

Title

Disparities in severe neonatal morbidity and mortality between Aboriginal and non-Aboriginal births in Western Australia: a decomposition analysis

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Abstract

Background: The health disadvantages faced by Australian Aboriginal peoples are evidenced in early life, although few studies have focused on the reasons for population-level inequalities in more severe adverse outcomes. This study aimed to examine the scale of disparity in severe neonatal morbidity (SNM) and mortality between Aboriginal and non-Aboriginal births and quantify the relative contributions of important maternal and infant factors.

Method: A retrospective cohort study with singleton live births (≥ 32 weeks' gestation) was conducted using Western Australia linked whole population datasets, from 1999-2015. Aboriginal status was determined based on the mothers' self-reported ethnic origin. An Australian validated indicator was adapted to identify neonates with SNM. The Oaxaca–Blinder method was employed to calculate the contribution of each maternal and infant factor to the disparity in SNM and mortality.

Results: Analyses included 425,070 births, with 15,967 (3.8%) SNM and mortality cases. The disparity in SNM and mortality between Aboriginal and non-Aboriginal births was 2.9 percentage points (95% confidence interval: 2.6, 3.2). About 71% of this gap was explained by differences in modelled factors including maternal area of residence (23.8%), gestational age (22.2%), maternal age (7.5%) and antenatal smoking (7.2%).

Conclusions: There is a considerable disparity in SNM and mortality between Aboriginal and non-Aboriginal births in Western Australia with the majority of this related to differences in maternal sociodemographic factors, antenatal smoking and gestational age. Public health programs targeting these factors may contribute to a reduction in early life health differentials and benefit Aboriginal population health through the life course.

What is already known on this subject?

Aboriginal women are more likely to have poorer perinatal outcomes than non-Aboriginal women. This issue requires urgent and effective intervention. However, the evidence is scarce regarding which factors contribute to the gap in severe adverse health events in the neonatal period between Aboriginal and non-Aboriginal populations.

What this study adds?

We demonstrate that the rate of severe neonatal morbidity and mortality was substantially higher for newborns of Aboriginal than non-Aboriginal women. Over two-thirds of this disparity was explained by maternal sociodemographic factors, such as maternal area of residence, along with gestational age. Public health interventions addressing these factors are likely to reduce this gap.

Introduction

Severe neonatal morbidity (SNM), a composite term based on diagnoses and procedures such as respiratory distress syndrome, broncho-pulmonary dysplasia, and resuscitation, affects a significant proportion of neonates, especially among those born preterm.¹ In addition to short-term impacts, SNM is associated with a greater risk of poor development, childhood hospitalisation and mortality.²⁻⁴

Several factors are impacted in adverse neonatal outcomes, although few studies have examined factors specifically associated with SNM.⁵⁻⁷ Misra and colleagues (2003) proposed a multiple determinants framework for conceptualizing the complex relationships that influence perinatal (including neonatal) health,⁸ and implicate inter-related distal social environmental factors (e.g., socioeconomic status, ethnicity), proximal biomedical (e.g., chronic diseases) and behavioural (e.g., smoking) responses, and intermediate diseases and pregnancy complications in the pathways to poor outcomes.

Persistent marked racial/ethnic variations in preterm birth, low birthweight and perinatal mortality rates have been documented in the US.⁹ Similarly, in Australia, the rates of these adverse perinatal outcomes have been shown to be substantially higher for Aboriginal and/or Torres Strait Islander (hereafter Aboriginal) than non-Aboriginal populations, although the overall perinatal mortality rate in Australia is comparable to most high-income countries.¹⁰ The factors driving these disparities are not yet fully understood and they are likely to be complex and contextual. The limited available US-only literature on ethnic disparities in SNM is exclusively focused on very preterm (born before 32 weeks of gestation)¹¹ or preterm births (born before 37 weeks of gestation)¹² ¹³, and features conflicting findings among this small subgroup of births (~10%).¹⁴

Accumulated data show that Aboriginal women in Australia are more likely to have greater risks to their pregnancy health than non-Aboriginal women.¹⁵ For instance, they are more likely to be younger at childbirth, live in remote and socioeconomically disadvantaged areas, smoke during pregnancy, have prenatal chronic conditions and pregnancy complications. Consequently, they are also at greater risk of having preterm and small for gestational age births.¹⁰ To date, there is a paucity of evidence to

ascertain the degree to which these risk profile differences contribute to the disparities in SNM and mortality.

The most recent US study¹¹ found that maternal and infant characteristics did not make a significant contribution to the ethnicity gap in SNM, but the analysis was limited to very preterm births. In contrast, other US studies¹⁶⁻¹⁹ have found that differences in maternal factors contributed significantly to the ethnic gap in preterm birth and low birthweight, although the relative contribution varies across studies. Notably, there are considerable differences in ethnic composition and healthcare between the US and Australia, which means these findings may not be applicable in Australia. Moreover, numerous factors are likely to be involved in perinatal morbidity/mortality, which impedes targeted interventions.²⁰ Therefore, to better understand the underlying causes of the disparity in SNM and mortality between Aboriginal and non-Aboriginal births in the Australian context, and to reduce the disparity, comprehensive context-based studies are urgently required. This study examined the scale of disparity in SNM and mortality between Aboriginal and non-Aboriginal births and calculated the relative contributions of key maternal and infant factors to the gap.

Methods

Study design and population

A whole population retrospective cohort study with singleton live births of ≥ 32 weeks' gestation in Western Australia (WA) from July 1999 to December 2015 was conducted. Neonates with major congenital anomalies ($n=19,879$), identified in the Western Australian Register of Developmental Anomalies (WARDA), were excluded. The scope of the sample was restricted to ≥ 32 weeks as all earlier births are, by definition, classified as having SNM by the composite indicator used.¹

Datasets and measures

Data were obtained from several datasets including the Midwives' Notification System (MNS), Hospital Morbidity Data Collection (HMDC), Birth and Death Registers, WARDA, and an Aboriginal status flag dataset. The MNS, the primary data source, records the circumstances of all births (≥ 20 weeks' gestation) in WA since 1980, while the HMDC

provides comprehensive information for all admitted patients in the state from 1970. Both datasets are periodically checked for data quality, accuracy and validity.^{21 22} In the rare instance where any of the key variables (such as dates of birth) varied between the administrative datasets, the value from the MNS was used. Similarly, the Birth and Death Registers collect information on all births and deaths across WA from the 1970s. The WARDA routinely records developmental anomalies in WA for children from birth to six years of age. These datasets were linked by the WA Department of Health's Data Linkage Branch using a probabilistic linkage method²³, with data securely transferred (with identifiers removed) to the researcher team.

As part of the MNS, women declared their ethnic origin (Caucasian, Aboriginal and/or Torres Strait Islander, Asian, Indian (sub-continent), African, Polynesian, Maori and Other). For this analysis, Aboriginal and/or Torres Strait Islander women were collapsed together while all other ethnic groups were classified as non-Aboriginal.

The SNM outcome variable was adapted from a validated composite outcome indicator which was developed to identify infants with severe adverse outcomes (includes death within 28 days of birth or before first discharge home from hospital) in routinely collected population health datasets in New South Wales.¹ The indicator includes conditions and procedures based on the International Statistical Classification of Diseases, Tenth Revision, Australian Modification (ICD-10-AM codes). In consultation with the WA Clinical Coding Authority, we made changes to some components of the indicator. For example, 'other' brachial plexus birth trauma (ICD-10-AM code P14.3) was added while intravenous fluids (ICD-10-AM code 96199) was excluded (Supplemental Table S1). Data on SNM and mortality were complete for 99.6% of singleton births, but 4.7% (n=21,005) of eligible births were excluded because of missing data on area-based socioeconomic measures (n=18,983), gestational age (n=1,960) and other covariates (n=62).

Other variables obtained as part of the above datasets were categorised as follows. Maternal age at childbirth (<20, 20-34, 35-39 and ≥40 years), parity (0, 1, 2-4, ≥5), antenatal smoking (yes/no), pre-existing condition (yes/no), pregnancy complication (yes/no), onset of labour (spontaneous, induced, no-labour), method of birth

(spontaneous vaginal, assisted vaginal, elective or emergency caesarean), infant sex (boy/girl), gestational age at birth (32-36, 37-38, 39-40 and ≥ 41 weeks), appropriateness for gestational age defined using Australian national birthweight centiles (severe growth restriction [$<3^{\text{rd}}$ percentile], small for gestational age [$3^{\text{rd}}-<10^{\text{th}}$ percentile], appropriate for gestational age [$10-90^{\text{th}}$ percentile], large for gestational age [$>90^{\text{th}}$ percentile])²⁴ and year of birth (1999-2003, 2004-2007, 2008-2011, 2012-2015). The MNS and HMDC data were used to define a pre-existing condition (pre-existing diabetes and/or hypertension) and a composite pregnancy complication variable (gestational hypertension, pre-eclampsia, gestational diabetes, placenta praevia, placental abruption or other antepartum haemorrhage).

We used an area-level socioeconomic status (SES) measure as no individual data were available. The area-level SES quintiles (most disadvantaged [first quintile] to least disadvantaged [fifth quintile]) were created based on the Socio-Economic Indexes for Areas (SEIFA); a product created by the Australian Bureau of Statistics.²⁵ Similarly, area of residence was determined by the Australian Bureau of Statistics Remoteness Area classification which divides Australia, based on a measure of relative access to services, into five classes: major cities, inner regional, outer regional, remote and very remote.²⁶ For this analysis, we have combined inner and outer regional areas ('regional') and remote and very remote areas ('remote') to establish categories with a sufficient sample size.

Statistical analysis

All statistical analyses were performed in STATA version 15 (StataCorp. 2017, College Station, TX, US). Chi-square tests were used to compare the percentage of maternal and infant characteristics by Aboriginal status. Log-binomial or Poisson (when the former does not converge) model with cluster-robust standard errors (accounting for multiple births per mother; maximum 10 births per mother) was used to calculate risk ratios (RRs) and 95% confidence intervals (CIs) for the association of maternal ethnic origin and other factors, and the risk of SNM and mortality. Model factors were selected based on the existing literature and the perinatal health framework developed by Misra et al. (2003).⁸ The available data included distal (area-level SES and area of residence),

proximal (maternal age, parity, smoking during pregnancy, and pre-existing condition) and intermediate (pregnancy complication, the onset of labour, appropriateness for GA, method of birth and GA) factors as well as covariates (infant sex and year of birth). Gestational age is a well-known predictor of SNM and mortality,¹ and Aboriginal women are more likely to have preterm births.¹⁰ Our preliminary analysis also showed a significant interaction between gestational age and ethnicity on SNM, particularly at 32-36 weeks of gestation ($P < 0.001$). Hence, we repeated the log-binomial model by gestational age group.

The Blinder–Oaxaca decomposition method was employed to estimate the percentage contribution of each maternal and infant variable to the disparity in SNM and mortality between Aboriginal and non-Aboriginal births. It partitions the ethnic gap in SNM and mortality into ‘explained’ and ‘unexplained’ parts. While the explained component shows the amount of the disparity accounted for by group differences in factors included in the model, the unexplained part represents the remaining gap in the outcome (i.e., SNM and mortality) which is not attributable to the distribution variations in those variables.²⁷
²⁸ A variable can contribute positively or negatively to the inequality (i.e., a negative contribution indicates that the predictor contributed towards decreasing the disparity).

Finally, to check consistency and robustness of results, we repeated both the log-binomial and decomposition models using an alternative Aboriginal status indicator, derived using an algorithm based on several administrative datasets held by the Department of Health²⁹. The decomposition analysis was also performed in subsamples restricted to one birth per woman (the most recent birth was included when two or more births were available) and births with spontaneous onset of labour and was replicated in a stratified analysis based on the gestational age group.

Results

We included 425,070 births (from 259,080 women), of which 23,665 (5.6%) births were to Aboriginal women. Overall, 15,967 (3.8%) neonates had SNM, including 184 (122 with SNM) deaths within the first month of life or before first discharge home. Aboriginal neonates had the highest SNM rate, while neonates born to other ethnic minority

women (included as non-Aboriginal) had a similar SNM rate to the births to Caucasian women (79% of total births) (Supplemental Table 2). Compared with non-Aboriginal women, Aboriginal women were more likely to be younger at birth, be in the highest quintile of socioeconomic disadvantage, live in remote areas, multiparous, have smoked during pregnancy, have a pre-existing condition, have spontaneous onset of labour at lower gestational age groups (32-36 and 37-38 weeks) and have preterm (32-36 weeks' gestation) and severely growth restricted or small for gestational age births. However, they were less likely to have births at advanced maternal age (≥ 40 years) and assisted vaginal or elective caesarean births (Table 1).

Table 1. Maternal and infant characteristics of live births ≥ 32 weeks' gestation by Aboriginal status, Western Australia, July 1999 - December 2015

	All (N=425,070)		Aboriginal (N=23,665)		Non-Aboriginal (N=401,405)		p value
	n	%	n	%	n	%	
<i>Maternal characteristics</i>							
Age at birth (years)							
<20	19,726	4.6	5,132	21.7	14,594	3.6	<0.001
20-34	321,834	75.7	16,809	71.0	305,025	76.0	
35-39	69,469	16.3	1,444	6.1	68,025	17.0	
≥ 40	14,041	3.3	280	1.2	13,761	3.4	
Area-level SES quintiles							
1 st (most disadvantaged)	91,307	21.5	14,909	63.0	76,398	19.0	<0.001
2 nd	89,874	21.1	4,682	19.8	85,192	21.2	
3 rd	83,149	19.6	2,367	10.0	80,782	20.1	
4 th	84,840	20.0	1,195	5.1	83,645	20.8	
5 th (least disadvantaged)	75,900	17.9	512	2.2	75,388	18.8	
Area of residence							
Major city	256,808	60.4	6,215	26.3	250,593	62.4	<0.001
Regional	127,180	29.9	6,579	27.8	120,601	30.0	
Remote	41,082	9.7	10,871	45.9	30,211	7.5	
Parity							
0	176,113	41.4	6,834	28.9	169,279	42.2	<0.001
1	145,540	34.2	5,652	23.9	139,888	34.9	
2-4	96,176	22.6	8,905	37.6	87,271	21.7	
≥ 5	7,241	1.7	2,274	9.6	4,967	1.2	
Smoking during pregnancy							
No	360,984	84.9	12,117	51.2	348,867	86.9	<0.001
Yes	64,086	15.1	11,548	48.8	52,538	13.1	
Pre-existing condition ¹							
No	416,859	98.1	22,842	96.5	394,017	98.2	<0.001
Yes	8,211	1.9	823	3.5	7,388	1.8	
Pregnancy complication ²							
No	351,547	82.7	19,624	82.9	331,923	82.7	0.355
Yes	73,523	17.3	4,041	17.1	69,482	17.3	
Year of birth							

1999-2003	97,688	23.0	5,873	24.8	91,815	22.9	<0.001
2004-2007	96,239	22.6	5,749	24.3	90,490	22.5	
2008-2011	111,324	26.2	6,077	25.7	105,247	26.2	
2012-2015	119,819	28.2	5,966	25.2	113,853	28.4	
<i>Newborn and birth characteristics</i>							
Onset of labour							
Spontaneous	220,336	51.8	15,962	67.5	204,374	50.9	<0.001
Induced	122,594	28.8	5,114	21.6	117,480	29.3	
No-labour	82,140	19.3	2,589	10.9	79,551	19.8	
Method of birth							
Spontaneous vaginal	231,203	54.4	16,723	70.7	214,480	53.4	<0.001
Assisted vaginal	60,073	14.1	1,692	7.2	58,381	14.5	
Elective caesarean	72,878	17.1	1,974	8.3	70,904	17.7	
Emergency caesarean	60,916	14.3	3,276	13.8	57,640	14.4	
Gestational age at birth (weeks)							
32-36	24,980	5.9	2,562	10.8	22,418	5.6	<0.001
37-38	136,585	32.1	7,562	32.0	129,023	32.1	
39-40	214,725	50.5	11,192	47.3	203,533	50.7	
≥41	48,780	11.5	2,349	9.9	46,431	11.6	
Appropriateness for gestational age							
SGR (<3rd percentile)	9,278	2.2	1,304	5.5	7,974	2.0	<0.001
SGA (3-<10 percentile)	25,293	6.0	2,498	10.6	22,795	5.7	
AGA (10-90 percentile)	344,600	81.1	17,826	75.3	326,774	81.4	
LGA (>90 percentile)	45,899	10.8	2,037	8.6	43,862	10.9	
Sex							
Girls	208,795	49.12	11,640	49.2	197,155	49.1	0.833
Boys	216,275	50.9	12,025	50.8	204,250	50.9	
SNM	15,967	3.8	1,538	6.5	14,429	3.6	

Abbreviations: AGA, appropriate for gestational age; LGA, large for gestational age; SES, socioeconomic status; SGR, severely growth restricted; SGA, small for gestational age; SNM, severe neonatal morbidity/mortality

¹ *Pre-existing condition was defined as having pre-existing diabetes and/or hypertension*

² *Pregnancy complication was defined as having any of the following: gestational hypertension, pre-eclampsia, gestational diabetes, placenta praevia, placenta abruption or other antepartum haemorrhage*

Table 2 shows the association between maternal and infant factors and SNM and mortality. In the unadjusted model, Aboriginal births were 1.81 (95% CI: 1.72,1.90) times more likely to have SNM or dies in the neonatal period, compared with non-Aboriginal births. The association remained in a model adjusted for a range of sociodemographic, medical and other factors, although the effect size was considerably attenuated. The largest effect size was observed for preterm births (at 32-36 weeks' gestation; risk ratio = 8.44, 95% CI 8.13, 8.76). Other notable maternal factors associated with a higher risk of SNM and mortality were younger maternal age, remote residence, grand multiparity, pre-existing medical condition and pregnancy complications. Additionally, birth-related and neonatal factors including the onset of

labour, method of birth and appropriateness for gestational age were significantly associated with SNM and mortality (Table 2).

Table 2. Relative risk of Severe Neonatal Morbidity (SNM) and mortality among live births ≥ 32 weeks' gestation, by Aboriginal status, and other maternal and infant factors, Western Australia, July 1999 - December 2015 (N=425,070)

	SNM		Unadjusted		Adjusted ¹		Adjusted ²	
	n	%	RR	95% CI	RR	95% CI	RR	95% CI
Maternal and infant characteristics								
Aboriginal status								
Aboriginal	1,538	6.5	1.81	1.72,1.90	1.43	1.34,1.52	1.23	1.16,1.31
Non-Aboriginal	14,429	3.6	1.00		1.00		1.00	
Age at birth (years)								
<20	1,003	5.1	1.39	1.31,1.48	1.13	1.06,1.21	1.20	1.12,1.28
20-34	11,738	3.7	1.00		1.00		1.00	
35-39	2,617	3.8	1.03	0.99,1.08	1.04	0.99,1.08	1.00	0.96,1.05
≥ 40	609	4.3	1.19	1.10,1.29	1.10	1.01,1.19	1.05	0.97,1.13
Area-level SES quintiles								
1 st (most disadvantaged)	3,991	4.4	1.30	1.24,1.37	1.09	1.04,1.15	1.08	1.03,1.14
2 nd	3,459	3.9	1.15	1.09,1.20	1.05	1.00,1.11	1.05	1.00,1.10
3 rd	2,963	3.6	1.06	1.01,1.12	1.01	0.95,1.06	1.01	0.96,1.06
4 th	3,003	3.5	1.05	1.00,1.11	1.02	0.97,1.08	1.02	0.97,1.07
5 th (least disadvantaged)	2,551	3.4	1.00		1.00		1.00	
Area of residence								
Major city	9,051	3.5	1.00		1.00		1.00	
Regional	4,849	3.8	1.08	1.04,1.12	1.06	1.02,1.10	1.09	1.05,1.13
Remote	2,067	5.0	1.43	1.36,1.50	1.24	1.17,1.30	1.30	1.24,1.37
Parity								
0	7,428	4.2	1.39	1.34,1.44	1.40	1.35,1.45	1.14	1.10,1.18
1	4,427	3.0	1.00		1.00		1.00	
2-4	3,687	3.8	1.26	1.21,1.32	1.18	1.13,1.23	1.14	1.09,1.19
≥ 5	425	5.9	1.93	1.75,2.13	1.47	1.33,1.63	1.36	1.23,1.50
Smoking during pregnancy (yes)	3,025	4.7	1.32	1.27,1.37	1.19	1.14,1.24	1.09	1.04,1.13
Pre-existing condition (yes) ³	701	8.5	2.33	2.16,2.51	1.70	1.58,1.84	1.22	1.14,1.31
Pregnancy complication (yes) ⁴	4,705	6.4	2.00	1.93,2.07	1.86	1.80,1.93	1.29	1.25,1.34
Onset of labour								
Spontaneous	7,819	3.6	1.00		1.00		1.00	
Induced	4,401	3.6	1.01	0.98,1.05	0.87	0.84,0.91	0.95	0.91,0.98
No-labour	3,747	4.6	1.29	1.24,1.34	1.24	1.19,1.29	1.30	1.23,1.38
Sex (boy)	9,443	4.4	1.40	1.35,1.44	1.39	1.35,1.43	1.34	1.30,1.38
Appropriateness for gestational age								
SGR (<3rd percentile)	690	7.4	2.16	2.00,2.32	1.85	1.71,1.99	1.81	1.68,1.94
SGA (3-<10 percentile)	1,039	4.1	1.19	1.12,1.27	1.09	1.02,1.16	1.08	1.01,1.14
AGA (10-90 percentile)	11,875	3.5	1.00		1.00		1.00	
LGA (>90 percentile)	2,363	5.2	1.49	1.43,1.56	1.46	1.40,1.52	1.33	1.27,1.39
Year of birth								
1999-2003	4,002	4.1	1.00		1.00		1.00	
2004-2007	3,496	3.6	0.89	0.85,0.93	0.88	0.85,0.92	0.85	0.82,0.89
2008-2011	3,501	3.1	0.77	0.73,0.80	0.79	0.76,0.83	0.76	0.72,0.79
2012-2015	4,968	4.2	1.01	0.97,1.05	1.03	0.98,1.07	0.99	0.95,1.04
Gestational age at birth (weeks)								

32-36	5,052	20.2	8.44	8.13,8.76	6.41	6.16,6.68
37-38	4,133	3.0	1.26	1.21,1.31	1.23	1.19,1.29
39-40	5,146	2.4	1.00		1.00	
≥41	1,636	3.4	1.40	1.32,1.48	1.34	1.27,1.42
Method of birth						
Spontaneous vaginal	6,493	2.8	1.00		1.00	
Assisted vaginal	2,668	4.4	1.58	1.51,1.65	1.64	1.57,1.72
Elective caesarean	2,153	3.0	1.05	1.00,1.10	0.83	0.77,0.90
Emergency caesarean	4,653	7.6	2.72	2.62,2.82	1.79	1.71,1.87

Abbreviations: AGA, appropriate for gestational age; CI, confidence interval; LGA, large for gestational age; RR, risk ratio; SES, socioeconomic status; SGR, severely growth restricted; SGA, small for gestational age; SNM, severe neonatal morbidity/mortality

¹ Mutually adjusted for all listed factors except gestational age and method of birth.

² Mutually adjusted for all listed factors

³ Pre-existing condition was defined as having pre-existing diabetes and/or hypertension

⁴ Pregnancy complication was defined as having any of the following: gestational hypertension, pre-eclampsia, gestational diabetes, placenta praevia, placenta abruption or other antepartum haemorrhage.

A stratified analysis based on gestational age revealed that the risk of SNM and mortality for Aboriginal births increased with gestational age. At 32-36 weeks of gestation, we observed no difference between Aboriginal and non-Aboriginal births in the risk of SNM and mortality, but the adjusted RR (95% CI) increased from 1.35 (1.20, 1.53) among neonates born at 37-38 weeks of gestation to 1.60 (1.32, 1.96) among those born at 41 or more weeks of gestation (Table 3).

Table 3. Relative risk of Severe Neonatal Morbidity (SNM) and mortality, by Aboriginal status—stratified by gestational age group, Western Australia, July 1999 - December 2015

	SNM		Unadjusted		Adjusted ¹	
	n	%	RR	95% CI	RR	95% CI
32-36 weeks						
Aboriginal	530	20.7	1.03	0.95, 1.11	0.98	0.89, 1.07
Non-Aboriginal	4,522	20.2	1.00		1.00	
37-38 weeks						
Aboriginal	408	5.4	1.87	1.69, 2.06	1.35	1.20, 1.53
Non-Aboriginal	3,725	2.9	1.00		1.00	
39-40 weeks						
Aboriginal	467	4.2	1.82	1.65, 2.00	1.45	1.30, 1.62
Non-Aboriginal	4,679	2.3	1.00		1.00	
≥41 weeks						
Aboriginal	133	5.7	1.75	1.47, 2.08	1.60	1.32, 1.96
Non-Aboriginal	1,503	3.2	1.00		1.00	
Overall (≥32 weeks) ²						
Aboriginal	1,538	6.5	1.81	1.72,1.90	1.23	1.16,1.31
Non-Aboriginal	14,429	3.6	1.00		1.00	

Abbreviations: CI, confidence interval; SNM, severe neonatal morbidity/mortality; RR, risk ratio

¹ Each model was adjusted for age, area-level SES, area of residence, parity, smoking during pregnancy, infant sex, appropriateness for gestational age, onset of labour, pre-existing condition (pre-existing diabetes and/or hypertension), pregnancy complication (gestational hypertension, pre-eclampsia, gestational diabetes, placenta praevia, placental abruption or other antepartum haemorrhage), method and year of birth.² The overall model was further adjusted for the gestational age.

The results of our supplemental analyses using the alternative Aboriginal status indicator (derived from algorithms) were similar to the main analysis, although there were slightly smaller effect sizes among births to Aboriginal mothers across all gestational age groups (Supplemental Tables S3 and S4).

As shown in Table 4, the disparity (in absolute scale) in SNM and mortality between Aboriginal and non-Aboriginal births was 2.9 percentage points (95% CI: 2.6, 3.2), and remained relatively stable over the study period (Supplemental Table S5). About 71% of the gap was attributable to factors included in the model and most of these variables contributed positively to the disparity. Overall, differences in socio-demographic factors (including age, area-level SES, area of residence and parity) and antenatal smoking accounted for the greatest proportion of the explained gap (53.3%), with area of residence being the biggest contributor (23.8%). The differences in birth-related and neonatal factors also made a considerable contribution to the SNM and mortality gap. While the onset of labour and method of birth contributed towards reducing the disparity, differences in gestational age and appropriateness for gestational age between Aboriginal and non-Aboriginal births were important drivers of the inequality. In other words, the onset of labour and method of birth were negative contributors to the disparity in which Aboriginal women had more favourable characteristics (a greater proportion of spontaneous onset of labour and spontaneous vaginal births). Without these differences in rates of spontaneous onset of labour and spontaneous vaginal births between Aboriginal women and their non-Aboriginal counterparts, the gap would have increased. Maternal pre-existing medical conditions and pregnancy complications did not contribute appreciably to the gap in SNM and mortality.

Table 4. Factors contributing to the gap in Severe Neonatal Morbidity (SNM) and mortality between Aboriginal and non-Aboriginal live births ≥ 32 weeks' gestation, Western Australia, July 1999 - December 2015

	β (%)	95% CI		Proportion
		Lower	Upper	
SMM prevalence				

Aboriginal	6.5	6.2	6.8	
Non-Aboriginal	3.6	3.5	3.7	
Absolute difference	2.9	2.6	3.2	
<i>Independent contribution of each variable to the disparity</i>				
Maternal socio-demographic and health behaviour factors				53.3
Age	0.22	0.13	0.31	7.5
Area-level SES	0.22	0.10	0.34	7.5
Area of residence	0.69	0.56	0.82	23.8
Parity	0.21	0.13	0.29	7.3
Smoking during pregnancy	0.21	0.11	0.31	7.2
Maternal medical conditions				0.8
Pre-existing condition ¹	0.03	0.02	0.04	0.9
Pregnancy complication ²	0.00	-0.02	0.01	-0.2
Pregnancy related factors				16.8
Onset of labour	-0.19	-0.24	-0.13	-6.4
Gestational age	0.64	0.58	0.71	22.2
Appropriateness for gestational age	0.13	0.10	0.16	4.5
Method of birth	-0.10	-0.17	-0.04	-3.5
Total disparity explained	2.06	1.88	2.23	70.8

Abbreviations: CI, confidence interval; SES, socioeconomic status; SNM, severe neonatal morbidity/mortality

¹ Pre-existing condition was defined as having pre-existing diabetes and/or hypertension

² Pregnancy complication was defined as having any of the following: gestational hypertension, pre-eclampsia, gestational diabetes, antepartum haemorrhage, placenta praevia or abruption.

While we found similar results in supplemental analyses using the alternative Aboriginal status indicator (Supplemental Table S6), although a higher proportion of the overall disparity was explained by modelled variables in the analysis restricted to one birth per woman (Supplemental Table S7) and a lower proportion was evident in the analysis limited to births with spontaneous onset of labour—largely because of the changes in the contributions of method of birth (i.e., negative contributor) (Supplemental Table S8). In the stratified analysis, based on gestational age, we observed smaller disparities in SNM and mortality between Aboriginal and non-Aboriginal births at 32-36 and 39-40 weeks of gestation. Moreover, the total inequality explained by included factors varied from 20.1% (≥ 41 weeks) to 60.4% (37-38 weeks), which were lower than that of the main analysis results (Supplemental Table S9).

Discussion

In this population-based cohort study, the rate of SNM (including mortality) was significantly higher in newborns of Aboriginal women than those of non-Aboriginal women, with the major proportion (70.8%) of this disparity explained by maternal

sociodemographic factors (including maternal area of residence) along with gestational age. Our results indicate that a reduction in the rate of neonatal morbidity/mortality among the Aboriginal population is possible with effective interventions and programs.

Our finding that newborns of Aboriginal women are more likely to have SNM than the non-Aboriginal population accords with the existing evidence of widespread inequalities in perinatal morbidity/mortality in Australia—this includes disproportionately greater rates of low birthweight, preterm birth and perinatal mortality among Indigenous populations.³⁰⁻³² Our evaluation of the relative contributions of salient maternal and infant factors to disparities in neonatal morbidity and mortality is a novel contribution to the literature. We highlight that the gap in SNM and mortality is largely attributable to differences in maternal sociodemographic factors (for example, area of residence, area-level SES and maternal age), antenatal smoking and gestational age. Although maternal pre-existing medical conditions and pregnancy complications were important predictors of SNM and mortality, they did not contribute meaningfully to the disparity in these outcomes. This underscores the common observation that inequalities in perinatal outcomes are primarily driven by social and behavioural health determinants.⁹

The available limited literature on the factors contributing to ethnic disparities in perinatal outcomes has exclusively focused on preterm birth and/or low birthweight outcomes.^{16 18 19} To our knowledge, only one recent US study,¹¹ limited to very preterm infants, has evaluated this issue and found that infant factors (birthweight, gestational age, sex, and multiple births) accounted for about 49% of the disparity in neonatal morbidity and mortality between non-Hispanic black and non-Hispanic white populations as well as between Hispanic and non-Hispanic white populations. However, in contrast to our study, they demonstrated no significant contributions by maternal sociodemographic (age, parity, educational level, and delivery type) and lifestyle (body mass index and antenatal smoking) factors. This may be because of differences in the socio-ethnic composition of the population (and their characteristics) and healthcare systems between Australia and the US, which reinforces the notion that ethnic-based analyses and interventions should be population and context-specific.³³

Because of the long-term sequelae and economic consequences,^{2 3 34} the findings of the current study underscore the urgent need to close the gap in perinatal morbidity/mortality between Aboriginal and other population groups in Western Australia. Our findings also suggest that comprehensive population-based interventions that aim to: improve maternal area-level SES; access to services and reduce teenage pregnancies, as well as preterm births, may narrow the ethnic disparities in severe neonatal outcomes. Remoteness is the single most important contributor to the disparity and may reflect the risks associated with a comparatively lower level of access (in terms of physical proximity and financial wherewithal) to culturally appropriate and high-quality antenatal and obstetric services in these settings.³⁵ These issues are acknowledged in the most recent pregnancy care guidelines,³⁶ and therefore, improvement in these services and implementation of Aboriginal-led programs may meaningfully reduce the gap.³⁷ This, in turn, may help to further reduce the overall SNM and mortality in the State. We also found that difference in the distribution of gestational age is the major infant factor responsible for SNM disparity. Interlinked factors such as maternal socioeconomic disadvantage, antenatal smoking, and urogenital infections are more prevalent in the Aboriginal population and are strongly linked to preterm birth.^{36 38} Therefore, to further reduce the gap in SNM, effective spontaneous preterm birth prevention strategies and interventions that improve preterm birth outcomes should be implemented.³⁹⁻⁴¹

To our knowledge, this is the first study to estimate individual variable contributions to the disparity in SNM and mortality between Australian Indigenous and non-Indigenous populations. We were able to include important variables that explained over two-thirds of the disparity. The use of a large total population cohort with linkages to detailed information on prenatal and early life circumstances is a considerable strength. Nevertheless, this study has some limitations. We used administrative data that are susceptible to errors and usually lack some salient covariates. For instance, data were not available or only available recently on antenatal care, obesity, alcohol consumption and mental health problems and thus some part of the disparity remained unexplained. Future studies may identify additional important factors for targeted interventions. Additionally, Aboriginal women could have been misclassified,⁴² although we found

similar results to the main analysis when we employed an Aboriginal indicator variable derived using the algorithms developed by the *Getting our Story Right* project—suggesting a minimal impact of any identification errors. The other limitation of this study is that we have excluded extremely preterm births (20-31 weeks' gestation) since the indicator we used classed all as being severely morbid. As these made up only 2.2% and 0.7% of total Aboriginal and non-Aboriginal live singleton births respectively during the time period of interest, they would have had a limited effect on the generalisability of our findings.

In conclusion, the findings of this large population-based study demonstrate that Aboriginal births are at higher risks of SNM and mortality, compared with non-Aboriginal births. The majority of this ethnic disparity was explained by maternal sociodemographic and antenatal smoking, along with gestational age. Reducing the gap will require a sustained focus on well-resourced, Aboriginal-led public health interventions and programs for the benefit of infant health.

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Contributors

AAA, CCJS and HDB conceived and designed the study. BMF, RM and SWW participated in the design of the study. AAA conducted all statistical analysis and drafted the manuscript. All authors critically reviewed and approved the final manuscript.

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Competing interests

None.

Patient consent for publication

Not required.

Ethics approval

Ethics approvals were obtained from the Western Australian Department of Health Human Ethics Research Committee (2016/51) and the Western Australian Aboriginal Health Ethics Committee (797).

Data Availability Statement

All data relevant to the study are included in the article or uploaded as supplementary information.

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Table S1. Components of the composite neonatal adverse outcome indicators, used as indicator for severe neonatal morbidity

NSW composite neonatal adverse outcome indicator		Modifications/ additional ICD-10-AM diagnosis and ACHI procedure codes
Conditions/diagnoses	Codes	
Gestational age<32 weeks		Births below 32 weeks' gestation excluded
Birthweight<1,500 g		
Death (within 28 days of birth or before a discharge home from hospital)		
Respiratory Distress Syndrome	P22.0	
Seizure	P90, R56	
Intraventricular haemorrhage, grades 2 - 4	P52.1, P52.2	
Cerebral infarction	I63	
Periventricular leukomalacia	P91.2	
Birth trauma (intracranial haemorrhage paralysis due to brachial plexus injury, skull or long bone fracture)	P10.0 to P10.3, P13.0, P13.2, P13.3, P14.0, P14.1	P14.3 other brachial plexus birth trauma
Hypoxic ischemic encephalopathy	P91.5, P91.81, P91.6	
Necrotising enterocolitis	P77	
Broncho-pulmonary dysplasia	P27.1	
Sepsis/septicaemia (streptococcus, staphylococcus, E. coli, unspecified Gram-negative)	P36, A40, A41.5, A41.9, B95.1, B96.2	A41.0 Sepsis due to Staphylococcus aureus A41.1 Sepsis due to other specified staphylococcus A41.2 Sepsis due to unspecified staphylococcus A41.4 Sepsis due to anaerobes (includes gram-ve anaerobes)
Pneumonia	P23, J12 to J18	
Other respiratory: primary atelectasis, respiratory failure	P28.0, P28.5	
Procedures		
Resuscitation	92052, 92053, 92042-00, 90225	
Ventilatory support (mechanical ventilation and/or CPAP)	13882, 13857-00, 13879-00, 22007, 90179, 92038, 92039	92211-00 Management of combined ventilatory support, ≥ 96 hours 92210-00 Nitric oxide therapy
Central venous or arterial catheter	38206, 13303-00, 34524-00, 34530-01,	

	13300-00, 13300-02, 13319-00, 13815	
Transfusion of blood or blood products	13706-01 to 04, 92206-00, 13306-00	13706-05 Administration of gamma globulin
Pneumothorax requiring an intercostal catheter	38409-00	38806-00 Insertion of intercostal catheter for drainage (replaced 38409-00 in 2008)
Any body cavity surgical procedure	30373, 30375, 30378-00, 30562, 30564 to 30566, 30571, 30601, 30615-00, 30617-00, 32123-00, 36516, 36537, 36564, 36579, 38403-00, 38600-00, all codes start with 387, 39015, 39640-00, 40003, 40100-00, 40103-00, 41883, 43801-00, 43807-00, 43816-02, 43837, 43843, 43852-00, 43864, 43867, 43870-00, 43873, 43876, 43900-00, 43915-00, 43930-00, 43945-00, 43963-00, 43978, 90180, 90224-00	

Adapted from Lain SJ, Algert CS, Nassar N, Bowen JR, Roberts CL. Incidence of severe adverse neonatal outcomes: use of a composite indicator in a population cohort. Matern Child Health J. 2012;16(3):600-608.

Table S2. The number and proportion of births and SNM cases by ethnic origin

Ethnic origin	Total births	Percent	SNM		
			No	Yes	%
Aboriginal	23,665	5.6	22,127	1,538	6.5
Non-Aboriginal	401,405	94.5	386,976	14,429	3.6
Caucasian	334,067	78.6	321,964	12,103	3.6
Asian	30,395	7.2	29,508	887	2.9
Indian	8,950	2.1	8,603	347	3.9
African	5,431	1.3	5,245	186	3.4
Polynesian	474	0.1	461	13	2.7
Maori	4,698	1.1	4,507	191	4.1
Other	17,390	4.1	16,688	702	4.0

Table S3. Aboriginal status (derived using the algorithms developed by the Getting our Story Right), and other maternal and infant factors and severe neonatal morbidity and mortality among live births ≥ 32 weeks' gestation, Western Australia, July 1999 - December 2015 (N=425,070)

	SNM		Unadjusted		Adjusted ¹		Adjusted ²	
	n	%	RR	95% CI	RR	95% CI	RR	95% CI
Maternal and infant characteristics								
Aboriginal status								
Aboriginal	1,726	6.2	1.74	1.65,1.83	1.39	1.31,1.48	1.21	1.15,1.28
Non-Aboriginal	14,241	3.6	1.00		1.00		1.00	
Age at birth (years)								
<20	1,003	5.1	1.39	1.31,1.48	1.13	1.06,1.21	1.19	1.12,1.28
20-34	11,738	3.7	1.00		1.00		1.00	
35-39	2,617	3.8	1.03	0.99,1.08	1.04	0.99,1.08	1.01	0.96,1.05
40+	609	4.3	1.19	1.10,1.29	1.10	1.02,1.20	1.05	0.97,1.13
Area-level SES quintiles								
1 st (most disadvantaged)	3,991	4.4	1.30	1.24,1.37	1.09	1.03,1.15	1.08	1.03,1.14
2 nd	3,459	3.9	1.15	1.09,1.20	1.05	1.00,1.11	1.05	1.00,1.10
3 rd	2,963	3.6	1.06	1.01,1.12	1.00	0.95,1.06	1.01	0.96,1.06
4 th	3,003	3.5	1.05	1.00,1.11	1.02	0.97,1.08	1.02	0.97,1.07
5 th (least disadvantaged)	2,551	3.4	1.00		1.00		1.00	
Area of residence								
Major city	9,051	3.5	1.00		1.00		1.00	
Regional	4,849	3.8	1.08	1.04,1.12	1.06	1.02,1.10	1.09	1.05,1.13
Remote	2,067	5.0	1.43	1.36,1.50	1.24	1.18,1.31	1.31	1.24,1.37
Parity								
0	7,428	4.2	1.39	1.34,1.44	1.40	1.35,1.45	1.14	1.10,1.18
1	4,427	3.0	1.00		1.00		1.00	
2-<5	3,687	3.8	1.26	1.21,1.32	1.18	1.13,1.23	1.14	1.09,1.19
≥ 5	425	5.9	1.93	1.75,2.13	1.48	1.33,1.64	1.36	1.23,1.50
Smoking during pregnancy (yes)	3,025	4.7	1.32	1.27,1.37	1.19	1.14,1.24	1.09	1.04,1.13
Pre-existing condition (yes) ³	701	8.5	2.33	2.16,2.51	1.71	1.58,1.84	1.22	1.14,1.32
Pregnancy complication (yes) ⁴	4,705	6.4	2.00	1.93,2.07	1.86	1.80,1.93	1.29	1.25,1.34
Onset of labour								
Spontaneous	7,819	3.6	1.00		1.00		1.00	
Induced	4,401	3.6	1.01	0.98,1.05	0.87	0.84,0.91	0.95	0.91,0.98

No-labour	3,747	4.6	1.29	1.24,1.34	1.24	1.19,1.29	1.30	1.23,1.38
Sex (boy)	9,443	4.4	1.40	1.35,1.44	1.39	1.35,1.43	1.34	1.30,1.38
Appropriateness for gestational age								
SGR (<3rd percentile)	690	7.4	2.16	2.00,2.32	1.85	1.72,1.99	1.81	1.68,1.94
SGA (3-<10 percentile)	1,039	4.1	1.19	1.12,1.27	1.09	1.02,1.16	1.08	1.02,1.15
AGA (10-90 percentile)	11,875	3.5	1.00		1.00		1.00	
LGA (>90 percentile)	2,363	5.2	1.49	1.43,1.56	1.46	1.40,1.52	1.33	1.27,1.39
Year of birth								
1999-2003	4,002	4.1	1.00		1.00		1.00	
2004-2007	3,496	3.6	0.89	0.85,0.93	0.88	0.85,0.92	0.85	0.82,0.89
2008-2011	3,501	3.1	0.77	0.73,0.80	0.79	0.75,0.83	0.76	0.72,0.79
2012-2015	4,968	4.2	1.01	0.97,1.05	1.03	0.98,1.07	0.99	0.95,1.04
Gestational age at birth (weeks)								
32-36	5,052	20.2	8.44	8.13,8.76			6.41	6.15,6.68
37-38	4,133	3.0	1.26	1.21,1.31			1.23	1.19,1.29
39-40	5,146	2.4	1.00				1.00	
≥41	1,636	3.4	1.40	1.32,1.48			1.34	1.27,1.42
Method of birth								
Spontaneous vaginal	6,493	2.8	1.00				1.00	
Assisted vaginal	2,668	4.4	1.58	1.51,1.65			1.64	1.57,1.72
Elective caesarean	2,153	3.0	1.05	1.00,1.10			0.83	0.78,0.90
Emergency caesarean	4,653	7.6	2.72	2.62,2.82			1.79	1.71,1.87

Abbreviations: AGA, appropriate for gestational age; CI, confidence interval; LGA, large for gestational age; RR, risk ratio; SES, socioeconomic status; SGR, severely growth restricted; SGA, small for gestational age; SNM, severe neonatal morbidity/mortality

¹ Mutually adjusted for all listed factors except gestational age and method of birth.

² Mutually adjusted for all listed factors

³ Pre-existing condition was defined as having pre-existing diabetes and/or hypertension

⁴ Pregnancy complication was defined as having any of the following: gestational hypertension, pre-eclampsia, gestational diabetes, placenta praevia, placenta abruption or other antepartum haemorrhage.

Table S4. Aboriginal status (derived using the algorithms developed by the Getting our Story Right) and severe neonatal morbidity and mortality, stratified by gestational age group, Western Australia, July 1999 - December 2015

	SNM		Unadjusted		Adjusted ¹	
	n	%	RR	95% CI	RR	95% CI
32-36 weeks						
Aboriginal	596	20.5	1.01	0.94, 1.09	0.97	0.89, 1.06
Non-Aboriginal	4,456	20.2	1.00		1.00	
37-38 weeks						
Aboriginal	440	5.0	1.73	1.57, 1.91	1.26	1.12, 1.41
Non-Aboriginal	3,693	2.9	1.00		1.00	
39-40 weeks						
Aboriginal	541	4.1	1.80	1.64, 1.96	1.47	1.33, 1.64
Non-Aboriginal	4,605	2.3	1.00		1.00	
≥41 weeks						
Aboriginal	149	5.3	1.63	1.38, 1.92	1.50	1.24, 1.82
Non-Aboriginal	1,487	3.2	1.00		1.00	

Abbreviations: CI, confidence interval; SNM, severe neonatal morbidity/mortality; RR, risk ratio

¹ Each model was adjusted for age, area-level socioeconomic status, area of residence, parity, smoking during pregnancy, infant sex, appropriateness for gestational age, onset of labour, pre-existing condition (pre-existing diabetes and/or hypertension), pregnancy complication (gestational hypertension, pre-eclampsia, gestational diabetes, placenta praevia, placental abruption or other antepartum haemorrhage), method and year of birth.

Table S5. The rate of SNM by Aboriginal status and year of birth

	Year of birth				Overall
	1999-2003	2004-2007	2008-2011	2012-2015	
SMN rate (n)					
Aboriginal	6.6 (390)	7.3 (422)	5.2 (314)	6.9 (412)	6.5 (1,538)
Non- Aboriginal	3.9 (3,612)	3.4 (3,074)	3.0 (3,187)	4.0 (4,556)	3.6 (14,429)
Absolute difference	2.7	3.9	2.1	2.9	2.9

Table S6. Factors contributing to the gap in severe neonatal morbidity and mortality between Aboriginal (derived using the algorithms developed by the Getting our Story Right) and Non-Aboriginal live births ≥ 32 weeks' gestation, Western Australia, July 1999 - December 2015

	β (%)	95% CI		Proportion
		Lower	Upper	
SMM prevalence				
Aboriginal	6.2	5.9	6.5	
Non-Aboriginal	3.6	3.5	3.6	
Absolute difference	2.6	2.4	2.9	
Independent contribution of each variable to the disparity				
Maternal socio-demographic and health behaviour factors				54.6
Age	0.21	0.12	0.29	7.9
Area-level SES	0.21	0.09	0.32	7.8
Area of residence	0.64	0.52	0.75	24.0
Parity	0.20	0.13	0.27	7.4
Smoking during pregnancy	0.20	0.10	0.30	7.5
Maternal medical conditions				0.6
Pre-existing condition ¹	0.02	0.01	0.03	0.8
Pregnancy complication ²	-0.01	-0.02	0.00	-0.3
Pregnancy related factors				15.6
Onset of labour	-0.18	-0.23	-0.13	-6.8
Gestational age	0.60	0.54	0.66	22.5
Appropriateness for gestational age	0.11	0.08	0.14	4.2
Method of birth	-0.11	-0.18	-0.05	-4.3
Total disparity explained	1.87	1.71	2.04	70.8

Abbreviations: CI, confidence interval; SES, socioeconomic status; SNM, severe neonatal morbidity/mortality

¹ Pre-existing condition was defined as having pre-existing diabetes and/or hypertension

² Pregnancy complication was defined as having any of the following: gestational hypertension, pre-eclampsia, gestational diabetes, antepartum haemorrhage, placenta praevia or abruption.

Table S7. Factors contributing to the disparities in severe neonatal morbidity and mortality between Aboriginal and Non-Aboriginal births, restricted to one delivery per a woman (n=259,080)

	β (%)	95% CI		Proportion
		Lower	Upper	
SMM prevalence				
Aboriginal	7.1	6.6	7.5	
Non-Aboriginal	3.7	3.7	3.8	
Absolute difference	3.3	2.9	3.8	
Independent contribution of each variable to the disparity				
Maternal socio-demographic and health behaviour factors				54.0
Age	0.14	0.04	0.25	4.2
Area-level SES	0.28	0.13	0.43	8.4
Area of residence	0.79	0.61	0.96	23.6
Parity	0.33	0.22	0.44	9.8
Smoking during pregnancy	0.26	0.13	0.40	7.9
Maternal medical conditions				2.4
Pre-existing condition ¹	0.04	0.02	0.06	1.3
Pregnancy complication ²	0.04	0.02	0.05	1.1
Pregnancy related factors				25.5
Onset of labour	-0.13	-0.18	-0.07	-3.9
Gestational age	0.80	0.71	0.90	24.1
Appropriateness for gestational age	0.14	0.10	0.18	4.2
Method of birth	0.04	-0.04	0.11	1.1
Total disparity explained	2.73	2.47	2.99	81.9

Abbreviations: CI, confidence interval; SES, socioeconomic status; SNM, severe neonatal morbidity/mortality

¹ Pre-existing condition was defined as having pre-existing diabetes and/or hypertension

² Pregnancy complication was defined as having any of the following: gestational hypertension, pre-eclampsia, gestational diabetes, placenta praevia, placenta abruption or other antepartum haemorrhage

Table S8. Factors contributing to the disparity in severe neonatal morbidity and mortality between Aboriginal and Non-Aboriginal live births ≥ 32 weeks' gestation, restricted to births with spontaneous onset of labour (n=)

	β (%)	95% CI		Proportion
		Lower	Upper	
SMM prevalence				
Aboriginal	6.0	5.7	6.4	
Non-Aboriginal	3.4	3.3	3.4	
Absolute difference	2.7	2.3	3.0	
Independent contribution of each variable to the disparity				
Maternal socio-demographic and health behaviour factors				48.4
Age	0.11	-0.01	0.23	4.2
Area-level SES	0.14	-0.02	0.29	5.2
Area of residence	0.63	0.47	0.79	23.7
Parity	0.09	-0.02	0.19	3.3
Smoking during pregnancy	0.32	0.18	0.46	12.0
Maternal medical conditions				0.4
Pre-existing condition ¹	0.01	0.00	0.02	0.5
Pregnancy complication ²	0.00	-0.01	0.01	-0.1
Pregnancy related factors				9.2
Gestational age	0.54	0.46	0.62	20.2
Appropriateness for gestational age	0.09	0.04	0.13	3.2
Method of birth	-0.38	-0.43	-0.32	-14.2
Total disparity explained	1.55	1.32	1.78	58.0

Abbreviations: CI, confidence interval; SES, socioeconomic status; SNM, severe neonatal morbidity/mortality

¹ Pre-existing condition was defined as having pre-existing diabetes and/or hypertension

² Pregnancy complication was defined as having any of the following: gestational hypertension, pre-eclampsia, gestational diabetes, placenta praevia, placenta abruption or other antepartum haemorrhage

Table S9. Factors contributing to the disparity in severe neonatal morbidity and mortality between Aboriginal and Non-Aboriginal live births ≥ 32 weeks' gestation, stratified by gestational age

	β (%)	95% CI		Proportion
		Lower	Upper	
32-36 weeks¹				
SMM prevalence				
Aboriginal	20.7	19.1	22.3	
Non-Aboriginal	20.2	19.6	20.7	
Absolute difference	0.5	-1.1	2.2	
37-38 weeks				
SMM prevalence				
Aboriginal	5.4	4.9	5.9	
Non-Aboriginal	2.9	2.8	3.0	
Absolute difference	2.5	2.0	3.0	
Independent contribution of each variable to the disparity				
Age	0.29	0.15	0.42	11.4
Area-level SES	0.16	-0.03	0.34	6.3
Area of residence	0.67	0.47	0.86	26.6
Parity	0.36	0.24	0.47	14.2
Smoking during pregnancy	0.29	0.13	0.45	11.7
Pre-existing condition ²	0.04	0.02	0.06	1.8
Pregnancy complication ³	-0.02	-0.04	-0.01	-0.8
Onset of labour	-0.15	-0.33	0.02	-6.1
Appropriateness for gestational age	0.11	0.06	0.16	4.3
Method of birth	-0.22	-0.41	-0.03	-8.8
Total disparity explained	1.52	1.22	1.81	60.4
39-40 weeks				
SMM prevalence				
Aboriginal	4.17	3.80	4.55	
Non-Aboriginal	2.30	2.23	2.36	
Absolute difference	1.87	1.49	2.25	
Independent contribution of each variable to the disparity				
Age	0.02	-0.06	0.10	1.1
Area-level SES	0.28	0.18	0.39	15.2
Area of residence	0.40	0.27	0.53	21.4
Parity	-0.04	-0.12	0.04	-2.0
Smoking during pregnancy	0.24	0.14	0.33	12.6
Pre-existing condition ²	0.01	0.00	0.01	0.3
Pregnancy complication ³	-0.01	-0.01	0.00	-0.4
Onset of labour	0.03	-0.01	0.08	1.7
Appropriateness for gestational age	0.04	0.01	0.07	2.1
Method of birth	-0.16	-0.22	-0.11	-8.8
Total disparity explained	0.81	0.60	1.02	43.2
≥ 41 weeks				
SMM prevalence				
Aboriginal	5.66	4.73	6.59	
Non-Aboriginal	3.24	3.08	3.40	

Absolute difference	2.42	1.48	3.37	
Independent contribution of each variable to the disparity				
Age	-0.13	-0.32	0.07	-5.3
Area-level SES	0.14	-0.11	0.40	6.0
Area of residence	0.52	0.17	0.86	21.3
Parity	-0.06	-0.25	0.13	-2.4
smoking during pregnancy	0.20	0.00	0.40	8.3
Pre-existing condition ²	0.01	-0.01	0.02	0.3
Pregnancy complication ³	0.01	0.00	0.03	0.6
Onset of labour	0.04	0.00	0.08	1.8
Appropriateness for gestational age	0.03	-0.03	0.09	1.4
Method of birth	-0.28	-0.38	-0.18	-11.6
Total disparity explained	0.49	-0.05	1.02	20.1

Abbreviations: CI, confidence interval; SES, socioeconomic status; SNM, severe neonatal morbidity/mortality

¹ No significant difference in severe neonatal morbidity and mortality between Aboriginal and Non-Aboriginal live births at this gestational age window, so results for decomposition analysis were not reported.

² Pre-existing condition was defined as having pre-existing diabetes and/or hypertension

³ Pregnancy complication was defined as having any of the following: gestational hypertension, pre-eclampsia, gestational diabetes, placenta praevia, placenta abruption or other antepartum haemorrhage