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Incidence of pre-eclampsia: effect of deprivation

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KEYWORDS: competing-risks model; deprivation; pre-eclampsia; race; screening; socioeconomic status

CONTRIBUTION

What are the novel findings of this work?
The incidence of pre-eclampsia (PE) is higher in women living in areas of higher *vs* lower deprivation and in black women *vs* those of other racial groups.

What are the clinical implications of this work?
Given the association between deprivation and higher incidence of PE, political efforts aimed at improving the socioeconomic status of the poorer segments of society have the potential to reduce the incidence of PE across racial groups.

ABSTRACT

Objectives *To examine the relationship between the English index of multiple deprivation (IMD) and the incidence of pre-eclampsia (PE), evaluate the distribution of IMD in a cohort of ethnically diverse pregnant women in South East England and assess whether IMD improves the prediction of PE compared with that provided by the 'history-only' competing-risks model (based on maternal characteristics and medical history).*

Methods *This was a prospective, observational study of 159 125 women with a singleton pregnancy who attended their first routine hospital visit at 11 + 0 to 13 + 6 weeks' gestation in two maternity hospitals in the UK. The inclusion criteria were delivery at ≥ 24 weeks' gestation of babies without major abnormality. Participants completed a questionnaire on demographic characteristics and obstetric and medical history, which was then reviewed by a doctor together with the woman. Patients were asked to self-identify as white, black, South Asian, East Asian or mixed race. IMD was used as a measure of socioeconomic status, which takes into account income, employment, education, skills and training, health and disability, crime, barriers to housing and services, and living environment. Each neighborhood is ranked according to their level of deprivation relative to that of other areas into one of five equal groups, with Quintile 1 containing the 20% most deprived areas and Quintile 5 containing the 20% least deprived areas. IMD was assigned based on a woman's postcode. Risk factors for PE and its incidence were assessed across IMD using chi-square test or* t*-test, as appropriate. The relationship between IMD and gestational age at delivery with PE was evaluated by fitting parametric survival models for IMD alone, IMD combined with race and IMD combined with the Fetal Medicine Foundation history-only competing-risks model.*

Results *The incidence of PE (*n = *4088, 2.6%) increased progressively across IMD quintiles, from 2.0% in Quintile 5 (least deprived) to 3.0% in Quintile 1 (most deprived). Compared with white women and those in other racial groups, black women had a higher incidence of PE (4.8%), were less often in IMD Quintiles 4 and 5, and were more often in IMD Quintiles 1 and 2. None of the IMD quintiles improved the prediction of PE compared with that provided by the history-only competing-risks model (which includes race). The history-only competing-risks model with* vs *without IMD had a similar detection rate for delivery with PE at < 37 weeks' gestation (44.1% (95% CI, 41.1–47.2%)* vs *43.9% (95% CI, 40.1–47.0%)) and at any gestational age (35.2% (95% CI, 33.8–36.7%)* vs *35.1% (95% CI, 33.7–36.6%)), at a 10% screen-positive rate.*

Conclusions *The incidence of PE is higher in women living in the most deprived areas in South East England and in black women (*vs *those of other racial groups), who also live in areas of higher deprivation. However, in screening for PE, inclusion of IMD does not improve*

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the prediction of PE provided by race and other maternal characteristics and elements of medical history. © 2022 International Society of Ultrasound in Obstetrics and Gynecology.

INTRODUCTION

Globally, pre-eclampsia (PE) complicates about 4% of pregnancies and is a major cause of short- and long-term mortality and morbidity for the mother and fetus/baby[1]. There are many risk factors for PE, including advanced maternal age, increased weight, black and South Asian race, medical history of chronic hypertension, diabetes mellitus and systemic lupus erythematosus (SLE) or antiphospholipid syndrome (APS), conception by *in-vitro* fertilization, family history of PE and personal history of PE[2,3]. While women with lower socioeconomic status are also at increased risk for PE[4], it is uncertain whether there is an independent contribution to PE risk from race and deprivation because women from minority groups living in high-income countries are more likely to live in areas of deprivation compared with white women.

Effective prediction of delivery with PE can be achieved by the competing-risks model, which combines the prior risk, based on maternal demographic characteristics and elements from medical history, with the results of biophysical and biochemical measurements[3,5]. This model assumes that, if the pregnancy was to continue indefinitely, all women would develop PE, and whether they would do so or not before a specified gestational age depends on competition between delivery before or after development of PE. Maternal factors modify the mean of the distribution of gestational age at delivery with PE. In pregnancies at low risk for PE, the gestational-age distribution is shifted to the right (i.e. to later gestational ages) with the implication that, in most pregnancies, delivery occurs before the development of PE. However, in high-risk pregnancies, the gestational-age distribution is shifted to the left (i.e. to earlier gestational ages) and to a greater degree with higher risk for PE.

The objectives of this study were to report the distribution of the English index of multiple deprivation (IMD) in a cohort of racially diverse pregnant women living in South East England, examine the relationship between IMD and the incidence of PE, and assess whether IMD improves the prediction of PE provided by the competing-risks model, which is based on maternal characteristics and medical history (history-only model).

METHODS

Study design and participants

The data for this study were derived from a cohort of 159 125 women with a singleton pregnancy who attended a routine hospital visit at 11 + 0 to 13 + 6 weeks' gestation at King's College Hospital, London, and Medway Maritime Hospital, Gillingham, UK, between March 2006 and November 2020. Gestational age was determined by the measurement of fetal crown–rump length at 11–13 weeks' gestation or the fetal head circumference at 19–24 weeks[6,7]. Women with a singleton pregnancy delivering a non-anomalous liveborn or stillborn fetus at ≥ 24 weeks' gestation were included. Pregnancies with aneuploidy or major fetal abnormality were excluded. Women gave written informed consent to take part in the study, which was approved by the NHS research ethics committee.

Race and other maternal characteristics

The first-trimester visit included recording of maternal demographic characteristics and medical history, measurement of maternal weight and height, and ultrasound examination for fetal anatomy and biometry. Participants completed a questionnaire, which was then reviewed by a doctor together with the woman. When there was a language barrier, professional translation services were offered to participants. Patient characteristics included maternal age, race, method of conception (natural or using assisted reproductive technology (ART), defined as *in-vitro* fertilization or use of ovulation drugs), cigarette smoking during pregnancy, medical history of chronic hypertension, diabetes mellitus and SLE or APS, family history of PE (woman's mother affected) and obstetric history, which included parity (parous or nulliparous if no previous pregnancy at ≥ 24 weeks' gestation) and, for parous women, history of PE and interpregnancy interval. Chronic hypertension was defined as hypertension (i.e. systolic blood pressure ≥ 140 mmHg or diastolic blood pressure ≥ 90 mmHg) diagnosed before pregnancy or before 20 weeks' gestation. In relation to race, patients were asked to self-identify as white, black, South Asian, East Asian or mixed race and to record their country of origin.

Index of multiple deprivation (IMD)

IMD was used as a measure of socioeconomic status. IMD is the official measure of relative deprivation for small areas (or neighborhoods) in England. IMD is designed to identify aspects of deprivation across seven domains: (i) income, which measures the proportion of the population with low income; (ii) employment, which measures the proportion of the working-age population in an area involuntarily excluded from the labor market; (iii) education, skills and training, which measures the lack of attainment and skills in the local population; (iv) health and disability, which measures the risk of premature death and impairment of quality of life through poor physical or mental health; (v) crime, which measures the risk of personal and material victimization at local level; (vi) barriers to housing and services, which measures the physical and financial accessibility of housing and local services; and (vii) living environment, which measures the quality of the local environment. The domains are combined using the following weights to produce the overall IMD: income

deprivation (22.5%), employment deprivation (22.5%), education, skills and training deprivation (13.5%), health deprivation and disability (13.5%), crime (9.3%), barriers to housing and services (9.3%), and living environment deprivation (9.3%). Each neighborhood in England is ranked according to its level of deprivation relative to that of other areas and categorized into one of five equal groups, with Quintile 1 containing the 20% most deprived areas and Quintile 5 containing the 20% least deprived areas. The postcode of each patient was used to determine their IMD (https://www.gov.uk/government/statistics/english-indices-of-deprivation-2019).

Outcome measure

The outcome measure was delivery with PE. Data on pregnancy outcome were collected from the hospital maternity or general practitioners' records. The obstetric records of women with chronic hypertension or gestational hypertension were examined to determine the diagnosis of PE. PE was defined according to the American College of Obstetricians and Gynecologists as chronic or gestational hypertension (i.e. systolic blood pressure $\geq$ 140 mmHg or diastolic blood pressure $\geq$ 90 mmHg on at least two occasions 4 h apart developing after 20 weeks' gestation in a previously normotensive woman) and at least one of the following: proteinuria ($\geq$ 300 mg/24 h, protein-to-creatinine ratio $\geq$ 30 mg/mmol or urinary dipstick testing $\geq$ 2+), renal insufficiency with serum creatinine > 97 μmol/L in the absence of underlying renal disease, hepatic dysfunction with blood concentration of transaminases more than twice the upper limit of normal ($\geq$ 65 IU/L for our laboratory), thrombocytopenia (platelet count < 100 000/μL), neurological complications (e.g. cerebral or visual symptoms) and pulmonary edema[8].

Statistical analysis

Data were presented as median and interquartile range (IQR) for continuous variables and *n* (%) for categorical variables. Student's *t*-test and chi-square or Fisher's exact test were used to compare outcome groups for continuous and categorical data, respectively.

In the competing-risks model, there is a Gaussian distribution of gestational age at delivery with PE for a reference population (white race, age < 35 years, weight of 69 kg, height of 164 cm, nulliparous, spontaneous conception, no family history of PE and no history of diabetes mellitus or SLE/APS), with a mean value of 54.4 weeks and a SD of 6.9[3]. In this model, the increased risk for PE is reflected by the shift to the left in the distribution of gestational age at delivery with PE (i.e. to earlier gestational ages); thus, this shift in weeks varies according to the importance of the risk factor for PE: parous women with previous PE (8.2 weeks), chronic hypertension (7.3 weeks), pregestational diabetes mellitus (3.4 weeks), SLE or APS (3.1 weeks), black race (2.7 weeks), family history of PE (1.7 weeks), conception by *in-vitro* fertilization (1.6 weeks) and South Asian race (1.1 weeks). During the development of the model, we took the pragmatic decision to exclude risk factors associated with a shift in the distribution of gestational age at delivery with PE that was less than 0.1 SD, equivalent to 0.69 weeks.

In this analysis, three parametric survival models were fitted, in which the dependent variable, gestational age at delivery with PE, had a Gaussian distribution with a mean determined by the independent variables of IMD, race and the prior mean gestational age at delivery with PE from the history-only competing-risks model[3]. The three models were defined by (i) IMD alone, (ii) IMD plus race and (iii) IMD plus the prior mean derived from the history-only competing-risks model, which includes race[3]. Estimates and 95% CI for the effect on mean time to delivery with PE (in weeks) were assessed and compared among the three models.

In addition, the detection rate for PE with delivery at < 34 weeks, < 37 weeks or at any gestational age was compared before and after the addition of IMD to the history-only competing-risks model, at a screen-positive rate of 10%. The statistical software package R was used for data analysis[9].

RESULTS

Study participants

Across the study population of 159 125 pregnancies, there was an unequal distribution of IMD quintiles, with lower proportions of women in the least deprived quintiles and higher proportions in the most deprived quintiles (Quintile 5, 12.9%; Quintile 4, 17.2%; Quintile 3, 22.7%; Quintile 2, 28.4%; Quintile 1, 18.9%) (Table 1). Maternal and pregnancy characteristics differed by IMD quintile, with significant differences between IMD Quintiles 1–4 and Quintile 5 (the least deprived group). In Quintiles 1–4 (*vs* Quintile 5), there were lower median maternal age, lower proportions of white and South Asian women, higher proportions of black and mixed race women, higher proportion of cigarette smokers, higher rate of natural conception and longer interpregnancy interval. In Quintiles 1–3 (*vs* Quintile 5), there were higher proportions of women with chronic hypertension. In Quintiles 1, 2 and 4 (*vs* Quintile 5), median body mass index (BMI) was higher. In Quintiles 1 and 2 (*vs* Quintile 5), there were lower proportions of women with Type-I diabetes mellitus, and higher proportions of women with Type-II diabetes mellitus and those with a previous pregnancy complicated by PE. In Quintiles 2–4 (*vs* Quintile 5), there were higher proportions of nulliparous women.

The incidence of PE was 2.6% (4088/159 125) overall. Compared with the incidence of PE among white women (2.2% (2590/120 065)), PE occurred more commonly among black women (4.8% (1175/24 291)) ($P < 0.0001$), but with a similar frequency among South Asian (2.4% (175/7446)) ($P = 0.285$), East Asian (2.0% (62/3107)) ($P = 0.582$) and mixed race (2.0% (86/4216)) ($P = 0.606$) women. Among all women, there was a progressive rise in the incidence of PE from Quintile 5 (2.0% (405/20 454))

to Quintile 1 (3.0% (907/30 123)) (Table 1). These results are presented graphically for white and black women in Figure 1, which shows a clear pattern of rising PE incidence with increasing deprivation in white women. Similarly, in black women, there is an overall tendency for increasing PE incidence with increasing deprivation. For white women, the incidence of PE was 1.9% in Quintile 5 and 2.3% in Quintiles 1 and 2 combined; the respective values for black women were 3.9% and 5.1%.

Distribution of IMD in different racial groups

Within each racial group, the proportions of women were not distributed evenly across IMD quintiles (Table 2, Figure 2). Compared with white, South Asian and East Asian women, there were higher proportions of black women in IMD Quintiles 1 and 2, and lower proportions of those in Quintiles 4 and 5. Significant differences in the distribution of IMD within racial groups were found between white and black women ($P < 0.0001$), black and South Asian women ($P < 0.0001$), and black and East Asian women ($P < 0.0001$), but not between white and South Asian women ($P = 0.689$).

Contribution of IMD to prediction of PE

In the first fitted survival model, with IMD alone as an independent variable and Quintile 5 as the reference,

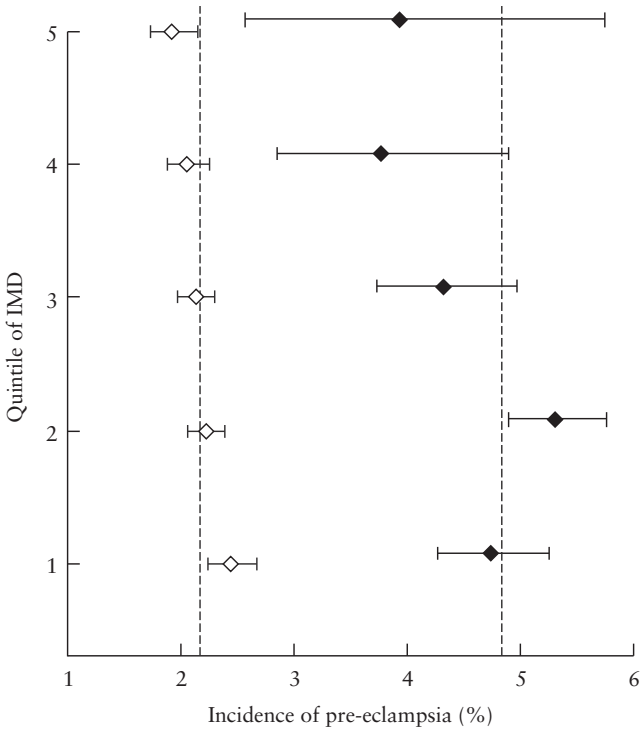

Figure 1 Relationship between index of multiple deprivation (IMD) and incidence of pre-eclampsia in black (◆) and white (◇) women in study population. Datapoints are percentage and bars are 95% CI.

Table 1 Maternal and pregnancy characteristics of study population according to quintile of index of multiple deprivation

	Index of multiple deprivation				
Characteristic	*Quintile 1* (n = *30 123*)	*Quintile 2* (n = *45 142*)	*Quintile 3* (n = *36 091*)	*Quintile 4* (n = *27 315*)	*Quintile 5* (n = *20 454*)
Maternal age (years)	28.6 (24.2–33.1)*	30.5 (25.9–34.5)*	32.1 (28.0–35.5)*	32.2 (28.5–35.6)*	32.7 (29.3–35.8)
Maternal weight (kg)	69.0 (60.0–82.0)*	68.0 (60.0–79.5)*	66.0 (59.0–76.0)*	66.0 (59.4–76.0)*	66.0 (59.0–75.0)
Body mass index (kg/m^2)	25.7 (22.5–30.4)*	25.0 (22.2–29.2)*	24.2 (21.8–27.8)	24.3 (21.9–27.7)*	24.2 (21.9–27.3)
Race	*	*	*	*	
White	19 942 (66.2)	30 451 (67.5)	28 585 (79.2)	23 297 (85.3)	17 790 (87.0)
Black	7507 (24.9)	10 435 (23.1)	4280 (11.9)	1432 (5.2)	637 (3.1)
South Asian	1266 (4.2)	1989 (4.4)	1543 (4.3)	1461 (5.3)	1187 (5.8)
East Asian	562 (1.9)	842 (1.9)	705 (2.0)	540 (2.0)	458 (2.2)
Mixed	846 (2.8)	1425 (3.2)	978 (2.7)	585 (2.1)	382 (1.9)
Medical history					
Chronic hypertension	546 (1.8)*	712 (1.6)*	416 (1.2)*	262 (1.0)	188 (0.9)
Type-I DM	126 (0.4)*	199 (0.4)*	136 (0.4)	130 (0.5)	94 (0.5)
Type-II DM	340 (1.1)*	413 (0.9)*	228 (0.6)	159 (0.6)	128 (0.6)
SLE/APS	63 (0.2)	107 (0.2)	78 (0.2)	55 (0.2)	47 (0.2)
Cigarette smoker	4899 (16.3)*	4602 (10.2)*	2332 (6.5)*	1403 (5.1)*	737 (3.6)
Family history of PE	1338 (4.4)	1847 (4.1)*	1554 (4.3)	1231 (4.5)	956 (4.7)
Method of conception	*	*	*	*	
Natural	29 509 (98.0)	43 801 (97.0)	34 551 (95.7)	26 069 (95.4)	19 389 (94.8)
In-vitro fertilization	381 (1.3)	941 (2.1)	1193 (3.3)	931 (3.4)	772 (3.8)
Ovulation drugs	233 (0.8)	400 (0.9)	347 (1.0)	315 (1.2)	293 (1.4)
Parity	*	*	*	*	
Parous, no previous PE	16 226 (53.9)	22 349 (49.5)	16 977 (47.0)	13 170 (48.2)	10 359 (50.6)
Parous, previous PE	1166 (3.9)	1516 (3.4)	1047 (2.9)	722 (2.6)	590 (2.9)
Nulliparous	12 731 (42.3)	21 277 (47.1)	18 067 (50.1)	13 423 (49.1)	9505 (46.5)
Interpregnancy interval (years)	3.2 (1.8–5.5)*	3.0 (1.8–5.2)*	2.7 (1.8–4.4)*	2.7 (1.8–4.3)*	2.6 (1.8–4.1)
PE	907 (3.0)*	1328 (2.9)*	868 (2.4)*	580 (2.1)	405 (2.0)

Data are given as median (interquartile range) or *n* (%). *Significant difference compared with Quintile 5. APS, antiphospholipid syndrome; DM, diabetes mellitus; PE, pre-eclampsia; SLE, systemic lupus erythematosus.

Table 2 Proportion of women belonging to each quintile of index of multiple deprivation according to race

	Index of multiple deprivation				
Race	*Quintile 1*	*Quintile 2*	*Quintile 3*	*Quintile 4*	*Quintile 5*
White	19 942	30 451	28 585	23 297	17 790
($n = 120\,065$)	(16.6)	(25.4)	(23.8)	(19.4)	(14.8)
Black	7507	10 435	4280	1432	637
($n = 24\,291$)	(30.9)	(43.0)	(17.6)	(5.9)	(2.6)
South Asian	1266	1989	1543	1461	1187
($n = 7446$)	(17.3)	(27.1)	(21.0)	(19.9)	(16.2)
East Asian	562	842	705	540	458
($n = 3107$)	(18.1)	(27.1)	(22.7)	(17.4)	(14.7)
Mixed	846	1425	978	585	382
($n = 4216$)	(20.1)	(33.8)	(23.2)	(13.9)	(9.1)

Data are given as *n* (%).

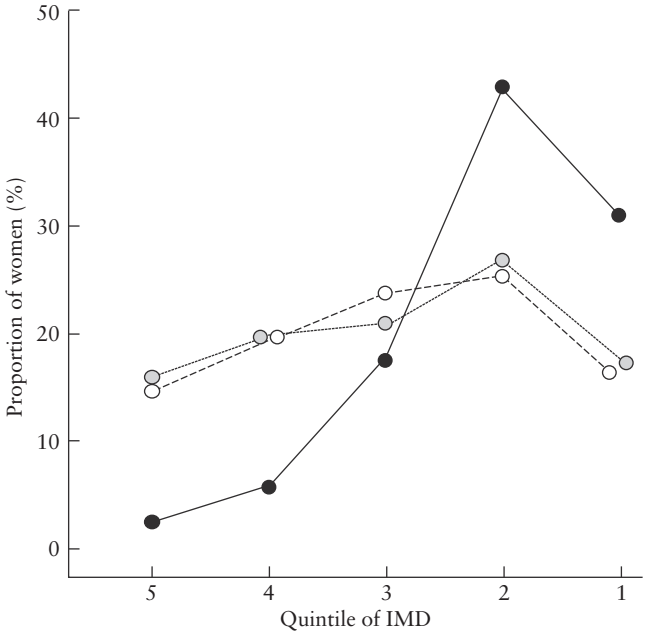

Figure 2 Proportion of women in each quintile of index of multiple deprivation (IMD) in black (●), white (○) and South Asian (◍) racial groups.

Quintiles 1, 2 and 3 were associated with a significant shift to the left in the distribution of gestational age at delivery with PE (Figure 3); however, the magnitude of the shift was more than 0.1 SD only for Quintiles 1 and 2.

In the model that included both IMD and race, only Quintiles 1 and 2 were associated with a significant shift to the left in the distribution of gestational age at delivery with PE, but the shifts were smaller than 0.1 SD (Figure 3). There was a 2.6-week shift to the left among black (*vs* white) women after taking into account IMD ($P < 0.0001$).

In the history-only competing-risks model (that includes race)[3] incorporating IMD, none of the IMD Quintiles 1–4 was associated with a significant shift to the left of the gestational-age distribution at delivery with PE (Figure 3).

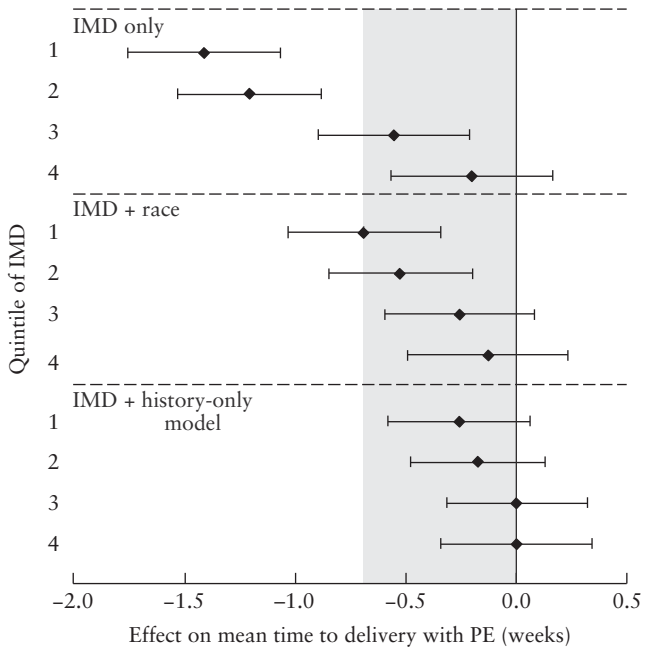

Figure 3 Effect of index of multiple deprivation (IMD) Quintiles 1–4 compared with Quintile 5 (mean of 0) on mean time to delivery with pre-eclampsia (PE), when screening based on IMD alone, a combination of IMD and race (using white group as a reference), and a combination of IMD and prior mean from history-only competing-risks model, which is based on maternal characteristics and elements from medical history[3]. Gray band represents 0.1 SD from mean. Datapoints are mean and bars are 95% CI.

When screening for PE based on the history-only competing-risks model, the detection of delivery with PE < 34 weeks, < 37 weeks and at any gestational age, at a 10% screen-positive rate, was 49.0% (95% CI, 44.3–53.7%), 43.9% (95% CI, 40.1–47.0%) and 35.1% (95% CI, 33.7–36.6%), respectively. The respective values for the history-only model incorporating IMD were similar: 48.3% (95% CI, 43.6–53.0%), 44.1% (95% CI, 41.1–47.2%) and 35.2% (95% CI, 33.8–36.7%). We found no evidence of an interaction between IMD and race.

DISCUSSION

Main findings

There are three main findings of this study of 159 125 pregnancies in racially and socioeconomically diverse South East England. First, the incidence of PE was higher in women living in the most (*vs* least) deprived areas. However, such a relationship between IMD and the incidence of PE is likely to be mediated by several maternal characteristics and elements from the maternal history that are known to be associated with an increased risk of PE. While women in the most (compared with the least) deprived IMD quintiles were more often black, they were also more often parous with previous PE, had a history of chronic hypertension or Type-II diabetes mellitus, and had higher BMI. Nevertheless, women in the most (*vs* least) deprived IMD quintiles were also more

likely to have characteristics associated with a lower risk for PE: younger maternal age, cigarette smoking, fewer conceptions by ART and nulliparity.

Second, the incidence of PE in black women was more than twice as high as the incidence in white women. This could be attributed to the lower socioeconomic status of black, compared with white, women; there was a higher proportion of black women at the most deprived end of the spectrum and lower proportion at the least deprived end of the spectrum when compared with white, South Asian and East Asian women (Table 2, Figure 2). However, after accounting for IMD, the incidence of PE in black women was still higher than in white women. We cannot rule out the possibility that this is a limitation of the IMD to measure the true extent of deprivation. However, the magnitude of the effect and the fact that it persists after accounting for confounding variables[3] (e.g. chronic hypertension, diabetes mellitus and maternal weight) suggests that the high incidence of PE in black (*vs* white) women is due to genetic susceptibility and/or other aspects of care, rather than social deprivation alone.

Third, in screening for PE by the competing-risks model, inclusion of IMD does not improve the prediction of PE provided by race, other maternal characteristics and elements of medical history.

Comparison with results of previous studies

Our findings (Figures 1 and 3) are consistent with those of Tanaka *et al.*, who examined New York State discharge data for 2.5 million hospitalized women with delivery between 1993 and 2002, and reported that the rate of PE was higher in black compared with white women (3.3% *vs* 2.0%) and in women residing in the poorest compared with the least poor neighborhoods (2.9% *vs* 2.0%)[10]. The increased rate of PE in black women was observed across all regions and poverty levels.

Mattsson *et al.* examined a cohort of 46 618 singleton births between 1999 and 2009 in an area in southern Sweden and linked the birth registries with sociodemographic variables from national statistics[11]. The risk ratio (RR) for PE was non-significantly higher among women in the lowest (*vs* highest) stratum for household income (RR, 1.25 (95% CI, 0.99–1.59)), after adjustment for maternal region of birth (their measure of race), age, BMI, parity and smoking. The authors interpreted their findings as indicating that the association between lower income and PE was due to modifiable, social determinants of health and not due to racial, genetic predisposition. However, only 2.1% of their cohort was of African origin (compared with 15% of ours), limiting their statistical power to detect any association between black race and PE after adjustment for deprivation, suggested by our findings.

Ross *et al.* drew a sample of 718 604 black and white women from a population-based California cohort of singleton births and reported that black women and women of low socioeconomic status, determined based on education and public health insurance status, were at increased risk for PE, compared with women who were white or of higher socioeconomic status, respectively[12]. An additional finding was that higher socioeconomic status attenuated the risk of PE in white women but not in black women, in line with a broader body of research indicating that black women do not necessarily gain the same health benefits from higher socioeconomic status as do white women[13–15]. This is somewhat contrary to our results, as Figure 1 illustrates a similar trend in the relationship between incidence of PE and IMD quintile in white and black women.

Consequences for political decisions and clinical practice

Given the association between deprivation and higher incidence of PE, political efforts aimed at improving the socioeconomic status of the poorer segments of society have the potential to reduce the incidence of PE across racial groups. Our findings suggest that this would likely be through decreasing deprivation as a social determinant of health to improve maternal characteristics and medical conditions that are risk factors for PE.

The relationship between race and PE has implications for prediction and diagnosis. In particular, the incidence of PE in black women is at least twice as high as that in white women[2]. However, the relationship between race and PE is not accounted for by deprivation. Previous work suggests that the relationship is at least partially accounted for by biology; black women have significantly higher serum levels of angiogenic markers, including placental growth factor (PlGF) and soluble fms-like tyrosine kinase-1 (sFlt-1)[16]. Thus, while some component of the relationship between race and PE may be modifiable, based on the care sought or received, it is essential that race is included both in screening algorithms for PE (as in the Fetal Medicine Foundation competing-risks model[3,5]) and when interpreting the results of biochemical testing for PE diagnosis.

Race as a risk factor for PE should be indicated in clinical practice guidelines. The UK National Institute for Health and Care Excellence (NICE) guidelines do not consider race to be a high or moderate risk factor for PE in the selection of patients for prophylactic treatment with low-dose aspirin[17]. However, race is an important component of the competing-risks model for PE screening[3,5], as supported by the International Federation of Gynecology and Obstetrics (FIGO)[18]. Similarly, race is not included in NICE guidance for the use of angiogenic markers in the assessment of women with suspected PE[19–22]. Given the higher levels of angiogenic markers in black women, they are disadvantaged by the use of fixed cut-offs, particularly when PlGF is used alone (rather than as part of the sFlt-1/PlGF ratio)[16].

Strengths and limitations

The first strength of this study is prospective examination of a large population of women with singleton pregnancy attending for routine pregnancy care at 11–13 weeks'

gestation and recording of maternal and pregnancy characteristics that are known to be associated with development of hypertensive disorders of pregnancy. Second, we examined the independent effects of race and deprivation to address whether the higher incidence of PE in black *vs* white women living in England is associated with racial or socioeconomic differences between the two groups, and whether IMD adds value to the prediction of PE over and above other known clinical risk factors, including race.

There are two main limitations of this study. First, race was classified into five aggregate groups, and while this is done commonly, even by the Office for National Statistics, it is likely that there would be variations in outcome according to specific subgroups; for example, in women classified as black, there may be differences between those who came to England from different regions in Africa, as opposed to the Caribbean, as well as differences between those who are first, second or third generation immigrants in England. Second, IMD is not a suitable tool for targeting individuals, but a measure of relative deprivation based on the postcode of residence; not every person in a highly deprived area is necessarily deprived and some deprived people live in the least deprived areas.

Conclusions

There are three main conclusions from this study. First, the incidence of PE is higher in women living in areas of higher *vs* lower deprivation, and in black women compared with those of other racial groups. Second, the proportion of black women living in the most deprived areas is higher than that of other racial groups. Third, in screening for PE by the competing-risks model, inclusion of IMD does not improve the prediction of PE provided by maternal characteristics and medical history.

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