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2 DR. JENNIFER JARDINE (JC ASSOCIATE) (Orcid ID : 0000-0002-9932-6865)

3 DR. IPEK GUROL-URGANCI (Orcid ID : 0000-0002-6517-3485)

4 PROF. JAN VAN DER MEULEN (Orcid ID : 0000-0002-9451-2335)

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10 **Corresponding author mail id:** jennifer.jardine@lshtm.ac.uk

11 **Title: Risk of postpartum haemorrhage is associated with ethnicity: a cohort**
12 **study of 981 801 births in England**

13

14 Authors: Jennifer Jardine(1,2), Ipek Gurol-Urganci(1,2), Tina Harris (3), Jane Hawdon (4), Dharmindra
15 Pasupathy (5,6), Jan van der Meulen (1), Kate Walker (1,7) on behalf of the NMPA Project Team

16

17 Affiliations

18 1. Faculty of Public Health and Policy, London School of Hygiene and Tropical Medicine, 15-17 Tavistock
19 Place, London WC1H 9SH UK

20 2. Centre for Quality Improvement and Clinical Audit, Royal College of Obstetricians and Gynaecologists,
21 10-18 Union Street, London SE1 1SZ UK

22 3. Centre for Reproduction Research, Faculty of Health and Life Sciences, De Montfort University, The
23 Gateway, Leicester LE1 9BH, UK

24 4. Royal Free London NHS Foundation Trust, Pond Street London NW3 2QG, UK

25 5. Department of Women and Children's Health, King's College London, 10th Floor, North Wing, St
26 Thomas's Hospital London SE1 7EH UK

27 6. Reproduction and Perinatal Centre, Faculty of Medicine and Health, University of Sydney NSW 2145
28 Australia

29 7. Clinical Effectiveness Unit, Royal College of Surgeons, 35-43 Lincoln's Inn Fields, Holborn, London WC2A
30 3PE UK

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35

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37

38

Accepted Article

39 Abstract

40 **Objective:** To determine the association between ethnic group and risk of postpartum haemorrhage in
41 women giving birth.

42 **Design:** Cohort study.

43 **Setting:** Maternity units in England.

44 **Population or Sample:** 981 801 records of births between 1st April 2015 and 31st March 2017 in a national
45 clinical database.

46 **Methods:** Multivariable logistic regression analyses with multiple imputation to account for missing data
47 and robust standard errors to account for clustering within hospitals.

48 **Main Outcome Measures:** Postpartum haemorrhage of 1500ml or more (PPH).

49 **Results:** 28 268 (2.9%) of births were complicated by PPH. Risks were higher in women from black (3.9%)
50 and other (3.5%) ethnic backgrounds. Following adjustment for maternal and fetal characteristics, and
51 care at birth, there was evidence of an increased risk of PPH in women from all ethnic minority groups,
52 with the largest increase seen in black women (adjusted odds ratio 1.54 (1.45 to 1.63)). The increase in
53 risk was robust to sensitivity analyses which included changing the outcome to PPH of 3000ml or more.

54 **Conclusions:** In England, women from ethnic minority backgrounds have an increased risk of PPH, when
55 maternal, fetal and birth characteristics are taken into account. Factors contributing to this increased risk
56 need further investigation. Perinatal care for women from ethnic minority backgrounds should focus on
57 preventative measures to optimise maternal outcomes.

58 **Funding:** HQIP.

59

60 **Tweetable abstract**

61 Women with an ethnic minority background giving birth in England have an increased risk of postpartum
62 haemorrhage, even when characteristics of the mother, the baby, and the care received are taken into
63 account.

64 Introduction

65 Postpartum haemorrhage (PPH), an increased loss of blood at the time of or after birth, is associated with
66 significant morbidity and is a leading cause of maternal death in all settings.^{1,2} The experience of PPH is
67 traumatic,³ and recovery is associated with secondary consequences including an increased risk of
68 postpartum depression and lower rates of breastfeeding.^{4,5}

69
70 PPH is the result of an interplay of pre-existing risk factors, and events which occur during the labour and
71 birth, and immediate management. It is generally considered that initiatives to reduce the risks related to
72 PPH require a three-step process of prevention, treatment, and rescue.⁶ The risk of PPH can be reduced,
73 at least partially, by the use of interventions such as the administration of oxytocin and tranexamic acid.^{7,8}

74
75 Ethnic background is known to be a determinant of variation in the outcomes of women receiving
76 maternity care across the world.¹ Women from black and south Asian ethnic groups are more likely to
77 experience severe morbidity at the time of birth.^{1,9} We have previously demonstrated that black women
78 in the UK have an increased risk of maternal admission to intensive care (ICU) and that haemorrhage is
79 the leading cause of an ICU admission among black women.¹⁰ However, not all women with PPH require
80 intensive care, and significant morbidity is not confined to those with ICU admission. In the US, it has
81 been shown that women from Hispanic and Pacific Islander ethnic backgrounds have an increased risk of
82 PPH,¹¹ and among non-Hispanic black women, there is an increased risk of severe sequelae of PPH.¹² A
83 national study in Sweden demonstrated that women born outside Sweden were at higher risk of
84 haemorrhage requiring a large transfusion.¹³ However, current clinical guidelines do not consider the
85 differential experience of severe morbidity, including postpartum haemorrhage, according to a woman's
86 ethnic background.^{8,14-16}

87
88 The aim of this study was to understand the association between ethnic background and the risk of PPH
89 using routinely collected data available in England, whether this association differs by level of
90 socioeconomic deprivation, and to what extent the association between ethnic background and PPH is
91 explained by maternal, fetal and birth characteristics.

93 Methods

94 **Data source**

95 We used a national maternity dataset that was created for the purpose of the National Maternity and
96 Perinatal Audit, a national programme to evaluate care for women giving birth and their babies in Britain
97 (www.maternityaudit.org.uk). This included data routinely collected in the course of clinical care, which
98 was extracted from the maternity information systems (MIS) used in National Health Service (NHS)
99 hospitals in England. These were cleaned, collated and linked to the Hospital Episode Statistics (HES), an
100 administrative dataset which contains information about all hospital admissions within NHS hospital
101 trusts. Trusts are administrative organisations which provide hospital and hospital-associated community
102 care, including home births, in a particular area in England. In England, all women are eligible to give
103 birth in the NHS and almost all do; in 2015-17, only 0.4% of births occurred in non-NHS settings (these are
104 most commonly private hospitals).¹⁷ The dataset collated for the NMPA includes approximately 94% of
105 births which occurred in England in the time period.^{18,19}

106

107 **Definition of cohort**

108 The eligible population was all births between 1st April 2015 and 31st March 2017 in the NHS in England.
109 We restricted the cohort to births in NHS hospital trusts in which over 80% of MIS records contained
110 information about blood loss. Records were included if they recorded either a live or stillbirth that
111 occurred at or after 24 completed gestational weeks and if the delivery record contained complete
112 information about blood loss. Characteristics of included and excluded records are described in Table S1
113 and the data flow is summarised in Figure 1.

114

115 **Definition of variables**

116 The primary outcome of this study was maternal blood loss at birth of 1500ml or more. Blood loss is
117 typically estimated using a combination of visual estimates, physiological assessment, and the results of
118 weighing drapes and pads.^{20,21} Clinical guidelines in the UK suggest that blood loss of 1500ml or more
119 should be treated as severe PPH with the mobilisation of appropriate staff.¹⁴ In other countries, clinical
120 guidelines include thresholds of 500 and 1000ml.^{22,23} Estimated blood loss has been identified as a core
121 outcome for studies related to prevention and treatment of PPH.²⁴ In our study, we defined PPH as blood

122 loss of 1500ml or more in line with the UK definition of severe PPH, but also examined risk of PPH at 500,
123 1000, 1500, 2000 and 3000ml.

124

125 Ethnicity was primarily derived from the hospital admission record (Hospital Episode Statistics (HES)) and
126 infilled where not useable (unknown (ethnos codes 9, X, Z) or missing) from the MIS record. Ethnic
127 background was classified using the ethnic groups defined for the 2001 UK Census. For the purposes of
128 this analysis, these ethnic groups were collapsed into five groups: 'white', 'south Asian', 'black', 'mixed'
129 and 'other'.²⁵ This was done because there is evidence that in routinely collected records, more granular
130 analyses can lead to misclassification bias,²⁶ and to avoid small numbers for some of the ethnic groups.

131

132 From the MIS, information was available about maternal characteristics including age, body mass index
133 (BMI), parity, and whether the woman had previously had a caesarean section; and about fetal
134 characteristics including live or stillbirth, multiple birth, and birthweight. Information was also available
135 about the birth: the onset of labour, mode of birth (unassisted vertex, breech vaginal, instrumental
136 vaginal, emergency caesarean or elective caesarean), and whether there was an episiotomy or manual
137 removal of the placenta. Where this information was missing in the MIS record, it was infilled if available
138 from the HES record, with information about parity and previous caesarean section derived from
139 historical records in HES as described elsewhere.¹⁹ Maternal health conditions complicating pregnancy
140 (grouped into hypertensive disorders including pre-existing or gestational; diabetes pre-existing or
141 gestational; conditions which make bleeding more likely; or placental abnormalities including placenta
142 praevia or accreta) were identified using ICD-10 codes²⁷ recorded in HES in the birth episode.²³
143 Information about socioeconomic group was available from the Index of Multiple Deprivation (IMD), an
144 area-level measure that encompasses information about social deprivation, economic status,
145 employment and health deprivation of each local area of approximately surrounding a woman's postcode
146 at the time of birth as recorded in the MIS.²⁸

147

148 **Statistical analyses**

149 Descriptive statistics, including the presence of risk factors, were tabulated according to ethnic
150 background, with continuous risk factors dichotomised for brevity. Chi squared statistics were used to
151 compare distributions of characteristics between groups. Logistic regression was used to estimate odds
152 ratios between each included characteristic and risk of PPH.

153

154 Multivariable logistic regression models, with robust standard errors to account for clustering within
155 hospital trusts (the Huber/White/sandwich estimator of variance, affecting the standard errors of the
156 estimates but not the estimated coefficients)²⁹, were used to estimate odds ratios for PPH by ethnic
157 group, with sequential adjustment for characteristics related to the mother, the baby, and the care
158 received. Within the models, we categorised continuous variables (7 categories for maternal age, 6
159 categories for BMI, 3 categories for gestational age and 4 categories for birthweight). We also
160 recategorised parity of 3 or more into the same group to account for smaller numbers with parity above
161 3. Details of all coding frameworks used are available in Table S1.

162

163 Crude odds ratios for PPH by ethnic group were estimated by logistic regression. The first multivariable
164 model adjusted for maternal characteristics: the mother's age, socioeconomic group, parity, BMI,
165 previous caesarean, and maternal health conditions complicating pregnancy. The second model included
166 these maternal characteristics, as well as fetal characteristics at birth: multiple birth, stillbirth and
167 birthweight. The third, 'full' model additionally included factors relating to the woman's maternity care:
168 induction of labour, mode of birth, episiotomy, and manual removal of placenta. All models also adjusted
169 for the financial year of birth.

170

171 For multiple births, the highest birthweight was used, and the birth was treated as a stillbirth if one baby
172 was stillborn.

173

174 Interactions between ethnic and socioeconomic background and between parity and previous caesarean
175 were considered plausible a priori. We evaluated whether there was evidence for these interactions by
176 including an additional interaction term in the full model and using a global Wald test to compare this to
177 the model without the interaction term. For both tests $p > 0.1$, so neither interaction was included in the
178 full model.

179

180 Missing values were imputed using multiple imputation by chained equations with statistical coefficients
181 obtained in 40 imputed data sets, with the number of datasets chosen to mirror the proportion of cases
182 with any missing data, and pooled using Rubin's rules.³⁰ Multiple imputation requires the assumption that
183 data is missing at random given the variables used in the imputation model. To test the sensitivity of
184 findings to this assumption, we conducted a sensitivity analysis in which the fully adjusted analysis was
185 repeated in cases with complete information about all covariates; analyses using complete cases have
186 been found to be robust to a wider range of missingness assumptions.³¹

187

188 We conducted two further sensitivity analyses to address concerns regarding incomplete information
189 about known risk factors for PPH. In the second sensitivity analysis, to address the lack of information
190 about previous PPH, we restricted the cohort to primiparous women. In the third, to address incomplete
191 information about augmentation of labour, we included additional adjustment for whether the labour
192 was augmented (as a binary variable) in 650 941 women where this was available. This variable was not
193 included in the primary analysis due to concerns about its quality and the high proportion of missing
194 data.¹⁹

195

196 In two further sensitivity analyses, we changed the outcome to PPH of 500ml or more and to 3000ml or
197 more to assess whether the same relationship was observed. These thresholds was chosen to, first,
198 represent the WHO definition of PPH;¹⁶ and second, to represent a cohort of women who were likely to
199 require additional care, such as in an intensive care unit.

200

201 All analyses were performed in Stata v16.

202

203 Results

204 The records of 981 801 births between 1st April 2015 and 31st March 2017 were included in the analysis.
205 Of these, 906 961 (92.4%) had complete information about ethnic background.(Figure 1, Table 1) 705 948
206 of those with complete ethnicity information (77.8%) were white, 107 382 (11.8%) were south Asian, 42
207 170 (4.6%) were black, 16 456 (1.8%) were mixed and 35 005 (3.9%) were from other ethnic
208 backgrounds.(Table 1)

209

210 28 268 (2.9%) of 981 801 births had a recorded blood loss of 1500ml or more (Table 2). When different
211 thresholds were examined, 322 606 (32.9%) of births had a recorded blood loss of 500ml or more; 75 674
212 (7.7%) had a recorded blood loss of 1000ml or more; 28 268 births (1.2%) had a blood loss of 2000ml or
213 more; and 249 (0.3%) births 3000ml or more. Regardless of definition, the risk of PPH was higher in black
214 women and in women from other ethnic backgrounds. Women with no recorded information about
215 ethnic group had elevated risk of PPH at all thresholds compared to the population average (Table 2).

216

217 Compared to white women, the unadjusted risk of PPH of 1500ml or more was increased in black women
218 (crude odds ratio 1.42, 95% CI: 1.35 to 1.50), and in women from other ethnic backgrounds (crude odds

219 ratio 1.27, 95% CI: 1.20 to 1.35) (Table 3). These associations were not substantially altered by
220 adjustment for maternal characteristics, fetal characteristics, or information about the woman's
221 maternity care (aOR for black women including all available information 1.54, 95% CI 1.45 to 1.63; aOR for
222 women from other groups 1.37, 95% CI 1.29 to 1.46).

223
224 There was evidence of an increase in the risk of PPH in women from mixed and south Asian ethnic groups
225 only following risk adjustment. For women from south Asian groups, the unadjusted odds of PPH was
226 lower than in white women (crude OR 0.94, 95% CI 0.90 to 0.97); however following adjustment for
227 maternal and fetal characteristics, the direction changed. Following adjustment for all maternal, fetal and
228 birth characteristics, women from south Asian groups had increased odds of PPH compared to white
229 women (aOR 1.14, 95% CI 1.09 to 1.19). For women from mixed groups, however, a stronger effect
230 emerged after adjustment for maternal and fetal characteristics at the time of birth (aOR 1.17, 95% CI
231 1.07 to 1.28) and persisted following adjustment for birth characteristics (aOR 1.20, 95% CI 1.09 to 1.32)
232 (Table 3). When fetal characteristics were compared between ethnic groups, women in south Asian
233 groups had smaller babies than women from other ethnic groups; women from mixed ethnic groups were
234 also more likely to have a smaller baby than white women (Table S3).

235
236 Many of the maternal, fetal and birth characteristics were strongly associated with an increased risk of
237 PPH. We found evidence of a substantially elevated risk of PPH in older women, women with higher BMI
238 and placental abnormalities; in women with stillbirth, preterm birth, multiple birth and increased fetal
239 weight, as well as with assisted or caesarean birth and births with episiotomy (Table S4). While increasing
240 socioeconomic deprivation was associated with a reduction in the risk of PPH (Table S4), we found no
241 evidence of any effect modification of the observed association with ethnicity by socioeconomic
242 deprivation (Table S5).

243
244 In sensitivity analyses restricting the cohort to primiparous women, including augmentation as an
245 additional covariate in the model and changing the outcome to PPH of 500ml or more and to 3000ml or
246 more, very similar patterns of association with ethnic group were seen (Table S6).

247

248 Discussion

249 **Summary of findings**

250 Women from black and other ethnic groups are more likely to experience postpartum haemorrhage at
251 the time of birth, regardless of the volume of blood loss used to define PPH. Following adjustment for
252 maternal and fetal characteristics, particularly birthweight, women from all ethnic minority groups have
253 an increased risk of PPH. This association remains following adjustment for characteristics of the
254 woman's birth.

255

256 **Strengths and Limitations**

257 This study uses data routinely collected in the course of clinical care, with a diverse population that covers
258 approximately 85% of births that occurred in England between 1st April 2015 and 31st March 2017.

259 Strengths of this study include its large size of nearly one million births, and the detailed information
260 available about the woman, her baby and her care, including maternal BMI, comorbidities occurring prior
261 to and during pregnancy, and care at the time of birth. These characteristics were not available to other
262 research groups evaluating association between ethnic group and PPH.^{12,32}

263

264 Our dataset contains limited information regarding some risk factors for PPH, including the administration
265 of oxytocin for augmentation, previous PPH, maternal anaemia, and length of labour. Although there is a
266 diagnosis code in ICD for PPH, which may be considered to enable 'look-back' it gives substantially lower
267 ascertainment of PPH than in our data, as found previously, and so was not used (Table S7).³³ Our
268 analyses were, however, robust to sensitivity analyses for inclusion of a binary variable for augmentation,
269 and restriction to primiparous women in whom historical PPH is not a factor.

270

271 Our central limitation is that, like many observational studies in maternity care, this study lacks
272 information about the measures taken to mitigate the risk of PPH such as the administration of
273 prophylactic synthetic oxytocin or tranexamic acid.^{7,8} As a consequence, the observed associations are
274 likely to be influenced by the risk mitigation measures and the initial treatment which may have
275 weakened the association that we report in this paper between the women's ethnic background and the
276 occurrence of post-partum haemorrhage.³⁴

277

278 A further limitation in this study is the lack of information about the methods used to estimate blood loss
279 at the time of birth. Measurement of blood loss through visual, or other, estimation is heterogenous;

280 more robust methods of estimation include the weighing of drapes or swabs.³⁵ Method of estimating
281 blood loss is, however, unlikely to vary by ethnic group.

282

283 **Interpretation**

284 In the UK, although maternity care is free at the point of access, ethnic and socioeconomic inequalities are
285 still observed in maternal and perinatal mortality.^{1,36} This association between maternal ethnic group and
286 risk of PPH, while observed by others, has not been recently evaluated in a setting where healthcare
287 availability is not associated with ethnic group and ability to pay.¹²

288

289 It is unlikely that the observed increased risk of PPH is mediated through a woman's socioeconomic
290 background: in our study, we observed no evidence of an increase in postpartum haemorrhage associated
291 with increased socioeconomic deprivation. This concurs with findings of a previous study using registry
292 data from the UK Obstetric Surveillance System, which demonstrated no statistically significant
293 relationship between maternal socioeconomic group and severe maternal morbidity,³⁷ and with a
294 previous study in our dataset which demonstrated no association between maternal intensive care
295 admission and socioeconomic deprivation. Postpartum haemorrhage is an emergency which occurs when
296 women are usually already in a healthcare setting: more widely, it has been shown that differences in
297 outcome by socioeconomic group are largely driven by richer individuals presenting earlier in their illness
298 and utilising their ability to exercise choice to improve their waiting periods, with little evidence of
299 differential quality of care based on socioeconomic group within the NHS once that care is accessed.^{38,39}

300

301 Our finding that women from an ethnic minority background are more likely to experience PPH has two
302 possible explanations. First, there may be additional confounding factors not accounted for in our analysis
303 that are associated with both PPH and ethnic minority group. Second, that women from ethnic minority
304 groups are not given the same level of intra- and postpartum observation and prophylactic treatment to
305 prevent PPH.

306

307 With respect to the first potential explanation, we were in our dataset unable to adjust for, or examine
308 through sensitivity analysis, the potential association with prolonged labour or previous PPH. However,
309 this is unlikely to have accounted for our results. There is some limited observational evidence that
310 women from black ethnic groups have shorter, rather than longer second stages of labour.⁴⁰ In a
311 sensitivity analysis restricting to primiparous women, who have no previous history of PPH, similar results
312 were seen. We were also unable to adjust for maternal anaemia, levels of which may be higher in women

313 from some ethnic groups⁴¹. Furthermore, while we were able to adjust for the presence of fibroids where
314 they were coded as a diagnosis, it is possible that this does not capture all fibroids present as not all will
315 be identified on antenatal scans, or considered clinically significant enough to modify care

316 recommendations and thus warrant coding.⁴² Further investigation is required to understand whether
317 there are biological considerations regarding effectiveness of medications commonly used to control PPH.

318 ⁴²

319

320 It is also possible that prophylactic treatment and observational measures are not equally considered and
321 offered between ethnic groups. Women from ethnic minority groups in the UK report poorer experiences
322 of antenatal and intrapartum care which may be reflected in less attention to risk factors, antenatal
323 symptoms of anaemia or concerns and symptoms indicative of PPH.^{43,44} Investigating this hypothesis
324 requires further detail regarding care pathways, which is not possible in this analysis of routinely
325 collected electronic health data. A case-control study could be used to assess treatment differences by
326 ethnic group.

327

328 However, while further investigations are ongoing, it would be prudent for healthcare professionals to be
329 aware of the increased observed risk in women from ethnic minority groups, with the aim of being
330 particularly attentive in monitoring for early identification and treatment of PPH.

331

332 **Conclusion**

333 Women from an ethnic minority background, and particularly women from a black ethnic group, are at
334 increased risk of PPH. This association persists following adjustment for maternal, fetal and birth
335 characteristics. Further investigation is needed to understand the unexplained increase in risk, including
336 possible mechanisms and the effectiveness of medications to control bleeding in women from different
337 ethnic groups. While the results of further investigations are awaited, clinical and policy action should
338 focus on the prediction, early identification and management of severe illness and postpartum
339 haemorrhage in women from ethnic minority groups, in order to reduce observed inequalities.

340 Healthcare professionals should be aware of this increased observed risk of postpartum haemorrhage in
341 ethnic minority groups, and, as with all women, be enabled to identify and treat PPH rapidly, to mitigate
342 risk of maternal morbidity and mortality.

343

344 **Supporting statements**

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347 writing of this study, or in approval of the study for publication.

348
349 **Author contribution:** JJ, JvdM, DP and KW conceived the study. All authors planned the analysis. JJ
350 conducted the analysis and wrote the first draft of the paper. All authors reviewed and redrafted the
351 study. KW supervised the study.

352
353 **Ethical approval:** This study used data routinely collected in clinical care to evaluate service provision and
354 performance and therefore individual consent was not sought. Institutional consent to access the data
355 was provided by the NHS Health Research Authority Confidentiality Advisory Group, approval number
356 16/CAG/0058. This study was approved by the LSHTM Ethics Committee, approval number 14544, on 4th
357 April 2018.

358
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369

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Table 1. Summary characteristics of 906 961 births in England with complete recorded information about maternal ethnic group between 1st April 2015 and 31st March 2017

	<i>Births with complete information about each characteristic (%)**</i>	<i>White</i>	<i>S Asian</i>	<i>Black</i>	<i>Mixed</i>	<i>Other</i>
Number of women	906 961	705 948	107 382	42 170	16 456	35 005
Postpartum haemorrhage $\geq 1500\text{ml}$	28 268 (2.9%)	19 633 (2.8%)	2 806 (2.6%)	1 652 (3.9%)	479 (2.9%)	1 225 (3.5%)
Maternal characteristics (n, %)*						
Most deprived socioeconomic quintile†	800 047 (88.2%)	160 437 (23.9%)	38 290 (38.5%)	18 641 (48.5%)	5 418 (35.2%)	10 652(33.3%)
Maternal age at birth 35 or over†	900 440 (99.3%)	146 832 (21.0%)	23 928 (22.3%)	12 510 (29.7%)	3 505 (21.4%)	9 423 (27.0%)
Maternal BMI 30 or over (obesity) †	762 767 (84.1%)	130 197 (21.8%)	16 000 (18.2%)	11 571 (33.7%)	3 141 (22.7%)	4 557 (15.6%)
Fibroids	880 534 (97.1%)	893 (0.1%)	271 (0.3%)	455 (1.1%)	60 (0.4%)	90 (0.3%)
Bleeding disorders	880 534 (97.1%)	3 795 (0.6%)	307 (0.3%)	100 (0.3%)	50 (0.3%)	117 (0.4%)
Diabetes	880 534 (97.1%)	32 096 (4.7%)	15 012 (14.3%)	3 492 (8.6%)	1 027 (6.5%)	2 802 (8.3%)
Hypertensive disease	880 534 (97.1%)	39 701 (5.8%)	5 683 (5.4%)	3 847 (9.5%)	875 (5.5%)	1 683 (5.0%)
Placental conditions	880 534 (97.1%)	8 451 (1.2%)	1 330 (1.3%)	545 (1.3%)	191 (1.2%)	451 (1.3%)
Nulliparous	902 245 (99.5%)	292 232 (41.6%)	36 285 (34.0%)	12 647 (30.2%)	6 496 (39.7%)	14 952(43.0%)
Previous caesarean section	902 474 (99.5%)	93 792 (13.4%)	20 161 (18.8%)	9 448 (22.5%)	2 411 (14.7%)	5 039 (14.5%)

Fetal characteristics (n, %)*						
Multiple birth	906 961 (100%)	11 267 (1.6%)	1 288 (1.2%)	807 (1.9%)	252 (1.5%)	501 (1.4%)
Stillbirth	906 961 (100%)	2 416 (0.3%)	587 (0.5%)	307 (0.7%)	82 (0.5%)	151 (0.4%)
Preterm birth†	906 961 (100%)	49 183 (7.0%)	8 046 (7.5%)	3 360 (8.0%)	1 189 (7.2%)	2 187 (6.2%)
Birthweight of 4500g or more†	904 377 (99.7%)	12 427 (1.8%)	603 (0.6%)	495 (1.2%)	198 (1.2%)	418 (1.2%)
Birth characteristics (n, %)*						
Induction	896 024 (98.8%)	206 201 (29.6%)	28 091 (26.3%)	10 556 (25.2%)	4 398 (26.9%)	8 417 (24.2%)
Birth assisted by instrument	904 603 (99.7%)	85 370 (12.1%)	13 366 (12.5%)	2 678 (6.4%)	1 624 (9.9%)	4 675 (13.4%)
Birth by caesarean section	904 603 (99.7%)	181 101 (25.7%)	30 775 (28.7%)	14 398 (34.2%)	4 449 (27.1%)	9 455 (27.1%)
Episiotomy	893 819 (98.6%)	106 252 (15.3%)	17 923 (16.9%)	3 655 (8.8%)	1 990 (12.3%)	5 858 (17.0%)
Manual removal of placenta	880 534 (97.1%)	13 061 (1.9%)	1 320 (1.3%)	484 (1.2%)	231 (1.5%)	502 (1.5%)

*percentages of women of each ethnicity with each characteristic are given among records with complete data for that characteristic only

**percentages of all births with complete data about the characteristic. †these variables are split into more categories for analysis; details in Suppl. Tables 1, 3

$p < 0.001$ for all characteristics using the χ^2 test to evaluate distribution between ethnic groups.

Table 2. Risks of postpartum haemorrhage of 500, 1000, 1500 and 2000ml by ethnic group among 981 801 women who gave birth in England between 1st April 2015 and 31st March 2017

	Recorded blood loss in millilitres*				
	500ml or more	1000ml or more	1500ml or more	2000ml or more	3000ml or more

Number of women	981 801	322 606	75 674	28 268	11 964	2 469
Risk of PPH		32.9%	7.7%	2.9%	1.2%	0.3%
Risk by ethnic group (n, %)						
White	705 948	223 641 (31.7%)	52 427 (7.4%)	19 633 (2.8%)	8 347 (1.2%)	1 723 (0.2%)
South Asian	107 382	37 123 (34.6%)	7 896 (7.4%)	2 806 (2.6%)	1 165 (1.1%)	258 (0.2%)
Black	42 170	16 331 (38.7%)	4 322 (10.2%)	1 652 (3.9%)	737 (1.7%)	165 (0.4%)
Mixed	16 456	5 241 (31.8%)	1 258 (7.6%)	479 (2.9%)	200 (1.2%)	38 (0.2%)
Other	35 005	13 027 (37.2%)	3 205 (9.2%)	1 225 (3.5%)	548 (1.6%)	122 (0.3%)
<i>Missing</i>	74 840	27 243 (36.4%)	6 566 (8.8%)	2 473 (3.3%)	967 (1.3%)	163 (0.2%)

*p<0.001 in Chi squared tests comparing distributions by ethnic group for all levels of blood loss

Table 3. Associations between postpartum haemorrhage of 1500ml or more and characteristics available at booking and at birth among 981 801 women who gave birth in England between 1st April 2015 and 31st March 2017

Characteristics	Risk	Crude OR (95% CI)	p value*	Model 1 (maternal characteristics)†	p value*	Model 2 (maternal and fetal characteristics)‡	P value*	Model 3 (maternal, fetal and birth characteristics)§	p value*
Maternal ethnic group**									
White	2.8%	Ref	<0.001	Ref	<0.001	Ref	<0.001	Ref	<0.001
South Asian /Asian British	2.6%	0.94 (0.90, 0.97)		0.98 (0.94, 1.02)		1.18 (1.13, 1.26)		1.14 (1.09, 1.19)	
Black / Black British	3.9%	1.42 (1.35, 1.50)		1.36 (1.29, 1.44)		1.49 (1.41, 1.58)		1.54 (1.45, 1.63)	
Mixed	2.9%	1.06 (0.97, 1.16)		1.09 (0.99, 1.19)		1.17 (1.07, 1.28)		1.20 (1.09, 1.32)	
Other	3.5%	1.27 (1.20, 1.35)		1.27 (1.19, 1.35)		1.34 (1.26, 1.43)		1.37 (1.29, 1.46)	
*Wald test **ethnic group was imputed where it was missing									
†maternal characteristics: maternal age, BMI, socioeconomic status, parity, previous caesarean section, medical conditions (diabetes, hypertension, bleeding disorders, fibroids, placental disorders)									
‡maternal characteristics and additional fetal characteristics: gestational age, birthweight, livebirth/stillbirth, multiplicity									
§maternal characteristics, fetal characteristics and additional birth characteristics: induction of labour, mode of birth, episiotomy, manual removal of placenta									

Figure 1. Data flow diagram

