RESEARCH REPORT

Area deprivation, individual factors and low birth weight in England: is there evidence of an "area effect"?

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Objective: To explore the relationship between low and very low birth weights, mother's age, individual socioeconomic status and area deprivation.
Design: Analysis of the incidence of low and very low birth weights by area deprivation, maternal age, social class of household and estimated income.
Setting: England 1996–2000.
Subjects: 2 894 440 singleton live births and the 10% sample of these births for which parents' individual-level socioeconomic measures were coded.
Results: Social class, estimated household income, lone-parenthood and mother's age were all associated with the risk of low and very low birth weight. Even when controlling for these individual level factors, area income deprivation was significantly associated with low and very low birth weight (p<0.00). For low birth weight there was a significant interaction between area income deprivation and mother's age. For very young mothers, the area effect was non-significant (p<0.37). For older mothers, particularly those aged 30–34 years, it was stronger (p<0.00). As a result, mothers aged <18 years, although at relatively high risk of low birth weight irrespective of area income deprivation, were actually at slightly lower risk than mothers aged >40 years in the most deprived areas.
Conclusions: For all but very young mothers, there seems to be a negative effect on birth weight from living in areas of income deprivation, whatever their individual circumstances.

There is much evidence suggesting that low and very low birth weights are associated with health risks both at the time of birth and in later life,[1] but whether this is a causal relationship remains an issue of debate.[2] It is also clear that birth weight outcomes are socially stratified. Mothers with partners in manual occupations are more likely than others to have children of low and very low birth weights.[3–6] At the same time, the relative importance of individual and area factors and their association with health has been a matter of debate for many decades, both generally[7 8] and in the context of the outcome of pregnancy.[3 9–11] In particular, there is growing interest in the US in the association between mothers' areas of residence and their babies' birth weights.[12–15] Potential explanations for a relationship between areas and birth weights can be broadly categorised as either arising from stressors such as crime,[14] racism[16] and pollution,[17] or the resources, such as social support[18] or access to healthcare,[19] available to residents in an area.[20] These area effects have often been operationalised by a general measure of area deprivation.

In the UK, two studies published in 1999 used a 1991 census-based index of area deprivation to examine social inequalities in birth weight. One of these studies used the Townsend Deprivation Index to evaluate how well area and individual level socioeconomic variables could account for variation in birth weight in the West Midlands region of England.[10] This study suggested that area deprivation may be more strongly associated with variations in birth weight than individual-level measures of socioeconomic status, such as social class. A second study looked at the combined associations between these two factors and low birth weight in England and Wales using the Carstairs Index.[9] It also found that using a measure of area deprivation rather than individual-level socioeconomic status accounted for more of the variation in low birth weight. It was also argued that, using the combined effects of area-level and individual-level

deprivation offered a more refined picture of the relationship between socioeconomic inequalities and birth weight.

Neither of these studies examined the relationship between mother's age and socioeconomic factors in the context of low birth weight. In England and Wales, the incidence of low birth weight is highest among babies born to the youngest mothers, particularly those aged <20 years, and among those born to women aged ≥35 years.[3 6 9] This has also been observed in other developed countries.[21–23] In addition, the two earlier studies described above did not analyse very low birth weight separately. Research in England and Wales,[24 25] France[26] and the US[27] has shown that the factors associated with very low birth weight are not necessarily the same as those associated with low birth weight as a whole. Finally, the two earlier studies analysed individual-level socioeconomic factors including social class, but not estimates of household income.

This article is part of a larger programme researching inequalities in the outcome of pregnancy.[6 24 28] It is the first of two describing cross-sectional analyses of data on births during a 5-year period. Its aim was to explore whether there was evidence of an "area effect" on the risk of low and very low birth weights and how this related to socioeconomic and sociodemographic variables, notably social class, income and mother's age.

METHODS

The data used in this article are based on the details recorded when births are registered in England and Wales. Data recorded by local Registrars of Births and Deaths and forwarded to the Office for National Statistics (ONS) include the mother's date of birth and usual place of residence, the marital status and occupations of the parents and whether

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Abbreviations: AID, area income deprivation; ONS, Office for National Statistics; SOA, super output areas
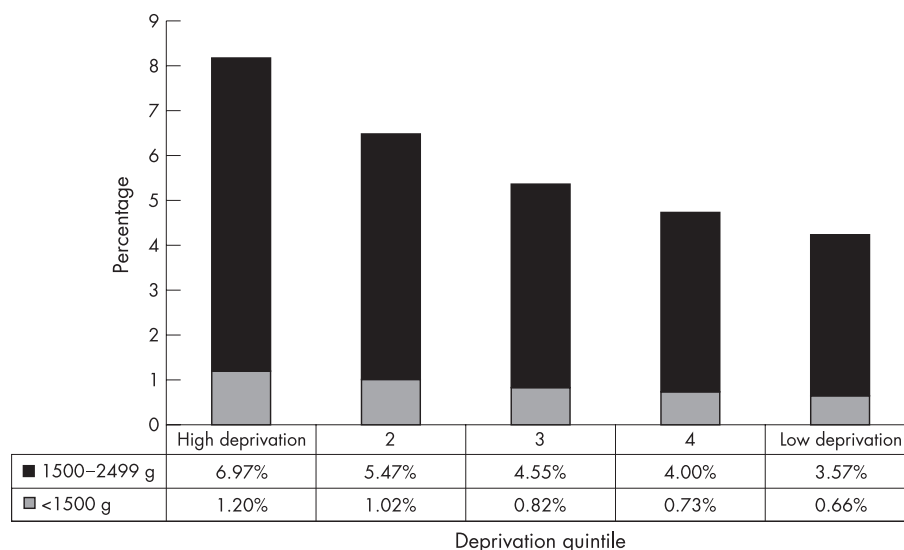
Figure 1 Births of low birth weight and very low birth weight, as a proportion of all singleton live births in the 10% sample, by multiple area deprivation (England, 1996–2000). χ^2 for trend: <2500 g, $\chi^2 = 775$, p<0.001; <1500 g, $\chi^2 = 111$, p<0.001.

the baby was a singleton or part of a multiple birth. The parents' ages at their baby's birth are obtained from the ONS. Additionally, birth weight is derived from birth notification by midwives or doctors and supplied to local registrars by the National Health Service.

Data on live births from 1996 to 2000 inclusive of women residents in England were extracted from the ONS's postcoded birth records. Records were included in the analyses if they contained complete information and had a valid postcode for the mother's usual place of residence. Analyses were restricted to singleton births and to babies with birth weights ranging from 500 to 6000 g. On the basis of the World Health Organization guidelines, birth weights <1500 g are classified as very low birth weights and all those <2500 g are classified as low birth weight.

Registration status
Births occurring outside marriage may be registered either jointly or solely. A joint registration records details of both parents, and usually requires both parents to be present, whereas a sole registration records only the mother's details. For the modelling, a variable indicating whether the baby was solely registered was used.

Social class
ONS coded a simple random 10% sample of parents' occupations using the 1990 Standard Occupational Classification. This was then combined with employment status to derive the registrar general's social class based on occupation. The father's social class was used for analyses in the case of births in marriage and jointly registered births outside marriage, as done in previous studies,[4 9] because many mothers do not record an occupation as they either do not have a paid occupation or do not choose to include it on their babies' birth certificates. In the case of sole registration, the mother's social class was used, if recorded. Table 1 shows the social class coding; entries in italics indicate mothers coded by their partners' social class and those in bold type indicate mothers of solely registered babies coded by their own social class.

The Index of Multiple Deprivation (2004)
Drawing on theories of deprivation, an Index of Multiple Deprivation was constructed using a variety of data held in administrative records to form an accumulation of single deprivation measures.[29–33] The Index of Multiple Deprivation 2004, which was used for the analyses in this study, has

Table 1 Social class coding of live born singleton babies by father's and mother's social class, 10% sample, England 1996–2002

| Father's social class | Mother's social class | | | | | | | | | |
	I	II	III Non-manual	III Manual	IV	V	Armed forces	Unclassified	Unoccupied	Total
I	3972	7881	3792	596	601	38	4	64	4714	21 662
II	2914	28 331	17 128	2869	3674	302	24	250	20 489	75 981
III Non-manual	583	6189	9228	1205	1641	170	13	78	8465	27 572
III Manual	748	12 781	20 688	6042	8886	1178	26	235	34 147	84 731
IV	316	5158	9060	2518	5949	702	7	111	19 004	42 825
V	35	1014	2429	764	1664	533	2	44	7962	14 447
Armed forces	59	819	793	211	270	34	206	17	1582	3991
Unclassified	40	244	241	56	93	14	1	52	556	1297
Unoccupied	75	582	581	203	343	57	2	11	7516	9370
Sole registration	**95**	**1666**	**2928**	**1134**	**2460**	**378**	**27**	**65**	**15 438**	24 191
Total	8837	64 665	66 868	15 598	25 581	3406	312	927	119 873	306 067

Entries in italics indicate mothers coded by their partners' social class and those in bold type indicates mothers of solely registered babies coded by their own social class.

Table 2 Multilevel logistic regression showing the odds (and their standard errors) of a singleton live birth being either low birth weight or very low birth weight, singleton live births, in the 10% sample (UK, 1996–2000)

	Low birth weight			Very low birth weight		
	Model 1	Model 2	Model 3	Model 1	Model 2	Model 3
	Odds (SE)	Odds (SE)	Odds (SE)	Odds (SE)	Odds (SE)	Odds (SE)
Level 1						
<18 years		Ref	Ref		Ref	Ref
18–19 years		0.85 (0.09)	0.84 (0.09)		0.90 (0.11)	0.89 (0.11)
20–24 years		0.71 (0.07)	0.70 (0.07)		0.83 (0.09)	0.82 (0.09)
25–29 years		0.57 (0.05)	0.57 (0.05)		0.77 (0.09)	0.79 (0.09)
30–34 years		0.55 (0.05)	0.56 (0.05)		0.79 (0.09)	0.82 (0.09)
35–39 years		0.64 (0.06)	0.66 (0.06)		0.98 (0.12)	1.02 (0.12)
≥40 years		0.79 (0.08)	0.80 (0.08)		1.29 (0.2)	1.33 (0.2)
I		Ref	Ref		Ref	Ref
II		0.97 (0.04)	0.98 (0.04)		1.07 (0.11)	1.08 (0.11)
III Non-manual		0.98 (0.05)	1.01 (0.05)		1.18 (0.14)	1.21 (0.14)
III Manual		1.11 (0.05)	1.10 (0.05)		1.28 (0.13)	1.27 (0.13)
IV		1.21 (0.05)	1.19 (0.05)		1.33 (0.15)	1.32 (0.15)
V		1.25 (0.07)	1.20 (0.06)		1.43 (0.19)	1.39 (0.18)
Unclassified/unoccupied		1.12 (0.06)	1.10 (0.06)		1.26 (0.16)	1.24 (0.16)
Non-lone parent v lone parent		0.84 (0.03)	0.86 (0.03)		0.86 (0.07)	0.87 (0.07)
Household income (HI)		1.12 (0.09)	1.10 (0.09)		0.86 (0.03)	0.90 (0.03)
HI* <18		Ref	Ref			
HI* 18–19		0.98 (0.1)	1.01 (0.1)			
HI* 20–24		0.82 (0.07)	0.87 (0.08)			
HI* 25–29		0.77 (0.07)	0.83 (0.07)			
HI* 30–34		0.73 (0.06)	0.81 (0.07)			
HI* 35–39		0.73 (0.06)	0.79 (0.07)			
HI* ≥40		0.74 (0.07)	0.79 (0.08)			
Level 2						
(AID)			1.03 (0.04)			1.14 (0.02)
Cross-level interaction						
<18			Ref			
18–19			1.05 (0.05)			
20–24			1.12 (0.05)			
25–29			1.11 (0.05)			
30–34			1.21 (0.05)			
35–39			1.16 (0.05)			
≥40			1.11 (0.07)			
Random effects						
Level 2 variation (logit scale)	0.11 (0.01)	0.06 (0.01)	0.04 (0.01)	0.01 (0.08)	0.00 (0.00)	0.00 (0.00)
Median OR	1.37	1.27	1.21	1.12	1.00	1.00
Intraclass correlation	0.66%	0.35%	0.23%	0.02%	0.00%	0.00%

AID, area income deprivation; HI, household income.

seven such domains.[32] These measure deprivation in income, employment, health and disability, education, skills and training, access to housing and services, living environment and crime. An overall deprivation score is derived by combining scores from each domain, weighted according to importance; income and employment receive the highest weight, followed by health and education, and then access to housing and services, the living environment and crime. These subindices together with the overall Index of Multiple Deprivation, were all constructed at the level of lower-level super output areas (SOA) having an average of 1500 residents. These areas are smaller than the electoral wards used to construct earlier indices.

For each birth record, the Index of Multiple Deprivation was derived from the postcode of the mother's usual place of residence. Two measures were used from the index. Firstly, the overall index of deprivation, where the SOAs were ranked by Index of Multiple Deprivation 2004 deprivation score and then split into five groupings containing equal numbers of SOAs to produce quintiles ranging from 1 (most multiply deprived area (SOA)) to 5 (least income-deprived area (SOA)). This measure was used to show the overall pattern of low and very low birth weights, and is important because it is the measure used commonly by the central government to identify areas needing priority when implementing policies to support deprived people and families. Secondly, the income domain from the index was used in the modelling process to identify low-income neighbourhoods. This measure is the proportion of an SOA's population living in households supported by means-tested benefits. The overall index was not used in this instance because of possible confounding between the health and disability domain and birthweight measures.

Estimated household income

For the 10% sample of records, for which parents' occupations were classified by standard occupation code (Standard Occupational Classification 90), the household's gross weekly earnings were estimated. This involved estimating the mean gross weekly income for each Standard Occupational Classification 90 code from the UK Labour Force Survey from December 1997 to November 1998 and attaching these estimates to the main dataset. An estimate of income was also made for parents not in paid employment, on the basis of typical social security payments. If the mother's occupation was recorded, her gross weekly income was added to that of the father if they were married or had registered the birth jointly. An income equalisation multiplier of 1.6 was applied to the estimated income of mothers of solely registered babies to account for the single adult in the household.

Statistical analysis

Multilevel logistic regression was used to model the risks of low and very low birth weights for the 10% of cases with
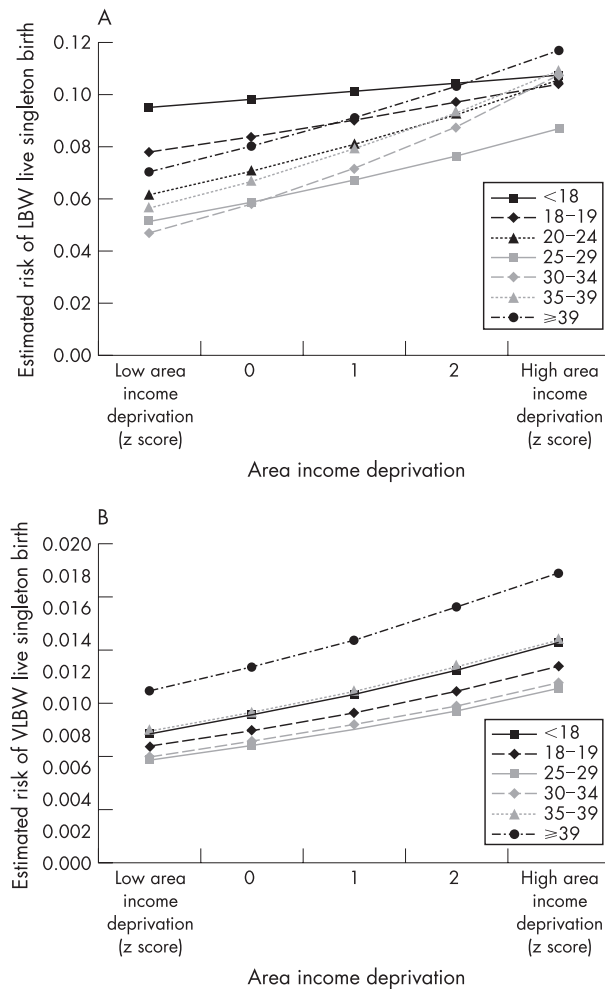
Figure 2 Risk of low birth weight (A) and very low birth weight (VLBW) (B) estimated from model 3 by mother's age and area income deprivation, controlling for household income, social class and lone parenthood.
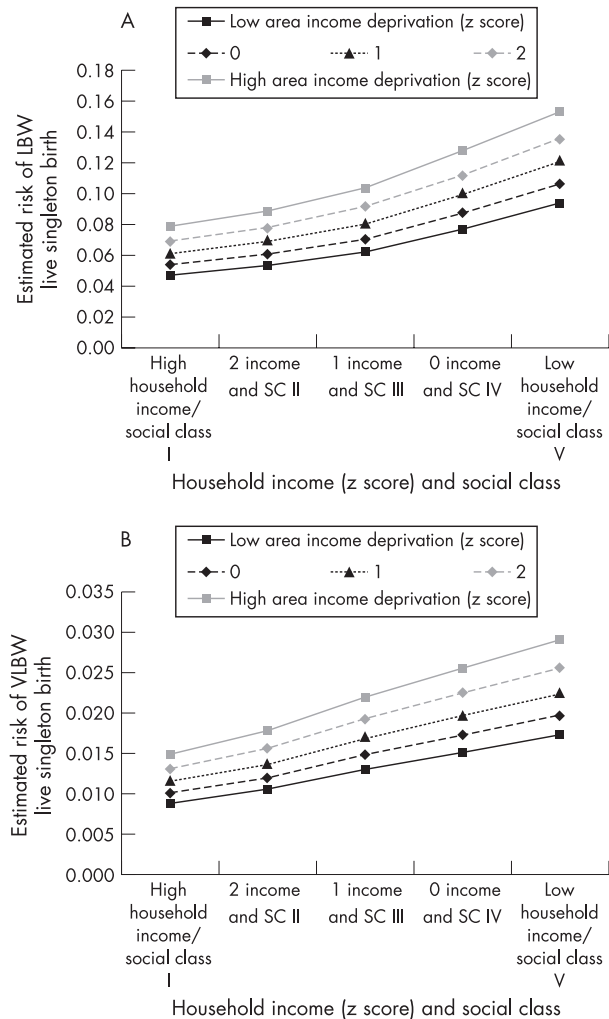

Figure 3 Risk of low birth weight (A) and very low birth weight (VLBW) (B) estimated from model 3 by household income or social class and area income deprivation, controlling for mother's age and sole registration.

parental occupational information. This meant that the analysis took into account the hierarchical nature of the data, with individuals nested within SOAs. It also allowed the clustering of mothers with similar levels of risk to be examined. Mothers were assigned to level 1 and SOAs to level 2. The same modelling approach was followed for low and very low birth weights, starting with a null or empty model; individual-level and then area-level measures were added. This allowed exploration of the relationships between birth weight, individual and area variables. Variables and interactions were included if they significantly improved the fit of the model. A more complex random slopes model was examined but was not found to improve the fit when compared with the random intercept model actually presented.

To aid the interpretation of the random effects model, two summary measures were calculated. The first was the variance partition coefficient or intraclass coefficient (ICC). This is the proportion of the total variance (v) related to the area or second level of the model:

$$ICC = \frac{V_{level2}}{V_{level2} + V_{level1}}$$

This measure was estimated using the simulation method suggested by Goldstein *et al*.[34] Because the level 1 variance is

dependent on the expected value of y, there is a range for the intraclass coefficient rather than a single value. For this analysis, a predicted value of y based on the average values of the independent variables was used.

The median odds ratio (MOR), the second summary measure derived, quantifies the area effect. It is the median difference between people, with all other covariates held constant, randomly drawn from two different SOAs.

$$MOR = \exp\left(\sqrt{2 \times V_{level2}} \times \Phi^{-1}(0.75)\right)$$

where $\Phi(\cdot)$ is the cumulative distribution of the normal function with mean 0 and variance 1 and $\Phi^{-1}(0.75)$ is its 75th centile.[35] [36]

A value of 1 indicates that there is no area effect. A difference >1 can be thought of as the average effect of moving an individual from one SOA to another. As such, it is comparable with the fixed coefficients in the model.

The models shown were fitted using the adaptive Gauss–Hermite quadrature method available in STATA.[37] The number of quadrature points used was tested, as was the assumption of no extra-binomial variation, using the method suggested by Browne *et al*.[38]

Table 3 Numbers of births and percentage of all births in each age group by quintile of multiple deprivation index

Qunitile	Age of the mother, n (%)		
	<18 years	18–39 years	≥40 years
Most deprived	34 460 (1.2)	72 5757 (25.1)	12 164 (0.4)
2	16 705 (0.6)	57 1829 (19.8)	11 203 (0.4)
3	9431 (0.3)	507 057 (17.5)	11 782 (0.4)
4	5681 (0.2)	479 465 (16.6)	12 689 (0.4)
Least deprived	3489 (0.1)	478 327 (16.5)	14 401 (0.5)

RESULTS

Between 1996 and 2000, there were 2 894 440 singleton live births in England, of which 6.04% were of low birth weight and 0.92% were of very low birth weight. The incidences of low and very low birth weights were higher in more multiply deprived areas, and there was a strong statistically significant linear gradient (fig 1). The incidence of low birth weight, ranged from 4.23% in the least multiply deprived areas to 8.17% in the most multiply deprived area and the incidence of very low birth weight ranged from 0.66% to 1.20%, an almost twofold difference in each case.

Table 2 presents the odds and their standard errors of a singleton live birth being either low birth weight or very low birth weight by age, social class of household, registration status, z score of estimated household income, age–household income interaction, z score of area income deprivation (AID) and age–AID interaction. Model 1 gives an indication of the amount of spatial clustering of low and very low births weights. For the low birthweight model the SOA level variance measure was significant, suggesting some clustering of mothers of similar risk; this was not true of very low birth weight where there was a relatively smaller and non-significant level 2 variation. However, the difficulty in estimating very low probabilities for groups with small populations may be affecting the estimates of very low birth weight. It would therefore be unwise to dismiss the possibility of clustering of very low birth weight risk, especially given the significant association between area income deprivation and very low birth weight in the final model.

As individual and household-level variables were added in model 2, the amount of level 2 variation decreased. This indicated that a proportion of the clustering of low and very low birthweight births was because of mothers with similar risk factors living close to each other rather than the significance of area of residence itself. For very low birth weight, this reduced the already small amount of level 2 variance considerably. The intraclass coefficient for low birth weight suggests that individual-level factors might explain about half of the variation between areas, although this does assume that the individual-level factors used capture all individual-level risk factors. In model 3, SOA level income deprivation was introduced. This led to a further reduction in the level 2 variance for the low birthweight model, from 0.06 to 0.04. This would tend to indicate that some of the apparent clustering of low birthweight births might be owing to area deprivation (eg, poor physical environments, high crime rates or low social capital). There was still a fairly large amount of "unexplained" variation between SOAs, however. This was probably related to other unmeasured individual-level and area-level factors.

The final models (model 3) each show that mother's age, parents' social class, income, registration status and area deprivation have a marked and independent association with low and very low birth weights. After controlling for social class, income and area deprivation score, babies with mothers aged between 20 and 34 years had lower predicted rates of low birth weight than older or younger women. Mothers

aged <18 years and those >40 years had similarly higher proportions of low birthweight babies. The level of income deprivation in the immediate area in which the mother lived had a significant association with the proportion of low and very low birthweight babies even after controlling for the mother's age, social class and income.

Figure 2 illustrates the interaction between mother's age and area income deprivation and rates of low birth weight (fig 2A) and very low birth weight (fig 2B). The figure shows that the area effect on low birth weight varied between mothers of different ages. For young mothers it was very weak and non-significant, with only a very slight increase in the estimated risk associated with increasing area income deprivation. In contrast the effect was strong for older mothers and in particular those aged 30–34 years, where the risk doubled for those living in the most income-deprived areas of England compared with those in the least deprived. This meant that although mothers aged <18 years had the highest estimated risk of low birth weight in the least income-deprived areas, in the most income-deprived areas the risk for mothers aged >39 years was higher. In fact, high area income deprivation seems to effectively "equalise" the risk for all mothers except for those aged 25–29 years who remain at lower risk. The estimated risks of very low birth weight were highest in the oldest group of mothers, irrespective of household income or area income deprivation, with mothers aged ≥40 years having an odds of 1.33 compared with those aged <18 years.

The interaction between estimated household income and age was slightly counterintuitive. For women <20 years, there was a positive association between low birth weight and income. This is likely to be a consequence of the measures of socioeconomic position used. Mothers aged <20 years in higher-income households were more likely to have been supported by their parents and remained in full-time education, but no information related to this is recorded at birth registration. They were therefore grouped with mothers with no recorded occupation.

DISCUSSION

This paper provides evidence that the characteristics of areas have an association with the outcome of pregnancy above and beyond the mothers' household-level socioeconomic status.[8] Although area income deprivation is, to some extent, only a concentration of people with low incomes in an area, these results indicate that excess low birth weights in these areas may not be explained simply as a sum of people's socioeconomic characteristics.[32]

The importance of measures of area income deprivation was evident in the higher estimated risks of low and very low birth weights among babies of parents with relatively high estimated income but who lived in more income-deprived areas compared with those living in less income-deprived areas (fig 3). This implies that whatever a parent's income, living in a poor neighbourhood is associated with a higher rate of low birth weight.

What is already known

- Birthweight outcomes are associated with individual parents' socioeconomic status, with growing evidence that the nature of their area of residence may also be important.

What this paper add

- There was strong evidence of an association between area deprivation, as measured by the Income domain of the Index of Deprivation 2004, and rates of low and very low birth weight, even when controlling for individual-level factors such as social class and estimated household income.
- For low birth weight, the area effect varied with age. For very young mothers there seemed to be no area effect at all. In contrast, for older mothers, particularly those aged 30–34 years, it was relatively strong.

Policy implications

- Tackling some of the more generic problems of areas experiencing multiple deprivation may be useful in reducing low birth weight, but concentrating solely on these areas will mean that many mothers having a low birthweight baby will be missed.

These findings, however, do not necessarily support a policy that concentrates only on the most deprived areas of England. As 64% of low and 65% of very low birthweight births occur outside the 25% of most multiply deprived areas of England, policies focusing solely on priority areas risk missing a major proportion of mothers and babies who might benefit from them.

The youngest and oldest groups of mothers living in the most income-deprived areas deserve attention, but for slightly different reasons. There is a high rate of low birth weight among babies born to mothers in both groups (fig 2). Births in the very youngest group of mothers account for 1.2% of live births and these outnumber those to the very oldest group, who account for 0.4% (table 3). They therefore represent a greater scale of problem, whereas the oldest group of mothers in these areas is at greater risk of delivering a low birthweight baby.

Babies registered by their parents jointly (married or not) were significantly less likely to be low birth weight than those whose mothers registered their births alone (lone parents) despite controlling for other potential risk factors. This suggests that there might be an added effect associated with lone parenthood. This may be associated with the higher level of stress and lower psychological well-being lone parents are often found to be experiencing,[39] and the extent to which this might lead to an amplification of the effect of other negative socioeconomic states.[40]

LIMITATIONS

Some important factors could not be included in this study as the relevant data were not available. Although mothers' ages

were taken into account, their parity could not be included in the models, as it is recorded only for births within marriage and even then a non-standard definition is used.

Another factor not recorded is how long the mothers had been living at their current address at the time of registering the birth. They may have moved relatively recently from a more or less income-deprived area. This "mixing" effect would have tended to reduce the association with area deprivation rather than increase it. It therefore seems unlikely that this would change the conclusions of this study.

Lastly, if further individual-level characteristics had been added to the model, it is possible that the strength of the association with area deprivation might have been reduced. Given the close relationship between wealth, income and residential location, weaker associations with area variables in a statistical model do not necessarily imply a lack of an area effect. The benefits that accrue to individuals from wealth includes a high degree of control over the types of environment they live in.

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