Associations between ethnicity and admission to intensive care among women giving birth: a cohort study

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Abstract

Objective: To determine the association between ethnic group and likelihood of admission to intensive care in pregnancy and the postnatal period.

Design: Cohort study.

Setting: Maternity and intensive care units in England and Wales.

Population or Sample: 631 851 women who had a record of a registerable birth between 1st April 2015 and 31st March 2016 in a database used for national audit.

Methods: Logistic regression analyses of linked maternity and intensive care records, with multiple imputation to account for missing data.

Main Outcome Measures: Admission to intensive care in pregnancy or postnatal period to six weeks after birth.

Results: 2.24 per 1000 maternities were associated with intensive care admission. Black women were more than twice as likely as women from other ethnic groups to be admitted (OR 2.21 (1.82, 2.68). This association was only partially explained by demographic, lifestyle, pregnancy and birth factors (adjOR 1.69 (95% CI 1.37, 2.09)). A higher proportion of intensive care admissions in Black women were for obstetric haemorrhage than in women from other ethnic groups.

Conclusions: Black women have an increased risk of intensive care admission which cannot be explained by demographic, health, lifestyle, pregnancy and birth factors. Clinical and policy intervention should focus on the early identification and management of severe illness, particularly obstetric haemorrhage, in Black women, in order to reduce inequalities in intensive care admission.

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Tweetable abstract

Black women are almost twice as likely as White women to be admitted to intensive care during pregnancy and the postpartum period; this risk remains after accounting for demographic, health, lifestyle, pregnancy and birth factors.

Introduction

Intensive care admission signifies severe illness requiring additional care and monitoring, with a high risk of mortality. In pregnancy and birth, there are additional short- and long-term consequences: during pregnancy, severe illness is associated with problems with fetal growth and development, and preterm birth; postnatal admissions frequently result in separation of the mother and baby, with associated impacts on breastfeeding rates and maternal mental health.[1] Admission to intensive care is considered a marker of severe maternal morbidity.[2,3]

Women from ethnic minority groups suffer poorer outcomes than women from White ethnic groups during pregnancy and birth in the UK.[4–7] In the triennium 2016-18, Black women were over four times more likely to die in pregnancy and childbirth than White women.[8] This is similar to the inequalities that exist in other high-income countries.[2,3,9–13] It is unclear to what extent this observed association is explained by differences between ethnic groups in demographic, lifestyle, pregnancy and birth factors, including co-morbidities such as gestational diabetes and hypertension, which are more common in women of ethnic minority backgrounds.[14,15] The extent to which intensive care admissions in pregnancy and birth varies by country of origin has been examined in cohorts from the Netherlands[16] and Canada;[17] in both, migrant women were more likely to have admissions to intensive care. Variation by ethnic group has been examined in the United States,[18] where Black women are more likely to be admitted. No study has previously examined ethnic variation in the UK. Investigating variation in intensive care admission may offer useful insights into potential mechanisms for addressing ethnic inequalities in maternal morbidity and mortality.[2,3]

This study uses linked maternity and intensive care data from England and Wales, collected for the purposes of national audits, to evaluate the relationship between maternal ethnicity and admissions to intensive care.[19–21] Routinely collected healthcare data sources offer efficient access to large population samples and the opportunity to examine uncommon outcomes such as admission to intensive care and any associations with maternal demographics or characteristics.

The aims of this study were to (1) quantify the association between ethnicity and severe morbidity requiring admission to intensive care in pregnancy and the six weeks following birth; (2) understand how this association is explained by adjustment for demographic, lifestyle, pregnancy and birth characteristics; and (3) to understand the reasons for maternal admission to critical care in different ethnic groups.

Methods

Data sources

We used a national maternity dataset that was linked to hospital admission data for the purposes of a national audit.[21] This included data routinely collected in the course of clinical care, which was extracted from the maternity information systems (MIS) used in NHS hospitals in England and Wales. In England, MIS data were linked at patient level using the mother's and baby's dates of birth, NHS numbers and postcodes to records from the Hospital Episode Statistics (HES), an administrative database containing records of all admissions to English NHS hospitals. Linkage was performed using a deterministic algorithm by a trusted third party (NHS Digital). In Wales, data from MIS are collated to form the Maternity Indicators dataset, MIds. This was linked at patient level using NHS numbers and dates of birth to PEDW, an administrative dataset by the National Welsh Informatics Service. Details of linkage processes are available elsewhere.[21] The linked data contained information on births between the 1st April 2015 and 31st March 2016 in five of six boards in Wales and 128 of 134 trusts in England with an obstetric unit.[21]

The maternity dataset was also linked to the Intensive Care National Audit and Research Centre (ICNARC) Case Mix Programme (CMP) Dataset. ICNARC routinely collects information on all admissions to adult general intensive care units in England, Wales, and Northern Ireland, together with some specialist intensive care units. The ICNARC Case Mix Programme dataset contains information about the source, type and reason for admission, and observations, diagnoses and procedures that occur within the intensive care unit.[19,22] Maternal identifiers (NHS number, date of birth and postcode) for women who gave birth in England and Wales were used by ICNARC to supply records matching all or some of these identifiers for women admitted to intensive care in England and Wales up to 31st March 2017. Further details about the linkage process are available.[22]

Definition of variables

Ethnicity was primarily derived from the hospital admission record (HES/PEDW) and infilled where not useable (unknown (ethnos codes 9, X, Z) or missing) from the MIS record. Ethnicity was categorised into groups: White; Asian or British Asian; Black or Black British; Mixed; Other; and unknown or missing. Ethnicity is self-reported to midwives at the time of booking pregnancy and is well, and generally consistently, recorded in hospital data in England at the level of these groups; there are inconsistencies between more granular classifications (e.g. Black African, Black Caribbean may be coded interchangeably).[23]

A woman was defined as having an intensive care admission if she had one or more recorded admissions to an intensive care unit in the ICNARC dataset within the time frame of estimated date of conception to six weeks after birth. The plausible date of conception was calculated as the date of

birth plus fourteen days minus the gestation in days at birth. She was recorded as having a Level 3 admission if her admitting or discharging level of care was level 3 (i.e. requiring ventilation support, or with multi-organ failure).

Demographic factors included maternal age and socioeconomic status. Maternal age was grouped into six categories (16-24, 25-29, 30-34, 35-39, 40-44, 45 or older). Wider age-bands were used for women under 25 and over 44, due to the small numbers of women admitted to intensive care at these ages. Socio-economic status was identified using the index of multiple deprivation (IMD) of the woman's postcode at the time of birth in England and the postcode of her GP surgery in Wales. IMD is an area-level ranking of relative deprivation which incorporates information about income, education, employment, crime, and the living environment for each of the 32,844 lower super output areas in England and 1,909 areas in Wales used for population analysis.[24] Using these rankings, areas were separated into population quintiles of relative deprivation.[25]

Obstetric history included parity (with parity of 3 or more handled as a single category) and previous caesarean section. Lifestyle factors included maternal BMI and smoking status recorded in MIS at the time of booking the pregnancy. Body mass index (BMI) was handled using WHO categories.[26]

Pregnancy and birth factors included: mode of birth (unassisted vaginal, instrumental vaginal or caesarean section); preterm birth (occurring before 37 weeks), multiple birth (twins or higher order multiple) and stillbirth.

Maternal health conditions complicating pregnancy were identified using ICD-10 codes[27] recorded in HES/ PEDW in the birth episode. These included diabetes (pre-existing and gestational, handled together due to low frequency of pre-existing diabetes), pre-eclampsia, pre-existing or gestational hypertension, and placental conditions of morbidly adherent placenta or abruption.

Details of all coding frameworks used are available in Supplementary Table S1.

Analysis

The primary outcome of interest was admission to an intensive care unit during pregnancy, birth and the postnatal period up to six weeks after birth.

To estimate crude odds ratios between ethnic group and intensive care admission, univariate logistic regression models were used. To investigate possible explanations for associations, a series of multivariable logistic regression models with robust estimates of standard errors to account for clustering within hospitals were used to estimate adjusted odds ratios. The first model adjusted for demographic factors: maternal age, ethnic and socioeconomic group. The second added the woman's obstetric history (parity and whether she had a previous caesarean section) and lifestyle factors that

were present at the onset of pregnancy (BMI and smoking status). The third, 'full' model additionally incorporated health conditions (diabetes, pre-eclampsia, hypertension, cardiac conditions and placental conditions) and pregnancy and birth factors (multiplicity, mode of birth, preterm birth and stillbirth).

Thresholds for admission to intensive care are known to vary with the provision of enhanced care for critically unwell women within maternity services, as some units provide higher level care within maternity units and only admissions to critical care units are captured in ICNARC.[20,22,28] However, care requiring ventilation and for multi-organ failure (level 3) is provided only in intensive care units. For this reason, a sensitivity analysis was carried out using level 3 admission as the outcome in the fully adjusted model.

Levels of missing data were low (less than 4%) for the majority of variables included in the analysis. However, 6% of women's records were missing information about postcode used to identify socio-economic status, 12% were missing information about ethnicity in both data sources, and 23% were missing information about each of smoking status and BMI at the time of booking. In the regression analyses, multiple imputation using chained equations was used to handle missing values, with regression coefficients estimated using ten imputed datasets and pooled using Rubin's rules.[29] Variables used in the imputed datasets included all variables in the multivariable regressions, and also the year of birth and the hospital in which the woman gave birth. Multiple imputation requires the assumption that data is missing at random given the variables used in the imputation model (MAR), which may not be met, in particular for ethnicity, smoking status or body mass index. To test the sensitivity of findings to these assumptions, the fully adjusted analysis was repeated using only those records with complete information; this has been found to be robust to a wider range of missingness assumptions.[30]

Primary reasons for admission were available from the intensive care record and were grouped into those directly related to pregnancy and birth and those indirectly related to pregnancy and birth, following a system used for classifying maternal death.[7,8,22] Details of this classification are available in Supplementary Table S2. The proportions admitted for each group of reasons were presented by ethnic group.

All analyses were performed in Stata version 14.1.

Results

631 851 women were included in the linked dataset, of whom 1 414 were recorded as being admitted to intensive care during pregnancy, birth and the postnatal period up to six weeks, a rate of 2.24 per 1000 maternities. These women each had at least one and a maximum of three recorded admissions

to intensive care, with a total of 1,619 admissions overall. 261 women (18.5%) had their first admission to intensive care before birth. 22.3% of women admitted to intensive care were recorded as being from ethnic minority groups. (Table 1, Supplementary Figure S1)

Women were more than twice as likely to be admitted to intensive care if their recorded ethnicity was Black (4.7 per 1000 maternities) than White (2.1 per 1000 maternities; crude OR for Black women compared with White women, 2.21 (1.82, 2.68)) but no difference was observed if the recorded ethnicity was Asian (2.3 per 1000), Mixed (1.9 per 1000) or Other (2.3 per 1000). (Table 1, Table 2)

We sought to understand the extent to which adjustment for various characteristics and risk factors could explain the higher ITU admissions for Black women compared with White women. This was explored using three different models: the first of which adjusted for demographic factors, the second additionally for obstetric history and lifestyle factors, and the third for these together with pregnancy and birth factors. The increased risk of ITU admission for Black women was partially explained by adjustment for demographic factors: maternal age and socioeconomic status (adjOR 2.02 (95% CI 1.65, 2.48)). Lifestyle and obstetric history present at the start of pregnancy explained very little of the association (adjOR 1.94 (1.57, 2.41)). More of the association was explained by pregnancy and birth characteristics, including presence of comorbidities, mode of birth, preterm birth and stillbirth (Table 2). Taking all these factors into account, Black women were 1.7 times more likely to be admitted to intensive care than White women (adjOR 1.69 (1.37, 2.09)).

Some complications were associated with particularly high rates of intensive care admission. Following adjustment for demographic, lifestyle, pregnancy and birth factors, women who had pre-eclampsia, or placental conditions such as abruption or accreta were three times as likely to be admitted to intensive care (adjOR for pre-eclampsia: 3.11 (2.59, 3.74); for placental conditions, 3.46 (2.84, 4.22)). Women with cardiac conditions were eleven times more likely than women without to be admitted to intensive care (adjOR 11.28 (8.62, 14.77)). Women who had a caesarean section were five times as likely (adjOR 5.04 (4.31, 5.90)) to be admitted. Women who had a preterm birth were more than three times as likely to be admitted (adjOR 3.53 (3.06, 4.06)) and women who had a stillbirth more than six times as likely (adjOR 6.50 (4.86, 8.68)).

These results were robust to a sensitivity analysis restricting to level 3 admissions, although a small increase in risk of ITU admission in women with diabetes was not apparent in the tighter definition of the outcome. Associations with caesarean birth, placental conditions and stillbirth were stronger with level 3 admission (Supplementary Table S3). In sensitivity analyses restricted to those women with complete data available (Supplementary Table S4), the associations with ethnicity were attenuated; this was most evident in the fully adjusted model (Wald p value for ethnicity overall 0.09). In these

complete case analyses there was much greater uncertainty in the estimates due to the smaller sample size; the adjusted odds ratios for Black ethnicity (in the fully adjusted model, adjOR 1.43 (95% CI 1.08, 1.90)) were within the confidence interval for the results using imputed data (full model adjOR 1.69 (1.37, 2.09)).

67.1% of admissions were for a reason directly related to pregnancy, such as obstetric haemorrhage, infection, pre-eclampsia and HELLP (haemolysis, elevated liver enzymes, low platelets). (Figure 1, Supplementary Table S5) The proportion of admissions that were due to direct, rather than indirect, reasons, and particularly due to obstetric haemorrhage, was higher among women from Black ethnic origin. 42% of admissions in Black women were for obstetric haemorrhage compared to 34% in White women. Women with no record of ethnic origin were more likely to have an admission for an indirect reason.

Discussion

Main findings

Of women who gave birth in England and Wales in 2015-16, 2.24 per 1000 were admitted to intensive care in pregnancy and the six weeks after birth. Black women were more than twice as likely than women from Other ethnic groups to be admitted. This association was only partially explained by adjustment for demographic, lifestyle, pregnancy and birth characteristics. Women with complications, such as placental factors, pre-eclampsia and stillbirth, were much more likely to be admitted to intensive care. These findings were robust to sensitivity analyses using different definitions of the outcome and methods of handling missing data.

Obstetric haemorrhage accounted for a higher proportion of admissions for Black women than for women from Other ethnic groups.

Strengths and Limitations

The main strengths of this study are its size and design. This is a large cohort study using routinely collected data with a high rate of coverage of births in England and Wales (approximately 92%). The use of electronic patient records, collected for payment purposes, reduces the risk of systematic bias: almost all births and intensive care admissions in the UK occur in the NHS. The ICNARC Case Mix Programme dataset for evaluating admissions to intensive care is well established and of high quality.[19] Linkage using identifiers such as NHS numbers ensures that matched records are very likely to be true matches, with women identified as having an intensive care admission being highly likely to have been admitted.

Although the linkage method using NHS number, date of birth and postcode is highly specific, the first limitation is in the potential for missed matches.[19,20] While completeness of identifiers is high in both datasets[19,21] there does not exist a 'gold standard'[22] dataset to enable evaluation of the linkage quality. This has the potential to cause bias if ethnicity is associated with the likelihood of complete identifiers. In this dataset, any bias would be to an under-estimation of effect, as women from ethnic minority groups were less likely to have an NHS number present in the MIS.

Further limitation to this study arises from the missing data within the dataset, in particular for ethnicity (12% of records). To account for this, in our primary analyses we use multiple imputation, a methodology which, provided the information about ethnicity is missing at random given all of the other variables in the model, will give unbiased estimates. However, it is possible that this assumption is not met. While it is reassuring that our findings are similar in a complete case analysis, where only those records with complete information about all covariates are included, in this supplementary analysis the association is substantially attenuated; this may be because the sample size is reduced, or because the true association between Black ethnicity and intensive care admission is smaller than in our primary analysis.

The third limitation is the chosen outcome. Admission to intensive care is considered when a woman is too unwell to be cared for in a maternity unit. The capability of maternity units to provide enhanced or high dependency maternity care varies,[31,32] therefore the threshold to consider admission may vary between units. It is possible that our findings could be due to systematically lower admission thresholds in hospitals with higher proportions of Black women. However, similar associations were found when the analysis was limited to women requiring care for multi-organ failure or ventilation (Supplementary Table S3), therapies not provided outside of intensive care settings.[33]

In our analyses, we adjust for factors related to the woman's demographics, lifestyle, pregnancy and birth. In women admitted prior to the day of birth (18.5% of our population) it is possible that the gestation at birth, mode of birth, and stillbirth are causally linked to both ethnic group and the antenatal episode of severe illness indicated by intensive care admission. This can introduce a form of bias where the association is inappropriately attenuated.[34] This may partially account for the attenuation of the association between Black ethnicity and likelihood of intensive care admission seen between Model 3 and Model 2.

It may also be that women who were admitted to intensive care differed from those who were not admitted but instead unfortunately died, due to a lack of care or escalation as is commonly reported in maternal death.[7,8,35] Data were not available to us for maternal death that occurred outside of the hospital admission in which the woman gives birth, limiting the use of death as an alternative

outcome in this study. Any change would be small as maternal death is rare, and any bias would be towards an under-estimation of the effect of ethnicity: Black and Asian women are more likely to die during pregnancy and birth in the UK than White women, with the estimated effect larger than that seen in our study.[7,8]

Interpretation (in light of other evidence)

The overall rate of admission to intensive care during pregnancy and the postnatal period was similar to that reported in other international studies (2-4:1000).[16,36] Studies from the Netherlands,[16] Canada,[17] and the United States[18], conducted in local populations, similarly show an association between Black ethnicity or African or Caribbean origin and admissions to intensive care in pregnancy and the postpartum period. In common with other studies examining severe maternal morbidity in the UK we found no association with socioeconomic grouping, reflective of the universal healthcare system.[37]

Studies from the UK Obstetric Surveillance System (UKOSS)[4,5,37] have demonstrated that women from Black African and Caribbean ethnic groups are more likely to experience severe morbidity, with a similar reported magnitude of effect. UKOSS also found that women from some Asian ethnic groups (Pakistani and Bengali) were more likely to experience severe maternal morbidity, which we did not find.[4] It is possible that this is masked in our data where we have treated ethnicity in larger groupings to deal with potential coding issues.

The reasons for the association between ethnicity and admission to intensive care or other markers of severe maternal morbidity have been widely hypothesised. Postulated reasons for this association include health at the start of pregnancy, reduced socioeconomic status, increased propensity to develop pregnancy related conditions such as eclampsia, differences in health behaviours, and differences in the way women are treated and listened to during maternity care.[4,5,38–41] In our study, some of the association between ethnicity and intensive care admission was explained by maternal age and comorbidity, and by pregnancy and birth factors including caesarean birth, preterm birth, placental conditions and stillbirth. However, even following this adjustment, a substantial association remained. We were unable to account for health behaviours, stress, home environment, experiences of maternal care and aspects of structural inequality which may account for the observed associations.[42–44]

In this cohort, intensive care admissions for Black women were more commonly due to obstetric haemorrhage than those for women from other ethnic groups. There is a possible biological explanation: Black women are more likely to have leiomyomata or fibroids, benign tumours of the uterine myometrium that prevent the uterus from contracting, which are associated with an increased

risk of postpartum haemorrhage.[45,46] For Black women with increased risk of haemorrhage, appropriate recognition and rapid escalation may avoid the need for additional support and intensive care admission.[47]

A secondary finding of our study was that stillbirth is strongly associated with admission to intensive care. This finding has also been demonstrated in a large study of over 6 million births in California;[48] which found an increased risk of severe maternal morbidity in women with stillbirth (RR 4.77, 95% CI 4.53-5.02). There may be common primary causes leading both to stillbirth and maternal admission to intensive care, such as placental abruption. This requires further study, which was not feasible in this analysis as information on timing of stillbirth and other events within labour was limited.

Conclusion

Women of Black ethnicity are over twice as likely as women of other ethnic backgrounds to be admitted to intensive care during pregnancy and birth. Even when demographic, lifestyle, pregnancy and birth characteristics are taken into account, these women are still 1.7 times more likely to be admitted to intensive care.

Further investigation is needed to understand the unexplained increase in risk. Clinical and policy action should focus on the prediction, early identification and management of severe illness and obstetric haemorrhage in Black women, in order to reduce these inequalities. Particular action is also needed to improve monitoring of women with complications including stillbirth, cardiac and placental conditions, given the high risk of intensive care admission in these groups, and to prevent and treat maternal conditions such as hypertension, diabetes and pre-eclampsia. Established procedures, such as the use of early warning scores at regular intervals, should be attentively used in Black women.[49] If targeted, this has the potential to reduce maternal admissions to intensive care significantly, with an associated reduction in clinical costs and trauma to women and their families.[1]

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Author contribution: JJ and KW conceived the study. All authors planned the analysis. JJ conducted the analysis and wrote the first draft of the paper. All authors reviewed and redrafted the study. KW supervised the study.

Ethical approval: This study used data routinely collected in clinical care to evaluate service provision and performance and therefore individual consent was not sought. Institutional consent to access the data was provided by the NHS Health Research Authority Confidentiality Advisory Group, approval number 16/CAG/0058. This study was approved by the LSHTM Ethics Committee, approval number 14544, on 4th April 2018.

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Patient and Public Involvement

There was no patient and public involvement in this study.

Table 1. Characteristics of 631 851 women who gave birth in England and Wales in 2015-16, and 1 414 of those women with recorded admissions to intensive care in pregnancy or the postpartum period up to six weeks

	All women		Women admitted to intensive care	Rate (per 1000 maternities) admitted		All women		Women admitted to intensive care	Rate (per 1000 maternities) admitted
Risk factor	n	%	n		**Risk factor**	n	%	n	
All	631 851		1 414	2.24					
Ethnic origin					**Smoking status**				
White	434 297	77.7	931	2.14	Non-smoker	417 542	85.6	923	2.21
Asian	63 795	11.4	147	2.30	Smoker	70 078	14.4	182	2.60
Black	26 900	4.8	125	4.65	*Missing*	*144 231*	*22.8*	*309*	*2.14*
Mixed	10 078	1.8	19	1.89					
Other	23 763	4.3	54	2.27	**Previous CS**	87 501	14.3	347	3.97
Missing	*73 018*	*11.6*	*138*	*1.89*	*Missing*	*20 149*	*3.2*	*40*	*1.99*
Age group					**Recorded diagnoses**				
Under 25	115 669	18.9	270	2.33	Hypertension	3 208	0.5	28	8.73
25-29	174 440	28.6	297	1.70	Placental factors	5 917	0.9	143	24.17
30-34	190 075	31.1	413	2.17	Pre-eclampsia	11 484	1.8	188	16.37
35-39	105 849	17.3	298	2.82	Cardiac conditions	2 036	0.3	67	32.91
40-44	23 340	3.8	92	3.94	Diabetes	32 706	5.2	143	4.37
45 or older	1 667	0.3	15	9.00					
Missing	20 811	3.3	29	1.39	**Gestation**				
					Term	565 436	92.9	865	1.53
Socioeconomic deprivation (quintile)					Preterm	42 889	7.1	492	11.47
Least deprived (1)	99 438	16.8	210	2.11	*Missing*	*23 526*	*3.7*	*57*	*2.42*
2	84 112	14.2	173	2.06					
3	112 183	18.9	236	2.10	**Multiplicity**				
4	134 759	22.8	294	2.18	Singleton birth	613 669	97.1	1 317	2.15
Most deprived (5)	161 850	27.3	396	2.45	Multiple birth	18 182	2.9	97	5.33
Missing	*39 509*	*6.3*	*105*	*2.66*					
					Fetal outcome				
Body Mass Index (kg/m²)					Livebirth	628 818	99.5	1 345	2.14
<18.5	14 347	2.9	32	2.23	Stillbirth	3 033	0.5	69	22.75
18.5-24.9	236 456	48.4	457	1.93					
25.0-29.9	131 161	26.8	295	2.25	**Mode of birth**				
30.0-34.9	67 672	13.8	163	2.41	Unassisted vaginal	380 772	61.6	328	0.86
35.0-39.9	25 832	5.2	81	3.14	Instrumental	75 280	12.2	115	1.52
>=40.0	13 447	2.8	62	4.61	Caesarean section	161 665	26.2	951	5.88
Missing	*142 936*	*22.6*	*324*	*2.27*	*Missing*	*14 134*	*2.2*	*20*	*1.42*
Parity									
0	264 133	42.7	621	2.35					
1	214 572	34.7	396	1.85					
2	86 037	13.9	189	2.20					
3 or more	53 208	8.6	175	3.29					
Missing	*13 901*	*2.2*	*33*	*2.37*					

Table 2. Maternal and pregnancy characteristics associated with admission to intensive care during pregnancy and the early postpartum period up to six weeks among women who gave birth in England and Wales in 2015-16

		Model 1† (Demographic)		**Model 2† (Lifestyle, history)**		**Model 3† (Pregnancy and birth)**	
Characteristic	Crude OR	Adjusted OR (95% CI)	P – value*	Adjusted OR (95% CI)	P – value*	Adjusted OR (95% CI)	P – value*
Ethnic origin			<0.001		<0.001		<0.001
White	Ref	Ref		Ref		Ref	
Asian	1.08 (0.91, 1.28)	1.06 (0.89, 1.27)		1.12 (0.94, 1.34)		0.98 (0.81, 1.19)	
Black	2.21 (1.82, 2.68)	2.02 (1.65, 2.48)		1.94 (1.57, 2.41)		1.69 (1.37, 2.09)	
Mixed	0.85 (0.54, 1.35)	0.83 (0.52, 1.32)		0.84 (0.53, 1.33)		0.83 (0.52, 1.33)	
Other	1.04 (0.79, 1.36)	1.00 (0.76, 1.32)		1.06 (0.80, 1.40)		1.07 (0.79, 1.43)	
Age group			<0.001		<0.001		<0.001
Under 25	1.37 (1.16, 1.62)	1.38 (1.17, 1.63)		1.35 (1.14, 1.60)		1.52 (1.27, 1.82)	
25-29	Ref	Ref		Ref		Ref	
30-34	1.27 (1.09, 1.47)	1.29 (1.11, 1.50)		1.28 (1.10, 1.49)		1.15 (0.99, 1.34)	
35-39	1.64 (1.40, 1.93)	1.66 (1.41, 1.95)		1.61 (1.36, 1.90)		1.28 (1.08, 1.51)	
40-44	2.31 (1.82, 2.92)	2.26 (1.78, 2.86)		2.07 (1.62, 2.64)		1.31 (1.01, 1.70)	
45 or older	5.35 (3.17, 9.04)	4.89 (2.89, 8.27)		4.39 (2.59, 7.47)		2.10 (1.23, 3.58)	
Socioeconomic deprivation (quintile)			0.44		0.93		0.93
Least deprived (1)	Ref	Ref		Ref		Ref	
2	0.96 (0.79, 1.18)	0.98 (0.80, 1.20)		0.95 (0.78, 1.17)		0.95 (0.77, 1.17)	
3	0.99 (0.82, 1.20)	1.01 (0.84, 1.22)		0.96 (0.79, 1.17)		0.93 (0.77, 1.13)	
4	1.03 (0.86, 1.23)	1.03 (0.85, 1.24)		0.95 (0.79, 1.15)		0.92 (0.76, 1.12)	
Most deprived (5)	1.15 (0.98, 1.36)	1.14 (0.95, 1.37)		1.01 (0.83, 1.22)		0.93 (0.77, 1.12)	
BMI (kg/m²)					<0.001		0.006
<18.5	1.21 (0.87, 1.69)			1.22 (0.88, 1.69)		1.22 (0.84, 1.65)	
18.5-24.9	Ref			Ref		Ref	
25.0-29.9	1.16 (1.01, 1.33)			1.11 (0.96, 1.28)		0.99 (0.85, 1.15)	
30.0-34.9	1.26 (1.05, 1.52)			1.15 (0.96, 1.38)		0.96 (0.79, 1.16)	
35.0-39.9	1.71 (1.33, 2.19)			1.46 (1.17, 1.83)		1.17 (0.90, 1.52)	
>=40.0	2.50 (1.91, 3.29)			2.10 (1.61, 2.75)		1.64 (1.23, 2.17)	
Parity					<0.001		0.008
0	Ref			Ref		Ref	
1	0.79 (0.70, 0.90)			0.58 (0.51, 0.67)		0.95 (0.82, 1.19)	
2	0.94 (0.80, 1.11)			0.62 (0.52, 0.73)		1.05 (0.86, 1.26)	
3 or more	1.40 (1.18, 1.66)			0.81 (0.68, 0.98)		1.33 (1.09, 1.61)	
Smoker	1.20 (1.02, 1.42)			1.33 (1.13, 1.58)	0.001	1.15 (0.95, 1.39)	0.14
Previous CS	2.23 (1.98, 2.51)			2.41 (2.10, 2.76)	<0.001	0.99 (0.85, 1.16)	0.92
Maternal conditions							
Diabetes	2.07 (1.74, 2.46)					1.26 (1.04, 1.53)	0.02
Pre-eclampsia /eclampsia	8.40 (7.20, 9.81)					3.11 (2.59, 3.74)	<0.001
Hypertension	3.98 (2.74, 5.80)					1.59 (1.04, 2.42)	0.03
Placental conditions	12.17 (10.22, 14.50)					3.46 (2.84, 4.22)	<0.001
Cardiac conditions	15.88 (12.37, 20.37)					11.28(8.62, 14.77)	<0.001
Mode of birth							<0.001
Unassisted vaginal	Ref					Ref	
Instrumental	1.78 (1.43, 2.20)					2.06 (1.65, 2.59)	
Caesarean section	6.81 (6.00, 7.73)					5.04 (4.31, 5.90)	
Fetal complications							
Preterm birth	7.57 (6.78, 8.46)					3.53 (3.06, 4.06)	<0.001
Multiple birth	4.11 (3.29, 5.14)					1.11 (0.86, 1.43)	0.41
Stillbirth	10.86 (8.50, 13.87)					6.50 (4.86, 8.68)	<0.001

†All models are adjusted for variables shown as complete. *p values for categorical variables are derived using the Wald test

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