The social gradient of birth weight in England assessed using the INTERGROWTH-21st gestational age specific standard

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Abstract

Objective: To determine the socio-economic gradient of birth weights in England with reference to the prescriptive INTERGROWTH-21st Birth Weight Standard.
Design: National cross-sectional study using data from Hospital Episode Statistics.
Setting: National Health Service in England.
Participants: All singleton babies, live born between 34 and 42 weeks' gestation, between 1st April 2011 and 31st March 2012.
Main outcome measures: Birth weight distribution of babies with a birth weight <10th centile or >90th centile, i.e. small (SGA) or large (LGA) for gestational age using Index of Multiple Deprivation quintiles as a proxy for socio-economic status.
Results: Of 508 230 babies born alive between 1st April 2011 and 31st March 2012, 38 838 (7.6%) were SGA and 81 026 (15.9%) LGA. Median birth weight was 3405 grams, median z score 0.25 (SD 1.06). Birth weight z score demonstrated a social gradient, from 0.26 (SD 1.1) in the most deprived areas to 0.53 (1.0) in the least deprived. Women in the most deprived areas were twice as likely to have SGA babies using the INTERGROWTH-21st chart (OR 1.94; 95% CI 1.87, 2.01) compared to those in the least deprived areas. If all women had the same rate of SGA equivalent to those living in the least deprived areas, approximately 12 410 (30%) fewer babies would be born SGA in England each year.
Conclusions: This study gives a measure of the social gradient in singleton SGA and LGA babies across England using an international standard of newborn size at birth.

Abstract word count: 243

Introduction

Size at birth indicates the quality of the intrauterine environment and identifies babies born at greater risk of adverse immediate and future outcomes. Being born small for gestational age (SGA) increases the risk of perinatal mortality,[1 2] infections in childhood,[3] and has been linked to lifelong disparities in cardiovascular and metabolic health,[4] shorter adult stature,[5] and decreased economic productivity.[6] Being born large for gestational age (LGA) places both mother and baby at higher risk of complications during birth, such as shoulder dystocia and Caesarean section,[7] and in some populations has been associated with childhood overweight and obesity.[8,9]

In 2014, the INTERGROWTH-21st Consortium published the first prescriptive, international standards for fetal growth[10] and newborn size at birth (weight, length and head circumference) for gestational age and sex,[11] based upon World Health Organization (WHO) recommendations for the construction of such standards.[12] The standards describe optimal intrauterine growth and size at birth for babies born to healthy, well-nourished women receiving adequate antenatal care and living in environments across the world with minimal constraints on growth. Under such conditions, babies grow similarly in utero and achieve a similar size at birth irrespective of their mothers' ancestry, skin colour or geographical location.[13~~4~~] The findings justify the use in routine clinical practice of a single set of international standards for all populations around the world. As these standards perfectly complement the existing WHO Child Growth Standards,[14~~6~~] there is now a unified approach to measuring growth and development from early pregnancy to childhood.[15]

Graded health inequalities are present throughout life. Ensuring a healthy start to life was a key policy objective in the 2010 report *Fair Society, Healthy Lives (the Marmot Review).*[16] The report emphasised interventions aimed only at the most deprived in society will miss many others who could also benefit from better health outcomes. It is known that birth weight displays a social gradient,[17-20] although many studies have failed to consider preterm babies (born less than 37 weeks' gestation) separately from those that are born small because of impaired fetal growth.

We aimed to determine the distribution birth weights in England and the proportion of babies born SGA and LGA using the INTERGROWTH-21st Birth Weight Standard for gestational age and sex, relative to the mother's residential area as a marker of her socio-economic status.

Methods

The study was a retrospective analysis of routinely collected national data on babies born in England between 1st April 2011 and 31st March 2012. Records were extracted from the Hospital Episode Statistics (HES) database to identify all births that took place in English NHS trusts (acute hospital organisations) during the study period. The HES database contains pseudonymised patient demographics, clinical information and administrative data for every inpatient episode of care. Episodes related to labour and birth capture additional information, including the baby's sex, gestational age in completed weeks and birth weight, in supplementary data fields known as the HES 'maternity tail'. Birth records were identified as any episode containing information about the mode of birth in either the procedure field (OPCS-4 codes R17–R25) or the maternity tail.

The study was limited to singleton, live born babies with complete data on sex, weight and gestational age at birth, and maternal postcode district. The analysis was limited to late preterm and term babies born between 34 and 42 weeks' gestation as these represent the overwhelming majority of births.

The birth weight centile and z score for gestational age and sex were calculated for each baby according to the INTERGROWTH-21st standard.[11] To determine the proportion of SGA and LGA, all newborns were categorised as: i) SGA (birth weight <10th centile); ii) appropriate for gestational age (AGA) (birth weight between 10th and 90th centile inclusive, or iii) LGA (birth weight >90th centile). Although the INTERGROWTH-21st standard presents centiles and z scores in days throughout pregnancy, gestational age at birth is only recorded in the HES database by completed week of gestation: therefore, 3 days (i.e. half a week) were added to each recorded gestational age to minimise potential misclassification bias of SGA and LGA babies.

The exposures studied were the baby's sex, gestational age at birth and an estimate of maternal social deprivation derived from the Index of Multiple Deprivation (IMD), a measure that combines economic, social and housing indicators based on postcodes.[21] Deprivation scores were based on data from 32 480 Lower Super Output Areas in England in 2010. The IMD score is presented in quintiles (quintile 1 being the least, and quintile 5 the most, deprived).

The distribution of birth weights and the proportion of SGA and LGA babies were compared across gestational ages, sexes, IMD quintiles. Univariable and multivariable logistic regression models were used to estimate crude and adjusted effects of gestational age, sex and IMD quintile on the SGA and LGA rates.

All statistical tests were two-sided, and the level of significance was set at $p<0.05$. All analyses were performed in Stata version 13 (StataCorp, College Station, TX, USA).

The presentation of the results was realised using a novel approach to spatial data visualisation. This was applied to allow a different geographic interpretation than it is possible in conventional maps. A density-equalising cartogram transformation based on Gastner & Newman's algorithm was used.[22-33-4] Each postcode area was resized according to the total number of babies born there. Areas with a low number of births is proportionally reduced in size. This makes these maps different from a land area map where the least populated areas (and those with usually also much lower absolute numbers of births) are proportionally overrepresented. Onto these maps the relative LGA and SGA rates were overlaid. This cartogram visualisation technique made it possible to highlight the varying birth rates across the geographic areas where most births occurred.

Results

From the 673 595 births during the study period, 508 230 singleton babies met the inclusion criteria with 260 103 (51.2%) males. The overall median birth weight was 3405 grams, corresponding to the 60th centile and z score of 0.25 of the INTERGROWTH-21[st] standard. Birth weight displayed a gradient across the IMD groups with the median weight of babies in the highest quintile 140 grams heavier than those born in the lowest quintile (table 1). There were 38 838 (7.6%) babies born SGA and 81 026 (15.9%) LGA.

There was a social gradient in the proportion of babies born SGA, with a similar trend observed between boys and girls (Figure 1 A). Amongst babies born to mothers in the least deprived areas 5.2% were SGA, compared to 9.8% in the most deprived, p <0.001. Median z score differed from +0.4 in the least deprived group to +0.11 in the most deprived.

The social gradient was also observed for the proportion of babies born SGA by week of birth, with the highest rates observed for babies born at 34 weeks of gestation (Figure 1 B). Whilst the highest proportion of SGA babies were both preterm and born to mothers living in the most deprived areas: 16.1% of babies born at 34 weeks' gestation were SGA in socioeconomic quintile 5 (most deprived) compared to 11.0% in quintile 1 at the same gestational age, this difference did not reach statistical significance, p=0.39.

After adjustment for sex and gestational age, mothers in the most deprived areas were twice as likely to give birth to an SGA baby (OR 1.94; 95% CI 1.87 to 2.01) compared to those in the least deprived areas (Table 2), with a dose-response trend observed across the social groups.

In contrast, more LGA babies were born to mothers in the least deprived areas (18.6% v. 13.5% in the most deprived areas, p-value<0.001). A small differential effect was observed between the sexes for LGA, with boys more frequently LGA than girls in quintiles 1 to 4, however no sex difference observed in quintile 5 (Figure 2A). There was an increase in the proportion of LGA babies across gestational age groups, with 8% of babies born at 34 weeks LGA, rising to 18% of those born at 42 weeks LGA. Whilst this trend was observed across all socio-economic groups, differences between the groups were only apparent after 37 weeks' gestation (Figure 2B).

After adjustment for sex and gestational age, mothers in the most deprived areas were less likely to give birth to an LGA baby (OR 0.68; 95% CI 0.67 to 0.70) than those in the least deprived areas (Table 2), with evidence of the reverse gradient to what was observed for SGA babies.

SGA and LGA rates differed by individual postcode area across England (Figures 3A and 3B). Density equalising cartograms of live births combined with SGA and LGA rates demonstrate regional differences in their quantitative dimension. The predominantly urban areas with the highest number of births are emphasised with this cartographic technique. It shows the relatively higher LGA prevalence in large parts of the North and South West, and higher SGA trends in the Midlands and other central urban areas, including in deprived parts of the North of England and East London.

Discussion

We present the first description of birth weight for babies born in England compared to an international standard. The observation that deprived women have smaller babies is consistent with previous reports. We have quantified the socio-economic gradient in size at birth that exists in England, highlighting that deprived woman have twice the rate of SGA babies compared to the least deprived. We estimate that if pregnancy outcomes for women across the entire population of England were equal to that of women living in the most well-off areas, 12,410 (30%) fewer babies would have been born SGA in 2011-12.

We also present evidence that the distribution of birth weight in England is, on the whole, heavier than that defined by the optimal birth weight standard. This has been observed in other western countries that have compared population birth weight distributions to the INTERGROWTH-21st standard.[24-5] When examined by gestational week, the proportion of babies born LGA increases particularly after 37 weeks' gestation, correlating with the period of maximal fetal fat deposition.[26] The significance of a higher proportion of LGA babies in the population compared to the standard is not known. Given the current high rates of childhood overweight and obesity, this observation merits further analysis.

In contrast, preterm babies were more likely to be SGA, with a graded social relationship between both SGA and being born preterm. Whilst it is plausible that a proportion of this could be explained by higher rates of risk factors such as smoking and adolescent pregnancy in more deprived groups, in practice, most cases of preterm birth and SGA do not have obvious risk factors and identifying direct causal factors can be challenging, particularly amongst minority groups.[27] Combinations of stress, poverty, subclinical infections, environmental pollution, poor nutrition, inadequate housing and barriers to seeking care may also be important contributory factors in reducing rates of SGA, and will require a multi-sectoral approach.

Strengths and Weaknesses of study

This study has several strengths: (i) it is population-based and nationally representative; (ii) birth weight was compared to a gestational age and sex-specific standard, which avoids the confounding effect from prematurity when birth weight alone is used; (iii) birth weight in England is compared against an optimal standard for the first time. However, we also acknowledge several limitations. Firstly, we relied on the accuracy of the recorded gestational age in the database (which was recorded to the nearest week only) and were unable to confirm the basis of this information (i.e. early or late ultrasound or maternal recall of last menstrual period). To reduce the potential for a misclassification bias when calculating SGA and LGA, we elected to add 3 days to the gestational age in full weeks. This meant our estimation of the prevalence of LGA was more conservative than our previous publication,[28] however the effect of place of birth of SGA and LGA remained unchanged (supplementary material). The categorisation of social standing by IMD group is based on postcode and whilst a validated indicator,[29] it cannot account for individual level factors with socioeconomic status a multidimensional construct.[30] More information is needed to understand the implications of these findings to guide public health interventions and clinical practice. It is also possible that clinician interventions may have influenced the proportion of SGA babies delivered at term, with current RCOG guidelines recommending planned delivery after 37 weeks.[31]

We defined SGA and LGA using the historical thresholds of the 10th and 90th centiles. This may be overly inclusive, given that the INTERGROWTH-21st standard was based on an optimal population. These traditional definitions were based on observations of increased perinatal mortality rate amongst babies within these groups, based on the observed weights and mortalities of babies born in Colorado in the 1960s.[32] True pathological growth may be better identified by the 3rd or 97th centile, corresponding to a z score of +1.88 or -1.88, as recommended in child anthropometry.[14] In the fetus and newborn, growth may be better approximated by a change in growth centile over time,[33] or body composition at birth[34] rather than a cross-sectional assessment of size at birth. Further work is urgently needed to demonstrate increased risks of adverse outcomes in childhood at different thresholds in order to inform clinical practice guidelines. A further limitation is that we present data for one year only. Populations are dynamic, and the point of comparing against a standard is to detect temporal changes. Future comparisons between years will now be possible as we work towards reducing inequality in society. We also focussed only on singleton births, as these are the babies for whom the INTERGROWTH standards were developed.

Several important pregnancy outcomes have been associated with socio-economic status, measured by IMD, education and employment status, including perinatal mortality,[35-68-9] cerebral palsy,[3740] and preterm birth.[3841] Interventions to flatten the social gradient and improve pregnancy outcomes will be complex, adopting of a life course approach to health, nutrition, education, social justice, and the rights of women and girls. Whilst pregnancy care plays an important role, true change will require a societal shift.

Implications for policy makers and clinicians

We highlight the ongoing importance of social inequalities on pregnancy and birth outcomes in England, with clear evidence of a graded effect across social groups for babies born throughout the late third trimester. Childhood obesity has become a national epidemic, with the UK estimated to have the highest rates in Europe, with evidence of higher prevalence in more deprived groups.[3935] It is recognised that SGA babies born to deprived parents are more likely to become overweight by age 7,[4036] possibly due to poor early feeding choices and environmental factors.[3417] Poor growth in utero is also linked to a number of epigenetic changes that may predispose to obesity and metabolic syndromes later in life. Correctly identifying SGA babies at birth is important to ensure parents are given the support they need to effectively exclusively breast feed for 6 months and thereafter initiate appropriate supplementary feeding. Ultimately however, we should try and prevent these disparities at birth occurring, working towards ensuring that all children have the best possible start in life. We believe it is time to hold governments accountable for narrowing the gap in pregnancy outcomes within and between societies. Reporting and comparing birthweight disparities using the INTERGROWTH-21st standard is a simple, yet powerful indicator to advocate for accelerated change.

What is already known on this topic:

- Low birth weight for gestational age, which is associated with adverse short- and long-term health outcomes, is more common in women from a lower socio-economic background

What this study adds

- Large regional differences in birth weight exist across England with evidence of a social gradient
- Women living in the most deprived areas of the country are most likely to have low birth weight babies across all gestational ages and more SGA babies
- The mean birth weight of babies born in England is heavier than the optimal international standard

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Table 1: Distribution of birth weights

Exposure		Total babies	Birth weight (median)				
			Grams	Standard deviation	z score	Standard deviation of z score	Percentile
Gestational age at birth (completed weeks)							
	34	3563	2240	472	-0.12	1.11	45
	35	5676	2495	465	-0.11	1.10	46
	36	11 240	2720	483	-0.049	1.14	48
	37	26 081	2950	470	0.041	1.11	52
	38	65 426	3175	463	0.20	1.09	58
	39	118 857	3340	443	0.23	1.03	59
	40	149 799	3490	444	0.29	1.03	61
	41	105 900	3640	454	0.36	1.04	64
	42	21 688	3710	473	0.32	1.08	62
Deprivation quintile							
	1	72 750	3480	498	0.40	1.01	65
	2	79 070	3455	509	0.35	1.03	64
	3	92 343	3430	513	0.30	1.05	62
	4	116 087	3400	520	0.22	1.06	59
	5	147 980	3340	527	0.11	1.08	54
Total		508 230	3405	518	0.25	1.06	60

Table 2: Relationship between SGA and LGA and IMD deprivation score

SGA	Deprivation score	Adjusted Odds Ratio[1]	95% confidence interval
	1	Reference	-
	2	1.16	1.11-1.21
	3	1.34	1.28-1.40
	4	1.60	1.54-1.66
	5	1.94	1.87-2.01
LGA			
	1	Reference	-
	2	0.95	0.93-0.98
	3	0.88	0.86-0.91
	4	0.80	0.78-0.82
	5	0.69	0.68-0.71

[1]Adjusted for gestational age at birth and sex