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Socioethnic disparities in severe maternal morbidity in Western Australia: a statewide retrospective cohort study

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ABSTRACT

Objectives To assess the scale of ethnic inequalities in severe maternal morbidity (SMM) rates and quantify the contribution of maternal characteristics to these disparities.

Design Retrospective cohort study.

Setting Whole-of-population linked administrative data from 2002 to 2015 in Western Australia.

Participants Women with 410 043 birth events (includes all births from the same pregnancy) of 20 weeks' or more gestation, including terminations for congenital anomalies.

Primary and secondary outcome measures Women with SMM were identified based on a composite indicator of SMM using diagnosis and procedure codes developed for use in routinely collected data. Mothers were classified into seven ethnic groups, based on their reported ethnic origin. The associations between maternal ethnic origin and SMM were examined using a log-binomial model, which estimates risk ratios (RRs) and 95% CIs. The Blinder-Oaxaca decomposition technique was employed to partition the disparity in SMM between Aboriginal and Caucasian populations into 'explained' and 'unexplained' components.

Results During the study period, 9378 SMM cases were documented. In the adjusted model, Aboriginal (RR 1.73, 95% CI 1.59 to 1.87), African (RR 1.64, 95% CI 1.43 to 1.89) and 'other' ethnicity (RR 1.49, 95% CI 1.37 to 1.63) women were at significantly higher risk of SMM compared with Caucasian women. Teenage and older mothers and socioeconomically disadvantaged women were also at greater risk of SMM. Differences in sociodemographic characteristics explained 33.2% of the disparity in SMM between Aboriginal and Caucasian women.

Conclusions There are distinct disparities in SMM by ethnicity in Western Australia, with a greater risk among Aboriginal and African women. While improvements in SES and a reduction in teenage pregnancy can potentially support a sizeable reduction in SMM rate inequalities, future research should investigate other potential pathways and targeted interventions to close the ethnicity disparity.

Strengths and limitations of this study

► A whole population-based linked data over 14 years with a validated severe maternal morbidity outcome indicator.

► Formal evaluation of the contribution of sociodemographic and other characteristics to the ethnicity disparity in severe maternal morbidity.

► We used data collected for administrative purposes that may contain errors and inconsistencies.

► A significant proportion of the severe maternal morbidity disparity remains unexplained by sociodemographic and comorbid conditions.

► We had limited data on prepregnancy obesity and no data about mental health problems, substance abuse and other behavioural risks that disproportionately affect the Aboriginal population.

morbidity (SMM) is increasing.[1–3] Accordingly, SMM has become a more pressing concern for preventative maternity care initiatives and a more relevant marker of care quality. Some countries now include SMM measures in routine surveillance, although its definition varies across countries.[4–7]

A large body of evidence highlights persistent disparities in SMM rates by maternal ethnicity.[8] For example, in the USA, the incidence of SMM is higher among non-Hispanic black women compared with non-Hispanic white women,[9] and in the UK, the greatest SMM risk was reported among black African and Caribbean women, compared with white women.[10] A Canadian study, using country of birth as the ethnicity indicator, found a twofold increased risk of SMM among migrants from sub-Saharan Africa.[11]

Australia is a diverse, multicultural country composed of a minority Indigenous population (Aboriginal and Torres Strait Islander peoples; hereafter respectfully referred to as Aboriginal) and migrants from a wide range

INTRODUCTION

Maternal mortality is now rare in high-income countries, while the rate of severe maternal

of ethnic backgrounds, but the SMM rate and associated risk factors have rarely been examined. Existing studies are inconsistent in regards to the association between ethnicity/country of birth and SMM.[12–14] For instance, a study using 10 years of birth data (1999–2008) from the Australian state of Victoria found that women from sub-Saharan Africa had double the risk of SMM,[14] while another study using only the subset of births in 2006–2008 and a different definition of SMM[13] found no such association. However, the second, smaller study did find a significant disparity in SMM between Aboriginal and non-Aboriginal populations,[13] a topic that was not investigated in the larger study.[14]

Maternal sociodemographic and lifestyle factors and comorbid conditions are commonly reported as SMM risk factors.[15–17] These include advanced maternal age (≥35 years),[18] nulliparity,[19] lower socioeconomic status (SES),[12] pre-existing medical conditions and pregnancy complications such as hypertension and gestational diabetes.[17] However, it is unknown to what extent differences in the distribution of these factors contribute to SMM disparities between different ethnic groups. A better understanding of risk factors and their relative contributions to SMM disparities is required to provide insights for addressing the ethnic disparities in maternal morbidity and mortality and to reduce overall rates. Thus, the aims of this study were: (1) to assess the scale of ethnic inequalities in SMM and (2) to quantify the contributions of maternal sociodemographic and other characteristics to differences, if any, in SMM rates between Aboriginal and Caucasian women.

METHODS
Study design and population
We conducted a retrospective cohort study using all births (singleton and multiple) of 20 weeks' or more gestation (including terminations for congenital anomalies) between 2002 and 2015 in Western Australia. This period was selected because data on maternal birthplace were available since 2002 only. As the outcomes of interest were related to mothers, not births, we reduced the sample to the pregnancy level and used the term 'birth event' to cover all births from the same pregnancy (figure 1). The base sample consisted of birth events with a matching hospital admission (n=410 218) and all planned non-hospital birth events (at home or a birth centre, n=2909). Planned non-hospital birth events without a matching hospital admission within 4 days of the birth event (median length of hospital stay for normal vaginal birth) were included and classified as non-SMM cases as only women with normal or low-risk pregnancies usually have a planned non-hospital birth event and any complications would have resulted in a hospital admission. Hospital birth events without a matching hospital admission and those missing any of the key variables were excluded (figure 1).
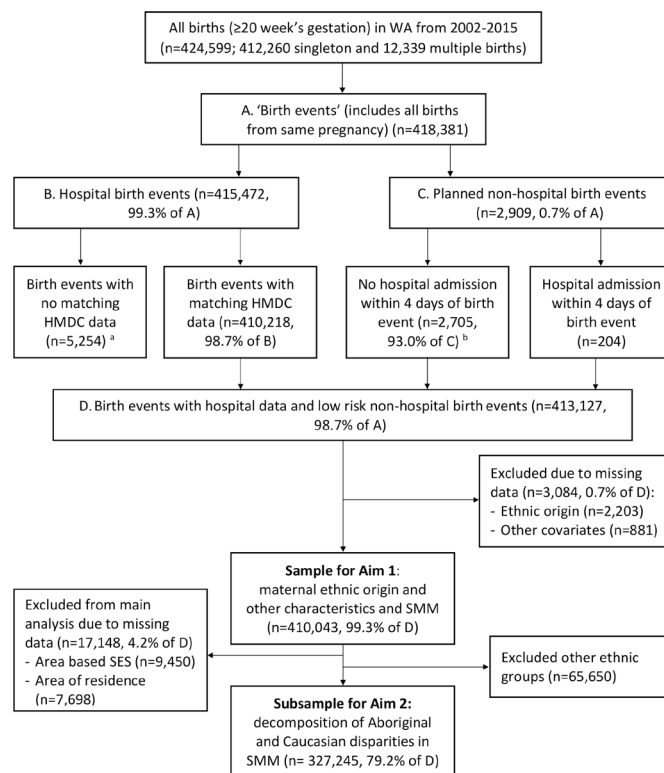
Figure 1 Study participant flow chart, Western Australia (WA), 2002–2015. HMDC, Hospital Morbidity Data Collection; SES, socioeconomic status; SMM, severe maternal morbidity.

Patient or public involvement
No patient or public were involved in the conception of the study or its design, conduct or interpretation of findings. As the study was based on anonymised population health data, there is no planned dissemination to study participants.

Datasets and variables
Data were obtained from four core population health datasets of the Western Australia Government Department of Health: the Midwives' Notification System (MNS), Hospital Morbidity Data Collection (HMDC) and birth and death registers.[20] While the MNS records the circumstances of all births of 20 weeks' or more gestation, with information received from attending practitioners, the HMDC includes information about all inpatient episodes in public and private hospitals in Western Australia, with both datasets available from 1980. These datasets were linked together by the Data Linkage Branch of the Western Australian Government Department of Health via probabilistic linkage method using common identifiers including name, address and birthdate. The data (with identifying fields removed) were securely transferred to the research team.

Exposure
Self-reported maternal ethnicity origin in the MNS is categorised as Caucasian (including Western European origin), Aboriginal, Asian, Indian, African, Polynesian, Maori and 'other' ethnicities. As part of the birth register,

maternal country of birth was available from 2002 onwards and was used to further classify mothers as being Australian or overseas born.

Outcome

The SMM outcome indicator variable was based on a previously validated indictor for use in routinely collected hospital morbidity data developed in New South Wales, which includes International Classification of Disease 10 Australian Modification diagnosis and Australian Classification of Health Interventions procedure codes.[21] The indicator comprised 14 diagnosis categories and 11 procedures, which range from rare but life-threatening conditions (including maternal death) such as acute renal failure, acute psychosis, disseminated intravascular coagulopathy, shock and uterine rupture to relatively more frequent procedures such as hysterectomy and blood transfusion. For this study, modifications were made to the indicator to reflect coding changes over time as advised by the Western Australian Clinical Coding Authority. The diagnostic and procedure codes included as components of SMM are available in the supplement (see online supplemental table S1).

Covariates

Maternal sociodemographic and other characteristics, obtained from the MNS dataset, were categorised as follows: age at childbirth (<20, 20–24, 25–29, 30–34, 35–39 and 40 years and above), parity (0, 1, 2–4 and 5 and above), area of residence (major city, inner regional, outer regional, remote and very remote), SES quintiles (most disadvantaged through least disadvantaged), smoking during pregnancy (yes/no) and multiple birth (yes/no). Area of residence was determined based on the Australian Statistical Geography Standard remoteness classification,[22] which divides Australia into broad regions that share common characteristics of remoteness for statistical use. Area-level SES disadvantage was derived based on the mother's place of residence at the time of the birth event and measured using the Australian Bureau of Statistics' Index of Relative Socioeconomic Disadvantage (IRSD) from the Census closest to the birth event. The IRSD ranks the relative level of disadvantage of areas using the attributes of all persons in each geographical area (Census Collection District; average population of 400 persons) and includes measures of income, educational attainment, employment status, occupational skill and housing. Quintiles were determined based on the Australian distribution of the small area values.[23]

Women were classified as having a pre-existing medical condition (essential hypertension and diabetes) and pregnancy complication (gestational diabetes or hypertension, pre-eclampsia, placenta praevia, placental abruption and antepartum haemorrhage) if they were recorded in the MNS or in the HMDC in any admission prior to pregnancy (pre-existing medical conditions) or during the index pregnancy (pregnancy complications). Due to the relatively small numbers, the essential hypertension

and any pre-existing diabetes variables were combined into a single 'any pre-existing medical condition variable'. Similarly, the individual pregnancy complications listed above were combined into a single 'any pregnancy complication variable'.

Statistical analyses

First, we used χ^2 tests to compare the distribution of maternal characteristics across ethnic origin groups. Second, we employed a log-binomial model with cluster-robust SEs (accounting for more than one birth event per woman during the study period) to estimate risk ratios (RRs) and 95% CIs for the association of maternal ethnic origin and other covariates and the risk of SMM. Factors included in the multivariable analysis were selected based on findings in the extant literature.[13 17]

Third, based on the results of the log-binomial model, we performed a decomposition analysis using a sample restricted to Aboriginal and Caucasian birth events. This analysis was not conducted on other ethnic groups as there was either insufficient sample size or relative similarity in SMM outcomes. We used the Blinder-Oaxaca decomposition technique to partition the disparity in SMM between Aboriginal women and Caucasians into 'explained' and 'unexplained' components.[24] The explained part, or endowment, is the proportion of SMM prevalence difference attributable to differences in the distributions of included factors (eg, age and SES). Whereas the unexplained portion (the differences in the intercepts and coefficient estimates), also called the coefficient effect, could be due to deferential effects of these factors on the risk of SMM, because of unmeasured factors or systematic discriminations within the data between Aboriginals and Caucasians.[25] In other words, the explained portion represents the amount by which the disparity in SMM would be reduced if the prevalence of each of the selected model covariates was the same for Aboriginal and Caucasian women. The unexplained portion, on the other hand, quantifies the ethnicity disparity in SMM proportion that would remain even if Aboriginal women had the same mean levels of included factors as Caucasian women. Although this decomposition method has mainly been employed in econometric research with continuous outcome variables, it is starting to be implemented in epidemiological studies with both continuous and categorical outcome variables.[26 27] The decomposition analysis was performed using the 'Oaxaca' command in STATA with logit option, and cluster-robust standard errors were used to account for correlations between birth events to the same women. The pooled model was used to calculate estimates and 95% CIs of the explained portion for each factor included.

Sensitivity analyses

Finally, we repeated the main analyses after excluding cases where blood transfusion (a most common cause of SMM) was the sole indicator of SMM and in a subsample restricted to one birth event per woman (the first

birth event was selected for women with two or more birth events during the study period). To check whether missing data on the SES and/or area of residence variables affected the results of the decomposition analysis, we re-ran the decomposition analysis with two extreme scenarios. In the first scenario, all SES missing values were considered as first (most disadvantaged) quintile, and all missing data on the area of residence were assumed as very remote (for the Aboriginal) and as fifth (least disadvantaged) quintile and as a major city (for Caucasian) women. In the second scenario, these values were reversed.

All analyses were performed using STATA V.15.

RESULTS
Aim 1: maternal ethnic origin and other characteristics and SMM risk

A total of 410 043 birth events (from 248 441 women; 128 305 women contributed one birth event and 120 136 women contributed two or more birth events) were included for the analysis of the first aim, with the majority birth events from Caucasian (n=318 839), Asian (n=29 956) or Aboriginal (n=22 650) women. During the study period, 9378 SMM cases were documented, with rates ranging from 201.9 per 10 000 birth events in Caucasian women to 448.6 per 10 000 birth events in Aboriginal women (table 1). Eight maternal deaths were recorded, and the SMM outcome indicator variable classified all of them as having SMM.

All characteristics listed in table 1 significantly differed by maternal ethnic origin (p<0.001, for each variable). A substantially higher proportion of Aboriginal mothers were aged <20 years at the birth event, living in the most socioeconomically disadvantaged areas, remote or very remote locations and had pre-existing medical conditions than Caucasian women. A greater percentage of African and Maori/Polynesian women were also living in the most socioeconomically disadvantaged areas, and Asian women were older at the birth event (≥35 years). Both Aboriginal and African women were more likely to be grand multiparous (parity five or more). Aboriginal and Maori/Polynesian women were more likely to have smoked during pregnancy, while Asian and Indian women were the most likely to have a pregnancy complication.

In the adjusted model, Aboriginal (RR 1.73, 95% CI 1.59 to 1.87), African (RR 1.64, 95% CI 1.43 to 1.89) and Asian women (RR 1.34, 95% CI 1.24 to 1.45) had an elevated risk of SMM compared with Caucasian women (table 2). Maternal age was also significantly associated with the development of SMM, with notable effects for teenage mothers (RR 1.58, 95% CI 1.45 to 1.73) and those aged 40 years and above (RR 1.25, 95% CI 1.12 to 1.39). In addition, those living in the lowest two quintiles of socioeconomic disadvantage (or those with no SES data) and very remote areas, birth events from 2007 to 2011, women with a pregnancy complication, multiple birth or who were nulliparous had an increased risk of SMM in

the multivariable model (table 2). Online supplemental table S2 shows whether the effect of maternal ethnic origin on SMM varied by maternal region of birth, and the cross-tabulation of the maternal region of birth by ethnic origin is shown in the online supplemental table S3. Compared with Australian-born Caucasian women, all overseas-born women except Caucasians were at a significantly higher risk of SMM.

Sensitivity analyses

When blood transfusion only cases were excluded (see online supplemental table S4), there were minor differences in the associations for Aboriginal women (decreased) and African women (increased) and a significantly lower risk of SMM for women living in outer regional and remote areas compared with women from the Perth metropolitan area (major cities). While the estimates for any pregnancy complication, and multiple births slightly decreased, smoking during pregnancy and pre-existing medical conditions became significant risk factors for SMM, although the actual effect sizes were relatively small. The results restricted to one birth event per woman were not substantially different from the results of the main analyses (see online supplemental table S5).

Aim 2: decomposition of disparities in SMM between Aboriginal and Caucasian women

This subsample analysis included 327 245 birth events from 197 853 women, after excluding 17 148 birth events from 15 019 women due to missing data on SES quintiles and/or area of residence. Table 3 shows the disparity in SMM between Aboriginal and Caucasian birth events and factors contributing to the disparity. In the adjusted model for multiple birth and year of birth event, there was a 2.6 percentage point disparity in the prevalence of SMM between Aboriginal and Caucasian women. About a third (33.2%) of this disparity was attributable to differences in all characteristics included in the decomposition model. Maternal sociodemographic factors including age, SES quintiles and area of residence explained the greater proportion of the disparity in the prevalence of SMM between Aboriginal and Caucasian women, while smoking during pregnancy and comorbid medical conditions made little contribution to the ethnic disparity in SMM.

Sensitivity analyses

After exclusion of blood transfusion only cases, there was a relatively smaller disparity in the prevalence of SMM between Aboriginal and Caucasian women and the area of residence contributed towards reducing this, although it was offset by smoking during pregnancy (see online supplemental table S6). The negative contribution for the area of residence indicates that the disparity would have been larger if birth events from Aboriginal women had similar area of residence distribution as that of the Caucasian women. In the subsample analysis restricted to one birth event per woman, there was a slight increase in the

Table 1 Distribution of population characteristics, including SMM, by maternal ethnic origin, Western Australia, 2002–2015

	Ethnic origin						
	Caucasian n=318839*	Aboriginal n=22650*	Asian n=29956*	Indian n=9568*	African n=5766*	Maori/Polynesian n=4953*	Other n=18311*
	%	%	%	%	%	%	%
Characteristics							
Age at birth (years)							
<20	3.6	22	1.1	0.4	4.2	9.6	3.6
20–24	14.2	32.8	8.3	9.8	18.6	29.6	17
25–29	27.5	24.1	27.8	40.1	30.3	27.6	29.4
30–34	33.4	13.5	37.9	36.6	29.4	20.7	29.7
35–39	17.7	6.4	20.3	11.1	14.3	10	16.3
40+	3.6	1.3	4.6	1.9	3.3	2.5	4.1
SES quintiles							
1st (most disadvantaged)	17.1	61	19.7	19.9	40.2	29.5	25.6
2nd	19.7	19.3	22.3	27.7	27.1	26.7	24
3rd	20.1	9.9	18.2	18.9	14.8	20.4	19
4th	21.5	5.2	17.7	15.1	10	14.8	16.5
5th (least disadvantaged)	19.4	2.1	19.3	14.5	5.9	6.7	12.6
Data not available	2.2	2.6	2.8	4	2	2	2.3
Area of residence							
Major city	58.9	26.3	80.3	86.4	86.2	58.6	77
Inner region	22.8	12.7	10.3	5.6	7.8	18.5	10.9
Outer region	7.4	13.3	2.6	1.9	1.7	11	4.4
Remote	4	14.6	1.9	1.1	0.6	4	2.6
Very remote	3.9	28.9	1.6	0.8	1	5.1	2.2
Data not available	3	4.2	3.3	4.2	2.7	2.8	3
Parity							
0	42.5	30.6	47.6	55.1	29	34.6	39.6
1	35.1	23.6	35.7	35.2	26.7	27.3	31.3
2–4	21.4	36.5	16.2	9.6	35.4	33.6	26.1
≥5	1	9.3	0.5	0.2	9	4.5	3
Smoking during pregnancy	13.2	48.7	2.1	1.1	2	35.2	8.6
Any pre-existing conditions†	2.1	3.9	1.4	1.6	1.9	2.1	2.1
Any pregnancy complications‡	16.3	17.6	22	25.6	18.2	17.5	19.4
Multiple birth	1.5	1.2	1	1.1	1.5	1.2	2
Year of birth							
2002–2006	33.2	34.2	22.5	10	15.3	20.6	18.9
2007–2011	37.4	36.9	32.9	29.2	40.6	34.2	36.5
2012–2015	29.4	28.9	44.6	60.9	44.1	45.2	44.6
SMM							
Number of cases	6436	1016	814	197	204	130	581
Rate per 10 000 birth events	201.9	448.6	271.7	205.9	353.8	262.5	317.3
Blood/coagulation factor transfusion							
Number of cases	2922	610	377	82	73	63	214
Rate per 10 000 birth events	92.3	269.5	126.1	85.8	126.7	128.4	117.7

*Birth event (this includes all births from the same pregnancy).
†Any pre-existing condition was defined as having pre-existing diabetes and/or hypertension.
‡Any pregnancy complication was defined as having any of the following: gestational hypertension, pre-eclampsia, gestational diabetes, antepartum haemorrhage, placenta praevia or abruption.
SES, socioeconomic status; SMM, severe maternal morbidity.

Table 2 The effect of maternal ethnic origin and other characteristics on SMM, Western Australia, 2002–2015

Characteristics	SMM		RR (95% CI)	
	N*	Rate per 10000 birth events	Unadjusted	Adjusted†
Ethnic origin				
Caucasian	6436	201.9	1.00 (reference)	1.00 (reference)
Aboriginal	1016	448.6	2.22 (2.08 to 2.38)	1.73 (1.59 to 1.87)
Asian	814	271.7	1.35 (1.25 to 1.45)	1.34 (1.24 to 1.45)
Indian	197	205.9	1.02 (0.89 to 1.17)	0.98 (0.85 to 1.13)
African	204	353.8	1.75 (1.53 to 2.01)	1.64 (1.43 to 1.89)
Maori/Polynesian	130	262.5	1.30 (1.10 to 1.54)	1.17 (0.99,1.39)
Other	581	317.3	1.57 (1.44 to 1.71)	1.49 (1.37 to 1.63)
Maternal age (years)				
<20	755	414.1	2.15 (1.99 to 2.33)	1.58 (1.45 to 1.73)
20–24	1757	285	1.48 (1.39 to 1.57)	1.29 (1.21 to 1.37)
25–29	2456	215.7	1.12 (1.05 to 1.19)	1.06 (1.00 to 1.12)
30–34	2550	192.5	1.00 (reference)	1.00 (reference)
35–39	1496	215.4	1.12 (1.05 to 1.19)	1.12 (1.05 to 1.19)
40+	364	252.5	1.31 (1.18 to 1.46)	1.25 (1.12 to 1.39)
SES quintiles				
1st (most disadvantaged)	2454	289.8	1.63 (1.53 to 1.75)	1.29 (1.20 to 1.39)
2nd	2089	249	1.40 (1.31 to 1.50)	1.25 (1.16 to 1.34)
3rd	1700	215.4	1.21 (1.13 to 1.31)	1.13 (1.05 to 1.22)
4th	1609	199.3	1.12 (1.04 to 1.21)	1.09 (1.01 to 1.17)
5th	1283	177.3	1.00 (reference)	1.00 (reference)
Data not available	243	257.1	1.45 (1.27 to 1.66)	1.34 (1.15 to 1.56)
Area of residence				
Major city	5500	221.7	1.00 (reference)	1.00 (reference)
Inner region	1768	214.2	0.97 (0.92 to 1.02)	0.99 (0.93 to 1.04)
Outer region	723	249.7	1.13 (1.04 to 1.22)	1.03 (0.95 to 1.12)
Remote	479	274.5	1.24 (1.13 to 1.36)	1.09 (0.99 to 1.19)
Very remote	644	318.2	1.44 (1.32 to 1.56)	1.15 (1.05 to 1.26)
Data not available	264	207.7	0.94 (0.83 to 1.06)	0.85 (0.75 to 0.98)
Parity				
0	4559	264.3	1.37 (1.31 to 1.44)	1.26 (1.20 to 1.32)
1	2689	192.3	1.00 (reference)	1.00 (reference)

Continued

Table 2 Continued

	SMM		RR (95% CI)	
	N*	Rate per 10000 birth events	Unadjusted	Adjusted†
2–4	1925	211.9	1.10 (1.04 to 1.17)	1.03 (0.97 to 1.10)
≥5	205	298.7	1.55 (1.34 to 1.80)	1.14 (0.98 to 1.33)
Smoking during pregnancy	1566	273	1.23 (1.17 to 1.30)	1.04 (0.98 to 1.10)
Any pre-existing conditions†	265	309.5	1.36 (1.21 to 1.54)	1.13 (1.00 to 1.28)
Any pregnancy complications‡	2522	358	1.77 (1.69 to 1.86)	1.70 (1.62 to 1.78)
Multiple birth	246	405.5	1.79 (1.58 to 2.03)	1.74 (1.54 to 1.97)
Year of birth				
2002–2006	2542	200.7	1.00 (reference)	1.00 (reference)
2007–2011	4006	265.4	1.32 (1.26 to 1.39)	1.32 (1.25 to 1.39)
2012–2015	2830	213.7	1.06 (1.01 to 1.12)	1.04 (0.99 to 1.11)

*Birth event (this includes all births from the same pregnancy).
†Any pre-existing condition was defined as having pre-existing diabetes and/or hypertension.
‡Any pregnancy complication was defined as having any of the following: gestational hypertension, pre-eclampsia, gestational diabetes, antepartum haemorrhage, placenta praevia or abruption.
§Mutually adjusted for listed factors.
RR, risk ratio; SES, socioeconomic status; SMM, severe maternal morbidity.

Table 3 Decomposition analysis of factors contributing to SMM disparity between Aboriginal and Caucasian birth events, Western Australia, 2002–2015

	Model 1		Model 2*	
	β (95% CI)	Proportion explained	β (95% CI)	Proportion explained
SMM				
Aboriginal	4.49		4.32	
Caucasian	2.02		1.72	
Difference	2.47		2.6	
Total difference explained	0.96 (0.78 to 1.14)	38.8	0.86 (0.70 to 1.02)	33.19
Age at delivery	0.45 (0.35 to 0.55)	18.17	0.40 (0.31 to 0.49)	15.26
SES quintiles	0.37 (0.26 to 0.49)	15.13	0.32 (0.22 to 0.42)	12.42
Area of residence	0.12 (0.01 to 0.24)	4.83	0.12 (0.02 to 0.23)	4.75
Any pregnancy complications†	0.03 (0.01 to 0.04)	1.1	0.02 (0.01 to 0.04)	0.9
Smoking during pregnancy	0.04 (−0.05 to 0.13)	1.6	0.04 (−0.04 to 0.12)	1.61
Any pre-existing conditions‡	0.01 (0.00 to 0.02)	0.4	0.01 (0.00 to 0.02)	0.32
Parity	−0.06 (−0.14 to 0.02)	−2.43	−0.05 (−0.12 to 0.02)	−2.07

Values shown as per cent.
*Adjusted for plurality and year of birth.
†Any pregnancy complication was defined as having any of the following: gestational hypertension, pre-eclampsia, gestational diabetes, antepartum haemorrhage, placenta praevia or abruption.
‡Any pre-existing condition was defined as having pre-existing diabetes and/or hypertension.
SES, socioeconomic status; SMM, severe maternal morbidity.

proportion of the model explained by available characteristics, and the contribution of area of residence attenuated and spanned the null value (see online supplemental table S7). We also found largely similar results to the main analyses in the extreme case scenarios, including missing data on the SES and/or area of residence variables (see online supplemental tables S8 and S9).

DISCUSSION

In this population-based study, we found a considerable disparity in SMM by ethnic origin. Aboriginal and African women were at a significantly higher risk of SMM compared with Caucasian women. Teenage and older (40 years and above) women, those living in the lowest quintiles of socioeconomic disadvantage and women with a pregnancy complication, multiple birth or who were nulliparous had an elevated risk of SMM. Importantly, our findings also demonstrated that one-third of the disparity in SMM between Aboriginal and Caucasian women was attributable to variations in sociodemographic factors.

This study confirms an increased risk of SMM among Aboriginal and African women, a finding consistent with other markers of maternal and fetal well-being in Australia.[28] The increased risk of SMM among African (black) or sub-Saharan migrant women in particular is well documented in the USA and in other high-income nations.[8 11] However, there is a paucity of research about the association of ethnicity and SMM in an Australian context. Together with the findings of an earlier study in the Australian state of Victoria,[13] the results from the first aim of this study underscore the greater well-being and perinatal healthcare needs of Aboriginal, African and other ethnic minority women.

The excess risk of SMM among Aboriginal and African women is the result of the interplay of multiple and complex factors, ranging from poorer antenatal care to issues of prenatal and perinatal health conditions.[29] Appropriate antenatal care is critical to identify high-risk pregnancies and promote healthy lifestyles that are important for both the mother and the newborn. However, a high proportion of Aboriginal women start their antenatal care late in their pregnancy and tend to have a lower visit frequency,[28] a reflection of both proximity to services, financial means and the level and perceptions of culturally safe care provision.[29 30] Discrimination is a common thread to issues of access to culturally safe care, with a plethora of studies highlighting that women from ethnic minority groups (including Australian Aboriginal cultures) often have diminished access to health promotion, medical and other resources or unequal access that leads to withdrawing from healthcare—all with consequences for pregnancy health.[29 31 32] For example, discriminatory practices may place Aboriginal mothers at risk of missing important screenings such as for anaemia, a common public health problem among Aboriginal populations[33] (which is associated with a higher risk of postpartum haemorrhage). As our findings have shown, African women share some of the

characteristics of Aboriginal women such as low SES and higher parity, which were significantly associated with the development of SMM. Additionally, the increased risk of SMM among African women (includes a diverse group of women with the most prevalent groups being from Sudan (27%), Somalia (14%), Zimbabwe (9%) and Ethiopia (8%)) could be because of a different sociocultural risk profile that includes genital mutilation and cultural practices related to pregnancy and childbirth.[34 35] For instance, in one study in the USA,[36] migrant women from Somali were found to be reluctant to have medical interventions during childbirth such as caesarean and induction. This underscores the need for comprehensive and culturally appropriate interventions to reduce the rate of SMM in both Aboriginal and African women.[29]

Our findings further support the extant literature on the impact of broader sociodemographic factors on SMM. We provide novel new insights on the contribution of teenage and advanced maternal age and low SES (both identified risks for SMM)[12 17–19] and other factors in the SMM disparity between Aboriginal and Caucasian women. We found that about one-third of the disparity was explained by sociodemographic, pre-existing medical conditions and pregnancy complications, with maternal age and SES being the most prominent drivers. However, it is important to note that although smoking during pregnancy, comorbid conditions and pregnancy complications were more common in Aboriginal than Caucasian women and they were associated with SMM, their contribution to the ethnic disparity in SMM was small, which runs counter to the existing paradigm.[8]

A reduction in the SMM disparity can be attained by mechanisms that address teenage pregnancy and that have a social determinants of health focus, although the greater proportion of the SMM disparity between Aboriginal and Caucasian women remains unexplained. However, if Aboriginal women experienced a similar SMM rate to that of Caucasian women, 559 (55 %) Aboriginal birth events could have been averted from SMM, and eliminating SES disadvantage and teenage pregnancy alone would prevent one-third of these cases (186 SMM cases). Prevention of unintended teenage pregnancy together with support and high-quality maternity care have been found to be effective in reducing the rates of both maternal and perinatal adverse birth outcomes.[37 38] These interventions are also likely to benefit other ethnic minority groups and populations with a high contemporary rate of SMM.

Strengths and limitations

The strengths of this study include the use of multiple and large population-based datasets and the application of a comprehensive and validated SMM outcome. To our knowledge, this is the first study to formally evaluate the contribution of sociodemographic and other characteristics to the ethnicity disparity in SMM.

However, there are some relevant limitations. We used data collected for administrative purposes that can contain errors and inconsistencies. For example, there may have been some misclassification of maternal ethnic origin, but we do not believe that this is differentially related to SMM and therefore expect minimal bias on our results. Furthermore, in our previous analysis,[39] we have documented similar perinatal mortality trends among Aboriginal populations when comparing the results based on a single indicator of maternal Aboriginal status reported in the midwives' forms (MNS) to an alternative approach that considers the Aboriginal status of babies from multiple administrative systems—this suggests a minimal impact of ethnic origin misclassification. Our SES measure was constructed using the characteristics of people living in areas and may not necessarily reflect the SES circumstances of individuals. Accordingly, our measure is a proxy for neighbourhood environment and offers only a partial view of the broad constructs of SES. A small proportion of birth events had missing data on the area of residence and/or SES measures (4.2%), and those women with no data on the SES quintile were more likely to develop SMM, which may have slightly biased our decomposition analysis findings. However, we observed similar results to the main analyses in the extreme case scenarios that included missing data on these variables. A significant proportion of the SMM ethnic disparity remains unexplained by sociodemographic and comorbid conditions, and we need to consider other preconception and prenatal factors. For example, we did not have systematically collected data on prepregnancy obesity (only available since 2012), mental health problems, substance abuse and other behavioural risks that disproportionately affect the Aboriginal population.[40] Furthermore, we were not able to evaluate the frequency of antenatal care visits (only available since 2012) and its quality, which are often reported to be poorer in Aboriginal women than non-Aboriginal women.[29] Nevertheless, in a sample analysis restricted to women with BMI and antenatal care data (available only from 2012 onwards), the explained part in SMM ethnic disparity increased to 45.9% when prepregnancy BMI, first antenatal care visit (≤12 vs >12 weeks' gestation) and total number of antenatal care visits were added to the model (data not shown). Another limitation of this study is that we had insufficient numbers to perform the decomposition analysis for other ethnic minorities who were at higher risk of SMM, for example, African women.

CONCLUSIONS

This whole-of-population study has demonstrated substantial ethnic disparities in SMM, with a greater risk among Aboriginal and African women compared with Caucasian women. Teenage and advanced maternal age groups and women living in the lowest socioeconomic quintiles were also found to be at higher risk of SMM. While we have quantified the contribution of sociodemographic factors and maternal conditions to the disparity in SMM between Aboriginal and Caucasian populations, there is an urgent

need to investigate other potential pathways to support fuller insights into effective strategies to reduce SMM in ethnic minority groups in Australia.

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