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Benefits of not smoking during pregnancy for non-Aboriginal women and their babies in New South Wales, Australia: a record linkage study

Jillian A. Patterson[1,2,*], Aaron Cashmore[3,4], Sally Ioannides[3,5], Andrew J. Milat[3,4], Tanya A. Nippita[1,2], Jonathan M. Morris[1,2], and Siranda Torvaldsen[1,2,5]

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[1]The University of Sydney Northern Clinical School, Women and Babies Research, St Leonards, 2065, New South Wales, Australia
[2]Northern Sydney Local Health District, Kolling Institute, New South Wales, Australia
[3]NSW Ministry of Health, Centre for Epidemiology and Evidence, St Leonards, 2065, New South Wales, Australia
[4]The University of Sydney School of Public Health, Faculty of Medicine and Health, Sydney, 2006, New South Wales, Australia
[5]School of Population Health, UNSW, Kensington, 2052, New South Wales, Australia

Abstract

Background

Smoking rates among pregnant women in New South Wales (NSW) have plateaued at 8–9%. To inform relevant smoking reduction efforts, we aimed to quantify the benefits of *not* smoking during pregnancy for non-Aboriginal NSW mothers and their babies. The benefits of *not* smoking during pregnancy for NSW Aboriginal mothers have previously been described. These data are important inputs in modelling health and economic impacts of smoking cessation interventions.

Methods

This population-based cohort study used linked-data from routinely collected data sets. Not smoking during pregnancy was the exposure of interest among all NSW non-Aboriginal women who became mothers of singleton babies in 2012–2016. Unadjusted and adjusted relative risks (aRR) were used to examine associations between not smoking during pregnancy and adverse outcomes including severe morbidity, inter-hospital transfer, perinatal death, preterm birth and small-for-gestational age. Population attributable fractions (PAFs) were calculated to quantify adverse perinatal outcomes avoided in the population if all mothers were non-smokers.

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 = 0.68, 95%CI 0.61–0.76), preterm birth (aRR = 0.58, 95%CI 0.56–0.61) and small-for-gestational age (aRR = 0.48, 95%CI 0.47–0.50). PAFs(%) were 3.9% for perinatal death, 5.6% for preterm birth and 7.3% for small-for-gestational-age. Compared with women who smoked during pregnancy (n = 36,518), those who did not smoke (n = 413,072) had a lower risk of suffering severe maternal morbidity (aRR = 0.87, 95%CI 0.81–0.93) and being transferred to another hospital (aRR = 0.92, 95%CI 0.86–0.99).

Conclusions

Mothers who reported not smoking during pregnancy had a small reduction in their risk of morbidity and of being transferred to another hospital whilst their babies had substantially reduced risks of all adverse perinatal outcomes. Results have implications for clinician training, clinical care standards, and performance management.

Keywords

smoking cessation; pregnancy; stillbirth; neonatal outcomes

*Corresponding Author:
Email Address: jillian.patterson@sydney.edu.au (Jillian A. Patterson)

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Introduction

The NSW State Health Plan 'Towards 2021' aimed to reduce smoking rates among pregnant women in NSW by 0.5% per year, to 7.5% in 2015 [1]. Whilst smoking rates among pregnant women in NSW declined from 22.1% in 1994 to 8.3% in 2016 [2], the target of 7.5% has not been met and there are concerns that the rates have plateaued.

Although the risks of smoking during pregnancy are well established, 8.8% of pregnant women in NSW reported smoking in 2019 [3]. A recent study clearly demonstrated the benefits of not smoking during pregnancy among NSW Aboriginal women and showed that babies born to Aboriginal mothers who did not smoke during pregnancy were at a significantly reduced risk of adverse perinatal outcomes compared to infants born to similar mothers who did not smoke [4]. Results from that study are currently being used to inform smoking cessation materials for Aboriginal women and their families. As there are large differences in smoking rates between Aboriginal and non-Aboriginal mothers, smoking cessation strategies which may be effective for Aboriginal women may have little or no effect in non-Aboriginal women. A need for similar evidence on benefits of not smoking during pregnancy among the remainder of the NSW population has been identified. This evidence is needed in both system level planning and individual patient counselling. Hence, this study aimed to quantify the benefits of *not* smoking during pregnancy for non-Aboriginal NSW mothers and their babies.

Methods

The study population was all singleton babies born to non-Aboriginal NSW mothers residing in NSW between 1 January 2012 and 31 December 2016, and their mothers. Births were identified from the NSW Perinatal Data Collection (birth data), which is a statutory record of all livebirths and stillbirth of at least 20 weeks gestation or 400g birthweight in NSW. Women who were recorded as Australian Aboriginal in the birth data or who were assigned Aboriginal status according to the Enhanced Reporting of Aboriginality algorithm used in the previous study [5] were excluded from this study.

The birth data were probabilistically linked with the Admitted Patient Data Collection (hospital data) and the Registry of Births, Deaths and Marriages deaths data (death data). Record linkage was performed by the NSW Centre for Health Record Linkage using personal identifiers, with de-identified data provided to researchers. The rate of false links was low (5 per 1000) [6], meaning it was rare that records belonging to different people were wrongly assessed as belonging to the same person. The hospital data contain information on diagnoses and procedures for all inpatient admissions to public and private hospitals for both mothers and infants coded according to the International Classification of Diseases version 10-Australian modification and the Australian Classification of Health Interventions [7]. The death data, recording fact of death for deaths registered within NSW, was used in conjunction with birth and hospital data to identify neonatal deaths.

The exposure of interest was absence of maternal smoking throughout the pregnancy ('Non-Smokers'), as opposed to any smoking during pregnancy ('Smokers'). Smoking was identified through self-report in the birth data and/or a diagnosis code indicating current smoking (Z72.0, F17) in the hospital record associated with the delivery. The sensitivity of current smoking from the most recent separation in the hospital data is estimated to be 58.5% and the specificity 98.4% [8].

Two maternal outcomes of interest were identified from the birth data and the hospital record(s) related to the delivery. Outcomes considered were a composite indicator of severe maternal morbidity which includes transfusion, assisted ventilation and organ failure (Supplementary Table 1 [9]) and inter-hospital transfer (reflecting the need for higher level care). Both these outcomes were binary.

Perinatal outcomes included those occurring at birth and within the first 28 days of life, and were identified from the hospital, birth and death data. Perinatal outcomes were preterm birth (<37 weeks gestation), birthweight less than the 3^{rd} and 10^{th} centiles for gestational age and sex [10], severe neonatal morbidity, and perinatal death (stillbirth and neonatal death) and its components. Severe neonatal morbidity was measured using a validated composite indicator [11] containing procedures and diagnoses associated with severe morbidity and was calculated amongst live births only (Supplementary Table 2).

Maternal age was obtained from the birth data. Other covariates included any hypertension and any diabetes and were obtained from the birth and hospital data. Socioeconomic status and remoteness were assigned based on the statistical local area of residence of the mother using the NSW ranking of the Australian Bureau of Statistics 2011 Socio-Economic Index for Areas (SEIFA) Index of Relative Socio-Economic Disadvantage and the 2011 Remoteness Areas. Hospitals were grouped according to birth volume, location and ownership [12].

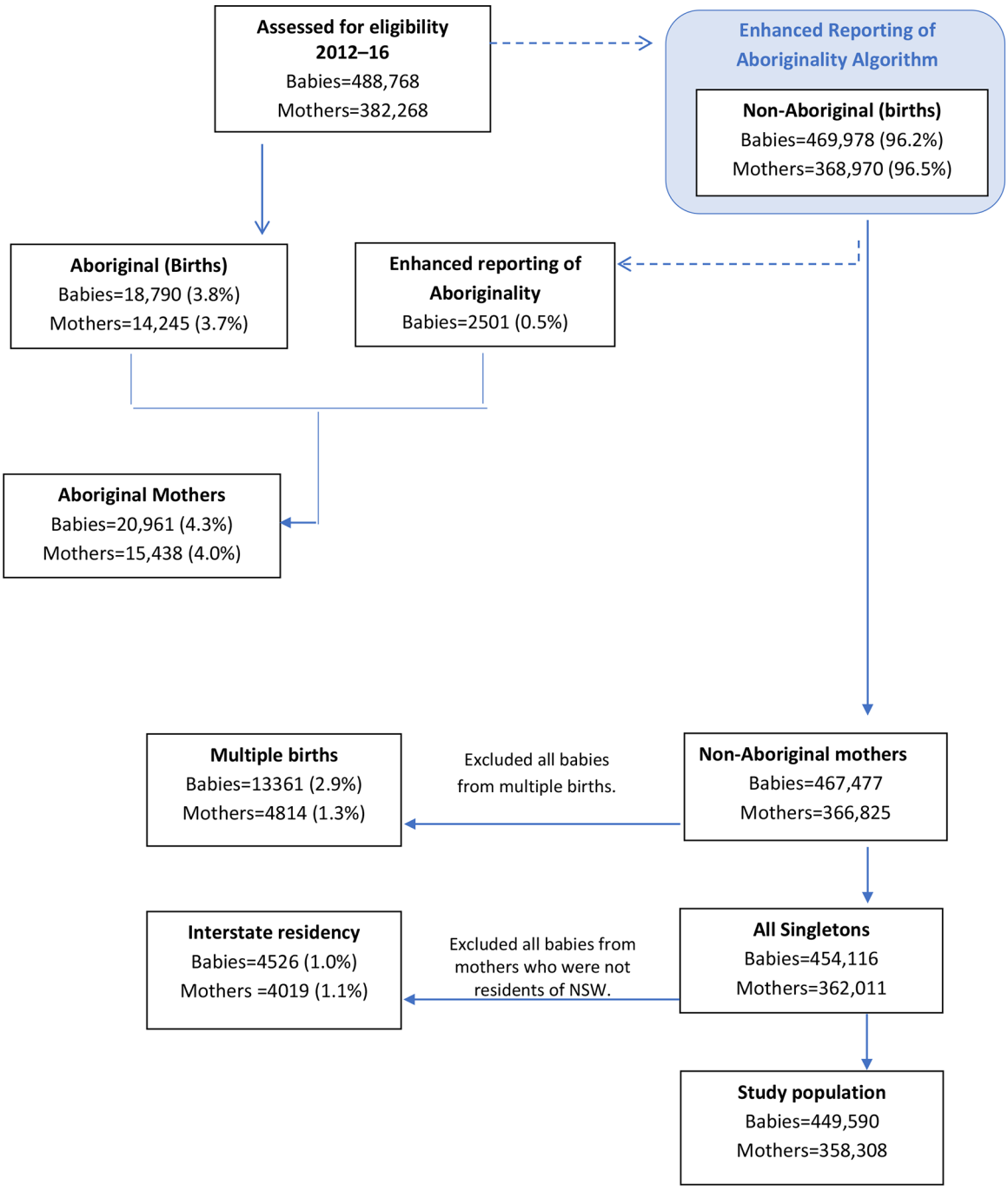
Unadjusted and adjusted relative risks were calculated using modified Poisson regression with robust error variances. All analysis was performed in SAS [13]. Given the established causal relationship between smoking and adverse perinatal outcomes, we also quantified the proportion of adverse perinatal outcomes that would not have occurred in this population if all the mothers had been non-smokers during pregnancy. We used the formula: PAF = [Ps(RRs-1)]/RRs, where Ps is the proportion of babies with the given outcome whose mothers smoked and RRs is the adjusted RR for smokers. The RRs is the inverse of the RR for non-smokers.

Results

Between 2012 and 2016 there were 488,768 babies born to 382,268 mothers in NSW. Of these, 20,961 (4.3%) babies were identified as having Aboriginal mothers (15,438 mothers). After restricting the population to singletons and NSW residents there were 449,590 babies born to 358,308 non-Aboriginal mothers (Figure 1).

Most (92%) mothers reported not smoking during their pregnancy and this proportion increased slightly over time, from 90.8% in 2012 to 92.8% in 2016. Mothers who reported not smoking in pregnancy were more likely to be older, be having their first baby, live in an area with the least disadvantage (i.e. more likely to be high socioeconomic

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



status), live in a city, and not suffer from any chronic conditions (Table 1). The same proportion (8%) of smoking and non-smoking mothers suffered from hypertension in their pregnancy, and a slightly greater proportion of non-smoking mothers had a diagnosis of diabetes than smoking mothers (12.4% vs 10.5%).

Overall rates of severe maternal morbidity and transfer to another hospital during the birth admission were low (<3%) and both outcomes were lower among non-smoking mothers than mothers who smoked (Table 2). These differences remained statistically significant after adjustment (Table 2). Not smoking during pregnancy was associated with a 13% reduction in risk of severe maternal morbidity (adjusted Relative Risk, aRR: 0.87 (0.81,0.93)) and 8% lower risk for transfer during the birth admission (aRR 0.92 (0.86,0.99)).

Babies born to non-smoking mothers had substantially lower risks of all adverse perinatal outcomes, compared with babies born to mothers who reported smoking during their pregnancy (Table 3). These differences remained statistically significant after adjusting for maternal age, socioeconomic status, parity, any hypertension and any diabetes. Adjusted relative risks varied from as low as 0.36 for being born with a birthweight lower than the third percentile for gestational age and sex, to 0.69 for being stillborn (Table 3). As indicated by the PAFs (%) in Table 3, between 3.7 and 11.4% of all these adverse perinatal outcomes were attributable to smoking in this cohort of babies.

Table 1: Demographics at the time of birth of mothers who gave birth to at least one singleton baby in NSW between 2012 and 2016 reported for all births and by smoking status during pregnancy

	All births $N = 449{,}590$		**Non-smoking** $N_{ns} = 413{,}072$ (91.9%)		**Smoking** $N_{s} = 36{,}518$ (8.1%)	
	n	**%**	**n**	**%**	**n**	**%**
Year (Baby's DOB)						
2012	91,732	20.4	83,322	90.8*	8,410	9.2*
2013	89,095	19.8	81,506	91.5*	7,589	8.5*
2014	89,664	19.9	82,427	91.9*	7,237	8.1*
2015	88,759	19.7	81,955	92.3*	6,804	7.7*
2016	90,340	20.1	83,862	92.8*	6,478	7.2*
Maternal age						
Under 20	9,754	2.2	7,085	1.7	2,669	7.3
20–24	50,808	11.3	41,782	10.1	9,026	24.7
25–29	121,393	27.0	110,993	26.9	10,400	28.5
30–34	159,555	35.5	150,966	36.5	8,589	23.5
35 and over	108,080	24.0	102246	24.8	5,834	16.0
Total	449,590	100	413,072	100	36,518	100
Parity						
0	199,082	44.3	186,760	45.2	12,322	33.7
1	153,926	34.2	143,852	34.8	10,074	27.6
2	62,100	13.8	55,308	13.4	6,792	18.6
3+	34,278	7.6	26,959	6.5	7,319	20.0
Total	449,386	100	412,879	100	36,507	100
SEIFA IRSD quintiles**						
1st – most disadvantaged	97,232	21.6	85,864	20.8	11,368	31.1
2nd	81,278	18.1	70,972	17.2	10,306	28.2
3rd	90,765	20.2	82,405	19.9	8,360	22.9
4th	89,672	19.9	85,045	20.6	4,627	12.7
5th – least disadvantaged	87,577	19.5	85,894	20.8	1,683	4.6
Total	446,524	99.3	410,180	99.3	36,344	99.5
Remoteness area						
Major cities	360,860	80.3	337,783	81.8	23,077	63.2
Inner regional	67,506	15.0	57,359	13.9	10,147	27.8
Outer regional	16,546	3.7	13,662	3.3	2,884	7.9
Remote	1,401	0.3	1193	0.3	208	0.6
Very remote	215	0.0	186	0.0	29	0.1
Total	446,528	99.3	410,183	99.3	36,345	99.6
Hospital level						
Tertiary	132,913	29.6	122,386	29.6	10,527	28.8
Small and medium urban	12,282	2.7	11,413	2.8	869	2.4
Large urban	114,370	25.4	103,461	25.0	10,909	29.9
Small and medium regional	47,989	10.7	39,744	9.6	8,245	22.6
Large regional	30,878	6.9	26,171	6.3	4,707	12.9
Private	110,504	24.6	109,288	26.5	1,216	3.3
Other	654	0.1	609	0.1	45	0.1
Total	449,590	100	413,072	99.9	36,518	100
Chronic conditions^						
Yes	11,425	2.5	9,866	2.4	1,559	4.3
Any hypertension						
Yes	36,571	8.1	33,659	8.1	2,912	8.0
Any diabetes						
Yes	55,127	12.3	51,295	12.4	3,832	10.5

*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 1^{st} quintile and the highest 20% (least disadvantaged) fall in 5^{th} quartile.

^Chronic conditions encompasses renal, cardiac, thyroid, asthma, psychiatric, and autoimmune conditions [14].

Table 2: Frequencies of maternal outcomes at the time of birth by smoking status during pregnancy

	All births N = 449,590		Non-smoking N_{ns} = 413,072		Smoking N_s = 36,518		Unadjusted	Adjusted
	n	%	n	%	n	%	RR (95% CI)	RR (95% CI)
Severe maternal morbidity								
Yes	9,742	2.2	8,763	2.1	979	2.7	0.79 (0.74,0.85)	0.87 (0.81,0.93)*
Inter-hospital transfer								
Yes	7,302	1.6	6,398	1.5	904	2.5	0.63 (0.58,0.67)	0.92 (0.86,0.99)**

*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 by maternal smoking status

	NSW population	All births N = 449,590		Non-smoking N_{ns} = 413,072		Smoking N_s = 36,518		Unadjusted	Adjusted*	PAF (%)
	%	n	%	n	%	n	%	RR (95% CI)	RR (95% CI)	
Preterm birth (<37 weeks)										
Yes	8	26,722	5.9	23,160	5.6	3,562	9.8	0.57 (0.56,0.60)	0.58 (0.56,0.61)	5.6
SGA (<3rd population centile)										
Yes	3	10,826	2.4	8,890	2.2	1,936	5.3	0.40 (0.39,0.43)	0.36 (0.34,0.38)	11.4
SGA (<10th population centile)										
Yes	10	41,679	9.3	35,797	8.7	5,882	16.1	0.54 (0.52,0.55)	0.48 (0.47,0.50)	7.3
Severe neonatal morbidity						**Among live births only**				
Yes	5	19,778	4.4	17,487	4.2	2,291	6.3	0.67 (0.64,0.70)	0.68 (0.65,0.71)	3.7
Perinatal death						**Rate per 1,000 total births**				
Yes	8	3,469	0.8	3,043	0.7	426	1.2	0.63 (0.57,0.70)	0.68 (0.61,0.76)	3.9
Stillborn	6	2,486	0.6	2,192	0.5	294	0.8	0.66 (0.58,0.74)	0.69 (0.60,0.78)	3.7
						Rate per 1,000 live births				
Neonatal death	2	983	0.2	851	0.2	132	0.4	0.57 (0.47,0.68)	0.66 (0.54,0.81)	4.6

*Adjusted for maternal age, any hypertension, any diabetes, parity and socioeconomic status.
**SGA: small for gestational age.

Discussion

This study quantifies the benefits of not smoking during pregnancy for non-Aboriginal mothers and their babies in NSW. The reduction in risk of all adverse perinatal outcomes for babies whose mothers did not smoke during pregnancy was considerable. After adjusting for the effects of maternal age, socioeconomic status, parity, any hypertension and any diabetes, babies born to mothers who reported not smoking during pregnancy had a 31% lower risk of being stillborn, 34% less risk of dying in the first 28 days of life, a 42% lower risk of being born preterm, 52% less risk of being born small for gestational age ($< 10^{th}$ percentile) and a 64% lower risk of being born with a birthweight lower than the third percentile for gestational age and sex. The PAFs for the adverse perinatal outcomes highlight the potential for the reduction in the rates of these adverse events in NSW if smoking rates during pregnancy could be reduced. Currently there is a focus in Australian maternity care on reducing the rates of stillbirth (The Safer Baby Bundle) [15] and preterm birth (the focus of the Australian Preterm Birth Prevention Alliance) [16]. Our findings show that among singleton babies born to non-Aboriginal women in NSW, 5.6% of preterm births and 3.7% of stillbirths are attributable to maternal smoking during pregnancy. These fractions are likely to be higher in areas with higher smoking rates. Addressing maternal smoking is an important contributor to reducing both stillbirth and preterm birth rates. Across Australia, rates of smoking during pregnancy range from 5.6% in the Australian Capital Territory to 20.7% in the Northern Territory, with an overall rate of 10.2% in 2019 [17] Although all states and territories have seen a reduction in smoking over the last decade, in some areas smoking rates have started to increase. Reducing smoking rates in regions with higher smoking rates could have greater even returns in stillbirth and preterm birth prevention.

Consistent with the widely-documented association between smoking and socioeconomic status, non-smoking mothers tended to be less disadvantaged, older, reside in cities and have had fewer previous pregnancies than mothers who smoked during their pregnancy. Almost one third of the mothers who smoked lived in an area classified as the most disadvantaged SEIFA quintile and/or were aged less than 25 years. Mothers who are young and/or of low socioeconomic status are known to be at higher risk of smoking and less likely to quit, both in Australia and overseas [2, 18–20]. However, similarly to the findings of a Victorian study which considered

absolute and relative risk reduction in tobacco control policy [18], each high risk group comprised only a small proportion of mothers, with the greatest *number* of smokers in the 25–29 year age group and resident of a major city. The authors of the Victorian study commented that high risk group approaches only have the potential to make very small reductions in overall smoking during pregnancy rates, and argue that although these priority groups should not be forgotten, they must not detract from population-wide and cost-effective policies that have been shown to reduce the prevalence of antenatal smoking [18]. Elsewhere this is referred to as the 'Prevention Paradox' [21]. A recent study in NSW also illustrated the benefit of targeting groups with higher numbers, rather than rates, of smokers [2]. The same study also highlighted that smoking rates in NSW are not distributed evenly across the 15 Local Health Districts and showed that over half the mothers who smoked during their pregnancy lived in just four Local Health Districts [2]. Targeting these four Local Health Districts with an effective program to reduce smoking in pregnancy has the greatest potential to reduce adverse perinatal outcomes, including stillbirth and preterm birth.

As the costs of any intervention need to be balanced against the potential benefits, the results of this study are potentially important inputs into modelling the impact of smoking cessation interventions in NSW and broader economic analyses that can inform strategic decision making. Births with adverse events such as preterm birth and stillbirth, are associated with increased healthcare costs [22, 23] and savings through avoiding these via reductions in smoking can be balanced against the costs associated with an intervention. A recent American study by Bacheller et al used similar estimates from the American population to assess the cost-effectiveness of a hypothetical smoking cessation intervention [24]. As there are differences between smoking rates, demographics and healthcare provision and access between Australia and the United States, it is important that these data be available on a local population.

The results of this study could be used to enhance current training for NSW Health staff on delivering smoking cessation support during pregnancy, including online modules offered by The Health Education & Training Institute [25]. Although the risks of smoking during pregnancy are well documented, presentation of the benefits of not smoking may be more beneficial in encouraging pregnant women to stop smoking. A recent review of attitudes towards smoking cessation programs found that healthcare workers found it difficult to communicate health advice on smoking during pregnancy without making the pregnant woman feel guilty and damaging the relationship with the pregnant woman [26]. The same study reported pregnant women feeling pressured and stigmatized for smoking. Positive reframing of the situation to present the expected benefits of not smoking may be more effective in prompting behavior change [27]. Highlighting the proportion of small for gestational age and other adverse outcomes that would be avoided if antenatal smoking rates were negligible could be particularly motivating at both the health service and individual levels.

Results might also inform an NSW-wide plan for enhancing clinician training, clinical care standards to improve the management of smoking before, during and after pregnancy, and monitoring and management of the performance of NSW Health services. Reducing antenatal smoking and increasing quitting during pregnancy are key performance targets for Local Health Districts [28]. The findings of this study highlight the flow on benefits to the health service of lower rates of smoking during pregnancy in terms of adverse outcomes and associated healthcare burden avoided, which underscores the public health significance of the afore-mentioned performance targets and may provide an additional incentive to change.

In addition to providing system level insights, this study provides local information, which can be used by health professionals to further engage the community on the benefits of not smoking for mothers and their babies. A similar study [4], focusing on the benefits of not smoking in Aboriginal women is being used to inform culturally relevant educational material for that population. The data from the current study can likewise be used to tailor advice given to local women. Studies have found that policy makers, practitioners and researchers tend to value locally generated evidence over studies conducted abroad [29, 30].

A key strength of this study is that it was co-produced by academic researchers at Women and Babies Research and policy makers and practitioner-scholars at the NSW Ministry of Health, from conception and planning through to results dissemination and translation. This way of working has been shown to increase the policy-relevance of research, the translation of results into practice, and the exchange of knowledge and skills [31–34]. Another strength of this study is that it was a large population-based cohort study capturing data from almost half a million babies. The main limitation is the lack of information on variables of interest such as heaviness of smoking as well as potential confounders such as alcohol consumption. In addition, smoking status was based on self-report supplemented by diagnosis codes within the medical record. As such, this might underestimate the smoking rate and bias effects towards the null.

Conclusion

Babies born to mothers who reported not smoking during their pregnancy were at a significantly reduced risk of all adverse maternal and perinatal outcomes compared with those born to mothers of similar demographics who reported smoking during their pregnancy. Mothers who reported not smoking during pregnancy had a small reduction in their risk of morbidity and of being transferred to another hospital.

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Conflicts of interest

The authors have no conflicts of interest to declare.

Ethics statement

Ethics approval was obtained from the NSW Population and Health Services Research Ethics Committee (HREC/12/CIPHS/85). A waiver of informed consent was granted by the Ethics Committee.

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Abbreviations

aRR: adjusted relative risk
DOB: date of birth
IRSD: Index of Relative Socio-Economic Disadvantage
NSW: New South Wales
PAF: population attributable fraction
SEIFA: Socio-Economic Index for Areas
SGA: small for gestational age

Supplementary Appendices

Supplementary table 1: Diagnoses and procedures included in severe maternal morbidity indicator [32]

Diagnoses	Procedures
• Acute abdomen • Acute renal failure • Acute psychosis • Cardiac arrest, failure or infarction • Cerebral oedema or coma • Disseminated intravascular coagulopathy • Cerebro-vascular coagulopathy • Major complications of anaesthesia • Obstetric embolism • Shock • Sickle cell anaemia with crisis • Status asthmaticus • Status epilepticus • Uterine rupture	• Assisted ventilation including tracheostomy • Curettage in combination with a general anaesthetic • Dialysis • Evacuation of haematoma • Hyeterectomy • Procedures to reduce blood flow to uterus • Reclosure of disrupted CS wound • Repair of bladder or cystostomy • Repair of intestine • Repair ruptured or inverted uterus • Transfusion of blood or coagulation factors

Supplementary table 2: Diagnoses and procedures included in neonatal adverse outcome indicator [33]

Diagnoses	Procedures
• Gestational age <32 weeks • Birthweight <1500g • Death (within 28 days of birth or before a discharge home from hospital) • Respiratory distress syndrome • Seizure • Intraventricular haemorrhage (grades 2,3,4) • Cerebral infarction • Periventricular leukomalacia • Birth trauma (intracranial haemorrhage, paralysis due to brachial plexus injury, skull or long bone fracture) • Hypoxic ischaemic encephalopathy • Necrotising enterocolitis • Broncho-pulmonary dysplasia • Sepsis/septicaemia (streptococcus, staphylococcus, *E. coli*, unspecified Gram-negative) • Pneumonia • Other respiratory: primary atelectasis, respiratory failure	• Resuscitation • Ventilatory support (mechanical ventilation and/or CPAP) • Central venous or arterial catheter • Transfusion of blood or blood products • Pneumothorax requiring an intercostal catheter