population	All births		Non-smoking		Smoking		Unadjusted	Adjusted*
		N = 18,154		N_{ns} = 9,235		N_s = 8,919			
Preterm birth (<37 wks)	**%**	**n**	**%**	**n**	**%**	**n**	**%**	**RR (95% CI)**	**RR (95% CI)**
Yes	8	2,045	11	760	8.2	1,285	14	0.59 (0.54, 0.64)	0.58 (0.53, 0.64)
Total		18,154	100	9,235	100	8,919	100		
Small for gestational age (<3rd population percentile)									
Yes	3	835	4.6	183	2.0	652	7.3	0.28 (0.23, 0.32)	0.27 (0.23, 0.32)
Total		18,132	100	9,229	100	8,903	100		
Small for gestational age (<10th population percentile)									
Yes	10	2,381	13	641	7.0	1,740	20	0.36 (0.33, 0.39)	0.35 (0.32, 0.39)
Total		18,132	100	9,229	100	8,903	100		
Severe neonatal morbidity	**Among live births only**								
Yes	5	1,470	8.2	636	6.9	834	9.5	0.74 (0.67, 0.81)	0.70 (0.63, 0.77)
Total		17,978	100	9,169	100	8,809	100		
Admission to SCN or NICU^									
Yes	15	3,957	22	1,645	18	2,312	26	0.70 (0.66, 0.75)	0.66 (0.63, 0.70)
Total		17,809	100	9,059	100	8,750	100		
Perinatal death		**Rate per 1,000 total births**							
Yes	8	254	14	92	10	162	18	0.54 (0.42, 0.70)	0.58 (0.44, 0.76)
Stillborn	6	162		60	6.5	102	11	0.57 (0.41, 0.78)	0.60 (0.43, 0.84)
		Rate per 1,000 live births							
Neonatal death	2	92		32	3.5	60	6.8	0.50	0.54

								(0.33, 0.78)	(0.34, 0.86)

*adjusted for maternal age, any hypertension, any diabetes, parity and socio-economic status (SEIFA).

^Admission to Special Care Nursery (SCN) or Neonatal Intensive Care Unit (NICU) was restricted to those babies recorded as being born in a hospital of maternity service level 3 or higher or a private hospital.

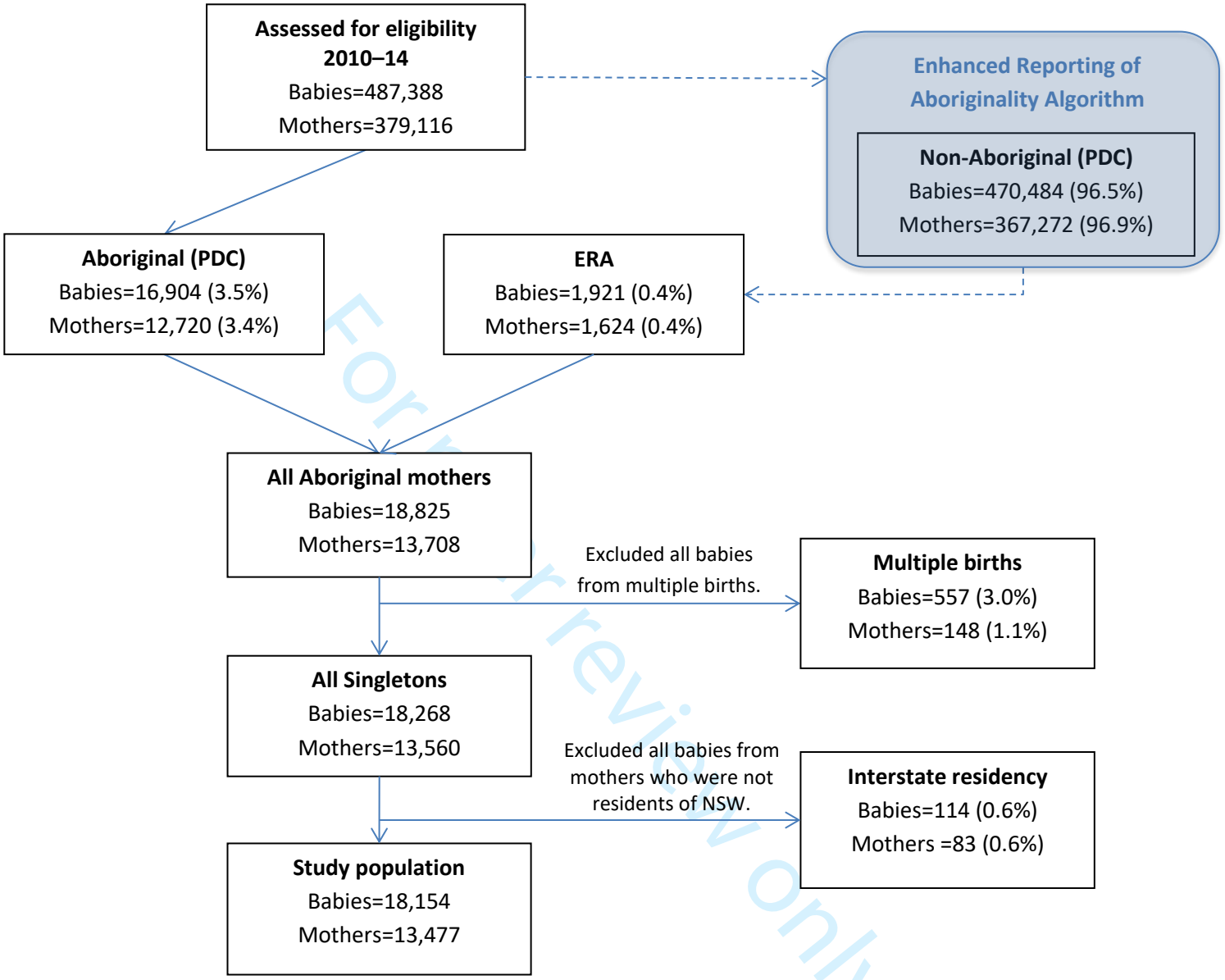

Figure 1 Flow diagram of mothers and babies eligible for inclusion in the final study population.

STROBE Statement—Checklist of items that should be included in reports of ***cohort studies***

Manuscript for: Benefits of not smoking during pregnancy for Australian Aboriginal and Torres Strait Islander women and their babies: a retrospective cohort study using linked data

	Item No	Recommendation	Page No
Title and abstract	1	(*a*) Indicate the study's design with a commonly used term in the title or the abstract	1
		(*b*) Provide in the abstract an informative and balanced summary of what was done and what was found	1
Introduction			
Background/rationale	2	Explain the scientific background and rationale for the investigation being reported	2
Objectives	3	State specific objectives, including any prespecified hypotheses	2
Methods			
Study design	4	Present key elements of study design early in the paper	2
Setting	5	Describe the setting, locations, and relevant dates, including periods of recruitment, exposure, follow-up, and data collection	2
Participants	6	(*a*) Give the eligibility criteria, and the sources and methods of selection of participants. Describe methods of follow-up	2-3
		(*b*) For matched studies, give matching criteria and number of exposed and unexposed	2-3
Variables	7	Clearly define all outcomes, exposures, predictors, potential confounders, and effect modifiers. Give diagnostic criteria, if applicable	3-4
Data sources/ measurement	8*	For each variable of interest, give sources of data and details of methods of assessment (measurement). Describe comparability of assessment methods if there is more than one group	3-4
Bias	9	Describe any efforts to address potential sources of bias	4
Study size	10	Explain how the study size was arrived at	2
Quantitative variables	11	Explain how quantitative variables were handled in the analyses. If applicable, describe which groupings were chosen and why	4
Statistical methods	12	(*a*) Describe all statistical methods, including those used to control for confounding	4-5
		(*b*) Describe any methods used to examine subgroups and interactions	
		(*c*) Explain how missing data were addressed	5
		(*d*) If applicable, explain how loss to follow-up was addressed	
		(*e*) Describe any sensitivity analyses	
Results			
Participants	13*	(a) Report numbers of individuals at each stage of study—eg numbers potentially eligible, examined for eligibility, confirmed eligible, included in the study, completing follow-up, and analysed	Fig 1
		(b) Give reasons for non-participation at each stage	Fig 1
		(c) Consider use of a flow diagram	Fig 1
Descriptive data	14*	(a) Give characteristics of study participants (eg demographic, clinical, social) and information on exposures and potential confounders	Table 1
		(b) Indicate number of participants with missing data for each variable of interest	Table 1,2,3
		(c) Summarise follow-up time (eg, average and total amount)	
Outcome data	15*	Report numbers of outcome events or summary measures over time	Table

			2,3
Main results	16	(*a*) Give unadjusted estimates and, if applicable, confounder-adjusted estimates and their precision (eg, 95% confidence interval). Make clear which confounders were adjusted for and why they were included	Table 2,3
		(*b*) Report category boundaries when continuous variables were categorized	
		(*c*) If relevant, consider translating estimates of relative risk into absolute risk for a meaningful time period	
Other analyses	17	Report other analyses done—eg analyses of subgroups and interactions, and sensitivity analyses	
Discussion			
Key results	18	Summarise key results with reference to study objectives	6
Limitations	19	Discuss limitations of the study, taking into account sources of potential bias or imprecision. Discuss both direction and magnitude of any potential bias	8
Interpretation	20	Give a cautious overall interpretation of results considering objectives, limitations, multiplicity of analyses, results from similar studies, and other relevant evidence	6,7
Generalisability	21	Discuss the generalisability (external validity) of the study results	8
Other information			
Funding	22	Give the source of funding and the role of the funders for the present study and, if applicable, for the original study on which the present article is based	10

*Give information separately for exposed and unexposed groups.

Note: An Explanation and Elaboration article discusses each checklist item and gives methodological background and published examples of transparent reporting. The STROBE checklist is best used in conjunction with this article (freely available on the Web sites of PLoS Medicine at http://www.plosmedicine.org/, Annals of Internal Medicine at http://www.annals.org/, and Epidemiology at http://www.epidem.com/). Information on the STROBE Initiative is available at http://www.strobe-statement.org.

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Benefits of not smoking during pregnancy for Australian Aboriginal and Torres Strait Islander women and their babies: a retrospective cohort study using linked data

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Keywords:	Pregnancy, smoking, Aboriginal health, preterm birth, stillbirth, linked data

Benefits of not smoking during pregnancy for Australian Aboriginal and Torres Strait Islander women and their babies: a retrospective cohort study using linked data

Carol McInerney,[1,2,3] Ibinabo Ibiebele,[1,3]Jane Ford,[1,3] Deborah Randall,[1,3] Jonathan Morris,[1,3,4] David Meharg,[5,6] Jo Mitchell,[7] Andrew Milat[8] and Siranda Torvaldsen[1,3,9]

[1] The University of Sydney Northern Clinical School, Women and Babies Research, St Leonards, New South Wales, Australia
[2] NSW Biostatistics Training Program, NSW Ministry of Health, Australia
[3] Northern Sydney Local Health District, Kolling Institute, New South Wales, Australia
[4] Department of Obstetrics and Gynaecology, Royal North Shore Hospital, Australia
[5] The University of Sydney, Faculty of Health Sciences, Sydney, New South Wales, Australia.
[6]Poche Centre for Indigenous Health, The University of Sydney, Sydney, New South Wales, Australia.
[7] Centre for Population Health, NSW Ministry of Health, Sydney, Australia
[8] Centre for Epidemiology and Evidence, NSW Ministry of Health, Sydney, Australia
[9] School of Public Health and Community Medicine, UNSW Sydney, Australia

Corresponding author:
Associate Professor Siranda Torvaldsen
Women and Babies Research,
Level 5 Douglas Building,
Royal North Shore Hospital,
St Leonards NSW 2065
AUSTRALIA
Email: siranda.torvaldsen@sydney.edu.au
Tel: +612 9462 9812

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Benefits of not smoking during pregnancy for Australian Aboriginal and Torres Strait Islander women and their babies: a retrospective cohort study using linked data

Abstract

Objectives

To provide evidence for targeted smoking cessation policy, the aim of this study was to compare pregnancy outcomes of Aboriginal mothers who reported *not* smoking during pregnancy with Aboriginal mothers who reported smoking during pregnancy.

Design

Population based retrospective cohort study using linked data.

Setting

New South Wales, the most populous Australian state.

Population

18,154 singleton babies born to 13,477 Aboriginal mothers between 2010–2014 were identified from routinely collected New South Wales datasets. Aboriginality was determined from birth records and from four linked datasets through an Enhanced Reporting of Aboriginality algorithm.

Exposure

Not smoking at any time during pregnancy.

Main outcome measures

Unadjusted and adjusted relative risks and 95% confidence intervals from modified Poisson regression were used to examine associations between not smoking during pregnancy and maternal and perinatal outcomes including severe morbidity, inter-hospital transfer, perinatal death, preterm birth and small-for-gestational age. Population attributable fractions (PAFs) were calculated using adjusted relative risks.

Results

Compared with babies born to mothers who smoked during pregnancy, babies born to non-smoking mothers had a lower risk of all adverse perinatal outcomes including perinatal death (aRR=0.58, 95%CI 0.44–0.76), preterm birth (aRR=0.58, 95%CI 0.53–0.64) and small-for-gestational age (aRR=0.35, 95%CI 0.32–0.39). PAFs(%) were 27% for perinatal death, 26% for preterm birth and 48% for small-for-gestational-age. Compared with women who smoked during pregnancy (n=8,919), those who did not smoke (n=9,235) had a lower risk of being transferred to another hospital (aRR=0.76, 95%CI 0.66–0.89).

Conclusions

Babies born to women who did not smoke during pregnancy had a lower risk of adverse perinatal outcomes. Rates of adverse outcomes among Aboriginal non-smokers were similar to those among the

general population. These results quantify the proportion of adverse perinatal outcomes due to smoking and highlight why effective smoking cessation programs are urgently required for this population.

Article summary

Strengths and limitations of this study

- The first study to examine the association between *not* smoking in pregnancy and pregnancy outcomes among Aboriginal women
- A large population-based cohort study using whole-of-population linked data
- To improve ascertainment of Aboriginal status, which is under-recorded on routinely collected health datasets, we linked four databases and applied an enhanced reporting of Aboriginality algorithm
- The inclusion of population attributable fractions quantifies the potential reduction in adverse perinatal outcomes if it was possible to reduce the smoking during pregnancy rate to zero.
- Data on history, heaviness, or passive smoking were not available, nor were data on some potential confounders such as alcohol consumption

Introduction

In 2008 the Australian federal, state and territory governments committed to reducing the national adult daily smoking rate by 2018, including halving the Aboriginal adult smoking rate.(1) Although smoking rates have substantially declined over this time, they remain high among pregnant Aboriginal women. In 2016, 41% of all pregnant Aboriginal women reported smoking at some time during their pregnancy compared to just 7% of non-Aboriginal women.(2) Smoking during pregnancy is the 'most important preventable risk factor for maternal and infant health'(3), thus smoking cessation for pregnant Aboriginal women remains a key priority for New South Wales (NSW) Health.(4) For the purposes of this study, Aboriginal and/or Torres Strait Islander people were considered together in one group. The reason for this was the small proportion of Torres Strait Islander people living in NSW (an estimated 2.6% of all females of Aboriginal and/or Torres Strait Islander descent(5))and that some people were recorded as both. We respectfully use the term Aboriginal as Aboriginal people are the original inhabitants of NSW.(6)

Australia's anti-tobacco campaigns and smoking cessation strategies are among the most comprehensive in the world, and there is growing evidence that programs specifically targeted to Aboriginal Australians are more effective.(7) There have been several campaigns to promote smoking cessation among pregnant Aboriginal mothers with varying efficacy.(8) To date these have been grounded in evidence from a general population. Although the benefits of not smoking during pregnancy are unlikely to be any different for Aboriginal mothers from the general population, quantifying the benefits of not smoking among Aboriginal mothers may be regarded as more relevant by this population and thus have the potential to influence smoking cessation. The benefits of not smoking during pregnancy are well established (9-13), but no previous studies have demonstrated associations between not smoking in pregnancy and positive pregnancy outcomes *among* Aboriginal women. This study aims to compare pregnancy outcomes of mothers who reported not smoking during pregnancy with those who reported any smoking during pregnancy from the Aboriginal population of NSW. Findings from this study will provide the most relevant evidence to date for pregnant Aboriginal women.

Methods

Study population and data sources

The study population consisted of all singleton babies born to Aboriginal women residing in NSW between 1 January 2010 and 31 December 2014 and their mothers. This population-based retrospective cohort study used linked data from routinely collected NSW datasets. The study population was identified from all records in the NSW Perinatal Data Collection ('birth data') for the period 1 January 2010 to 31 December 2014. All births in the population, including births at NSW public and private hospitals and home births are recorded in the birth data. This surveillance system includes all live births and stillbirths of at least 400 grams birthweight or at least 20 weeks gestation.(14)

All deaths within NSW are registered in the Registry of Births, Deaths and Marriages and fact of death was retrieved from these data between 1 January 2010 and 31 December 2015. Public and private hospital admission records were drawn from the NSW Admitted Patient Data Collection ('hospital data')

for admissions from 1 September 2009 to 31 December 2014. An additional 4 months of hospital data were retrieved prior to the start of the study period to allow for admissions to hospital for births early in 2010. Diagnoses coded in the hospital data are applied according to the International Classification of Diseases, Australian Modification (ICD-10-AM). Records within and across all datasets were probabilistically linked using personal identifiers by the NSW Centre for Health Record Linkage with an estimated false linkage rate of less than 5 per 1,000 records.(15) Hospital birth records were those where the birth was recorded to have occurred between the mother's admission and discharge dates using the linked birth data. It's estimated that 96% of records from the birth data link to the mother's and infant's hospital records from the birth.(16)

Aboriginal women were defined as those who were recorded as Australian Aboriginal in the birth data or who were assigned Aboriginal status according to the Enhanced Reporting of Aboriginality (ERA) algorithm.

Enhanced Reporting of Aboriginality (ERA)

It is widely acknowledged that Aboriginal status is under-recorded on routinely collected health datasets nationwide.(17) Enhancement of reporting of Aboriginal people using linked records creates a statistical construct that results in improved information about Aboriginal people. It does not define a person as being Aboriginal, nor does it replace efforts to improve the overall quality of recording Aboriginal status at the point of care.

Information surrounding individuals' Aboriginal status was pooled via linkage of the birth data, NSW Registry of Births, Deaths and Marriages birth registrations, hospital data and the NSW Emergency Department Data Collection. Using this information, a weight of evidence surrounding a woman's Aboriginal status was determined by a multistage median algorithm.(18) Since multiple datasets were used and some women had multiple records in each of these datasets, the algorithm initially assigned a separate status for each woman and dataset. Aboriginal or Torres Strait Islander status was assigned to a mother if: one or two linked records were available and at least one reported her as Aboriginal; three or more linked records were available and at least two reported her as Aboriginal. A comparable algorithm using dataset-specific statuses instead of records was used to determine the inclusion of each woman in the study population.

The enhanced reporting of Aboriginality is a technique used by many research groups.(19-21) Although this combination of datasets and algorithm has not been used before, similar methods have been found to minimise the risk of incorrect inclusion while capturing more women than simply relying on a single record.(22) Details on the algorithm, the data used and the mothers identified through the ERA have been described in more detail elsewhere.(23)

Exposure

The exposure of interest for this study was not smoking at any time during pregnancy. Mothers who reported not smoking during pregnancy will henceforth be referred to as non-smokers and those who reported any smoking during pregnancy are referred to as smokers. To increase ascertainment, birth data and mother's hospital birth record(s) were used to assign smoking status. If the birth data indicated that a mother smoked at any time during her pregnancy and/or recorded her as a current smoker within

the hospital birth record(s) (according to the ICD-10-AM diagnosis codes Z72.0 and F17) then she was considered to be a smoker. The sensitivity and specificity of current smoking from the most recent separation in the hospital data is estimated to be 58.5% and 98.4% respectively.(24) Where a mother had multiple hospital records associated with the birth and those records contradicted each other according to smoking status, her smoking status defaulted to that recorded in the birth data.

Outcomes

Maternal outcomes were identified using the birth data and the mother's hospital birth record and included two binary outcomes: severe maternal morbidity and inter-hospital transfer. Severe maternal morbidity was defined using a validated composite indicator that captures a broad range of diagnoses and procedures such as cardiac arrest, renal failure or assisted ventilation.(25) Mothers requiring inter-hospital transfer were defined as those with at least one record with a mode of separation indicating transfer or where multiple hospitalisation records were present with differing hospital codes.

Perinatal outcomes, including birth outcomes and those occurring within the first 28 days of life for the baby were retrieved from the birth data and the baby's linked hospital and birth registration records. These included perinatal death (stillbirth and neonatal death), preterm birth (<37 completed weeks of gestation), and small for gestational age (birth weight <3rd and/or 10th percentile for sex and age (26)). Admissions to a special care nursery (SCN) or neonatal intensive care unit (NICU) were assessed among an eligible population of babies born in a hospital classified as level 3 or above (NSW Ministry of Health's *Guide to the Role Delineation of Hospitals*) or a private hospital. Severe neonatal morbidity, measured according to a validated composite indicator (27), was assessed among all live births.

Covariates

Maternal age and parity were reported according to the birth data. The mother's chronic conditions, hypertension and diabetes information were obtained from the birth data and the hospital birth record(s). We used the broad category of any hypertension rather than the specific categories of chronic hypertension, pregnancy hypertension, preeclampsia and eclampsia, as there is known misclassification among types of hypertension (28). The NSW ranking of the Australian Bureau of Statistics (ABS) 2011 Socio-Economic Index for Areas (SEIFA) Index of Relative Socio-Economic Disadvantage (IRSD) and the 2011 Remoteness Areas were used to assess the mother's relative socio-economic status and access to services respectively. Where available, the mother's 2011 Statistical Local Area (SLA) according to her birth data was used to assign these measures. Otherwise, and for all babies born in 2010, the mother's 2010 SLA was used. Hospital type is an indicator of the size of a hospital and its location (urban or regional)(29) and was assigned using the hospital code recorded in the birth data.

Statistical analyses

The study population was described using frequencies and percentages by potential confounders and the mother's smoking status. Summary statistics were calculated by mother's smoking status to investigate the associations between smoking during pregnancy and maternal and child outcomes. To estimate the unadjusted and adjusted relative risk (RR) of binary outcomes while accounting for the correlation within the data (some mothers had more than one baby during the study period), an extension to the modified Poisson regression (30) was used with an unstructured correlation matrix. Those observations where data were missing for an outcome were excluded from analysis for that

outcome. SAS for Windows 9.4 (SAS Institute, Cary, NC, USA) was used for all data manipulation and analysis.

In view of the established causal relationship between smoking and adverse perinatal outcomes, we quantified the proportion and number of adverse perinatal outcomes that would not have occurred in this population if all the mothers had been non-smokers during pregnancy. We used the formula: PAF $=[P_s(RR_s-1)]/RR_s$, where P_s is the proportion of babies with the outcome whose mothers smoked and RR_s is the adjusted RR for smokers. The RR_s is the inverse of the RR for non-smokers.

Patient and public involvement

An Aboriginal advisory committee was consulted prior to submission of the study proposal to ethics committees and throughout the process. The committee provided guidance on presentation and interpretation of results. It was of particular importance to members of the committee that the results were framed positively, ie the *benefits* of not smoking, rather than the risks of smoking. It was also important to committee members that all comparisons were among Aboriginal women and that Aboriginal women were not compared with non-Aboriginal women. There are plans to develop culturally appropriate educational material based on the results of this research and in collaboration with Aboriginal Health Workers and others involved in the care of Aboriginal women who are pregnant or may be planning a pregnancy.

Results

Following exclusion of duplicates (n=76), a total of 487,388 babies were born to 379,116 mothers in NSW and were assessed for inclusion in this study. Records for 16,904 babies born to 12,720 mothers who were recorded as Aboriginal in the birth data were available for analysis. An additional 1,921 babies born to 1,624 mothers were identified as eligible for inclusion in the study using the ERA. Of the total 18,825 babies, 557 were from a multiple birth and 114 were born to mothers who were not residents of NSW. These babies did not meet the eligibility criteria and were excluded. Thus the final study population consisted of 18,154 singleton babies born to 13,477 Aboriginal mothers. Figure 1 outlines the flow of participants in this study.

Among the study population, 9,235 (51%) babies were born to non-smoking mothers and 8,919 (49%) were born to smoking mothers (Table 1). Only two percent of all linked records had contradictory smoking statuses from the birth and hospital data. For comparison, when smoking status was assigned only according to the birth data, 52% of babies were born to non-smoking mothers and 48% were born to smoking mothers. Mothers who reported not smoking at any time during their pregnancy were generally less disadvantaged than their smoking counterparts; approximately 8.1% of non-smoking mothers were in the highest SEIFA quintile, compared to just 4.1% of smoking mothers. Non-smoking mothers were older, lived in less remote regions and had fewer previous pregnancies than smoking mothers. The number of non-smoking mothers with hypertension (1,106) was almost double that of smoking mothers (578) and slightly more non-smoking mothers had diabetes (Table 1).

The majority (70%) of mothers only had one baby during the study period however a substantial number had multiple: 25% had two, 4.4% had three and 0.4% had four. For 564 (4%) mothers, their smoking

status changed between pregnancies, 6,814 (53%) mothers reported not smoking in all pregnancies during the study period and 6,099 (47%) consistently reported smoking. For the mothers whose smoking status changed between pregnancies, 47% changed from smoking to non-smoking and 48% changed from non-smoking to smoking in all subsequent pregnancies.

The rate of severe maternal morbidity was low (<3%) and not significantly different between smoking and non-smoking mothers (Table 2). The rate of inter-hospital transfer was lower in the non-smoking group at 3.7% compared with the smoking group (5.1%), with an adjusted relative risk of RR=0.76 (95% CI 0.66, 0.89).

Adverse perinatal outcomes occurred less frequently among babies born to non-smoking mothers (Table 3). Perinatal deaths were rare in both populations however the rate was lower in the non-smoking group with perinatal death occurring in 1.0% of babies born to non-smoking mothers, compared to 1.8% in smoking mothers. Also, severe neonatal morbidity and admission to SCN or NICU was less frequent in babies born to non-smoking mothers when compared to those born to smoking mothers. Overall, the gestational age of babies from the non-smoking group was closer to term than those from the smoking group; more babies born to non-smoking mothers (66%) were born between 39 and 41 weeks than those born to smoking mothers (55%). Preterm birth was considerably less frequent among babies born to mothers who did not smoke during pregnancy; 8.2% of births to non-smoking mothers were preterm compared to 14% from smoking mothers. Similarly, babies born to non-smoking mothers were less often small for gestational age, with 2.0% and 7.0% of these babies having a birthweight below the 3rd and 10th percentiles respectively compared to 7.3% and 20% of babies of smoking mothers. All relative risks were less than 1, suggesting a reduced risk of all adverse outcomes among babies born to non-smoking mothers when compared to those born to smoking mothers. Of note were the relative risks for perinatal death (RR=0.58 95% CI 0.44, 0.76), preterm birth (RR=0.58 95% CI 0.53, 0.64) and small for gestational age (<10th percentile; RR=0.35 95% CI 0.32, 0.39) . As indicated by the PAFs (%) in Table 3, more than a quarter of the perinatal deaths and preterm births were attributable to smoking and almost half the small for gestational age births. Among this cohort of babies, this equates to 68 perinatal deaths, 540 preterm births and 1,131 small for gestational age (<10th percentile) babies attributable to smoking.

Discussion

This study of a recent population of pregnant Aboriginal women clearly demonstrates improved pregnancy outcomes among Aboriginal mothers who reported not smoking during pregnancy when compared to Aboriginal mothers who reported smoking during pregnancy. Benefits of not smoking were found for all the perinatal outcomes we examined. We also found non-smoking mothers had a 24% lower risk of being transferred to another hospital during the birth admission than smoking mothers of similar demographics. Inter-hospital transfers may be due to complications arising before, during or after the birth. This means women are less likely to be away from their family and country during this challenging time. Although a slightly lower risk of severe maternal morbidity was found in the non-smoking group, there was not sufficient evidence to suggest a true difference existed as the confidence interval included 1 (RR=0.92, 95% CI 0.77–1.11). Other risk factors may be more strongly associated with severe maternal morbidity than smoking.

Among babies born to mothers of a similar age, with similar pre-existing conditions (any diabetes or hypertension), parity and socio-economic status, those with a non-smoking mother had a 42% less risk of perinatal death and preterm birth, 65% less risk of being small-for-gestational age (<10th percentile), 30% less risk of severe neonatal morbidity, and 33% less risk of being admitted to a SCN or NICU than those born to a mother who smoked at any time during her pregnancy. The reductions in adverse outcomes for babies born to non-smoking mothers were statistically and clinically significant and remained so even after adjustment. Encouragingly, despite some rates being marginally higher, overall very little difference exists between the rates of adverse perinatal outcomes among the non-smoking Aboriginal mothers in this study and the general NSW population.(14) The high PAFs for the adverse perinatal outcomes highlight the enormous potential for health improvements in this population. Over a quarter of the perinatal deaths and preterm births were attributable to smoking. Being born small for gestational age is associated with short and long-term health sequelae, and these risks are even greater for babies born with a birthweight less than the third percentile for gestational age and sex. The PAF(%) was highest (57%) for being born with a birthweight less than the third percentile. Almost half (48%) the babies born small for gestational age (<10th percentile) could have had a normal birthweight (≥10th percentile) in the absence of smoking. Our results are consistent with a recent study of a cohort of 697,003 children born in Scotland from 1997–2009 (31). In addition to the adverse perinatal outcomes attributable to smoking, this study followed children until five years of age and found that maternal smoking during pregnancy also increased the risk of the child being hospitalized with acute respiratory infections, bronchiolitis, asthma and bacterial meningitis (31).

As expected, and similar to findings from other studies, (31, 32) mothers from the non-smoking group were less disadvantaged, older, resided in less remote regions and had fewer previous pregnancies than those from the smoking group. Diabetes and hypertension were more prevalent among non-smoking mothers than smoking mothers. The small difference in prevalence of diabetes (8.7% vs 6.5%) could be due to the non-smoking group being slightly older than the smoking group. However the prevalence of hypertension in non-smoking mothers was almost double that of smoking mothers (12% vs 6.5%). Whilst this finding may surprise some, it is consistent with findings from previous studies (33-36). A systematic review of 48 studies concluded that smoking during pregnancy reduces the risk of preeclampsia by up to 50% and that there is a dose-response relationship (34). Similar results have been reported when the outcome includes gestational hypertension as well as preeclampsia, and the protective effect appears to continue even after women quit smoking later in pregnancy (36). This protective effect may be mediated via the biological effects of carbon monoxide that is formed during smoking (35). However, when preeclampsia does occur, the outcomes are much worse for babies whose mothers smoked (33). Although preeclampsia is associated with adverse pregnancy outcomes, and smoking reduces the incidence of preeclampsia, the net effect of smoking is still a worsening of pregnancy outcomes and there are dose-dependent increases in perinatal deaths and SGA babies among mothers who smoke (33). Hence these findings in no way indicate any benefit to mothers or babies if the mother smokes during pregnancy.

As well as being a national health priority in Australia, reducing smoking during pregnancy is a key performance indicator in the annual service agreements between the NSW Ministry of Health and Local Health Districts.(37) As part of this commitment, the Quit for New Life program was established in 2013

with the aim to support women having an Aboriginal baby to quit smoking. The program was integrated into Aboriginal Maternal and Infant Health Services and has supported over 2,500 pregnant women, 950 postnatal women and 1,650 cohabitants in their quit attempt.(38) However, further efforts including health professional training, expansion to other maternal health services and community programs, and improved data collection and reporting are required to reduce the prevalence of smoking in pregnancy in this population. Investment to discourage women, especially young women, from taking up smoking and encouraging and appropriately supporting smokers to quit need to remain priorities.

Health professionals have a critical role in communicating the benefits of not smoking during pregnancy found in this study. However some practitioners perceive intervention to be ineffective and thus may not raise this issue with their patients.(39) The highly relevant evidence from this study may increase the salience of the issue and provide further motivation for health professionals to consistently ask and advise about smoking.

While the health impacts of smoking on maternal and child health are well known (9-13), this study provides local information that can be used to further engage Australian health professionals and community members on the benefits of not smoking. Building on the strength and resilience of Aboriginal people is an important foundation for efforts to reduce smoking among this population.(40) Using local evidence on the *benefits* of not smoking during pregnancy has the potential to re-frame health messages for women, their families and communities and to mobilise community action to achieve better health outcomes.

Strengths and limitations

This is the first study we are aware of that examines associations between smoking in pregnancy and adverse pregnancy outcomes exclusively among Aboriginal and/or Torres Strait Islander women. This was a large population-based study. Using data linkage, we were able to capture more women through the ERA, further increasing our sample size. Despite the unavailability of information surrounding some potential confounders, including individual level socioeconomic status, our findings were consistent with those among other populations from the literature (9-13). Limited data on the heaviness of smoking during pregnancy meant that potential dose effects could not be calculated. However, new data around quitting in pregnancy is available from 2016 onward so there is potential for future work to examine this phenomenon further. Similarly, no information was available on the mother's history of smoking, exposure to environmental tobacco smoke or alcohol consumption and so effects from longer term smoking and potential confounding from alcohol consumption could not be accounted for. A lack of data surrounding history and heaviness of smoking means that the treatment effects estimated in this study are likely to be biased toward the null and thus underestimate the true benefits of not smoking in pregnancy. Under-ascertainment of smoking status would similarly bias toward the null.

Conclusions

Babies born to Aboriginal mothers who did not smoke during pregnancy were at a significantly reduced risk of adverse perinatal outcomes compared to those born to smoking mothers of similar

demographics. Rates of these adverse outcomes among Aboriginal women who did not smoke were very similar to those among the general NSW population.

These results reinforce the importance of targeted smoking cessation policy for Aboriginal women. Barriers to smoking cessation in this population are complex and it is vital that this evidence is provided concurrently with sufficient support to enable Aboriginal women to quit smoking. Distributing this information in isolation runs the risk of furthering shame and stress experienced by pregnant women and may discourage them from seeking further help, highlighting the importance of systematic approaches to encourage and support Aboriginal women to quit smoking.

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Footnotes

Contributors

JMitchell and AM had the initial idea for this study. ST wrote the study proposal and was responsible for the ethics application and revisions to the manuscript. CM undertook all analyses, with guidance from ST, II and DR, and drafted the manuscript. JF, JMorris, JMitchell, AM and ST all contributed to the design of the study and, with DM, the interpretation of the results. All authors commented on drafts and read and approved the final manuscript. The corresponding author attests that all listed authors meet authorship criteria and that no others meeting the criteria have been omitted. CM and ST are guarantors.

Statement of Conflicts of Interest

All authors have completed the ICMJE uniform disclosure form at www.icmje.org/coi_disclosure.pdf and declare: CM and ST's salaries came from a Prevention Research Support Program grant from the NSW Ministry of Health, no other relationships or activities that could appear to have influenced the submitted work.

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Ethics approval

Ethics approval for this study was given by the Aboriginal Health and Medical Research Council of New South Wales, Australia (HREC reference number: 1326/17) and was exempt from informed consent requirements as there was no contact with the study population and the authors only had access to de-identified data.

Transparency statement

The lead author affirms that the manuscript is an honest, accurate, and transparent account of the study being reported; that no important aspects of the study have been omitted; and that any discrepancies from the study as planned have been explained.

Data sharing

No additional data are available.

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Figure caption:

Figure 1 Flow diagram of mothers and babies eligible for inclusion in the final study population.

Table 1 Demographics at the time of birth of all Aboriginal or Torres Strait Islander mothers who gave birth to at least one singleton baby in NSW between 2010 and 2014 reported for all births and by smoking status during pregnancy.

	All births		Non-smoking		Smoking	
	N = 18,154		N_{ns} = 9,235 (51%)		N_s = 8,919 (49%)	
Year of baby's birth	**n**	**%**	**n**	**%**	**n**	**%**
2010	3,487	19	1,740	50*	1,747	50*
2011	3,380	19	1,638	48*	1,742	52*
2012	3,680	20	1,833	50*	1,847	50*
2013	3,716	20	1,944	52*	1,772	48*
2014	3,891	21	2,080	53*	1,811	47*
Maternal age						
Under 20	3,214	18	1,568	17	1,646	19
20–24	6,014	33	2,983	32	3,031	34
25–29	4,608	25	2,381	26	2,227	25
30–34	2,729	15	1,455	16	1,274	14
35 and over	1,589	8.8	848	9.2	741	8.3
Total	18,154	100	9,235	100	8,919	100
Parity						
0	6,259	35	3,720	40	2,539	29
1	4,709	26	2,589	28	2,120	24
2	3,107	17	1,490	16	1,617	18
3+	4,072	22	1,431	16	2,641	30
Total	18,147	100	9,230	100	8,917	100
SEIFA IRSD quintiles**						
1st – most disadvantaged	4,827	27	2,131	23	2,696	30
2nd	3,674	20	1,887	21	1,787	20
3rd	5,375	30	2,806	31	2,569	29
4th	3,068	17	1,617	18	1,451	16
5th – least disadvantaged	1,115	6.2	748	8.1	367	4.1
Total	18,059	100	9,189	100	8,870	100
Remoteness area						
Major cities	4,193	23	2,246	24	1,947	22
Inner regional	6,147	34	3,310	36	2,837	32
Outer regional	6,097	34	2,966	32	3,131	35
Remote	1,027	5.7	421	4.6	606	6.8
Very remote	595	3.3	245	2.7	350	4.0
Total	18,059	100	9,188	100	8,871	100

Hospital level						
Tertiary	4,099	23	2,108	23	1,991	22
Small and medium urban	308	1.7	178	1.8	130	1.5
Large urban	2,895	16	1,607	9	1,288	14
Small regional	3,441	19	1,519	16	1,922	22
Medium regional	3,042	17	1,550	17	1,492	17
Large regional	3,897	21	1,896	21	2,001	22
Private	336	1.7	323	3.2	13	0.2
Other	136	0.7	54	0.6	82	0.9
Total	18,154	100	9,235	100	8,919	100
Chronic conditions^						
Yes	343	1.9	147	1.6	196	2.2
Total	18,154	100	9,235	100	8,919	100
Any hypertension						
Yes	1,684	9.3	1,106	12	578	6.5
Total	18,154	100	9,235	100	8,919	100
Any diabetes						
Yes	1,413	7.8	804	8.7	609	6.5
Total	18,154	100	9,235	100	8,919	100

* Percentage of all births within each year.

**Socio-Economic Index for Areas – Index of Relative Socio-Economic Disadvantage (SEIFA IRSD). When ranking areas within NSW in order of their relative disadvantage, the lowest 20% (most disadvantaged) fall in the 1st quintile and the highest 20% (least disadvantaged) fall in 5th quartile.

^Chronic conditions encompasses renal, cardiac, thyroid, asthma, psychiatric, and other autoimmune conditions(41).

Table 2 Frequencies of maternal outcomes at the time of birth of all Aboriginal mothers by smoking status during pregnancy.

	All births		Non-smoking		Smoking		Unadjusted	Adjusted
	N = 18,154		N_{ns} = 9,235		N_s = 8,919			
Severe maternal morbidity	**n**	**%**	**n**	**%**	**n**	**%**	**RR (95% CI)**	**RR (95% CI)**
Yes	523	2.9	257	2.8	266	3.0	0.94 (0.79, 1.12)	0.92* (0.77, 1.11)
Inter-hospital transfer								
Yes	793	4.4	337	3.7	456	5.1	0.73 (0.63, 0.84)	0.76** (0.66, 0.89)

*adjusted for maternal age, any hypertension, any diabetes, parity and socio-economic status (SEIFA).
** adjusted for maternal age, any hypertension, any diabetes, parity and remoteness area.

Table 3 Frequencies of perinatal outcomes among all babies born to Aboriginal or Torres Strait Islander mothers by maternal smoking status.

	NSW population	All births		Non-smoking		Smoking		Unadjusted	Adjusted*	PAF (%)
		N = 18,154		N_{ns} = 9,235		N_s = 8,919				
Preterm birth (<37 wks)	**%**	**n**	**%**	**n**	**%**	**n**	**%**	**RR (95% CI)**	**RR (95% CI)**	
Yes	8	2,045	11	760	8.2	1,285	14	0.59 (0.54, 0.64)	0.58 (0.53, 0.64)	26
Total		18,154	100	9,235	100	8,919	100			
Small for gestational age (<3rd population percentile)										
Yes	3	835	4.6	183	2.0	652	7.3	0.28 (0.23, 0.32)	0.27 (0.23, 0.32)	57
Total		18,132	100	9,229	100	8,903	100			
Small for gestational age (<10th population percentile)										
Yes	10	2,381	13	641	7.0	1,740	20	0.36 (0.33, 0.39)	0.35 (0.32, 0.39)	48
Total		18,132	100	9,229	100	8,903	100			
Severe neonatal morbidity	**Among live births only**									
Yes	5	1,470	8.2	636	6.9	834	9.5	0.74 (0.67, 0.81)	0.70 (0.63, 0.77)	17
Total		17,978	100	9,169	100	8,809	100			
Admission to SCN or NICU^										
Yes	15	3,957	22	1,645	18	2,312	26	0.70 (0.66, 0.75)	0.66 (0.63, 0.70)	20
Total		17,809	100	9,059	100	8,750	100			
Perinatal death		**Rate per 1,000 total births**								
Yes	8	254	14	92	10**	162	18**	0.54 (0.42, 0.70)	0.58 (0.44, 0.76)	27
Stillborn	6	162		60	6.5**	102	11**	0.57 (0.41, 0.78)	0.60 (0.43, 0.84)	20
		Rate per 1,000 live births								
Neonatal death	2	92		32	3.5^^	60	6.8^^	0.50	0.54	30

								(0.33, 0.78)	(0.34, 0.86)	

*adjusted for maternal age, any hypertension, any diabetes, parity and socio-economic status (SEIFA).
^Admission to Special Care Nursery (SCN) or Neonatal Intensive Care Unit (NICU) was restricted to those babies recorded as being born in a hospital of maternity service level 3 or higher or a private hospital.
**Rate per 1,000 total births
^^ Rate per 1,000 live births
PAF, Population Attributable Fraction

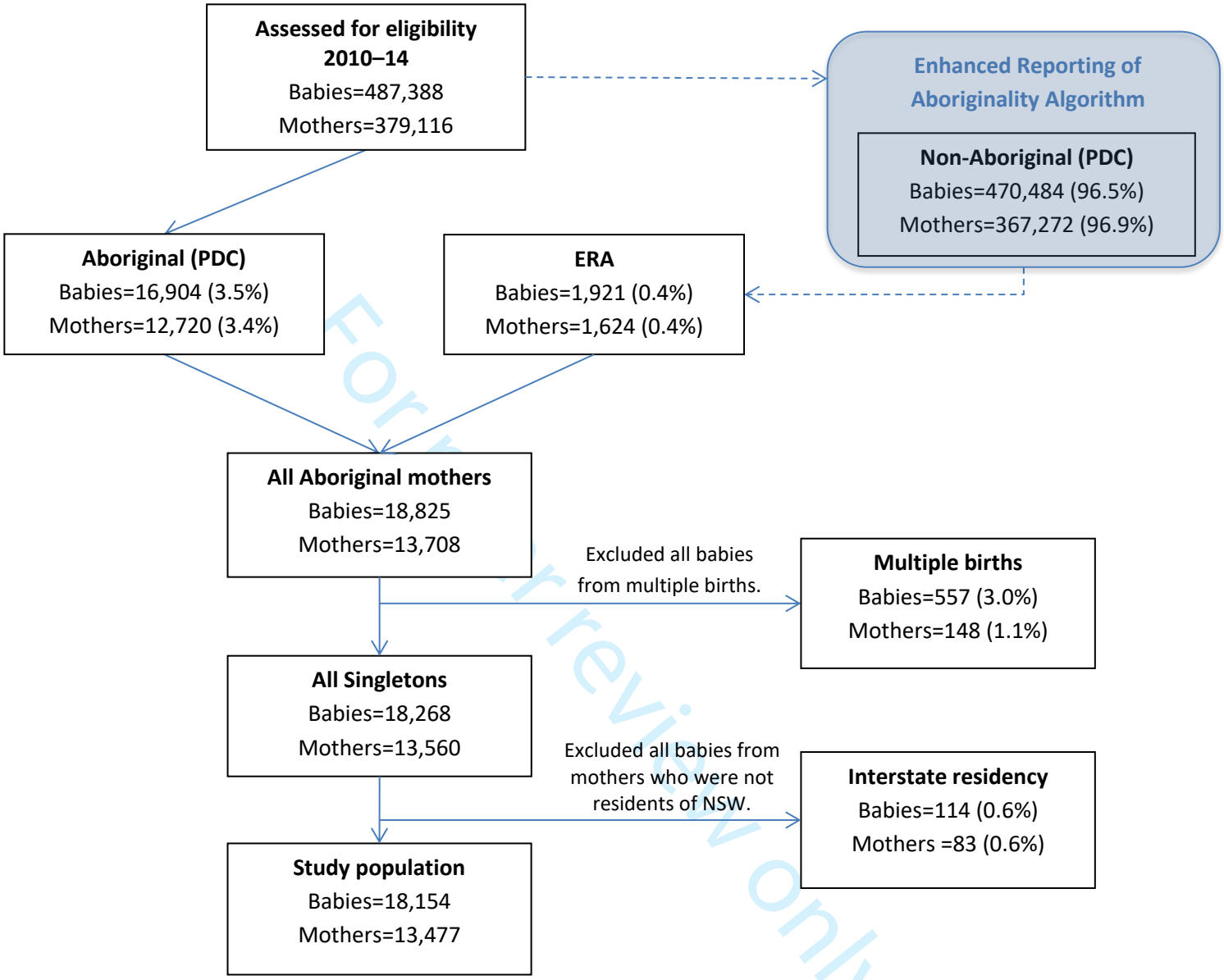

Figure 1 Flow diagram of mothers and babies eligible for inclusion in the final study population.

STROBE Statement—Checklist of items that should be included in reports of ***cohort studies***

Manuscript for: Benefits of not smoking during pregnancy for Australian Aboriginal and Torres Strait Islander women and their babies: a retrospective cohort study using linked data

	Item No	Recommendation	Page No
Title and abstract	1	(*a*) Indicate the study's design with a commonly used term in the title or the abstract	1
		(*b*) Provide in the abstract an informative and balanced summary of what was done and what was found	1
Introduction			
Background/rationale	2	Explain the scientific background and rationale for the investigation being reported	2
Objectives	3	State specific objectives, including any prespecified hypotheses	2
Methods			
Study design	4	Present key elements of study design early in the paper	2
Setting	5	Describe the setting, locations, and relevant dates, including periods of recruitment, exposure, follow-up, and data collection	2
Participants	6	(*a*) Give the eligibility criteria, and the sources and methods of selection of participants. Describe methods of follow-up	2-3
		(*b*) For matched studies, give matching criteria and number of exposed and unexposed	2-3
Variables	7	Clearly define all outcomes, exposures, predictors, potential confounders, and effect modifiers. Give diagnostic criteria, if applicable	3-4
Data sources/ measurement	8*	For each variable of interest, give sources of data and details of methods of assessment (measurement). Describe comparability of assessment methods if there is more than one group	3-4
Bias	9	Describe any efforts to address potential sources of bias	4
Study size	10	Explain how the study size was arrived at	2
Quantitative variables	11	Explain how quantitative variables were handled in the analyses. If applicable, describe which groupings were chosen and why	4
Statistical methods	12	(*a*) Describe all statistical methods, including those used to control for confounding	4-5
		(*b*) Describe any methods used to examine subgroups and interactions	
		(*c*) Explain how missing data were addressed	5
		(*d*) If applicable, explain how loss to follow-up was addressed	
		(*e*) Describe any sensitivity analyses	
Results			
Participants	13*	(a) Report numbers of individuals at each stage of study—eg numbers potentially eligible, examined for eligibility, confirmed eligible, included in the study, completing follow-up, and analysed	Fig 1
		(b) Give reasons for non-participation at each stage	Fig 1
		(c) Consider use of a flow diagram	Fig 1
Descriptive data	14*	(a) Give characteristics of study participants (eg demographic, clinical, social) and information on exposures and potential confounders	Table 1
		(b) Indicate number of participants with missing data for each variable of interest	Table 1,2,3
		(c) Summarise follow-up time (eg, average and total amount)	
Outcome data	15*	Report numbers of outcome events or summary measures over time	Table

			2,3
Main results	16	(*a*) Give unadjusted estimates and, if applicable, confounder-adjusted estimates and their precision (eg, 95% confidence interval). Make clear which confounders were adjusted for and why they were included	Table 2,3
		(*b*) Report category boundaries when continuous variables were categorized	
		(*c*) If relevant, consider translating estimates of relative risk into absolute risk for a meaningful time period	
Other analyses	17	Report other analyses done—eg analyses of subgroups and interactions, and sensitivity analyses	
Discussion			
Key results	18	Summarise key results with reference to study objectives	6
Limitations	19	Discuss limitations of the study, taking into account sources of potential bias or imprecision. Discuss both direction and magnitude of any potential bias	8
Interpretation	20	Give a cautious overall interpretation of results considering objectives, limitations, multiplicity of analyses, results from similar studies, and other relevant evidence	6,7
Generalisability	21	Discuss the generalisability (external validity) of the study results	8
Other information			
Funding	22	Give the source of funding and the role of the funders for the present study and, if applicable, for the original study on which the present article is based	10

*Give information separately for exposed and unexposed groups.

Note: An Explanation and Elaboration article discusses each checklist item and gives methodological background and published examples of transparent reporting. The STROBE checklist is best used in conjunction with this article (freely available on the Web sites of PLoS Medicine at http://www.plosmedicine.org/, Annals of Internal Medicine at http://www.annals.org/, and Epidemiology at http://www.epidem.com/). Information on the STROBE Initiative is available at http://www.strobe-statement.org.

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Benefits of not smoking during pregnancy for Australian Aboriginal and Torres Strait Islander women and their babies: a retrospective cohort study using linked data

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Keywords:	Pregnancy, smoking, Aboriginal health, preterm birth, stillbirth, linked data

Benefits of not smoking during pregnancy for Australian Aboriginal and Torres Strait Islander women and their babies: a retrospective cohort study using linked data

Carol McInerney,[1,2,3] Ibinabo Ibiebele,[1,3]Jane Ford,[1,3] Deborah Randall,[1,3] Jonathan Morris,[1,3,4] David Meharg,[5,6] Jo Mitchell,[7] Andrew Milat[8] and Siranda Torvaldsen[1,3,9]

[1] The University of Sydney Northern Clinical School, Women and Babies Research, St Leonards, New South Wales, Australia
[2] NSW Biostatistics Training Program, NSW Ministry of Health, Australia
[3] Northern Sydney Local Health District, Kolling Institute, New South Wales, Australia
[4] Department of Obstetrics and Gynaecology, Royal North Shore Hospital, Australia
[5] The University of Sydney, Faculty of Health Sciences, Sydney, New South Wales, Australia.
[6]Poche Centre for Indigenous Health, The University of Sydney, Sydney, New South Wales, Australia.
[7] Centre for Population Health, NSW Ministry of Health, Sydney, Australia
[8] Centre for Epidemiology and Evidence, NSW Ministry of Health, Sydney, Australia
[9] School of Public Health and Community Medicine, UNSW Sydney, Australia

Corresponding author:
Associate Professor Siranda Torvaldsen
Women and Babies Research,
Level 5 Douglas Building,
Royal North Shore Hospital,
St Leonards NSW 2065
AUSTRALIA
Email: siranda.torvaldsen@sydney.edu.au
Tel: +612 9462 9812

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Benefits of not smoking during pregnancy for Australian Aboriginal and Torres Strait Islander women and their babies: a retrospective cohort study using linked data

Abstract

Objectives

To provide evidence for targeted smoking cessation policy, the aim of this study was to compare pregnancy outcomes of Aboriginal mothers who reported *not* smoking during pregnancy with Aboriginal mothers who reported smoking during pregnancy.

Design

Population based retrospective cohort study using linked data.

Setting

New South Wales, the most populous Australian state.

Population

18,154 singleton babies born to 13,477 Aboriginal mothers between 2010–2014 were identified from routinely collected New South Wales datasets. Aboriginality was determined from birth records and from four linked datasets through an Enhanced Reporting of Aboriginality algorithm.

Exposure

Not smoking at any time during pregnancy.

Main outcome measures

Unadjusted and adjusted relative risks and 95% confidence intervals from modified Poisson regression were used to examine associations between not smoking during pregnancy and maternal and perinatal outcomes including severe morbidity, inter-hospital transfer, perinatal death, preterm birth and small-for-gestational age. Population attributable fractions (PAFs) were calculated using adjusted relative risks.

Results

Compared with babies born to mothers who smoked during pregnancy, babies born to non-smoking mothers had a lower risk of all adverse perinatal outcomes including perinatal death (aRR=0.58, 95%CI 0.44–0.76), preterm birth (aRR=0.58, 95%CI 0.53–0.64) and small-for-gestational age (aRR=0.35, 95%CI 0.32–0.39). PAFs(%) were 27% for perinatal death, 26% for preterm birth and 48% for small-for-gestational-age. Compared with women who smoked during pregnancy (n=8,919), those who did not smoke (n=9,235) had a lower risk of being transferred to another hospital (aRR=0.76, 95%CI 0.66–0.89).

Conclusions

Babies born to women who did not smoke during pregnancy had a lower risk of adverse perinatal outcomes. Rates of adverse outcomes among Aboriginal non-smokers were similar to those among the

general population. These results quantify the proportion of adverse perinatal outcomes due to smoking and highlight why effective smoking cessation programs are urgently required for this population.

Article summary

Strengths and limitations of this study

- The first study to examine the association between *not* smoking in pregnancy and pregnancy outcomes among Aboriginal women
- A large population-based cohort study using whole-of-population linked data
- To improve ascertainment of Aboriginal status, which is under-recorded on routinely collected health datasets, we linked four databases and applied an enhanced reporting of Aboriginality algorithm
- The inclusion of population attributable fractions quantifies the potential reduction in adverse perinatal outcomes if it was possible to reduce the smoking during pregnancy rate to zero.
- Data on history, heaviness, or passive smoking were not available, nor were data on some potential confounders such as alcohol consumption

Introduction

In 2008 the Australian federal, state and territory governments committed to reducing the national adult daily smoking rate by 2018, including halving the Aboriginal adult smoking rate.(1) Although smoking rates have substantially declined over this time, they remain high among pregnant Aboriginal women. In 2016, 41% of all pregnant Aboriginal women reported smoking at some time during their pregnancy compared to just 7% of non-Aboriginal women.(2) Smoking during pregnancy is the 'most important preventable risk factor for maternal and infant health'(3), thus smoking cessation for pregnant Aboriginal women remains a key priority for New South Wales (NSW) Health.(4) For the purposes of this study, Aboriginal and/or Torres Strait Islander people were considered together in one group. The reason for this was the small proportion of Torres Strait Islander people living in NSW (an estimated 2.6% of all females of Aboriginal and/or Torres Strait Islander descent(5))and that some people were recorded as both. We respectfully use the term Aboriginal as Aboriginal people are the original inhabitants of NSW.(6)

Australia's anti-tobacco campaigns and smoking cessation strategies are among the most comprehensive in the world, and there is growing evidence that programs specifically targeted to Aboriginal Australians are more effective.(7) There have been several campaigns to promote smoking cessation among pregnant Aboriginal mothers with varying efficacy.(8) To date these have been grounded in evidence from a general population. Although the benefits of not smoking during pregnancy are unlikely to be any different for Aboriginal mothers from the general population, quantifying the benefits of not smoking among Aboriginal mothers may be regarded as more relevant by this population and thus have the potential to influence smoking cessation. The benefits of not smoking during pregnancy are well established (9-13), but no previous studies have demonstrated associations between not smoking in pregnancy and positive pregnancy outcomes *among* Aboriginal women. This study aims to compare pregnancy outcomes of mothers who reported not smoking during pregnancy with those who reported any smoking during pregnancy from the Aboriginal population of NSW. Findings from this study will provide the most relevant evidence to date for pregnant Aboriginal women.

Methods

Study population and data sources

The study population consisted of all singleton babies born to Aboriginal women residing in NSW between 1 January 2010 and 31 December 2014 and their mothers. This population-based retrospective cohort study used linked data from routinely collected NSW datasets. The study population was identified from all records in the NSW Perinatal Data Collection ('birth data') for the period 1 January 2010 to 31 December 2014. All births in the population, including births at NSW public and private hospitals and home births are recorded in the birth data. This surveillance system includes all live births and stillbirths of at least 400 grams birthweight or at least 20 weeks gestation.(14)

All deaths within NSW are registered in the Registry of Births, Deaths and Marriages and fact of death was retrieved from these data between 1 January 2010 and 31 December 2015. Public and private hospital admission records were drawn from the NSW Admitted Patient Data Collection ('hospital data')

for admissions from 1 September 2009 to 31 December 2014. An additional 4 months of hospital data were retrieved prior to the start of the study period to allow for admissions to hospital for births early in 2010. Diagnoses coded in the hospital data are applied according to the International Classification of Diseases, Australian Modification (ICD-10-AM). Records within and across all datasets were probabilistically linked using personal identifiers by the NSW Centre for Health Record Linkage with an estimated false linkage rate of less than 5 per 1,000 records.(15) Hospital birth records were those where the birth was recorded to have occurred between the mother's admission and discharge dates using the linked birth data. It's estimated that 96% of records from the birth data link to the mother's and infant's hospital records from the birth.(16)

Aboriginal women were defined as those who were recorded as Australian Aboriginal in the birth data or who were assigned Aboriginal status according to the Enhanced Reporting of Aboriginality (ERA) algorithm.

Enhanced Reporting of Aboriginality (ERA)

It is widely acknowledged that Aboriginal status is under-recorded on routinely collected health datasets nationwide.(17) Enhancement of reporting of Aboriginal people using linked records creates a statistical construct that results in improved information about Aboriginal people. It does not define a person as being Aboriginal, nor does it replace efforts to improve the overall quality of recording Aboriginal status at the point of care.

Information surrounding individuals' Aboriginal status was pooled via linkage of the birth data, NSW Registry of Births, Deaths and Marriages birth registrations, hospital data and the NSW Emergency Department Data Collection. Using this information, a weight of evidence surrounding a woman's Aboriginal status was determined by a multistage median algorithm.(18) Since multiple datasets were used and some women had multiple records in each of these datasets, the algorithm initially assigned a separate status for each woman and dataset. Aboriginal or Torres Strait Islander status was assigned to a mother if: one or two linked records were available and at least one reported her as Aboriginal; three or more linked records were available and at least two reported her as Aboriginal. A comparable algorithm using dataset-specific statuses instead of records was used to determine the inclusion of each woman in the study population.

The enhanced reporting of Aboriginality is a technique used by many research groups.(19-21) Although this combination of datasets and algorithm has not been used before, similar methods have been found to minimise the risk of incorrect inclusion while capturing more women than simply relying on a single record.(22) Details on the algorithm, the data used and the mothers identified through the ERA have been described in more detail elsewhere.(23)

Exposure

The exposure of interest for this study was not smoking at any time during pregnancy. Mothers who reported not smoking during pregnancy will henceforth be referred to as non-smokers and those who reported any smoking during pregnancy are referred to as smokers. To increase ascertainment, birth data and mother's hospital birth record(s) were used to assign smoking status. If the birth data indicated that a mother smoked at any time during her pregnancy and/or recorded her as a current smoker within

the hospital birth record(s) (according to the ICD-10-AM diagnosis codes Z72.0 and F17) then she was considered to be a smoker. The sensitivity and specificity of current smoking from the most recent separation in the hospital data is estimated to be 58.5% and 98.4% respectively.(24) Where a mother had multiple hospital records associated with the birth and those records contradicted each other according to smoking status, her smoking status defaulted to that recorded in the birth data.

Outcomes

Maternal outcomes were identified using the birth data and the mother's hospital birth record and included two binary outcomes: severe maternal morbidity and inter-hospital transfer. Severe maternal morbidity was defined using a validated composite indicator that captures a broad range of diagnoses and procedures such as cardiac arrest, renal failure or assisted ventilation.(25) Mothers requiring inter-hospital transfer were defined as those with at least one record with a mode of separation indicating transfer or where multiple hospitalisation records were present with differing hospital codes.

Perinatal outcomes, including birth outcomes and those occurring within the first 28 days of life for the baby were retrieved from the birth data and the baby's linked hospital and birth registration records. These included perinatal death (stillbirth and neonatal death), preterm birth (<37 completed weeks of gestation), and small for gestational age (birth weight <3rd and/or 10th percentile for sex and age (26)). Admissions to a special care nursery (SCN) or neonatal intensive care unit (NICU) were assessed among an eligible population of babies born in a hospital classified as level 3 or above (NSW Ministry of Health's *Guide to the Role Delineation of Hospitals*) or a private hospital. Severe neonatal morbidity, measured according to a validated composite indicator (27), was assessed among all live births.

Covariates

Maternal age and parity were reported according to the birth data. The mother's chronic conditions, hypertension and diabetes information were obtained from the birth data and the hospital birth record(s). We used the broad category of any hypertension rather than the specific categories of chronic hypertension, pregnancy hypertension, preeclampsia and eclampsia, as there is known misclassification among types of hypertension (28). The NSW ranking of the Australian Bureau of Statistics (ABS) 2011 Socio-Economic Index for Areas (SEIFA) Index of Relative Socio-Economic Disadvantage (IRSD) and the 2011 Remoteness Areas were used to assess the mother's relative socio-economic status and access to services respectively. Where available, the mother's 2011 Statistical Local Area (SLA) according to her birth data was used to assign these measures. Otherwise, and for all babies born in 2010, the mother's 2010 SLA was used. Hospital type is an indicator of the size of a hospital and its location (urban or regional)(29) and was assigned using the hospital code recorded in the birth data.

Statistical analyses

The study population was described using frequencies and percentages by potential confounders and the mother's smoking status. Summary statistics were calculated by mother's smoking status to investigate the associations between smoking during pregnancy and maternal and child outcomes. To estimate the unadjusted and adjusted relative risk (RR) of binary outcomes while accounting for the correlation within the data (some mothers had more than one baby during the study period), an extension to the modified Poisson regression (30) was used with an unstructured correlation matrix. Those observations where data were missing for an outcome were excluded from analysis for that

outcome. SAS for Windows 9.4 (SAS Institute, Cary, NC, USA) was used for all data manipulation and analysis.

In view of the established causal relationship between smoking and adverse perinatal outcomes, we quantified the proportion and number of adverse perinatal outcomes that would not have occurred in this population if all the mothers had been non-smokers during pregnancy. We used the formula: PAF $=[P_s(RR_s-1)]/RR_s$, where P_s is the proportion of babies with the outcome whose mothers smoked and RR_s is the adjusted RR for smokers. The RR_s is the inverse of the RR for non-smokers.

Patient and public involvement

An Aboriginal advisory committee was consulted prior to submission of the study proposal to ethics committees and throughout the process. The committee provided guidance on presentation and interpretation of results. It was of particular importance to members of the committee that the results were framed positively, ie the *benefits* of not smoking, rather than the risks of smoking. It was also important to committee members that all comparisons were among Aboriginal women and that Aboriginal women were not compared with non-Aboriginal women. There are plans to develop culturally appropriate educational material based on the results of this research and in collaboration with Aboriginal Health Workers and others involved in the care of Aboriginal women who are pregnant or may be planning a pregnancy.

Results

Following exclusion of duplicates (n=76), a total of 487,388 babies were born to 379,116 mothers in NSW and were assessed for inclusion in this study. Records for 16,904 babies born to 12,720 mothers who were recorded as Aboriginal in the birth data were available for analysis. An additional 1,921 babies born to 1,624 mothers were identified as eligible for inclusion in the study using the ERA. Of the total 18,825 babies, 557 were from a multiple birth and 114 were born to mothers who were not residents of NSW. These babies did not meet the eligibility criteria and were excluded. Thus the final study population consisted of 18,154 singleton babies born to 13,477 Aboriginal mothers. Figure 1 outlines the flow of participants in this study.

Among the study population, 9,235 (51%) babies were born to non-smoking mothers and 8,919 (49%) were born to smoking mothers (Table 1). Only two percent of all linked records had contradictory smoking statuses from the birth and hospital data. For comparison, when smoking status was assigned only according to the birth data, 52% of babies were born to non-smoking mothers and 48% were born to smoking mothers. Mothers who reported not smoking at any time during their pregnancy were generally less disadvantaged than their smoking counterparts; approximately 8.1% of non-smoking mothers were in the highest SEIFA quintile, compared to just 4.1% of smoking mothers. Non-smoking mothers were older, lived in less remote regions and had fewer previous pregnancies than smoking mothers. The number of non-smoking mothers with hypertension (1,106) was almost double that of smoking mothers (578) and slightly more non-smoking mothers had diabetes (Table 1).

The majority (70%) of mothers only had one baby during the study period however a substantial number had multiple: 25% had two, 4.4% had three and 0.4% had four. For 564 (4%) mothers, their smoking

status changed between pregnancies, 6,814 (53%) mothers reported not smoking in all pregnancies during the study period and 6,099 (47%) consistently reported smoking. Of the 564 mothers whose smoking status changed between pregnancies, 266 (47%) changed from smoking to non-smoking, 271 (48%) changed from non-smoking to smoking in all subsequent pregnancies and 27 (5%) moved between smoker and non-smoker status.

The rate of severe maternal morbidity was low (<3%) and not significantly different between smoking and non-smoking mothers (Table 2). The rate of inter-hospital transfer was lower in the non-smoking group at 3.7% compared with the smoking group (5.1%), with an adjusted relative risk of RR=0.76 (95% CI 0.66, 0.89).

Adverse perinatal outcomes occurred less frequently among babies born to non-smoking mothers (Table 3). Perinatal deaths were rare in both populations however the rate was lower in the non-smoking group with perinatal death occurring in 1.0% of babies born to non-smoking mothers, compared to 1.8% in smoking mothers. Also, severe neonatal morbidity and admission to SCN or NICU was less frequent in babies born to non-smoking mothers when compared to those born to smoking mothers. Overall, the gestational age of babies from the non-smoking group was closer to term than those from the smoking group; more babies born to non-smoking mothers (66%) were born between 39 and 41 weeks than those born to smoking mothers (55%). Preterm birth was considerably less frequent among babies born to mothers who did not smoke during pregnancy; 8.2% of births to non-smoking mothers were preterm compared to 14% from smoking mothers. Similarly, babies born to non-smoking mothers were less often small for gestational age, with 2.0% and 7.0% of these babies having a birthweight below the 3rd and 10th percentiles respectively compared to 7.3% and 20% of babies of smoking mothers. All relative risks were less than 1, suggesting a reduced risk of all adverse outcomes among babies born to non-smoking mothers when compared to those born to smoking mothers. Of note were the relative risks for perinatal death (RR=0.58 95% CI 0.44, 0.76), preterm birth (RR=0.58 95% CI 0.53, 0.64) and small for gestational age (<10th percentile; RR=0.35 95% CI 0.32, 0.39). As indicated by the PAFs (%) in Table 3, more than a quarter of the perinatal deaths and preterm births were attributable to smoking and almost half the small for gestational age births. Among this cohort of babies, this equates to 68 perinatal deaths, 540 preterm births and 1,131 small for gestational age (<10th percentile) babies attributable to smoking.

Discussion

This study of a recent population of pregnant Aboriginal women clearly demonstrates improved pregnancy outcomes among Aboriginal mothers who reported not smoking during pregnancy when compared to Aboriginal mothers who reported smoking during pregnancy. Benefits of not smoking were found for all the perinatal outcomes we examined. We also found non-smoking mothers had a 24% lower risk of being transferred to another hospital during the birth admission than smoking mothers of similar demographics. Inter-hospital transfers may be due to complications arising before, during or after the birth. This means women are less likely to be away from their family and country during this challenging time. Although a slightly lower risk of severe maternal morbidity was found in the non-smoking group, there was not sufficient evidence to suggest a true difference existed as the confidence

interval included 1 (RR=0.92, 95% CI 0.77–1.11). Other risk factors may be more strongly associated with severe maternal morbidity than smoking.

Among babies born to mothers of a similar age, with similar pre-existing conditions (any diabetes or hypertension), parity and socio-economic status, those with a non-smoking mother had a 42% less risk of perinatal death and preterm birth, 65% less risk of being small-for-gestational age (<10th percentile), 30% less risk of severe neonatal morbidity, and 33% less risk of being admitted to a SCN or NICU than those born to a mother who smoked at any time during her pregnancy. The reductions in adverse outcomes for babies born to non-smoking mothers were statistically and clinically significant and remained so even after adjustment. Encouragingly, despite some rates being marginally higher, overall very little difference exists between the rates of adverse perinatal outcomes among the non-smoking Aboriginal mothers in this study and the overall NSW population of mothers giving birth in 2014, of whom 9.3% reported smoking and 3.9% were recorded as Aboriginal.(14) The high PAFs for the adverse perinatal outcomes highlight the enormous potential for health improvements in this population. Over a quarter of the perinatal deaths and preterm births were attributable to smoking. Being born small for gestational age is associated with short and long-term health sequelae, and these risks are even greater for babies born with a birthweight less than the third percentile for gestational age and sex. The PAF(%) was highest (57%) for being born with a birthweight less than the third percentile. Almost half (48%) the babies born small for gestational age (<10th percentile) could have had a normal birthweight (≥10th percentile) in the absence of smoking. Our results are consistent with a recent study of a cohort of 697,003 children born in Scotland from 1997–2009 (31). In addition to the adverse perinatal outcomes attributable to smoking, this study followed children until five years of age and found that maternal smoking during pregnancy also increased the risk of the child being hospitalized with acute respiratory infections, bronchiolitis, asthma and bacterial meningitis (31).

As expected, and similar to findings from other studies, (31, 32) mothers from the non-smoking group were less disadvantaged, older, resided in less remote regions and had fewer previous pregnancies than those from the smoking group. Diabetes and hypertension were more prevalent among non-smoking mothers than smoking mothers. The small difference in prevalence of diabetes (8.7% vs 6.5%) could be due to the non-smoking group being slightly older than the smoking group. However the prevalence of hypertension in non-smoking mothers was almost double that of smoking mothers (12% vs 6.5%). Whilst this finding may surprise some, it is consistent with findings from previous studies (33-36). A systematic review of 48 studies concluded that smoking during pregnancy reduces the risk of preeclampsia by up to 50% and that there is a dose-response relationship (34). Similar results have been reported when the outcome includes gestational hypertension as well as preeclampsia, and the protective effect appears to continue even after women quit smoking later in pregnancy (36). This protective effect may be mediated via the biological effects of carbon monoxide that is formed during smoking (35). However, when preeclampsia does occur, the outcomes are much worse for babies whose mothers smoked (33). Although preeclampsia is associated with adverse pregnancy outcomes, and smoking reduces the incidence of preeclampsia, the net effect of smoking is still a worsening of pregnancy outcomes and there are dose-dependent increases in perinatal deaths and SGA babies among mothers who smoke (33). Hence these findings in no way indicate any benefit to mothers or babies if the mother smokes during pregnancy.

As well as being a national health priority in Australia, reducing smoking during pregnancy is a key performance indicator in the annual service agreements between the NSW Ministry of Health and Local Health Districts.(37) As part of this commitment, the Quit for New Life program was established in 2013 with the aim to support women having an Aboriginal baby to quit smoking. The program was integrated into Aboriginal Maternal and Infant Health Services and has supported over 2,500 pregnant women, 950 postnatal women and 1,650 cohabitants in their quit attempt.(38) However, further efforts including health professional training, expansion to other maternal health services and community programs, and improved data collection and reporting are required to reduce the prevalence of smoking in pregnancy in this population. Investment to discourage women, especially young women, from taking up smoking and encouraging and appropriately supporting smokers to quit need to remain priorities.

Health professionals have a critical role in communicating the benefits of not smoking during pregnancy found in this study. However some practitioners perceive intervention to be ineffective and thus may not raise this issue with their patients.(39) The highly relevant evidence from this study may increase the salience of the issue and provide further motivation for health professionals to consistently ask and advise about smoking.

While the health impacts of smoking on maternal and child health are well known (9-13), this study provides local information that can be used to further engage Australian health professionals and community members on the benefits of not smoking. Building on the strength and resilience of Aboriginal people is an important foundation for efforts to reduce smoking among this population.(40) Using local evidence on the *benefits* of not smoking during pregnancy has the potential to re-frame health messages for women, their families and communities and to mobilise community action to achieve better health outcomes.

Strengths and limitations

This is the first study we are aware of that examines associations between smoking in pregnancy and adverse pregnancy outcomes exclusively among Aboriginal and/or Torres Strait Islander women. This was a large population-based study. Using data linkage, we were able to capture more women through the ERA, further increasing our sample size. Despite the unavailability of information surrounding some potential confounders, including individual level socioeconomic status, our findings were consistent with those among other populations from the literature (9-13). Limited data on the heaviness of smoking during pregnancy meant that potential dose effects could not be calculated. However, new data around quitting in pregnancy is available from 2016 onward so there is potential for future work to examine this phenomenon further. Similarly, no information was available on the mother's history of smoking, exposure to environmental tobacco smoke or alcohol consumption and so effects from longer term smoking and potential confounding from alcohol consumption could not be accounted for. A lack of data surrounding history and heaviness of smoking means that the treatment effects estimated in this study are likely to be biased toward the null and thus underestimate the true benefits of not smoking in pregnancy. Under-ascertainment of smoking status would similarly bias toward the null. Mothers who smoked in one pregnancy but not in a subsequent pregnancy were classified as non-smokers in the subsequent pregnancy. If these mothers were more likely to have worse outcomes in the subsequent

pregnancy compared with never smoking mothers, this would also bias towards the null. However, any effect would be negligible due to the very low numbers (<2% of the study population).

Conclusions

Babies born to Aboriginal mothers who did not smoke during pregnancy were at a significantly reduced risk of adverse perinatal outcomes compared to those born to smoking mothers of similar demographics. Rates of these adverse outcomes among Aboriginal women who did not smoke were very similar to those among the general NSW population.

These results reinforce the importance of targeted smoking cessation policy for Aboriginal women. Barriers to smoking cessation in this population are complex and it is vital that this evidence is provided concurrently with sufficient support to enable Aboriginal women to quit smoking. Distributing this information in isolation runs the risk of furthering shame and stress experienced by pregnant women and may discourage them from seeking further help, highlighting the importance of systematic approaches to encourage and support Aboriginal women to quit smoking.

Acknowledgements

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Footnotes

Contributors

JMitchell and AM had the initial idea for this study. ST wrote the study proposal and was responsible for the ethics application and revisions to the manuscript. CM undertook all analyses, with guidance from ST, II and DR, and drafted the manuscript. JF, JMorris, JMitchell, AM and ST all contributed to the design of the study and, with DM, the interpretation of the results. All authors commented on drafts and read and approved the final manuscript. The corresponding author attests that all listed authors meet authorship criteria and that no others meeting the criteria have been omitted. CM and ST are guarantors.

Statement of Conflicts of Interest

All authors have completed the ICMJE uniform disclosure form at www.icmje.org/coi_disclosure.pdf and declare: CM and ST's salaries came from a Prevention Research Support Program grant from the NSW Ministry of Health, no other relationships or activities that could appear to have influenced the submitted work.

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Ethics approval

Ethics approval for this study was given by the Aboriginal Health and Medical Research Council of New South Wales, Australia (HREC reference number: 1326/17) and was exempt from informed consent requirements as there was no contact with the study population and the authors only had access to de-identified data.

Transparency statement

The lead author affirms that the manuscript is an honest, accurate, and transparent account of the study being reported; that no important aspects of the study have been omitted; and that any discrepancies from the study as planned have been explained.

Data sharing

No additional data are available.

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Figure caption:

Figure 1 Flow diagram of mothers and babies eligible for inclusion in the final study population.

Table 1 Demographics at the time of birth of all Aboriginal or Torres Strait Islander mothers who gave birth to at least one singleton baby in NSW between 2010 and 2014 reported for all births and by smoking status during pregnancy.

	All births		Non-smoking		Smoking	
	N = 18,154		N_{ns} = 9,235 (51%)		N_s = 8,919 (49%)	
Year of baby's birth	**n**	**%**	**n**	**%**	**n**	**%**
2010	3,487	19	1,740	50*	1,747	50*
2011	3,380	19	1,638	48*	1,742	52*
2012	3,680	20	1,833	50*	1,847	50*
2013	3,716	20	1,944	52*	1,772	48*
2014	3,891	21	2,080	53*	1,811	47*
Maternal age						
Under 20	3,214	18	1,568	17	1,646	19
20–24	6,014	33	2,983	32	3,031	34
25–29	4,608	25	2,381	26	2,227	25
30–34	2,729	15	1,455	16	1,274	14
35 and over	1,589	8.8	848	9.2	741	8.3
Total	18,154	100	9,235	100	8,919	100
Parity						
0	6,259	35	3,720	40	2,539	29
1	4,709	26	2,589	28	2,120	24
2	3,107	17	1,490	16	1,617	18
3+	4,072	22	1,431	16	2,641	30
Total	18,147	100	9,230	100	8,917	100
SEIFA IRSD quintiles**						
1st – most disadvantaged	4,827	27	2,131	23	2,696	30
2nd	3,674	20	1,887	21	1,787	20
3rd	5,375	30	2,806	31	2,569	29
4th	3,068	17	1,617	18	1,451	16
5th – least disadvantaged	1,115	6.2	748	8.1	367	4.1
Total	18,059	100	9,189	100	8,870	100
Remoteness area						
Major cities	4,193	23	2,246	24	1,947	22
Inner regional	6,147	34	3,310	36	2,837	32
Outer regional	6,097	34	2,966	32	3,131	35
Remote	1,027	5.7	421	4.6	606	6.8
Very remote	595	3.3	245	2.7	350	4.0
Total	18,059	100	9,188	100	8,871	100

Hospital level						
Tertiary	4,099	23	2,108	23	1,991	22
Small and medium urban	308	1.7	178	1.8	130	1.5
Large urban	2,895	16	1,607	9	1,288	14
Small regional	3,441	19	1,519	16	1,922	22
Medium regional	3,042	17	1,550	17	1,492	17
Large regional	3,897	21	1,896	21	2,001	22
Private	336	1.7	323	3.2	13	0.2
Other	136	0.7	54	0.6	82	0.9
Total	18,154	100	9,235	100	8,919	100
Chronic conditions^						
Yes	343	1.9	147	1.6	196	2.2
Total	18,154	100	9,235	100	8,919	100
Any hypertension						
Yes	1,684	9.3	1,106	12	578	6.5
Total	18,154	100	9,235	100	8,919	100
Any diabetes						
Yes	1,413	7.8	804	8.7	609	6.5
Total	18,154	100	9,235	100	8,919	100

* Percentage of all births within each year.

**Socio-Economic Index for Areas – Index of Relative Socio-Economic Disadvantage (SEIFA IRSD). When ranking areas within NSW in order of their relative disadvantage, the lowest 20% (most disadvantaged) fall in the 1st quintile and the highest 20% (least disadvantaged) fall in 5th quartile.

^Chronic conditions encompasses renal, cardiac, thyroid, asthma, psychiatric, and other autoimmune conditions(41).

Table 2 Frequencies of maternal outcomes at the time of birth of all Aboriginal mothers by smoking status during pregnancy.

	All births		Non-smoking		Smoking		Unadjusted	Adjusted
	N = 18,154		N_{ns} = 9,235		N_s = 8,919			
Severe maternal morbidity	**n**	**%**	**n**	**%**	**n**	**%**	**RR (95% CI)**	**RR (95% CI)**
Yes	523	2.9	257	2.8	266	3.0	0.94 (0.79, 1.12)	0.92* (0.77, 1.11)
Inter-hospital transfer								
Yes	793	4.4	337	3.7	456	5.1	0.73 (0.63, 0.84)	0.76** (0.66, 0.89)

*adjusted for maternal age, any hypertension, any diabetes, parity and socio-economic status (SEIFA).
** adjusted for maternal age, any hypertension, any diabetes, parity and remoteness area.

Table 3 Frequencies of perinatal outcomes among all babies born to Aboriginal or Torres Strait Islander mothers by maternal smoking status.

	NSW population	All births		Non-smoking		Smoking		Unadjusted	Adjusted*	PAF (%)
		N = 18,154		N_{ns} = 9,235		N_s = 8,919				
Preterm birth (<37 wks)	**%**	**n**	**%**	**n**	**%**	**n**	**%**	**RR (95% CI)**	**RR (95% CI)**	
Yes	8	2,045	11	760	8.2	1,285	14	0.59 (0.54, 0.64)	0.58 (0.53, 0.64)	26
Total		18,154	100	9,235	100	8,919	100			
Small for gestational age (<3rd population percentile)										
Yes	3	835	4.6	183	2.0	652	7.3	0.28 (0.23, 0.32)	0.27 (0.23, 0.32)	57
Total		18,132	100	9,229	100	8,903	100			
Small for gestational age (<10th population percentile)										
Yes	10	2,381	13	641	7.0	1,740	20	0.36 (0.33, 0.39)	0.35 (0.32, 0.39)	48
Total		18,132	100	9,229	100	8,903	100			
Severe neonatal morbidity	**Among live births only**									
Yes	5	1,470	8.2	636	6.9	834	9.5	0.74 (0.67, 0.81)	0.70 (0.63, 0.77)	17
Total		17,978	100	9,169	100	8,809	100			
Admission to SCN or NICU^										
Yes	15	3,957	22	1,645	18	2,312	26	0.70 (0.66, 0.75)	0.66 (0.63, 0.70)	20
Total		17,809	100	9,059	100	8,750	100			
Perinatal death		**Rate per 1,000 total births**								
Yes	8	254	14	92	10**	162	18**	0.54 (0.42, 0.70)	0.58 (0.44, 0.76)	27
Stillborn	6	162		60	6.5**	102	11**	0.57 (0.41, 0.78)	0.60 (0.43, 0.84)	20
		Rate per 1,000 live births								
Neonatal death	2	92		32	3.5^^	60	6.8^^	0.50	0.54	30

								(0.33, 0.78)	(0.34, 0.86)	

*adjusted for maternal age, any hypertension, any diabetes, parity and socio-economic status (SEIFA).
^Admission to Special Care Nursery (SCN) or Neonatal Intensive Care Unit (NICU) was restricted to those babies recorded as being born in a hospital of maternity service level 3 or higher or a private hospital.
**Rate per 1,000 total births
^^ Rate per 1,000 live births
PAF, Population Attributable Fraction

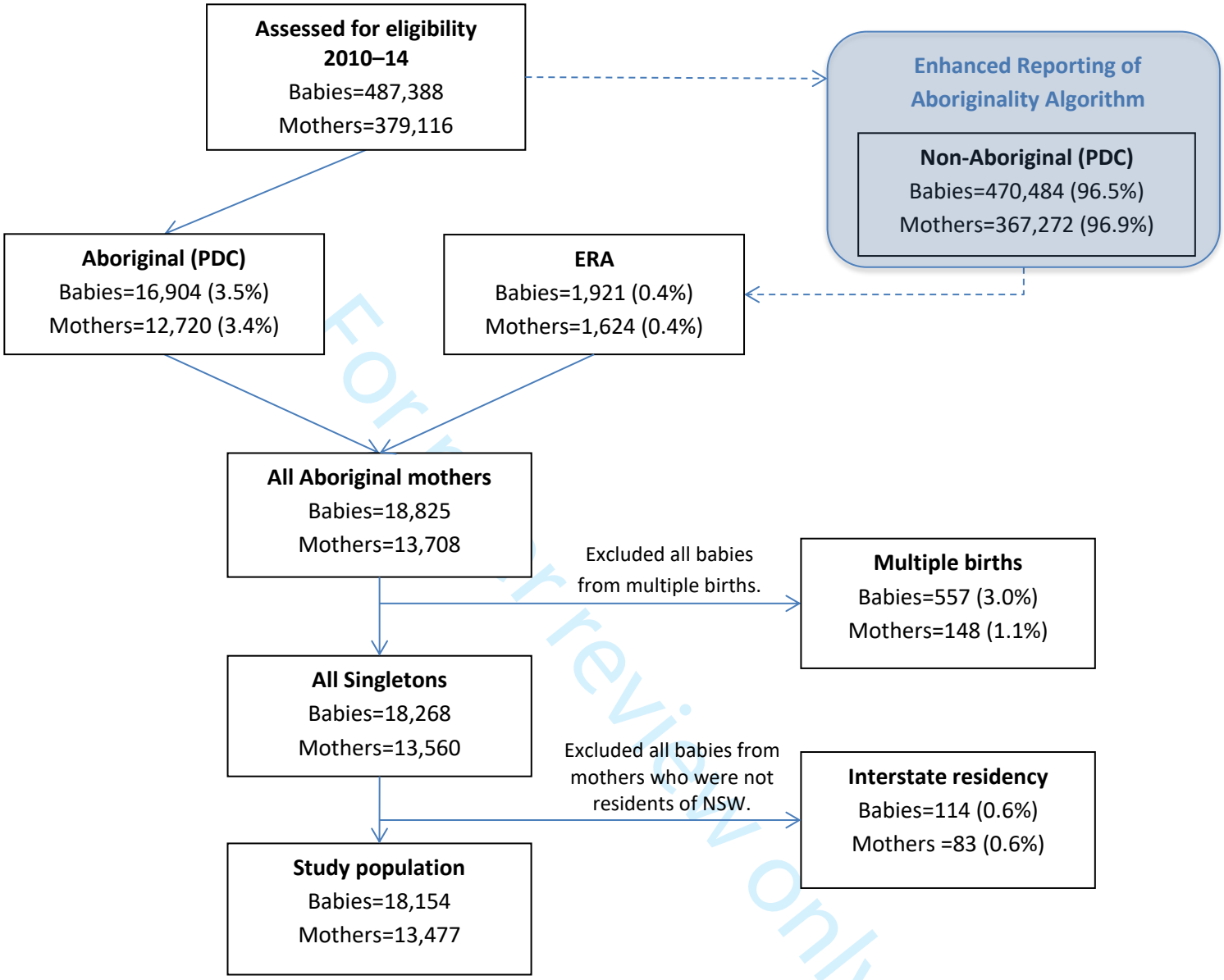

Figure 1 Flow diagram of mothers and babies eligible for inclusion in the final study population.

STROBE Statement—Checklist of items that should be included in reports of ***cohort studies***

Manuscript for: Benefits of not smoking during pregnancy for Australian Aboriginal and Torres Strait Islander women and their babies: a retrospective cohort study using linked data

	Item No	Recommendation	Page No
Title and abstract	1	(*a*) Indicate the study's design with a commonly used term in the title or the abstract	1
		(*b*) Provide in the abstract an informative and balanced summary of what was done and what was found	1
Introduction			
Background/rationale	2	Explain the scientific background and rationale for the investigation being reported	2
Objectives	3	State specific objectives, including any prespecified hypotheses	2
Methods			
Study design	4	Present key elements of study design early in the paper	2
Setting	5	Describe the setting, locations, and relevant dates, including periods of recruitment, exposure, follow-up, and data collection	2
Participants	6	(*a*) Give the eligibility criteria, and the sources and methods of selection of participants. Describe methods of follow-up	2-3
		(*b*) For matched studies, give matching criteria and number of exposed and unexposed	2-3
Variables	7	Clearly define all outcomes, exposures, predictors, potential confounders, and effect modifiers. Give diagnostic criteria, if applicable	3-4
Data sources/ measurement	8*	For each variable of interest, give sources of data and details of methods of assessment (measurement). Describe comparability of assessment methods if there is more than one group	3-4
Bias	9	Describe any efforts to address potential sources of bias	4
Study size	10	Explain how the study size was arrived at	2
Quantitative variables	11	Explain how quantitative variables were handled in the analyses. If applicable, describe which groupings were chosen and why	4
Statistical methods	12	(*a*) Describe all statistical methods, including those used to control for confounding	4-5
		(*b*) Describe any methods used to examine subgroups and interactions	
		(*c*) Explain how missing data were addressed	5
		(*d*) If applicable, explain how loss to follow-up was addressed	
		(*e*) Describe any sensitivity analyses	
Results			
Participants	13*	(a) Report numbers of individuals at each stage of study—eg numbers potentially eligible, examined for eligibility, confirmed eligible, included in the study, completing follow-up, and analysed	Fig 1
		(b) Give reasons for non-participation at each stage	Fig 1
		(c) Consider use of a flow diagram	Fig 1
Descriptive data	14*	(a) Give characteristics of study participants (eg demographic, clinical, social) and information on exposures and potential confounders	Table 1
		(b) Indicate number of participants with missing data for each variable of interest	Table 1,2,3
		(c) Summarise follow-up time (eg, average and total amount)	
Outcome data	15*	Report numbers of outcome events or summary measures over time	Table

			2,3
Main results	16	(*a*) Give unadjusted estimates and, if applicable, confounder-adjusted estimates and their precision (eg, 95% confidence interval). Make clear which confounders were adjusted for and why they were included	Table 2,3
		(*b*) Report category boundaries when continuous variables were categorized	
		(*c*) If relevant, consider translating estimates of relative risk into absolute risk for a meaningful time period	
Other analyses	17	Report other analyses done—eg analyses of subgroups and interactions, and sensitivity analyses	
Discussion			
Key results	18	Summarise key results with reference to study objectives	6
Limitations	19	Discuss limitations of the study, taking into account sources of potential bias or imprecision. Discuss both direction and magnitude of any potential bias	8
Interpretation	20	Give a cautious overall interpretation of results considering objectives, limitations, multiplicity of analyses, results from similar studies, and other relevant evidence	6,7
Generalisability	21	Discuss the generalisability (external validity) of the study results	8
Other information			
Funding	22	Give the source of funding and the role of the funders for the present study and, if applicable, for the original study on which the present article is based	10

*Give information separately for exposed and unexposed groups.

Note: An Explanation and Elaboration article discusses each checklist item and gives methodological background and published examples of transparent reporting. The STROBE checklist is best used in conjunction with this article (freely available on the Web sites of PLoS Medicine at http://www.plosmedicine.org/, Annals of Internal Medicine at http://www.annals.org/, and Epidemiology at http://www.epidem.com/). Information on the STROBE Initiative is available at http://www.strobe-statement.org.

BMJ Open

Benefits of not smoking during pregnancy for Australian Aboriginal and Torres Strait Islander women and their babies: a retrospective cohort study using linked data

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Secondary Subject Heading:	Smoking and tobacco, Epidemiology, Public health
Keywords:	Pregnancy, smoking, Aboriginal health, preterm birth, stillbirth, linked data

Benefits of not smoking during pregnancy for Australian Aboriginal and Torres Strait Islander women and their babies: a retrospective cohort study using linked data

Carol McInerney,[1,2,3] Ibinabo Ibiebele,[1,3]Jane Ford,[1,3] Deborah Randall,[1,3] Jonathan Morris,[1,3,4] David Meharg,[5,6] Jo Mitchell,[7] Andrew Milat[8] and Siranda Torvaldsen[1,3,9]

[1] The University of Sydney Northern Clinical School, Women and Babies Research, St Leonards, New South Wales, Australia
[2] NSW Biostatistics Training Program, NSW Ministry of Health, Australia
[3] Northern Sydney Local Health District, Kolling Institute, New South Wales, Australia
[4] Department of Obstetrics and Gynaecology, Royal North Shore Hospital, Australia
[5] The University of Sydney, Faculty of Health Sciences, Sydney, New South Wales, Australia.
[6]Poche Centre for Indigenous Health, The University of Sydney, Sydney, New South Wales, Australia.
[7] Centre for Population Health, NSW Ministry of Health, Sydney, Australia
[8] Centre for Epidemiology and Evidence, NSW Ministry of Health, Sydney, Australia
[9] School of Public Health and Community Medicine, UNSW Sydney, Australia

Corresponding author:
Associate Professor Siranda Torvaldsen
Women and Babies Research,
Level 5 Douglas Building,
Royal North Shore Hospital,
St Leonards NSW 2065
AUSTRALIA
Email: siranda.torvaldsen@sydney.edu.au
Tel: +612 9462 9812

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Benefits of not smoking during pregnancy for Australian Aboriginal and Torres Strait Islander women and their babies: a retrospective cohort study using linked data

Abstract

Objectives

To provide evidence for targeted smoking cessation policy, the aim of this study was to compare pregnancy outcomes of Aboriginal mothers who reported *not* smoking during pregnancy with Aboriginal mothers who reported smoking during pregnancy.

Design

Population based retrospective cohort study using linked data.

Setting

New South Wales, the most populous Australian state.

Population

18,154 singleton babies born to 13,477 Aboriginal mothers between 2010–2014 were identified from routinely collected New South Wales datasets. Aboriginality was determined from birth records and from four linked datasets through an Enhanced Reporting of Aboriginality algorithm.

Exposure

Not smoking at any time during pregnancy.

Main outcome measures

Unadjusted and adjusted relative risks and 95% confidence intervals from modified Poisson regression were used to examine associations between not smoking during pregnancy and maternal and perinatal outcomes including severe morbidity, inter-hospital transfer, perinatal death, preterm birth and small-for-gestational age. Population attributable fractions (PAFs) were calculated using adjusted relative risks.

Results

Compared with babies born to mothers who smoked during pregnancy, babies born to non-smoking mothers had a lower risk of all adverse perinatal outcomes including perinatal death (aRR=0.58, 95%CI 0.44–0.76), preterm birth (aRR=0.58, 95%CI 0.53–0.64) and small-for-gestational age (aRR=0.35, 95%CI 0.32–0.39). PAFs(%) were 27% for perinatal death, 26% for preterm birth and 48% for small-for-gestational-age. Compared with women who smoked during pregnancy (n=8,919), those who did not smoke (n=9,235) had a lower risk of being transferred to another hospital (aRR=0.76, 95%CI 0.66–0.89).

Conclusions

Babies born to women who did not smoke during pregnancy had a lower risk of adverse perinatal outcomes. Rates of adverse outcomes among Aboriginal non-smokers were similar to those among the

general population. These results quantify the proportion of adverse perinatal outcomes due to smoking and highlight why effective smoking cessation programs are urgently required for this population.

Article summary

Strengths and limitations of this study

- The first study to examine the association between *not* smoking in pregnancy and pregnancy outcomes among Aboriginal women
- A large population-based cohort study using whole-of-population linked data
- To improve ascertainment of Aboriginal status, which is under-recorded on routinely collected health datasets, we linked four databases and applied an enhanced reporting of Aboriginality algorithm
- The inclusion of population attributable fractions quantifies the potential reduction in adverse perinatal outcomes if it was possible to reduce the smoking during pregnancy rate to zero.
- Data on history, heaviness, or passive smoking were not available, nor were data on some potential confounders such as alcohol consumption

Introduction

In 2008 the Australian federal, state and territory governments committed to reducing the national adult daily smoking rate by 2018, including halving the Aboriginal adult smoking rate.[1] Although smoking rates have substantially declined over this time, they remain high among pregnant Aboriginal women. In 2016, 41% of all pregnant Aboriginal women reported smoking at some time during their pregnancy compared to just 7% of non-Aboriginal women.[2] Smoking during pregnancy is the 'most important preventable risk factor for maternal and infant health'[3], thus smoking cessation for pregnant Aboriginal women remains a key priority for New South Wales (NSW) Health.[4] For the purposes of this study, Aboriginal and/or Torres Strait Islander people were considered together in one group. The reason for this was the small proportion of Torres Strait Islander people living in NSW (an estimated 2.6% of all females of Aboriginal and/or Torres Strait Islander descent[5])and that some people were recorded as both. We respectfully use the term Aboriginal as Aboriginal people are the original inhabitants of NSW.[6]

Australia's anti-tobacco campaigns and smoking cessation strategies are among the most comprehensive in the world, and there is growing evidence that programs specifically targeted to Aboriginal Australians are more effective.[7] There have been several campaigns to promote smoking cessation among pregnant Aboriginal mothers with varying efficacy.[8] To date these have been grounded in evidence from a general population. Although the benefits of not smoking during pregnancy are unlikely to be any different for Aboriginal mothers from the general population, quantifying the benefits of not smoking among Aboriginal mothers may be regarded as more relevant by this population and thus have the potential to influence smoking cessation. The benefits of not smoking during pregnancy are well established [9-13], but no previous studies have demonstrated associations between not smoking in pregnancy and positive pregnancy outcomes *among* Aboriginal women. This study aims to compare pregnancy outcomes of mothers who reported not smoking during pregnancy with those who reported any smoking during pregnancy from the Aboriginal population of NSW. Findings from this study will provide the most relevant evidence to date for pregnant Aboriginal women.

Methods

Study population and data sources

The study population consisted of all singleton babies born to Aboriginal women residing in NSW between 1 January 2010 and 31 December 2014 and their mothers. This population-based retrospective cohort study used linked data from routinely collected NSW datasets. The study population was identified from all records in the NSW Perinatal Data Collection ('birth data') for the period 1 January 2010 to 31 December 2014. All births in the population, including births at NSW public and private hospitals and home births are recorded in the birth data. This surveillance system includes all live births and stillbirths of at least 400 grams birthweight or at least 20 weeks gestation.[14]

All deaths within NSW are registered in the Registry of Births, Deaths and Marriages and fact of death was retrieved from these data between 1 January 2010 and 31 December 2015. Public and private hospital admission records were drawn from the NSW Admitted Patient Data Collection ('hospital data')

for admissions from 1 September 2009 to 31 December 2014. An additional 4 months of hospital data were retrieved prior to the start of the study period to allow for admissions to hospital for births early in 2010. Diagnoses coded in the hospital data are applied according to the International Classification of Diseases, Australian Modification (ICD-10-AM). Records within and across all datasets were probabilistically linked using personal identifiers by the NSW Centre for Health Record Linkage with an estimated false linkage rate of less than 5 per 1,000 records.[15] Hospital birth records were those where the birth was recorded to have occurred between the mother's admission and discharge dates using the linked birth data. It's estimated that 96% of records from the birth data link to the mother's and infant's hospital records from the birth.[16]

Aboriginal women were defined as those who were recorded as Australian Aboriginal in the birth data or who were assigned Aboriginal status according to the Enhanced Reporting of Aboriginality (ERA) algorithm.

Enhanced Reporting of Aboriginality (ERA)

It is widely acknowledged that Aboriginal status is under-recorded on routinely collected health datasets nationwide.[17] Enhancement of reporting of Aboriginal people using linked records creates a statistical construct that results in improved information about Aboriginal people. It does not define a person as being Aboriginal, nor does it replace efforts to improve the overall quality of recording Aboriginal status at the point of care.

Information surrounding individuals' Aboriginal status was pooled via linkage of the birth data, NSW Registry of Births, Deaths and Marriages birth registrations, hospital data and the NSW Emergency Department Data Collection. Using this information, a weight of evidence surrounding a woman's Aboriginal status was determined by a multistage median algorithm.[18] Since multiple datasets were used and some women had multiple records in each of these datasets, the algorithm initially assigned a separate status for each woman and dataset. Aboriginal or Torres Strait Islander status was assigned to a mother if: one or two linked records were available and at least one reported her as Aboriginal; three or more linked records were available and at least two reported her as Aboriginal. A comparable algorithm using dataset-specific statuses instead of records was used to determine the inclusion of each woman in the study population.

The enhanced reporting of Aboriginality is a technique used by many research groups.[19-21] Although this combination of datasets and algorithm has not been used before, similar methods have been found to minimise the risk of incorrect inclusion while capturing more women than simply relying on a single record.[22] Details on the algorithm, the data used and the mothers identified through the ERA have been described in more detail elsewhere.[23]

Exposure

The exposure of interest for this study was not smoking at any time during pregnancy. Mothers who reported not smoking during pregnancy will henceforth be referred to as non-smokers and those who reported any smoking during pregnancy are referred to as smokers. To increase ascertainment, birth data and mother's hospital birth record(s) were used to assign smoking status. If the birth data indicated that a mother smoked at any time during her pregnancy and/or recorded her as a current smoker within

the hospital birth record(s) (according to the ICD-10-AM diagnosis codes Z72.0 and F17) then she was considered to be a smoker. The sensitivity and specificity of current smoking from the most recent separation in the hospital data is estimated to be 58.5% and 98.4% respectively.[24] Where a mother had multiple hospital records associated with the birth and those records contradicted each other according to smoking status, her smoking status defaulted to that recorded in the birth data.

Outcomes

Maternal outcomes were identified using the birth data and the mother's hospital birth record and included two binary outcomes: severe maternal morbidity and inter-hospital transfer. Severe maternal morbidity was defined using a validated composite indicator that captures a broad range of diagnoses and procedures such as cardiac arrest, renal failure or assisted ventilation.[25] Mothers requiring inter-hospital transfer were defined as those with at least one record with a mode of separation indicating transfer or where multiple hospitalisation records were present with differing hospital codes.

Perinatal outcomes, including birth outcomes and those occurring within the first 28 days of life for the baby were retrieved from the birth data and the baby's linked hospital and birth registration records. These included perinatal death (stillbirth and neonatal death), preterm birth (<37 completed weeks of gestation), and small for gestational age (birth weight <3rd and/or 10th percentile for sex and age [26]). Admissions to a special care nursery (SCN) or neonatal intensive care unit (NICU) were assessed among an eligible population of babies born in a hospital classified as level 3 or above (NSW Ministry of Health's *Guide to the Role Delineation of Hospitals*) or a private hospital. Severe neonatal morbidity, measured according to a validated composite indicator [27], was assessed among all live births.

Covariates

Maternal age and parity were reported according to the birth data. The mother's chronic conditions, hypertension and diabetes information were obtained from the birth data and the hospital birth record(s). We used the broad category of any hypertension rather than the specific categories of chronic hypertension, pregnancy hypertension, preeclampsia and eclampsia, as there is known misclassification among types of hypertension [28]. The NSW ranking of the Australian Bureau of Statistics (ABS) 2011 Socio-Economic Index for Areas (SEIFA) Index of Relative Socio-Economic Disadvantage (IRSD) and the 2011 Remoteness Areas were used to assess the mother's relative socio-economic status and access to services respectively. Where available, the mother's 2011 Statistical Local Area (SLA) according to her birth data was used to assign these measures. Otherwise, and for all babies born in 2010, the mother's 2010 SLA was used. Hospital type is an indicator of the size of a hospital and its location (urban or regional)[29] and was assigned using the hospital code recorded in the birth data.

Statistical analyses

The study population was described using frequencies and percentages by potential confounders and the mother's smoking status. Summary statistics were calculated by mother's smoking status to investigate the associations between smoking during pregnancy and maternal and child outcomes. To estimate the unadjusted and adjusted relative risk (RR) of binary outcomes while accounting for the correlation within the data (some mothers had more than one baby during the study period), an extension to the modified Poisson regression [30] was used with an unstructured correlation matrix. Those observations where data were missing for an outcome were excluded from analysis for that

outcome. SAS for Windows 9.4 (SAS Institute, Cary, NC, USA) was used for all data manipulation and analysis.

In view of the established causal relationship between smoking and adverse perinatal outcomes, we quantified the proportion and number of adverse perinatal outcomes that would not have occurred in this population if all the mothers had been non-smokers during pregnancy. We used the formula: PAF $=[P_s(RR_s-1)]/RR_s$, where P_s is the proportion of babies with the outcome whose mothers smoked and RR_s is the adjusted RR for smokers. The RR_s is the inverse of the RR for non-smokers.

Patient and public involvement

An Aboriginal advisory committee was consulted prior to submission of the study proposal to ethics committees and throughout the process. The committee provided guidance on presentation and interpretation of results. It was of particular importance to members of the committee that the results were framed positively, ie the *benefits* of not smoking, rather than the risks of smoking. It was also important to committee members that all comparisons were among Aboriginal women and that Aboriginal women were not compared with non-Aboriginal women. There are plans to develop culturally appropriate educational material based on the results of this research and in collaboration with Aboriginal Health Workers and others involved in the care of Aboriginal women who are pregnant or may be planning a pregnancy.

Results

Following exclusion of duplicates (n=76), a total of 487,388 babies were born to 379,116 mothers in NSW and were assessed for inclusion in this study. Records for 16,904 babies born to 12,720 mothers who were recorded as Aboriginal in the birth data were available for analysis. An additional 1,921 babies born to 1,624 mothers were identified as eligible for inclusion in the study using the ERA. Of the total 18,825 babies, 557 were from a multiple birth and 114 were born to mothers who were not residents of NSW. These babies did not meet the eligibility criteria and were excluded. Thus the final study population consisted of 18,154 singleton babies born to 13,477 Aboriginal mothers. Figure 1 outlines the flow of participants in this study.

Among the study population, 9,235 (51%) babies were born to non-smoking mothers and 8,919 (49%) were born to smoking mothers (Table 1). Only two percent of all linked records had contradictory smoking statuses from the birth and hospital data. For comparison, when smoking status was assigned only according to the birth data, 52% of babies were born to non-smoking mothers and 48% were born to smoking mothers. Mothers who reported not smoking at any time during their pregnancy were generally less disadvantaged than their smoking counterparts; approximately 8.1% of non-smoking mothers were in the highest SEIFA quintile, compared to just 4.1% of smoking mothers. Non-smoking mothers were older, lived in less remote regions and had fewer previous pregnancies than smoking mothers. The number of non-smoking mothers with hypertension (1,106) was almost double that of smoking mothers (578) and slightly more non-smoking mothers had diabetes (Table 1).

The majority (70%) of mothers only had one baby during the study period however a substantial number had multiple: 25% had two, 4.4% had three and 0.4% had four. For 564 (4%) mothers, their smoking

status changed between pregnancies, 6,814 (53%) mothers reported not smoking in all pregnancies during the study period and 6,099 (47%) consistently reported smoking. Of the 564 mothers whose smoking status changed between pregnancies, 266 (47%) changed from smoking to non-smoking, 271 (48%) changed from non-smoking to smoking in all subsequent pregnancies and 27 (5%) moved between smoker and non-smoker status.

The rate of severe maternal morbidity was low (<3%) and not significantly different between smoking and non-smoking mothers (Table 2). The rate of inter-hospital transfer was lower in the non-smoking group at 3.7% compared with the smoking group (5.1%), with an adjusted relative risk of RR=0.76 (95% CI 0.66, 0.89).

Adverse perinatal outcomes occurred less frequently among babies born to non-smoking mothers (Table 3). Perinatal deaths were rare in both populations however the rate was lower in the non-smoking group with perinatal death occurring in 1.0% of babies born to non-smoking mothers, compared to 1.8% in smoking mothers. Also, severe neonatal morbidity and admission to SCN or NICU was less frequent in babies born to non-smoking mothers when compared to those born to smoking mothers. Overall, the gestational age of babies from the non-smoking group was closer to term than those from the smoking group; more babies born to non-smoking mothers (66%) were born between 39 and 41 weeks than those born to smoking mothers (55%). Preterm birth was considerably less frequent among babies born to mothers who did not smoke during pregnancy; 8.2% of births to non-smoking mothers were preterm compared to 14% from smoking mothers. Similarly, babies born to non-smoking mothers were less often small for gestational age, with 2.0% and 7.0% of these babies having a birthweight below the 3rd and 10th percentiles respectively compared to 7.3% and 20% of babies of smoking mothers. All relative risks were less than 1, suggesting a reduced risk of all adverse outcomes among babies born to non-smoking mothers when compared to those born to smoking mothers. Of note were the relative risks for perinatal death (RR=0.58 95% CI 0.44, 0.76), preterm birth (RR=0.58 95% CI 0.53, 0.64) and small for gestational age (<10th percentile; RR=0.35 95% CI 0.32, 0.39). As indicated by the PAFs (%) in Table 3, more than a quarter of the perinatal deaths and preterm births were attributable to smoking and almost half the small for gestational age births. Among this cohort of babies, this equates to 68 perinatal deaths, 540 preterm births and 1,131 small for gestational age (<10th percentile) babies attributable to smoking.

Discussion

This study of a recent population of pregnant Aboriginal women clearly demonstrates improved pregnancy outcomes among Aboriginal mothers who reported not smoking during pregnancy when compared to Aboriginal mothers who reported smoking during pregnancy. Benefits of not smoking were found for all the perinatal outcomes we examined. We also found non-smoking mothers had a 24% lower risk of being transferred to another hospital during the birth admission than smoking mothers of similar demographics. Inter-hospital transfers may be due to complications arising before, during or after the birth. This means women are less likely to be away from their family and country during this challenging time. Although a slightly lower risk of severe maternal morbidity was found in the non-smoking group, there was not sufficient evidence to suggest a true difference existed as the confidence

interval included 1 (RR=0.92, 95% CI 0.77–1.11). Other risk factors may be more strongly associated with severe maternal morbidity than smoking.

Among babies born to mothers of a similar age, with similar pre-existing conditions (any diabetes or hypertension), parity and socio-economic status, those with a non-smoking mother had a 42% less risk of perinatal death and preterm birth, 65% less risk of being small-for-gestational age (<10th percentile), 30% less risk of severe neonatal morbidity, and 33% less risk of being admitted to a SCN or NICU than those born to a mother who smoked at any time during her pregnancy. The reductions in adverse outcomes for babies born to non-smoking mothers were statistically and clinically significant and remained so even after adjustment. Encouragingly, despite some rates being marginally higher, overall very little difference exists between the rates of adverse perinatal outcomes among the non-smoking Aboriginal mothers in this study and the overall NSW population of mothers giving birth in 2014, of whom 9.3% reported smoking and 3.9% were recorded as Aboriginal.[14] The high PAFs for the adverse perinatal outcomes highlight the enormous potential for health improvements in this population. Over a quarter of the perinatal deaths and preterm births were attributable to smoking. Being born small for gestational age is associated with short and long-term health sequelae, and these risks are even greater for babies born with a birthweight less than the third percentile for gestational age and sex. The PAF(%) was highest (57%) for being born with a birthweight less than the third percentile. Almost half (48%) the babies born small for gestational age (<10th percentile) could have had a normal birthweight (≥10th percentile) in the absence of smoking. Our results are consistent with a recent study of a cohort of 697,003 children born in Scotland from 1997–2009 [31]. In addition to the adverse perinatal outcomes attributable to smoking, this study followed children until five years of age and found that maternal smoking during pregnancy also increased the risk of the child being hospitalized with acute respiratory infections, bronchiolitis, asthma and bacterial meningitis [31].

As expected, and similar to findings from other studies, [31,32] mothers from the non-smoking group were less disadvantaged, older, resided in less remote regions and had fewer previous pregnancies than those from the smoking group. Diabetes and hypertension were more prevalent among non-smoking mothers than smoking mothers. The small difference in prevalence of diabetes (8.7% vs 6.5%) could be due to the non-smoking group being slightly older than the smoking group. However the prevalence of hypertension in non-smoking mothers was almost double that of smoking mothers (12% vs 6.5%). Whilst this finding may surprise some, it is consistent with findings from previous studies [33-36]. A systematic review of 48 studies concluded that smoking during pregnancy reduces the risk of preeclampsia by up to 50% and that there is a dose-response relationship [34]. Similar results have been reported when the outcome includes gestational hypertension as well as preeclampsia, and the protective effect appears to continue even after women quit smoking later in pregnancy [36]. This protective effect may be mediated via the biological effects of carbon monoxide that is formed during smoking [35]. However, when preeclampsia does occur, the outcomes are much worse for babies whose mothers smoked [33]. Although preeclampsia is associated with adverse pregnancy outcomes, and smoking reduces the incidence of preeclampsia, the net effect of smoking is still a worsening of pregnancy outcomes and there are dose-dependent increases in perinatal deaths and SGA babies among mothers who smoke [33]. Hence these findings in no way indicate any benefit to mothers or babies if the mother smokes during pregnancy.

As well as being a national health priority in Australia, reducing smoking during pregnancy is a key performance indicator in the annual service agreements between the NSW Ministry of Health and Local Health Districts.[37] As part of this commitment, the Quit for New Life program was established in 2013 with the aim to support women having an Aboriginal baby to quit smoking. The program was integrated into Aboriginal Maternal and Infant Health Services and has supported over 2,500 pregnant women, 950 postnatal women and 1,650 cohabitants in their quit attempt.[38] However, further efforts including health professional training, expansion to other maternal health services and community programs, and improved data collection and reporting are required to reduce the prevalence of smoking in pregnancy in this population. Investment to discourage women, especially young women, from taking up smoking and encouraging and appropriately supporting smokers to quit need to remain priorities.

Health professionals have a critical role in communicating the benefits of not smoking during pregnancy found in this study. However some practitioners perceive intervention to be ineffective and thus may not raise this issue with their patients.[39] The highly relevant evidence from this study may increase the salience of the issue and provide further motivation for health professionals to consistently ask and advise about smoking.

While the health impacts of smoking on maternal and child health are well known [9-13], this study provides local information that can be used to further engage Australian health professionals and community members on the benefits of not smoking. Building on the strength and resilience of Aboriginal people is an important foundation for efforts to reduce smoking among this population.[40] Using local evidence on the *benefits* of not smoking during pregnancy has the potential to re-frame health messages for women, their families and communities and to mobilise community action to achieve better health outcomes.

Strengths and limitations

This is the first study we are aware of that examines associations between smoking in pregnancy and adverse pregnancy outcomes exclusively among Aboriginal and/or Torres Strait Islander women. This was a large population-based study. Using data linkage, we were able to capture more women through the ERA, further increasing our sample size. Despite the unavailability of information surrounding some potential confounders, including individual level socioeconomic status, our findings were consistent with those among other populations from the literature [9-13]. Limited data on the heaviness of smoking during pregnancy meant that potential dose effects could not be calculated. However, new data around quitting in pregnancy is available from 2016 onward so there is potential for future work to examine this phenomenon further. Similarly, no information was available on the mother's history of smoking, exposure to environmental tobacco smoke or alcohol consumption and so effects from longer term smoking and potential confounding from alcohol consumption could not be accounted for. A lack of data surrounding history and heaviness of smoking means that the treatment effects estimated in this study are likely to be biased toward the null and thus underestimate the true benefits of not smoking in pregnancy. Under-ascertainment of smoking status would similarly bias toward the null. Mothers who smoked in one pregnancy but not in a subsequent pregnancy were classified as non-smokers in the subsequent pregnancy. If these mothers were more likely to have worse outcomes in the subsequent

pregnancy compared with never smoking mothers, this would also bias towards the null. However, any effect would be negligible due to the very low numbers (<2% of the study population).

Conclusions

Babies born to Aboriginal mothers who did not smoke during pregnancy were at a significantly reduced risk of adverse perinatal outcomes compared to those born to smoking mothers of similar demographics. Rates of these adverse outcomes among Aboriginal women who did not smoke were very similar to those among the general NSW population.

These results reinforce the importance of targeted smoking cessation policy for Aboriginal women. Barriers to smoking cessation in this population are complex and it is vital that this evidence is provided concurrently with sufficient support to enable Aboriginal women to quit smoking. Distributing this information in isolation runs the risk of furthering shame and stress experienced by pregnant women and may discourage them from seeking further help, highlighting the importance of systematic approaches to encourage and support Aboriginal women to quit smoking.

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Footnotes

Contributors

JMitchell and AM had the initial idea for this study. ST wrote the study proposal and was responsible for the ethics application and revisions to the manuscript. CM undertook all analyses, with guidance from ST, II and DR, and drafted the manuscript. JF, JMorris, JMitchell, AM and ST all contributed to the design of the study and, with DM, the interpretation of the results. All authors commented on drafts and read and approved the final manuscript. The corresponding author attests that all listed authors meet authorship criteria and that no others meeting the criteria have been omitted. CM and ST are guarantors.

Statement of Conflicts of Interest

All authors have completed the ICMJE uniform disclosure form at www.icmje.org/coi_disclosure.pdf and declare: CM and ST's salaries came from a Prevention Research Support Program grant from the NSW Ministry of Health, no other relationships or activities that could appear to have influenced the submitted work.

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Ethics approval

Ethics approval for this study was given by the Aboriginal Health and Medical Research Council of New South Wales, Australia (HREC reference number: 1326/17) and was exempt from informed consent requirements as there was no contact with the study population and the authors only had access to de-identified data.

Transparency statement

The lead author affirms that the manuscript is an honest, accurate, and transparent account of the study being reported; that no important aspects of the study have been omitted; and that any discrepancies from the study as planned have been explained.

Data sharing

No additional data are available.

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Figure caption:

Figure 1 Flow diagram of mothers and babies eligible for inclusion in the final study population.

Table 1 Demographics at the time of birth of all Aboriginal or Torres Strait Islander mothers who gave birth to at least one singleton baby in NSW between 2010 and 2014 reported for all births and by smoking status during pregnancy.

	All births		Non-smoking		Smoking	
	N = 18,154		N_{ns} = 9,235 (51%)		N_s = 8,919 (49%)	
Year of baby's birth	**n**	**%**	**n**	**%**	**n**	**%**
2010	3,487	19	1,740	50*	1,747	50*
2011	3,380	19	1,638	48*	1,742	52*
2012	3,680	20	1,833	50*	1,847	50*
2013	3,716	20	1,944	52*	1,772	48*
2014	3,891	21	2,080	53*	1,811	47*
Maternal age						
Under 20	3,214	18	1,568	17	1,646	19
20–24	6,014	33	2,983	32	3,031	34
25–29	4,608	25	2,381	26	2,227	25
30–34	2,729	15	1,455	16	1,274	14
35 and over	1,589	8.8	848	9.2	741	8.3
Total	18,154	100	9,235	100	8,919	100
Parity						
0	6,259	35	3,720	40	2,539	29
1	4,709	26	2,589	28	2,120	24
2	3,107	17	1,490	16	1,617	18
3+	4,072	22	1,431	16	2,641	30
Total	18,147	100	9,230	100	8,917	100
SEIFA IRSD quintiles**						
1st – most disadvantaged	4,827	27	2,131	23	2,696	30
2nd	3,674	20	1,887	21	1,787	20
3rd	5,375	30	2,806	31	2,569	29
4th	3,068	17	1,617	18	1,451	16
5th – least disadvantaged	1,115	6.2	748	8.1	367	4.1
Total	18,059	100	9,189	100	8,870	100
Remoteness area						
Major cities	4,193	23	2,246	24	1,947	22
Inner regional	6,147	34	3,310	36	2,837	32
Outer regional	6,097	34	2,966	32	3,131	35
Remote	1,027	5.7	421	4.6	606	6.8
Very remote	595	3.3	245	2.7	350	4.0
Total	18,059	100	9,188	100	8,871	100

Hospital level						
Tertiary	4,099	23	2,108	23	1,991	22
Small and medium urban	308	1.7	178	1.8	130	1.5
Large urban	2,895	16	1,607	9	1,288	14
Small regional	3,441	19	1,519	16	1,922	22
Medium regional	3,042	17	1,550	17	1,492	17
Large regional	3,897	21	1,896	21	2,001	22
Private	336	1.7	323	3.2	13	0.2
Other	136	0.7	54	0.6	82	0.9
Total	18,154	100	9,235	100	8,919	100
Chronic conditions^						
Yes	343	1.9	147	1.6	196	2.2
Total	18,154	100	9,235	100	8,919	100
Any hypertension						
Yes	1,684	9.3	1,106	12	578	6.5
Total	18,154	100	9,235	100	8,919	100
Any diabetes						
Yes	1,413	7.8	804	8.7	609	6.5
Total	18,154	100	9,235	100	8,919	100

* Percentage of all births within each year.

**Socio-Economic Index for Areas – Index of Relative Socio-Economic Disadvantage (SEIFA IRSD). When ranking areas within NSW in order of their relative disadvantage, the lowest 20% (most disadvantaged) fall in the 1st quintile and the highest 20% (least disadvantaged) fall in 5th quartile.

^Chronic conditions encompasses renal, cardiac, thyroid, asthma, psychiatric, and other autoimmune conditions[41].

Table 2 Frequencies of maternal outcomes at the time of birth of all Aboriginal mothers by smoking status during pregnancy.

	All births		Non-smoking		Smoking		Unadjusted	Adjusted
	N = 18,154		N_{ns} = 9,235		N_s = 8,919			
Severe maternal morbidity	**n**	**%**	**n**	**%**	**n**	**%**	**RR (95% CI)**	**RR (95% CI)**
Yes	523	2.9	257	2.8	266	3.0	0.94 (0.79, 1.12)	0.92* (0.77, 1.11)
Inter-hospital transfer								
Yes	793	4.4	337	3.7	456	5.1	0.73 (0.63, 0.84)	0.76** (0.66, 0.89)

*adjusted for maternal age, any hypertension, any diabetes, parity and socio-economic status (SEIFA).
** adjusted for maternal age, any hypertension, any diabetes, parity and remoteness area.

Table 3 Frequencies of perinatal outcomes among all babies born to Aboriginal or Torres Strait Islander mothers by maternal smoking status.

	NSW population [14]	All births		Non-smoking		Smoking		Unadjusted	Adjusted*	PAF (%)
		N = 18,154		N_{ns} = 9,235		N_s = 8,919				
Preterm birth (<37 wks)	**%**	**n**	**%**	**n**	**%**	**n**	**%**	**RR (95% CI)**	**RR (95% CI)**	
Yes	8	2,045	11	760	8.2	1,285	14	0.59 (0.54, 0.64)	0.58 (0.53, 0.64)	26
Total		18,154	100	9,235	100	8,919	100			
Small for gestational age (<3rd population percentile)										
Yes	3	835	4.6	183	2.0	652	7.3	0.28 (0.23, 0.32)	0.27 (0.23, 0.32)	57
Total		18,132	100	9,229	100	8,903	100			
Small for gestational age (<10th population percentile)										
Yes	10	2,381	13	641	7.0	1,740	20	0.36 (0.33, 0.39)	0.35 (0.32, 0.39)	48
Total		18,132	100	9,229	100	8,903	100			
Severe neonatal morbidity		**Among live births only**								
Yes	5	1,470	8.2	636	6.9	834	9.5	0.74 (0.67, 0.81)	0.70 (0.63, 0.77)	17
Total		17,978	100	9,169	100	8,809	100			
Admission to SCN or NICU^										
Yes	15	3,957	22	1,645	18	2,312	26	0.70 (0.66, 0.75)	0.66 (0.63, 0.70)	20
Total		17,809	100	9,059	100	8,750	100			
Perinatal death		**Rate per 1,000 total births**								
Yes	8	254	14	92	10**	162	18**	0.54 (0.42, 0.70)	0.58 (0.44, 0.76)	27
Stillborn	6	162		60	6.5**	102	11**	0.57 (0.41, 0.78)	0.60 (0.43, 0.84)	20
		Rate per 1,000 live births								
Neonatal death	2	92		32	3.5^^	60	6.8^^	0.50 (0.33, 0.78)	0.54 (0.34, 0.86)	30

*adjusted for maternal age, any hypertension, any diabetes, parity and socio-economic status (SEIFA).
^Admission to Special Care Nursery (SCN) or Neonatal Intensive Care Unit (NICU) was restricted to those babies recorded as being born in a hospital of maternity service level 3 or higher or a private hospital.
**Rate per 1,000 total births
^^ Rate per 1,000 live births
PAF, Population Attributable Fraction

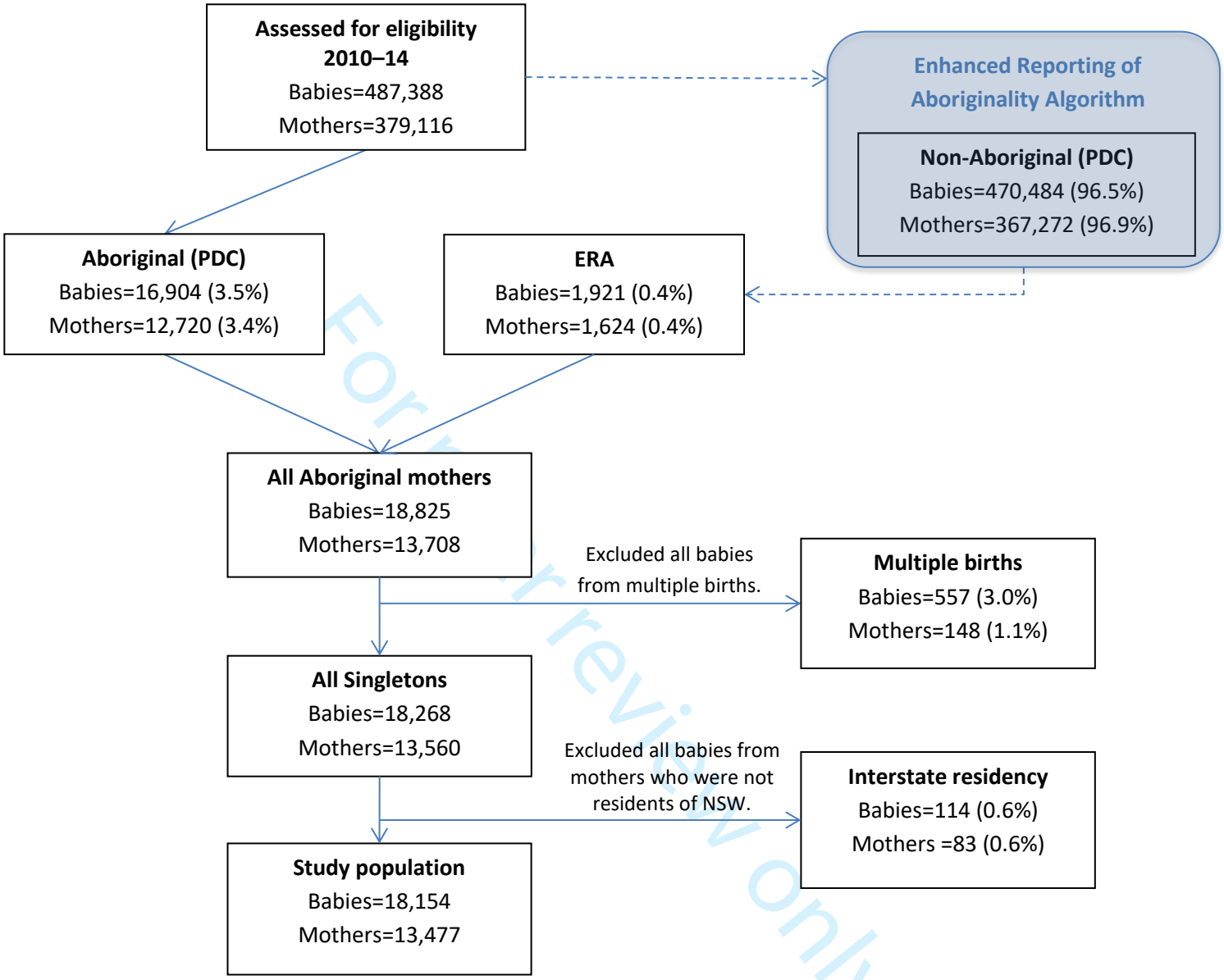

Figure 1 Flow diagram of mothers and babies eligible for inclusion in the final study population.

STROBE Statement—Checklist of items that should be included in reports of ***cohort studies***

Manuscript for: Benefits of not smoking during pregnancy for Australian Aboriginal and Torres Strait Islander women and their babies: a retrospective cohort study using linked data

	Item No	Recommendation	Page No
Title and abstract	1	(*a*) Indicate the study's design with a commonly used term in the title or the abstract	1
		(*b*) Provide in the abstract an informative and balanced summary of what was done and what was found	1
Introduction			
Background/rationale	2	Explain the scientific background and rationale for the investigation being reported	2
Objectives	3	State specific objectives, including any prespecified hypotheses	2
Methods			
Study design	4	Present key elements of study design early in the paper	2
Setting	5	Describe the setting, locations, and relevant dates, including periods of recruitment, exposure, follow-up, and data collection	2
Participants	6	(*a*) Give the eligibility criteria, and the sources and methods of selection of participants. Describe methods of follow-up	2-3
		(*b*) For matched studies, give matching criteria and number of exposed and unexposed	2-3
Variables	7	Clearly define all outcomes, exposures, predictors, potential confounders, and effect modifiers. Give diagnostic criteria, if applicable	3-4
Data sources/ measurement	8*	For each variable of interest, give sources of data and details of methods of assessment (measurement). Describe comparability of assessment methods if there is more than one group	3-4
Bias	9	Describe any efforts to address potential sources of bias	4
Study size	10	Explain how the study size was arrived at	2
Quantitative variables	11	Explain how quantitative variables were handled in the analyses. If applicable, describe which groupings were chosen and why	4
Statistical methods	12	(*a*) Describe all statistical methods, including those used to control for confounding	4-5
		(*b*) Describe any methods used to examine subgroups and interactions	
		(*c*) Explain how missing data were addressed	5
		(*d*) If applicable, explain how loss to follow-up was addressed	
		(*e*) Describe any sensitivity analyses	
Results			
Participants	13*	(a) Report numbers of individuals at each stage of study—eg numbers potentially eligible, examined for eligibility, confirmed eligible, included in the study, completing follow-up, and analysed	Fig 1
		(b) Give reasons for non-participation at each stage	Fig 1
		(c) Consider use of a flow diagram	Fig 1
Descriptive data	14*	(a) Give characteristics of study participants (eg demographic, clinical, social) and information on exposures and potential confounders	Table 1
		(b) Indicate number of participants with missing data for each variable of interest	Table 1,2,3
		(c) Summarise follow-up time (eg, average and total amount)	
Outcome data	15*	Report numbers of outcome events or summary measures over time	Table

			2,3
Main results	16	(*a*) Give unadjusted estimates and, if applicable, confounder-adjusted estimates and their precision (eg, 95% confidence interval). Make clear which confounders were adjusted for and why they were included	Table 2,3
		(*b*) Report category boundaries when continuous variables were categorized	
		(*c*) If relevant, consider translating estimates of relative risk into absolute risk for a meaningful time period	
Other analyses	17	Report other analyses done—eg analyses of subgroups and interactions, and sensitivity analyses	
Discussion			
Key results	18	Summarise key results with reference to study objectives	6
Limitations	19	Discuss limitations of the study, taking into account sources of potential bias or imprecision. Discuss both direction and magnitude of any potential bias	8
Interpretation	20	Give a cautious overall interpretation of results considering objectives, limitations, multiplicity of analyses, results from similar studies, and other relevant evidence	6,7
Generalisability	21	Discuss the generalisability (external validity) of the study results	8
Other information			
Funding	22	Give the source of funding and the role of the funders for the present study and, if applicable, for the original study on which the present article is based	10

*Give information separately for exposed and unexposed groups.

Note: An Explanation and Elaboration article discusses each checklist item and gives methodological background and published examples of transparent reporting. The STROBE checklist is best used in conjunction with this article (freely available on the Web sites of PLoS Medicine at http://www.plosmedicine.org/, Annals of Internal Medicine at http://www.annals.org/, and Epidemiology at http://www.epidem.com/). Information on the STROBE Initiative is available at http://www.strobe-statement.org.