

# Prenatal risk factors for Caesarean section. Analyses of the ALSPAC cohort of 12 944 women in England

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**Background** There has been an escalation in Caesarean section rates globally. Numerous prenatal factors have been associated with elective and emergency Caesarean section, some of which may be amenable to change.

**Methods** A population-based cohort of 12 944 singleton, liveborn, term pregnancies were used to investigate risk factors for Caesarean section using multivariable logistic regression modelling. Numerous prenatal factors were investigated for their associations with the following outcomes: first, with Caesarean section (both elective and emergency) compared with vaginal delivery (spontaneous and assisted); second, for their associations with elective Caesarean section compared with attempted vaginal delivery; and finally emergency Caesarean section compared with spontaneous vaginal delivery.

**Results** 11 791 women had vaginal delivery and 1153 had Caesarean section (685 emergency, 468 elective). Non-cephalic (breech) presentation (all Caesareans odds ratio (OR) 36.6, 95% confidence interval (CI) 26.8–50.0; elective Caesarean OR 86.4, 95% CI 58.5–127.8; emergency Caesarean OR 9.58, 95% CI 6.06–15.1) and previous Caesarean section (all Caesareans OR 27.8, 95% CI 20.9–37.0, elective Caesarean OR 54.4, 95% CI 38.4–77.5; emergency Caesarean OR 13.0, 95% CI 7.76–21.7) were associated in all analyses with an increased risk of Caesarean section. Extremes of neonatal birthweight were associated with an increased risk of Caesarean section (all Caesareans and emergency section) compared with vaginal delivery as was increasing neonatal head circumferences. In all analyses increasing maternal age (OR 1.07 per year, 95% CI 1.04–1.09; OR 1.04 per year, 95% CI 1.01–1.08; OR 1.11 per year, 95% CI 1.08–1.15) was independently associated with increased odds of Caesarean section. Increasing parity was associated with a decrease in risk for all Caesareans and emergency section (OR 0.63, 95% CI 0.53–0.75 and OR 0.46, 95% CI 0.33–0.63, respectively), as was the outcome of the last pregnancy being a live child. Increasing gestation was independently associated with a decreased risk of both all Caesareans and elective Caesarean (OR 0.86, 95% CI 0.80–0.93 and OR 0.52, 95% CI 0.46–0.58 respectively), whereas diabetes mellitus was associated with increased risk. These variables were not associated with emergency section. However, epidural use was associated with an increased risk of emergency Caesarean (OR 6.49, 95% CI 4.78–8.82) while being in a preferred labour position decreased the risk (OR 0.59, 95% CI 0.49–0.73).

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**Conclusions** A careful exploration of risk factors may allow us to identify reasons for the increasing rates of Caesarean section and the marked variation between institutions.

**Keywords** Emergency, elective, Caesarean section, aetiology, maternal age

There is considerable interest in determining the driving forces behind the global rise in Caesarean section rates. This attention is intensified by a widespread desire to halt and reverse this trend.<sup>1</sup> To achieve this, a detailed understanding of the factors contributing to the increase is required, which may also help to explain the variations observed across units. Many purely obstetric factors have of course affected Caesarean section rates—for example, breech presentations are now increasingly delivered by elective Caesarean section following the publication of a large multi-centred trial.<sup>2,3</sup> National guidelines have attempted to balance these effects with alternative approaches to clinical management, though, such as external cephalic version.<sup>3</sup>

As well as obstetric factors, numerous characteristics of individual women have been cited in the literature as being associated with Caesarean section. If these factors can be clarified it may indicate key areas that could be targeted to control Caesarean section rates. Conversely, it may reveal features of the maternity population that are not readily amenable to change. For example, there has been an increase in the proportion of older women giving birth<sup>4</sup> who, after accounting for other complications, are at a greater risk of Caesarean section.<sup>5</sup>

In these analyses, data collected prospectively at several points in pregnancy for a population-based cohort of singleton, liveborn, term pregnancies were used to investigate the prenatal risk factors associated with Caesarean section. The specific objectives were first to investigate the sociodemographic, medical, antenatal, and fetal factors associated with vaginal delivery (spontaneous and assisted) compared with Caesarean section (elective and emergency). The second objective was to consider the same factors in terms of their associations with women who attempted vaginal delivery compared with those who delivered by elective Caesarean section. Finally, the same factors were considered for their association with women who had spontaneous vaginal delivery compared with those who delivered by emergency Caesarean section. That is, the first analysis considered the factors in terms of the delivery women experienced with the second and third analyses investigating the factors in terms of the delivery that was planned.

## Methods

The Avon Longitudinal Study of Parents and Children (ALSPAC) is a longitudinal cohort study of over 14 000 women recruited during their antenatal period in 1990/1991 in Avon, England. Full details of the study are available elsewhere (<http://www.alspac.bris.ac.uk/>).<sup>6</sup> The ALSPAC research programme is governed by the four Local Research Ethics Committees, with ethical approval and consent for this project given by the ALSPAC ethics committee.

The present work involved three separate analyses of a total of 14 663 women with a singleton, liveborn infant, and a term pregnancy mode of delivery. For the first analysis this compared all women who had undergone a Caesarean section (elective or

emergency) with those who had had a vaginal delivery (home birth, spontaneous, assisted vaginal, or breech delivery). The second analysis compared women who had undergone an elective Caesarean section with all those who had attempted a vaginal delivery (the latter included women who had a spontaneous vaginal delivery, assisted vaginal delivery, or emergency Caesarean section). The third analysis compared women who delivered by emergency Caesarean section with those who had a spontaneous vaginal delivery. The mode of delivery was determined from computerized records of the relevant hospitals, the data having been recorded by the attendant midwife. The very large number of variables from the ALSPAC questionnaires was reduced in advance by selecting those highlighted in the literature and/or on the grounds of biological plausibility in terms of their likely relationships with the three Caesarean section (outcome) variables.

All factors included were those identifiable prenatally. Two factors (birthweight and head circumference) that were recorded after birth were regarded as proxies for immediate pre-birth measurements. Several 'categories' of the variables were created in which similar risk factors were grouped together. These nine categories were: sociodemographic; past medical history; obstetric history; subfertility; pregnancy activity/work since 18 weeks' gestation; antenatal history; diet; infant size and infant characteristics, and a tenth category of labour, used only in the emergency Caesarean section analysis. In addition to basic descriptive statistics, the relationships between each variable and the Caesarean section 'outcome' variables were first investigated using univariable logistic regression to obtain odds ratios (ORs), 95% confidence intervals (CIs), and two-sided *P*-values. Variables statistically significant at the 5% level in univariable analysis were retained for further analysis using multivariable logistic regression modelling. This was performed first within each of the above ten categories and then across categories<sup>7</sup> resulting in a final model associated with the outcome measure for each category. Missing data were managed by exclusion in all of the analyses. That is, we performed a complete case analysis. At each stage in this modelling procedure, full attention was paid to the effects of adjusting for other variables on the ORs and CIs as well as on the *P*-values. Moreover, the relationships for continuous variables such as birthweight were assessed for non-linearity by including quadratic as well as linear terms. Finally, differential effects of the variables in the final model according to parity were investigated by introducing appropriate interaction terms. For this purpose parity was dichotomized to primiparous and multiparous, which itself had no effects on the main effect model results. All analyses were conducted in Stata.<sup>8</sup>

## Results

A total of 12 944 women fulfilled the inclusion criteria. Of these 11 791 women (91.1%) had vaginal delivery and 1153 (8.9%)

had Caesarean section. Of those who had Caesarean section 685 underwent emergency operations and 468 had elective procedures. A total of 3270 variables were obtained from the ALSPAC questionnaires, of which 78 were selected a priori for the analyses of all Caesareans and elective Caesarean section and 87 for the analysis of emergency Caesarean section.

### Caesarean section (elective and emergency) compared with vaginal delivery (spontaneous and assisted)

Details of the univariable analyses performed are available online (Supplementary Table A). Of the 78 variables used, 38 (49%) showed some evidence ( $P < 0.05$ ) of an association with the mode of delivery (Table 1), and as described these were retained for multivariable analyses. The final model involved 8006 women and comprised nine variables. (Table 2).

The ORs in Table 2 represent the odds of Caesarean section compared with the odds of vaginal delivery after full adjustment for all other factors in the model. There was very strong evidence for eight of the risk factors, the exception being neonatal head circumference. Exclusion of neonatal head circumference from the final model increased the sample size by over 2000 women but resulted in virtually no change in the ORs or  $P$ -values. The associations of greatest magnitude (ORs around 30) were those for a previous Caesarean section and for non-cephalic presentation (for example, breech compared with cephalic presentation). The relationship between birthweight and the outcome was non-linear (J-shaped), with the two ORs in Table 2 indicating an increase in the odds of Caesarean section at the extremes of birthweight, especially at the upper end. Gestational or pre-existing diabetes mellitus increased the odds (OR 4.5) of Caesarean delivery, as did increasing maternal age by about 7% per year of age. Increased gestational age and parity, on the other hand, both decreased the odds of a Caesarean section (about 14% per completed week and 37% per unit increase in parity). Recent obstetric history was also found to be influential: primigravid women and women whose previous pregnancy ended in miscarriage, termination, or stillbirth had odds of Caesarean section increased between 2- and 4-fold compared with parous women who had a living child (Table 2). Adding interactions with the (dichotomous) parity variable indicated strong evidence ( $P < 0.002$  in each case) that the patterns according to maternal age and head circumference were only apparent among the primiparous women. In addition, the positive relationship with gestational age pertained only to the primiparous women. Among the multiparous women there was decrease in the risk of Caesarean section as gestation increased, and similarly the J-shaped relationship with birthweight was diminished amongst the parous women.

### Elective Caesarean section compared with planned vaginal delivery

Of the 78 variables three variables were not included in this analysis given that no events occurred in the comparison group. Again detailed descriptive and univariable analysis are available online (Supplementary Table B), with the 26 (35%) factors demonstrating initial evidence of an association with elective Caesarean section shown in Table 3. Following extensive multivariable analyses as described, the final model comprises

five variables for a total of 10 547 women as shown in Table 4, where the ORs represent the odds of elective Caesarean section compared with the odds of attempting vaginal delivery. In this model there is strong evidence of an association with the outcome for four variables, with weaker evidence for diabetes mellitus status. There were very large ORs for previous Caesarean section and non-cephalic fetal presentation. Diabetes mellitus in pregnancy increased the odds of an elective Caesarean section approximately 4-fold, as did increasing maternal age by about 4% per year (Table 4). Increased gestational age was associated with decreased odds of elective Caesarean section—specifically, by about 48% per completed week. Investigations of interactions with parity for the variables in the final model (apart from previous Caesarean section) again indicated strong evidence ( $P < 0.0001$  in all cases) of a concentration of the maternal age gradient amongst primiparous women. Moreover, in this case there was an exaggeration of the other relationships in Table 4 amongst the primiparous women.

### Emergency Caesarean section compared with spontaneous vaginal delivery

There were 87 variables in this analysis. The detailed descriptive and univariable analysis are available online (Supplementary Table C). There were 40 (46%) variables that had initial evidence of an association with emergency Caesarean section (Table 5). Multivariable analysis was performed as previously. This gave a final model comprising 6454 women and nine variables. This is shown in Table 6, where the ORs represent the odds of emergency Caesarean section compared with spontaneous vaginal delivery. All of the variables showed very strong evidence of an association. There were large ORs for previous Caesarean section, non-cephalic fetal presentation and epidural use in labour. The extremes of neonatal birthweight were associated with emergency Caesarean section (J-shaped relationship as before) as was increasing neonatal head circumference. Recent obstetric history was found to be important, with women whose previous pregnancy ended in miscarriage, termination, or stillbirth having an >2-fold increase in the odds of emergency Caesarean section. Maternal age was once again found to be an independent risk factor (11% per year increase). Two factors were associated with decreased odds of emergency Caesarean section; increasing parity and being in a preferred labour position were associated with an approximately 50% decrease in the odds of emergency section. There was no strong evidence of interactions with parity in this model.

## Discussion

### Principal findings

The first analysis investigated the prenatal factors independently associated with emergency and elective Caesarean section. The highest ORs of Caesarean section in this analysis were for previous Caesarean section and non-cephalic fetal presentation. Increasing maternal age, neonatal head circumference, and (broadly speaking) birthweight were also associated with increased odds of Caesarean section, as was diabetes mellitus and either no previous pregnancy or a poor outcome of the last pregnancy. Increasing gestational age and

**Table 1** Variables with evidence of an association ( $P < 0.05$ ) from univariable analysis comparing Caesarean section with vaginal delivery

| Aetiological category    | Variable                           | <i>n</i> = 12 944 | Vaginal delivery<br><i>n</i> = 11 791 (91%) | Caesarean section<br><i>n</i> = 1153 (9%) | OR <sup>b</sup> | 95% CI    |
|--------------------------|------------------------------------|-------------------|---|---|-----------------|-----------|
| <b>Sociodemographic</b>  | Home ownership status              | 12 078            |   |   |                 |           |
|                          | Own/mortgage                       |                   | 8047 (90.7)                                 | 830 (9.4)                                 | 1.00            | –         |
|                          | Private/rental                     |                   | 805 (92.0)                                  | 70 (8.0)                                  | 0.84            | 0.65–1.09 |
|                          | Council/housing association        |                   | 1764 (92.7)                                 | 140 (7.4)                                 | 0.77            | 0.64–0.93 |
|                          | Other                              |                   | 378 (89.6)                                  | 44 (10.4)                                 | 1.13            | 0.82–1.55 |
|                          | Maternal age at delivery (years)   | 12 944            | Mean 27.9, SD 5.0                           | Mean 29.1, SD 5.0                         | 1.05            | 1.04–1.06 |
|                          | Marital status                     | 12 141            |   |   |                 |           |
|                          | Never                              |                   | 2131 (92.4)                                 | 176 (7.6)                                 | 1.00            | –         |
|                          | 1st marriage                       |                   | 7581 (90.8)                                 | 764 (9.2)                                 | 1.22            | 1.03–1.45 |
|                          | 2nd/3rd marriage                   |                   | 691 (89.4)                                  | 82 (10.6)                                 | 1.44            | 1.09–1.89 |
|                          | Widowed/divorced/separated         |                   | 649 (90.6)                                  | 67 (9.4)                                  | 1.25            | 0.93–1.68 |
|                          | Ethnic group                       | 11 478            |   |   |                 |           |
|                          | White                              |                   | 10 208 (91.2)                               | 984 (8.8)                                 | 1.00            | –         |
|                          | Black                              |                   | 102 (88.7)                                  | 13 (11.3)                                 | 1.32            | 0.74–2.36 |
|                          | Asian                              |                   | 61 (81.3)                                   | 14 (18.7)                                 | 2.38            | 1.33–4.27 |
|                          | Other                              |                   | 84 (87.5)                                   | 12 (12.5)                                 | 1.48            | 0.81–2.72 |
|                          | Maternal social class <sup>a</sup> | 8925              |   |   |                 |           |
|                          | Professional                       |                   | 352 (90.3)                                  | 38 (9.7)                                  | 1.00            | –         |
|                          | Managerial/technical               |                   | 2419 (89.6)                                 | 281 (10.4)                                | 1.08            | 0.75–1.54 |
|                          | Skilled non manual                 |                   | 3631 (90.9)                                 | 364 (9.1)                                 | 0.93            | 0.65–1.32 |
|                          | Skilled manual                     |                   | 680 (94.2)                                  | 42 (5.8)                                  | 0.57            | 0.36–0.90 |
|                          | Partly skilled                     |                   | 824 (91.0)                                  | 82 (9.1)                                  | 0.92            | 0.62–1.38 |
|                          | Unskilled                          |                   | 190 (89.6)                                  | 22 (10.4)                                 | 1.07            | 0.62–1.87 |
| <b>Medical history</b>   | Cigarettes per day/10              | 10 572            | Mean 0.2, SD 0.5                            | Mean 0.2, SD 0.5                          | 0.85            | 0.74–0.97 |
|                          | Had appendicectomy                 | 11 399            |   |   |                 |           |
|                          | No                                 |                   | 9622 (91.1)                                 | 943 (8.9)                                 | 1.00            | –         |
|                          | Yes                                |                   | 737 (88.4)                                  | 97 (11.6)                                 | 1.34            | 1.08–1.68 |
|                          | Had convulsions and fever          | 11 578            |   |   |                 |           |
|                          | No                                 |                   | 10 327 (91.0)                               | 1019 (9.0)                                | 1.00            | –         |
|                          | Yes                                |                   | 200 (86.2)                                  | 32 (13.8)                                 | 1.62            | 1.11–2.37 |
|                          | Had haemorrhoids/piles             | 11 578            |   |   |                 |           |
|                          | No                                 |                   | 7077 (90.4)                                 | 751 (9.6)                                 | 1.00            | –         |
|                          | Yes                                |                   | 3450 (92.0)                                 | 300 (8.0)                                 | 0.82            | 0.71–0.94 |
| <b>Obstetric history</b> | Had pelvic inflammatory disease    | 11 578            |   |   |                 |           |
|                          | No                                 |                   | 10 284 (91.0)                               | 1016 (9.0)                                | 1.00            | –         |
|                          | Yes                                |                   | 243 (87.4)                                  | 35 (12.6)                                 | 1.46            | 1.02–2.09 |
|                          | Number of miscarriages             | 12 038            | Mean 0.3, SD 0.7                            | Mean 0.4, SD 0.8                          | 1.17            | 1.08–1.26 |
|                          | Previous stillbirth                | 12 014            |   |   |                 |           |
|                          | No                                 |                   | 10 856 (91.2)                               | 1054 (8.9)                                | 1.00            | –         |
|                          | Yes                                |                   | 86 (82.7)                                   | 18 (17.3)                                 | 2.16            | 1.29–3.60 |
|                          | Child born alive but died later    | 12 021            |   |   |                 |           |
|                          | No                                 |                   | 10 826 (91.2)                               | 1041 (8.8)                                | 1.00            | –         |
|                          | Yes                                |                   | 125 (81.2)                                  | 29 (18.8)                                 | 2.41            | 1.60–3.63 |
|                          | Previous Caesarean section         | 11 666            |   |   |                 |           |
|                          | No                                 |                   | 10 240 (93.4)                               | 719 (6.6)                                 | 1.00            | –         |
|                          | Yes                                |                   | 394 (55.7)                                  | 313 (44.3)                                | 11.3            | 9.58–13.4 |

Table 1 continued

| Aetiological category | Variable                             | n = 12 944 | Vaginal delivery<br>n = 11 791 (91%) | Caesarean section<br>n = 1153 (9%) | OR <sup>b</sup> | 95% CI    |
|-----------------------|--------------------------------------|------------|--------------------------------------|------------------------------------|-----------------|-----------|
| Subfertility          | Outcome of last pregnancy            | 11 946     |                                      |                                    |                 |           |
|                       | Child alive                          |            | 5211 (92.9)                          | 399 (7.1)                          | 1.00            | –         |
|                       | No previous pregnancy                |            | 3597 (89.7)                          | 414 (10.3)                         | 1.50            | 1.30–1.74 |
|                       | Miscarriage/termination              |            | 2015 (90.0)                          | 225 (10.0)                         | 1.46            | 1.23–1.73 |
|                       | Stillbirth/child died                |            | 62 (72.9)                            | 23 (27.1)                          | 4.84            | 2.97–7.90 |
|                       | Parity                               | 11 996     | Mean 0.9, SD 1.0                     | Mean 0.7, SD 0.9                   | 0.85            | 0.79–0.91 |
|                       | Seen doctor for possible infertility | 11 474     |                                      |                                    |                 |           |
|                       | No                                   |            | 9235 (91.4)                          | 875 (8.7)                          | 1.00            | –         |
|                       | Yes                                  |            | 1198 (87.8)                          | 166 (12.2)                         | 1.46            | 1.23–1.74 |
|                       | Used help/treatments to conceive     | 11 480     |                                      |                                    |                 |           |
| Activity/work         | No                                   |            | 10 183 (91.1)                        | 999 (8.9)                          | 1.00            | –         |
|                       | Yes                                  |            | 256 (85.9)                           | 42 (14.1)                          | 1.67            | 1.20–2.33 |
|                       | Mostly sitting                       | 11 808     |                                      |                                    |                 |           |
|                       | No                                   |            | 6089 (91.8)                          | 546 (8.2)                          | 1.00            | –         |
|                       | Yes                                  |            | 4654 (90.0)                          | 519 (10.0)                         | 1.24            | 1.10–1.41 |
|                       | Bending a lot                        | 11 817     |                                      |                                    |                 |           |
|                       | No                                   |            | 6691 (90.2)                          | 724 (9.8)                          | 1.00            | –         |
|                       | Yes                                  |            | 4062 (92.3)                          | 340 (7.7)                          | 0.77            | 0.68–0.89 |
|                       | Standing a lot                       | 11 819     |                                      |                                    |                 |           |
|                       | No                                   |            | 7167 (90.3)                          | 766 (9.7)                          | 1.00            | –         |
| Antenatal history     | Yes                                  |            | 3586 (92.3)                          | 300 (7.7)                          | 0.78            | 0.68–0.90 |
|                       | Demanding tasks                      | 11 812     |                                      |                                    |                 |           |
|                       | No                                   |            | 6164 (91.6)                          | 565 (8.4)                          | 1.00            | –         |
|                       | Yes                                  |            | 4582 (90.1)                          | 501 (9.9)                          | 1.19            | 1.05–1.35 |
|                       | Physical exertion                    | 11 819     |                                      |                                    |                 |           |
|                       | No                                   |            | 7202 (90.5)                          | 753 (9.5)                          | 1.00            | –         |
|                       | Yes                                  |            | 3551 (91.9)                          | 313 (8.1)                          | 0.84            | 0.73–0.97 |
|                       | Worked during pregnancy              | 10 697     |                                      |                                    |                 |           |
|                       | No                                   |            | 3063 (92.8)                          | 238 (7.2)                          | 1.00            | –         |
|                       | Yes                                  |            | 6697 (90.4)                          | 709 (9.6)                          | 1.36            | 1.17–1.58 |
| Antenatal history     | Work per week (hours/50)             | 11 208     | Mean 0.2, SD 0.3                     | Mean 0.2, SD 0.3                   | 1.27            | 1.02–1.57 |
|                       | Vaginal bleeding in 1st 3 months     | 11 238     |                                      |                                    |                 |           |
|                       | No                                   |            | 8750 (91.3)                          | 838 (8.7)                          | 1.00            | –         |
|                       | Yes                                  |            | 1474 (89.3)                          | 176 (10.7)                         | 1.25            | 1.05–1.48 |
|                       | Test result suggesting abnormality   | 10 916     |                                      |                                    |                 |           |
|                       | No                                   |            | 9586 (91.2)                          | 930 (8.8)                          | 1.00            | –         |
|                       | Yes                                  |            | 348 (87.0)                           | 52 (13.0)                          | 1.54            | 1.14–2.08 |
|                       | Diabetes mellitus                    | 11 515     |                                      |                                    |                 |           |
|                       | None                                 |            | 10 403 (91.1)                        | 1020 (8.9)                         | 1.00            | –         |
|                       | Gestational                          |            | 47 (79.7)                            | 12 (20.3)                          | 2.60            | 1.38–4.92 |
| Antenatal history     | Pre-pregnancy                        |            | 18 (54.6)                            | 15 (45.5)                          | 8.50            | 4.27–16.9 |
|                       | Antenatal class attendance           | 11 016     |                                      |                                    |                 |           |
|                       | Yes                                  |            | 5987 (90.5)                          | 627 (9.5)                          | 1.00            | –         |
|                       | No                                   |            | 4058 (92.2)                          | 344 (7.8)                          | 0.81            | 0.71–0.93 |
|                       | Admitted to hospital                 | 11 259     |                                      |                                    |                 |           |
|                       | No                                   |            | 9620 (91.3)                          | 923 (8.8)                          | 1.00            | –         |
|                       | Yes                                  |            | 633 (88.4)                           | 83 (11.6)                          | 1.37            | 1.08–1.73 |

Table 1 continued

| Aetiological category | Variable                            | <i>n</i> = 12 944 | Vaginal delivery<br><i>n</i> = 11 791 (91%) | Caesarean section<br><i>n</i> = 1153 (9%) | OR <sup>b</sup> | 95% CI       |
|-----------------------|-------------------------------------|-------------------|---|---|-----------------|--------------|
| <b>Diet</b>           | Been on a diet this pregnancy       | 11 268            |   |   |                 |              |
|                       | No                                  |                   | 9997 (91.2)                                 | 960 (8.8)                                 | 1.00            | —            |
|                       | Yes                                 |                   | 266 (85.5)                                  | 45 (14.5)                                 | 1.76            | 1.28–2.43    |
|                       | Vegetarian                          | 11 359            |   |   |                 |              |
|                       | No                                  |                   | 9769 (90.9)                                 | 979 (9.1)                                 | 1.00            | —            |
|                       | Yes                                 |                   | 571 (93.5)                                  | 40 (6.6)                                  | 0.70            | 0.50–0.97    |
| <b>Infant size</b>    | Birthweight (kg) <sup>c</sup>       | 12 788            | Mean 3.5, SD 0.5                            | Mean 3.4, SD 0.6                          | 0.0058          | 0.0023–0.014 |
|                       |                                     |                   |   |   | 2.03            | 1.79–2.31    |
|                       | Head circumference (cm)             | 9948              | Mean 34.9, SD 1.4                           | Mean 35.0, SD 1.6                         | 1.08            | 1.03–1.13    |
|                       | Crownheel length (cm)               | 9834              | Mean 50.9, SD 2.3                           | Mean 50.5, SD 2.5                         | 0.94            | 0.92–0.97    |
| <b>Infant</b>         | Gestational age at delivery (weeks) | 12 944            | Mean 39.8, SD 1.3                           | Mean 39.3, SD 1.5                         | 0.75            | 0.71–0.78    |
|                       | Survived to 28 days                 | 12 944            |   |   |                 |              |
|                       | Yes                                 |                   | 11 779 (91.1)                               | 1148 (8.9)                                | 1.00            | —            |
|                       | No                                  |                   | 12 (70.6)                                   | 5 (29.4)                                  | 4.28            | 1.50–12.2    |
|                       | Fetal presentation                  | 12 672            |   |   |                 |              |
|                       | Cephalic                            |                   | 11 632 (94.9)                               | 629 (5.1)                                 | 1.00            | —            |
|                       | Breech                              |                   | 138 (37.3)                                  | 232 (62.7)                                | 31.1            | 24.8–39.0    |
|                       | Other                               |                   | 11 (26.8)                                   | 30 (73.2)                                 | 50.4            | 25.2–101.0   |

<sup>a</sup> Based on the Registrar General's Social Scale.<sup>b</sup> Unadjusted odds of Caesarean section (elective and emergency) compared with vaginal (assisted and spontaneous) delivery.<sup>c</sup> ORs based on linear and quadratic terms.

Table 2 Final model to show the prenatal factors associated with Caesarean section compared with vaginal delivery

| Aetiological factors                       | <i>n</i> = 8006 | Adjusted OR <sup>a</sup> | 95% CI     | <i>P</i> value <sup>b</sup> |
|--|-----------------|--------------------------|------------|-----------------------------|
| <b>Maternal age at delivery (years)</b>    |                 | 1.07                     | 1.04–1.09  | <0.0001                     |
| <b>Previous Caesarean section</b>          |                 |                          |            |                             |
| No   | 7519            | 1.00                     | —          | <0.0001                     |
| Yes  | 487             | 27.8                     | 20.9–37.0  |                             |
| <b>Outcome of last pregnancy</b>           |                 |                          |            | <0.0001                     |
| Child alive                                | 3777            | 1.00                     | —          |                             |
| No previous pregnancy                      | 2919            | 2.17                     | 1.57–3.02  |                             |
| Miscarriage/termination                    | 1243            | 1.78                     | 1.31–2.42  |                             |
| Stillbirth/child died                      | 67              | 4.01                     | 1.88–8.53  |                             |
| <b>Parity</b>                              |                 | 0.63                     | 0.53–0.75  | 0.0007                      |
| <b>Diabetes mellitus</b>                   |                 |                          |            | 0.0002                      |
| None                                       | 7941            | 1.00                     | —          |                             |
| Pre-pregnancy/gestational                  | 65              | 4.51                     | 2.18–9.31  |                             |
| <b>Birthweight (kg)</b>                    |                 | 0.01                     | 0.00–0.03  |                             |
| <b>Birthweight (kg<sup>2</sup>)</b>        |                 | 2.12                     | 1.70–2.64  | <0.0001 <sup>c</sup>        |
| <b>Neonatal head circumference (cm)</b>    |                 | 1.09                     | 1.01–1.17  | 0.034                       |
| <b>Gestational age at delivery (weeks)</b> |                 | 0.86                     | 0.80–0.93  | 0.0002                      |
| <b>Fetal presentation</b>                  |                 |                          |            | <0.0001                     |
| Cephalic                                   | 7725            | 1.00                     | —          |                             |
| Breech                                     | 249             | 36.6                     | 26.8–50.0  |                             |
| Other                                      | 32              | 49.3                     | 20.6–118.0 |                             |

<sup>a</sup> Odds of elective and emergency Caesarean section compared with assisted and spontaneous vaginal delivery.<sup>b</sup> Adjusted for all other variables within the group.<sup>c</sup> Based on 2 degrees of freedom—non-linear (J-shaped) relationship for birthweight.



**Table 3** Variables with evidence of an association ( $P < 0.05$ ) from univariable analysis comparing elective Caesarean section (CS) with attempted vaginal delivery (VD)

| Aetiological category    | Variable                             | <i>n</i> = 12 944 | Attempt VD<br><i>n</i> = 12 476 (96%) | Elective CS<br><i>n</i> = 468 (4%) | OR <sup>b</sup> | 95% CI    |
|--------------------------|--------------------------------------|-------------------|---------------------------------------|------------------------------------|-----------------|-----------|
| <b>Sociodemographic</b>  | Home ownership status                | 12 078            |                                       |                                    |                 |           |
|                          | Own/mortgage                         |                   | 8522 (96.0)                           | 355 (4.0)                          | 1.00            | –         |
|                          | Private/rental                       |                   | 862 (98.5)                            | 13 (1.5)                           | 0.36            | 0.21–0.63 |
|                          | Council/Housing association          |                   | 1846 (97.0)                           | 58 (3.1)                           | 0.75            | 0.57–1.00 |
|                          | Other                                |                   | 412 (97.6)                            | 10 (2.4)                           | 0.58            | 0.31–1.10 |
|                          | Maternal age at delivery (years)     | 12 944            | Mean 27.9, SD 5.0                     | Mean 29.9, SD 4.9                  | 1.08            | 1.06–1.10 |
|                          | Marital status                       | 12 141            |                                       |                                    |                 |           |
|                          | Never                                |                   | 2267 (98.3)                           | 40 (1.7)                           | 1.00            | –         |
|                          | 1st marriage                         |                   | 8016 (96.1)                           | 329 (3.9)                          | 2.33            | 1.67–3.24 |
|                          | 2nd/3rd marriage                     |                   | 737 (95.3)                            | 36 (4.7)                           | 2.77            | 1.75–4.38 |
|                          | Widowed/divorced/separated           |                   | 681 (95.1)                            | 35 (4.9)                           | 2.91            | 1.84–4.62 |
|                          | Maternal social class <sup>a</sup>   | 8925              |                                       |                                    |                 |           |
|                          | Professional                         |                   | 377 (96.7)                            | 13 (3.3)                           | 1.00            | –         |
|                          | Managerial/technical                 |                   | 2581 (95.6)                           | 119 (4.4)                          | 1.34            | 0.75–2.39 |
|                          | Skilled non manual                   |                   | 3850 (96.4)                           | 145 (3.6)                          | 1.09            | 0.61–1.95 |
|                          | Skilled manual                       |                   | 705 (97.7)                            | 17 (2.4)                           | 0.70            | 0.33–1.46 |
|                          | Partly skilled                       |                   | 878 (96.9)                            | 28 (3.1)                           | 0.92            | 0.47–1.81 |
|                          | Unskilled                            |                   | 199 (93.9)                            | 13 (6.1)                           | 1.89            | 0.86–4.16 |
|                          | Cigarettes per day/10                | 10 572            | Mean 0.2, SD 0.5                      | Mean 0.1, SD 0.4                   | 0.67            | 0.52–0.86 |
| <b>Medical history</b>   | Had dilatation and curettage         | 11 352            |                                       |                                    |                 |           |
|                          | No                                   |                   | 8597 (96.6)                           | 301 (3.4)                          | 1.00            | –         |
|                          | Yes                                  |                   | 2341 (95.4)                           | 113 (4.6)                          | 1.38            | 1.11–1.72 |
| <b>Obstetric history</b> | Number of miscarriages               | 12 038            | Mean 0.3, SD 0.7                      | Mean 0.5, SD 0.9                   | 1.34            | 1.21–1.48 |
|                          | Previous stillbirth                  | 12 014            |                                       |                                    |                 |           |
|                          | No                                   |                   | 11 488 (96.5)                         | 422 (3.5)                          | 1.00            | –         |
|                          | Yes                                  |                   | 91 (87.5)                             | 13 (12.5)                          | 3.89            | 2.16–7.01 |
|                          | Child born alive but died later      | 12 021            |                                       |                                    |                 |           |
|                          | No                                   |                   | 11 451 (96.5)                         | 416 (3.5)                          | 1.00            | –         |
|                          | Yes                                  |                   | 135 (87.7)                            | 19 (12.3)                          | 3.87            | 2.37–6.32 |
|                          | Previous Caesarean section           | 11 666            |                                       |                                    |                 |           |
|                          | No                                   |                   | 10 766 (98.2)                         | 193 (1.8)                          | 1.00            | –         |
|                          | Yes                                  |                   | 473 (66.9)                            | 234 (33.1)                         | 27.6            | 22.3–34.1 |
|                          | Outcome of last pregnancy            | 11 946            |                                       |                                    |                 |           |
|                          | Child alive                          |                   | 5364 (95.6)                           | 246 (4.4)                          | 1.00            | –         |
|                          | No previous pregnancy                |                   | 3928 (97.9)                           | 83 (2.1)                           | 0.46            | 0.36–0.59 |
|                          | Miscarriage/termination              |                   | 2155 (96.2)                           | 85 (3.8)                           | 0.86            | 0.67–1.11 |
|                          | Stillbirth/child died                |                   | 69 (81.2)                             | 16 (18.8)                          | 5.06            | 2.89–8.84 |
| <b>Subfertility</b>      | Inter-pregnancy interval (months)    | 6893              | Mean 4.4, SD 1.6                      | Mean 4.6, SD 1.6                   | 1.08            | 1.01–1.17 |
|                          | Parity                               | 11 996            | Mean 0.8, SD 1.0                      | Mean 1.1, SD 1.0                   | 1.27            | 1.18–1.38 |
|                          | Seen doctor for possible infertility | 11 474            |                                       |                                    |                 |           |
|                          | No                                   |                   | 9750 (96.4)                           | 360 (3.6)                          | 1.00            | –         |
|                          | Yes                                  |                   | 1300 (95.3)                           | 64 (4.7)                           | 1.33            | 1.02–1.76 |
| <b>Antenatal history</b> | Vaginal bleeding in 1st 3 months     | 11 238            |                                       |                                    |                 |           |
|                          | No                                   |                   | 9250 (96.5)                           | 338 (3.5)                          | 1.00            | –         |
|                          | Yes                                  |                   | 1570 (95.2)                           | 80 (4.9)                           | 1.39            | 1.09–1.79 |

Table 3 continued

| Aetiological category | Variable                              | n = 12 944 | Attempt VD<br>n = 12 476 (96%) | Elective CS<br>n = 468 (4%) | OR <sup>b</sup> | 95% CI     |
|-----------------------|---------------------------------------|------------|--------------------------------|-----------------------------|-----------------|------------|
|                       | Hypertension                          | 11 346     |                                |                             |                 |            |
|                       | Never                                 |            | 9374 (96.5)                    | 341 (3.5)                   | 1.00            | –          |
|                       | Pre-pregnancy                         |            | 420 (95.7)                     | 19 (4.3)                    | 1.24            | 0.78–1.99  |
|                       | Gestational                           |            | 1130 (94.8)                    | 62 (5.2)                    | 1.51            | 1.14–1.99  |
|                       | Diabetes mellitus                     | 11 515     |                                |                             |                 |            |
|                       | Never                                 |            | 11 012 (96.4)                  | 411 (3.6)                   | 1.00            | –          |
|                       | Pre-pregnancy/gestational             |            | 77 (83.7)                      | 15 (16.3)                   | 5.22            | 2.98–9.15  |
|                       | Antenatal class attendance            | 11 016     |                                |                             |                 |            |
|                       | Yes                                   |            | 6430 (97.2)                    | 184 (2.8)                   | 1.00            | –          |
|                       | No                                    |            | 4191 (95.2)                    | 211 (4.8)                   | 1.76            | 1.44–2.15  |
|                       | Admitted to hospital in last 3 months | 11 259     |                                |                             |                 |            |
|                       | No                                    |            | 10 171 (96.5)                  | 372 (3.5)                   | 1.00            | –          |
|                       | Yes                                   |            | 677 (94.6)                     | 39 (5.5)                    | 1.58            | 1.12–2.21  |
|                       | Been on a diet this pregnancy         | 11 268     |                                |                             |                 |            |
|                       | No                                    |            | 10 565 (96.4)                  | 392 (3.6)                   | 1.00            | –          |
|                       | Yes                                   |            | 292 (93.9)                     | 19 (6.1)                    | 1.75            | 1.09–2.82  |
| Infant size           | Vegetarian                            | 11 359     |                                |                             |                 |            |
|                       | No                                    |            | 10 347 (96.3)                  | 401 (3.7)                   | 1.00            | –          |
|                       | Yes                                   |            | 599 (98.0)                     | 12 (2.0)                    | 0.52            | 0.29–0.92  |
| Infant                | Birthweight (kg) <sup>c</sup>         | 12 788     | Mean 3.5, SD 0.5               | Mean 3.3, SD 0.5            | 0.13            | 0.028–0.56 |
|                       |                                       |            |                                |                             | 1.25            | 1.00–1.56  |
|                       | Crownheel length (cm)                 | 9834       | Mean 50.9, SD 2.3              | Mean 50.0, SD 2.4           | 0.86            | 0.83–0.90  |
|                       | Gestational age at (weeks)            | 12 944     | Mean 39.8, SD 1.3              | Mean 38.5, SD 1.2           | 0.45            | 0.42–0.49  |
|                       | Season of delivery                    | 12 944     |                                |                             |                 |            |
|                       | Winter                                |            | 2360 (96.8)                    | 79 (3.2)                    | 1.00            | –          |
|                       | Spring                                |            | 2746 (95.7)                    | 124 (4.3)                   | 1.35            | 1.01–1.80  |
|                       | Summer                                |            | 3717 (96.0)                    | 155 (4.0)                   | 1.25            | 0.95–1.64  |
|                       | Autumn                                |            | 3653 (97.1)                    | 110 (2.9)                   | 0.90            | 0.67–1.21  |
|                       | Fetal presentation                    | 12 672     |                                |                             |                 |            |
|                       | Cephalic                              |            | 12 048 (98.3)                  | 213 (1.7)                   | 1.00            | –          |
|                       | Breech                                |            | 236 (63.8)                     | 134 (36.2)                  | 32.1            | 25.0–41.3  |
|                       | Other                                 |            | 30 (73.2)                      | 11 (26.8)                   | 20.7            | 10.3–41.9  |

<sup>a</sup> Based on the Registrar General's Social Scale.<sup>b</sup> Unadjusted odds of elective Caesarean section compared with women who attempt vaginal delivery.<sup>c</sup> OR based on linear and quadratic terms.

parity, on the other hand, were associated with a decreased risk of Caesarean section.

The second analysis evaluated the independent associations between prenatal factors and elective Caesarean section. Non-cephalic presentation and previous Caesarean section again had high ORs of Caesarean section. Diabetes mellitus, increasing maternal age, and decreasing gestational age were also independently associated with elevated odds of elective Caesarean delivery.

The third analysis considered the factors independently associated with emergency Caesarean section. Previous

Caesarean section, non-cephalic fetal presentation, and epidural use in labour had highly elevated ORs of emergency Caesarean section. Increasing neonatal birthweight and head circumference were also associated with increased odds of emergency Caesarean as was increasing maternal age and a poor recent obstetric history. Parity and being always in a preferred labour position were associated with decreased odds of emergency section.

### Strengths and limitations

In these analyses, prospectively collected data were used to evaluate the risk factors for Caesarean section, which is



**Table 4** Final model to show the prenatal factors associated with elective Caesarean section compared with attempted vaginal delivery

| Aetiological factors                       | <i>n</i> = 10 547 | OR <sup>a</sup> | 95% CI     | <i>P</i> value <sup>b</sup> |
|--|-------------------|-----------------|------------|-----------------------------|
| <b>Maternal age at delivery (years)</b>    |                   | 1.04            | 1.01–1.08  | 0.0067                      |
| <b>Previous Caesarean section</b>          |                   |                 |            | <0.0001                     |
| No   | 9550              | 1.00            | –          |                             |
| Yes  | 597               | 54.5            | 38.4–77.5  |                             |
| <b>Diabetes mellitus</b>                   |                   |                 |            | 0.011                       |
| Never                                      | 10 468            | 1.00            | –          |                             |
| Pre-pregnancy/<br>gestational              | 79                | 4.05            | 1.46–11.2  |                             |
| <b>Gestational age at delivery (weeks)</b> |                   | 0.52            | 0.46–0.58  | <0.0001                     |
| <b>Fetal presentation</b>                  |                   |                 |            | <0.0001                     |
| Cephalic                                   | 10 205            | 1.00            | –          |                             |
| Breech                                     | 308               | 86.4            | 58.5–128.0 |                             |
| Other                                      | 34                | 21.5            | 6.56–70.1  |                             |

<sup>a</sup> Odds of elective Caesarean section compared with women who attempt vaginal delivery.

<sup>b</sup> Adjusted for all other variables within the group.

increasing dramatically in many parts of the world, including the UK. Using data from an area within England is valuable if an understanding is to be developed of the increasing operative delivery rates, specifically within this country but potentially in other contexts as well. The data for these analyses were collected in the early 1990s. It is possible that since that time clinical practice may have altered or new factors may have emerged that influence mode of delivery. However, the variables identified in these models are equally pertinent to current clinical practice. The rise in Caesarean section rates may therefore be driven by either changing prevalences of these risk factors, a lowering in the threshold to operate, or a combination of both of these factors.

The ALSPAC cohort has the advantage of high recruitment from a population cohort with very little attrition in the early stages of the study. Nevertheless, this analysis is based on observational data and is therefore potentially subject to bias. The accuracy of the collected data is difficult to assess for all factors. In these analyses the outcome measure is likely to be accurate since the midwife involved in the delivery was responsible for recording this information data immediately after the birth. This study has the further advantage of providing a large sample, which means that there is adequate power to detect small but clinically important associations. Conversely there is danger of detecting spurious results when performing multiple tests on a large number of variables on so large a dataset. In this study there was a focused selection of risk factors (approximately 3%) from those available totally. In addition, the threshold for statistical significance at the initial (univariable) stages of the analyses was not as liberal as is commonly applied in similar situations. Most importantly, at all stages of the analyses including the final model, the main emphasis was on the estimates and their CIs, and in the event most of the factors in the final models demonstrated very strong

statistical evidence of associations with the relevant outcome. Lastly, while confounding has been minimized as a result of the full adjustment of all aetiological factors at every stage of analysis, there may nevertheless be residual confounding.

### Comparison with other studies

This research adds to previous work on trends and aetiological factors associated with Caesarean section and on the whole has similar findings.<sup>4,9</sup> In all three analyses, increasing maternal age was found to be independently associated with increased odds of Caesarean section, which is in keeping with other studies.<sup>5,10</sup> Hence the ageing maternity population in the UK will have an impact on overall Caesarean section rates and is not necessarily subject to alteration. It may also explain the higher Caesarean rates in some units. There are several sociodemographic factors identified in the literature as being associated with Caesarean section that have not been confirmed by this research. For instance, many studies have found ethnicity,<sup>11</sup> social class,<sup>11</sup> nature of employment,<sup>12</sup> and activity during pregnancy,<sup>13</sup> to be associated with Caesarean section, none of which were observed to have independent associations with mode of delivery in these analyses. In the case of ethnicity the study area has a low proportion of ethnic minorities and this may have underpowered this part of the analyses. For the other factors, this research has minimized confounding through multivariable modelling and suggests that they are not independently associated with mode of delivery in the study population. Obstetric history has been identified as influencing mode of delivery. The high rate of Caesarean section for women who attempt vaginal delivery after previous Caesarean section is consistent with the published literature.<sup>14,15</sup> Previous stillbirth or the death of a liveborn child was strongly associated with Caesarean section. This may reflect a desire to minimize anxiety and risk for the mother in the case of elective procedures and may indicate reluctance on the part of obstetricians to allow labour to continue if any complications arise. Interestingly, women whose previous pregnancy ended in miscarriage or termination were also at a higher risk of Caesarean section. A higher rate of elective Caesarean section for obstetric indications has been observed amongst women with an IVF pregnancy.<sup>16</sup> However, no association was found in this study—although all fertility treatments, and not solely IVF, were examined together. Nulliparity was found to be associated with increased odds of Caesarean section, which is similar to other studies.<sup>17,18</sup> Infant weight was associated with elective and emergency Caesarean section compared with vaginal delivery and emergency Caesarean compared with spontaneous vaginal delivery. There were broadly increased odds of Caesarean section as the birthweight in kilograms increased, albeit with a quadratic relationship. Thus, very low-weight infants and high-weight infants were at an increased risk of Caesarean section. Other studies have also found that amongst women who attempt vaginal delivery, increased fetal birthweight is associated with higher odds of emergency Caesarean section.<sup>19</sup> Poma also found that both large and small fetuses have more Caesarean deliveries than average-weight infants.<sup>20</sup> Increasing neonatal head circumference was found to be weakly associated with all Caesarean deliveries and strongly associated with emergency Caesarean section, and this is not a common finding in other published literature. It is possible that this association was

**Table 5** Variables with evidence of an association ( $P < 0.05$ ) from univariable analysis comparing emergency Caesarean section with spontaneous vaginal delivery

| Aetiological Category          | Variable                             | <i>n</i> = 11 022 | Vaginal delivery<br><i>n</i> = 10 337 (94%) | Caesarean section<br><i>n</i> = 685 (6%) | OR <sup>b</sup> | 95% CI    |
|--------------------------------|--------------------------------------|-------------------|---|--|-----------------|-----------|
| <b>Sociodemographic</b>        | Home ownership status                | 10 270            |   |  |                 |           |
|                                | Own/mortgage                         |                   | 6944 (93.6)                                 | 475 (6.4)                                | 1.00            | –         |
|                                | Private/rental                       |                   | 696 (92.4)                                  | 57 (7.6)                                 | 1.20            | 0.90–1.59 |
|                                | Social                               |                   | 1660 (95.3)                                 | 82 (4.7)                                 | 0.72            | 0.57–0.92 |
|                                | Other                                |                   | 332 (90.5)                                  | 33 (9.6)                                 | 1.54            | 1.07–2.22 |
|                                | Maternal age at delivery (years)     | 11 022            | Mean 27.9, SD 5.0                           | Mean 28.5, SD 5.1                        | 1.03            | 1.01–1.04 |
|                                | Alcohol pre-pregnancy (units)        | 10 306            | Mean 2.7, SD 0.9                            | Mean 2.7, SD 0.9                         | 1.20            | 1.09–1.32 |
|                                | Ethnic group                         | 9768              |   |  |                 |           |
|                                | White                                |                   | 8936 (93.9)                                 | 586 (6.2)                                | 1.00            | –         |
|                                | Non white                            |                   | 220 (89.4)                                  | 26 (10.6)                                | 1.80            | 1.19–2.73 |
|                                | Maternal social class <sup>a</sup>   | 7478              |   |  |                 |           |
|                                | Professional                         |                   | 296 (92.2)                                  | 25 (7.8)                                 | 1.00            | –         |
|                                | Managerial/technical                 |                   | 2028 (92.6)                                 | 162 (7.4)                                | 0.95            | 0.61–1.47 |
|                                | Skilled non-manual                   |                   | 3126 (93.5)                                 | 219 (6.6)                                | 0.83            | 0.54–1.28 |
|                                | Skilled manual                       |                   | 594 (96.0)                                  | 25 (4.0)                                 | 0.50            | 0.28–0.88 |
| <b>Medical history</b>         | Partly skilled                       |                   | 762 (93.4)                                  | 54 (6.6)                                 | 0.84            | 0.51–1.37 |
|                                | Unskilled                            |                   | 178 (95.2)                                  | 9 (4.8)                                  | 0.60            | 0.27–1.31 |
|                                | Had varicose veins                   | 9838              |   |  |                 |           |
|                                | No                                   |                   | 8106 (93.5)                                 | 568 (6.6)                                | 1.00            | –         |
|                                | Yes                                  |                   | 1108 (95.2)                                 | 56 (4.8)                                 | 0.72            | 0.54–0.96 |
|                                | Had haemorrhoids/piles               | 9838              |   |  |                 |           |
|                                | No                                   |                   | 6090 (92.8)                                 | 471 (7.2)                                | 1.00            | –         |
|                                | Yes                                  |                   | 3124 (95.3)                                 | 153 (4.7)                                | 0.63            | 0.53–0.76 |
|                                | Had convulsions/fever                | 9838              |   |  |                 |           |
|                                | No                                   |                   | 9035 (93.8)                                 | 598 (6.2)                                | 1.00            | –         |
| <b>Obstetric history</b>       | Yes                                  |                   | 179 (87.3)                                  | 26 (12.7)                                | 2.19            | 1.44–3.34 |
|                                | Previous Caesarean section           | 9967              |   |  |                 |           |
|                                | No                                   |                   | 9045 (94.5)                                 | 526 (5.5)                                | 1.00            | –         |
|                                | Yes                                  |                   | 317 (80.1)                                  | 79 (20.0)                                | 4.29            | 3.30–5.57 |
|                                | Outcome of last pregnancy            | 10 171            |   |  |                 |           |
|                                | Child alive                          |                   | 5050 (97.1)                                 | 153 (2.9)                                | 1.00            | –         |
|                                | No previous pregnancy                |                   | 2703 (89.1)                                 | 331 (10.9)                               | 4.04            | 3.32–4.92 |
|                                | Miscarriage/termination              |                   | 1728 (92.5)                                 | 140 (7.5)                                | 2.67            | 2.11–3.38 |
|                                | Stillbirth/child died                |                   | 59 (89.4)                                   | 7 (10.6)                                 | 3.91            | 1.76–8.71 |
|                                | Inter-pregnancy interval (months)    | 6271              | Mean 4.4, SD 1.6                            | Mean 4.2, SD 1.8                         | 0.91            | 0.84–0.99 |
| <b>Subfertility</b>            | Parity                               | 10 223            | Mean 1.0, SD 1.0                            | Mean 0.4, SD 0.8                         | 0.46            | 0.41–0.52 |
|                                | Seen doctor for possible infertility | 9749              |   |  |                 |           |
|                                | No                                   |                   | 8112 (94.0)                                 | 515 (6.0)                                | 1.00            | –         |
|                                | Yes                                  |                   | 1020 (90.9)                                 | 102 (90.1)                               | 1.58            | 1.26–1.97 |
|                                | Used help/treatments to conceive     | 9753              |   |  |                 |           |
|                                | No                                   |                   | 8931 (93.8)                                 | 588 (6.2)                                | 1.00            | –         |
|                                | Yes                                  |                   | 205 (87.6)                                  | 29 (12.4)                                | 2.15            | 1.44–3.20 |
| <b>Pregnancy activity/work</b> | Mostly sitting                       | 10 041            |   |  |                 |           |
|                                | No                                   |                   | 5538 (95.0)                                 | 294 (5.0)                                | 1.00            | –         |
|                                | Yes                                  |                   | 3865 (91.8)                                 | 344 (8.2)                                | 1.68            | 1.43–1.97 |

Table 5 continued

| Aetiological Category | Variable                           | n = 11 022 | Vaginal delivery<br>n = 10 337 (94%) | Caesarean section<br>n = 685 (6%) | OR <sup>b</sup> | 95% CI       |
|-----------------------|------------------------------------|------------|--------------------------------------|-----------------------------------|-----------------|--------------|
| Antenatal history     | Bending a lot                      | 10 051     |                                      |                                   |                 |              |
|                       | No                                 |            | 5759 (92.8)                          | 448 (7.2)                         | 1.00            | –            |
|                       | Yes                                |            | 3654 (95.1)                          | 190 (4.9)                         | 0.67            | 0.56–0.80    |
|                       | Standing a lot                     | 10 053     |                                      |                                   |                 |              |
|                       | No                                 |            | 6216 (93.0)                          | 465 (7.0)                         | 1.00            | –            |
|                       | Yes                                |            | 3198 (94.8)                          | 174 (5.2)                         | 0.73            | 0.61–0.87    |
|                       | Demanding tasks                    | 10 045     |                                      |                                   |                 |              |
|                       | No                                 |            | 5611 (94.8)                          | 309 (5.2)                         | 1.00            | –            |
|                       | Yes                                |            | 3795 (92.0)                          | 330 (8.0)                         | 1.58            | 1.34–1.85    |
|                       | Physical exertion                  | 10 053     |                                      |                                   |                 |              |
|                       | No                                 |            | 6224 (93.1)                          | 462 (6.9)                         | 1.00            | –            |
|                       | Yes                                |            | 3190 (94.7)                          | 177 (5.3)                         | 0.75            | 0.63–0.89    |
|                       | Worked during pregnancy            | 9077       |                                      |                                   |                 |              |
|                       | No                                 |            | 2914 (96.5)                          | 107 (3.5)                         | 1.00            | –            |
|                       | Yes                                |            | 5597 (92.4)                          | 459 (7.6)                         | 2.23            | 1.80–2.77    |
|                       | Work per week (hours/50)           | 9529       | Mean 0.1, SD 0.3                     | Mean 0.2, SD 0.3                  | 2.01            | 1.55–2.61    |
|                       | Have rest periods nowadays         | 9561       |                                      |                                   |                 |              |
|                       | Often                              |            | 2312 (92.6)                          | 185 (7.4)                         | 1.00            | –            |
|                       | Sometimes                          |            | 5961 (94.3)                          | 361 (5.7)                         | 0.76            | 0.63–0.91    |
|                       | Never                              |            | 693 (93.4)                           | 49 (6.6)                          | 0.88            | 0.64–1.22    |
|                       | Test result suggesting abnormality | 9284       |                                      |                                   |                 |              |
|                       | Yes                                |            | 300 (90.9)                           | 30 (9.1)                          | 1.00            | –            |
|                       | No                                 |            | 8410 (93.9)                          | 544 (6.1)                         | 0.65            | 0.44–0.95    |
|                       | Hypertension                       | 9642       |                                      |                                   |                 |              |
|                       | Never                              |            | 7696 (93.5)                          | 532 (6.5)                         | 1.00            | –            |
|                       | Pre-pregnancy                      |            | 331 (92.5)                           | 27 (7.5)                          | 1.18            | 0.79–1.76    |
|                       | Gestational                        |            | 1006 (95.3)                          | 50 (4.7)                          | 0.72            | 0.53–0.97    |
|                       | Diabetes mellitus                  | 9782       |                                      |                                   |                 |              |
|                       | Never                              |            | 9103 (93.7)                          | 609 (6.3)                         | 1.00            | –            |
|                       | Yes/gestational                    |            | 58 (82.9)                            | 12 (17.1)                         | 3.09            | 1.65–5.79    |
|                       | Antenatal class attendance         | 9365       |                                      |                                   |                 |              |
|                       | Yes                                |            | 4899 (91.2)                          | 443 (8.3)                         | 1.00            | –            |
|                       | No                                 |            | 3890 (96.7)                          | 133 (3.3)                         | 0.38            | 0.31–0.46    |
| Diet                  | Been on a diet this pregnancy      | 9578       |                                      |                                   |                 |              |
|                       | No                                 |            | 8746 (93.9)                          | 568 (6.1)                         | 1.00            | –            |
|                       | Yes                                |            | 238 (90.2)                           | 26 (9.9)                          | 1.68            | 1.11–2.54    |
|                       | No                                 |            | 8550 (93.7)                          | 578 (6.3)                         | 1.00            | –            |
| Diet                  | Vegetarian                         | 9653       |                                      |                                   |                 |              |
|                       | No                                 |            | 8550 (93.7)                          | 578 (6.3)                         | 1.00            | –            |
|                       | Yes                                |            | 497 (94.7)                           | 28 (5.3)                          | 0.83            | 0.56–1.23    |
| Infant size           | Birthweight (Kg) <sup>c</sup>      | 10 884     | Mean 3.47, SD 0.5                    | Mean 3.46, SD 0.6                 | 0.0024          | 0.0008–0.007 |
|                       |                                    |            |                                      |                                   | 2.36            | 2.03–2.75    |
| Infant                | Head circumference (cm)            | 8360       | Mean 34.8, SD 1.4                    | Mean 35.2, SD 1.5                 | 1.19            | 1.12–1.25    |
|                       | Survived to 28 days                | 11 022     |                                      |                                   |                 |              |
|                       | Yes                                |            | 10 328 (93.8)                        | 680 (6.2)                         | 1.00            | –            |
|                       | No                                 |            | 9 (64.3)                             | 5 (35.7)                          | 8.44            | 2.82–25.3    |

Table 5 continued

| Aetiological Category | Variable                        | n = 11 022 | Vaginal delivery<br>n = 10 337 (94%) | Caesarean section<br>n = 685 (6%) | OR <sup>b</sup> | 95% CI     |
|-----------------------|---------------------------------|------------|--------------------------------------|-----------------------------------|-----------------|------------|
| Labour                | Survived to 1 year              | 11 022     |                                      |                                   |                 |            |
|                       | Yes                             |            | 10 316 (93.8)                        | 679 (6.2)                         | 1.00            | –          |
|                       | No                              |            | 21 (77.8)                            | 6 (22.2)                          | 4.34            | 1.75–10.8  |
|                       | Fetal presentation              | 10 860     |                                      |                                   |                 |            |
|                       | Cephalic                        |            | 10 181 (96.1)                        | 416 (3.9)                         | 1.00            | –          |
|                       | Breech                          |            | 137 (58.3)                           | 98 (41.7)                         | 17.5            | 13.3–23.1  |
|                       | Other                           |            | 9 (32.1)                             | 19 (67.9)                         | 51.7            | 23.2–114.9 |
|                       | In preferred position           | 9169       |                                      |                                   |                 |            |
|                       | No/hardly                       |            | 1180 (86.4)                          | 186 (13.6)                        |                 |            |
|                       | Sometimes                       |            | 3663 (94.4)                          | 217 (5.6)                         |                 |            |
|                       | Always                          |            | 3853 (98.2)                          | 70 (1.8)                          |                 |            |
|                       | Trend test                      |            |                                      |                                   | 0.35            | 0.30–0.40  |
|                       | Lying in first stage            | 9206       |                                      |                                   |                 |            |
|                       | Always                          |            | 861 (88.6)                           | 111 (11.4)                        |                 |            |
|                       | Mostly                          |            | 1085 (91.3)                          | 103 (8.7)                         |                 |            |
|                       | Sometimes                       |            | 2973 (95.0)                          | 155 (5.0)                         |                 |            |
|                       | Never                           |            | 3800 (9.0)                           | 118 (3.0)                         |                 |            |
|                       | Trend test                      |            |                                      |                                   | 0.61            | 0.57–0.67  |
|                       | Standing/walking in first stage | 9206       |                                      |                                   |                 |            |
|                       | Always                          |            | 1198 (96.9)                          | 38 (3.1)                          |                 |            |
|                       | Mostly                          |            | 2549 (96.6)                          | 89 (3.4)                          |                 |            |
|                       | Sometimes                       |            | 3002 (94.4)                          | 179 (5.6)                         |                 |            |
|                       | Never                           |            | 1970 (91.6)                          | 181 (8.4)                         |                 |            |
|                       | Trend test                      |            |                                      |                                   | 1.52            | 1.37–1.68  |
|                       | Accompanying mother in labour   | 9400       |                                      |                                   |                 |            |
|                       | Partner                         |            | 7967 (94.6)                          | 451 (5.4)                         | 1.00            | –          |
|                       | Mother                          |            | 254 (95.9)                           | 11 (4.2)                          | 0.77            | 0.42–1.41  |
|                       | Other friend/relative           |            | 172 (96.1)                           | 7 (3.9)                           | 0.72            | 0.34–1.54  |
|                       | No one                          |            | 430 (79.9)                           | 108 (20.1)                        | 4.44            | 3.52–5.59  |
|                       | Lost control of behaviour       | 9133       |                                      |                                   |                 |            |
|                       | Mostly                          |            | 414 (89.8)                           | 47 (10.2)                         |                 |            |
|                       | Sometimes                       |            | 2685 (93.6)                          | 185 (6.5)                         |                 |            |
|                       | Not at all                      |            | 5574 (96.1)                          | 228 (3.9)                         |                 |            |
|                       | Trend test                      |            |                                      |                                   | 0.60            | 0.52–0.69  |
|                       | Epidural in labour              | 9400       |                                      |                                   |                 |            |
|                       | No                              |            | 7469 (97.6)                          | 186 (2.4)                         | 1.00            | –          |
|                       | Yes                             |            | 1354 (77.6)                          | 391 (22.4)                        | 11.6            | 9.65–13.9  |

<sup>a</sup> Based on the Registrar General's Social Scale.<sup>b</sup> Unadjusted odds of emergency Caesarean section compared to spontaneous vaginal delivery.<sup>c</sup> Odds based on linear and quadratic terms.

detected in this analysis because of the systematic method in which these data were collected immediately following birth. Increased Caesarean section rates have been observed in women with pre-pregnancy or gestational diabetes mellitus<sup>21</sup> and hypertension.<sup>22,23</sup> In this study only an association between diabetes mellitus and all Caesarean sections was observed.

These analyses have identified non-cephalic presentation as having very high ORs of Caesarean delivery. Breech presentation is known to be associated with an increased risk of emergency Caesarean section compared with the cephalic presenting fetus where vaginal delivery is attempted,<sup>2</sup> and this has been confirmed in the present analyses. Increasing

**Table 6** Final model to show the prenatal factors associated with emergency Caesarean section compared with spontaneous vaginal delivery

| Aetiological factors                    | <i>n</i> = 6454 | Adjusted OR <sup>a</sup> | 95% CI       | <i>P</i> value <sup>b</sup> |
|---|-----------------|--------------------------|--------------|-----------------------------|
| <b>Maternal age at delivery (years)</b> |                 | 1.11                     | 1.08–1.15    | <0.0001                     |
| <b>Previous Caesarean section</b>       |                 |                          |              |                             |
| No                                      | 6212            | 1.00                     | –            | <0.0001                     |
| Yes                                     | 242             | 13.0                     | 7.76–21.7    |                             |
| <b>Outcome of last pregnancy</b>        |                 |                          |              | 0.0012                      |
| Child alive                             | 3356            | 1.00                     | –            |                             |
| No previous pregnancy                   | 2047            | 2.65                     | 1.59–4.43    |                             |
| Miscarriage/termination                 | 1005            | 2.22                     | 1.37–3.58    |                             |
| Stillbirth/child died                   | 46              | 2.56                     | 0.44–15.0    |                             |
| <b>Parity</b>                           |                 | 0.46                     | 0.33–0.63    | <0.0001                     |
| <b>Birthweight (kg)</b>                 |                 | 0.003                    | 0.0003–0.026 |                             |
| <b>Birthweight (kg)<sup>2</sup></b>     |                 | 2.37                     | 1.73–3.24    | <0.0001 <sup>c</sup>        |
| <b>Neonatal head circumference (cm)</b> |                 | 1.20                     | 1.09–1.33    | 0.0006                      |
| <b>Fetal presentation</b>               |                 |                          |              | <0.0001                     |
| Cephalic                                | 6290            | 1.00                     | –            |                             |
| Breech                                  | 143             | 9.58                     | 6.06–15.1    |                             |
| Other                                   | 21              | 89.8                     | 29.4–274.0   |                             |
| <b>In preferred position in labour</b>  |                 |                          |              |                             |
| Never/sometimes/always                  |                 | 0.59 <sup>d</sup>        | 0.49–0.73    | <0.0001                     |
| <b>Epidural in labour</b>               |                 |                          |              | <0.0001                     |
| No                                      | 5236            | 1.00                     | –            |                             |
| Yes                                     | 1218            | 6.49                     | 4.78–8.82    |                             |

<sup>a</sup> Odds of emergency Caesarean section compared with spontaneous vaginal delivery.

<sup>b</sup> Adjusted for all other variables within the group.

<sup>c</sup> Based on 2 degrees of freedom—non-linear (J-shaped) relationship for birth weight.

<sup>d</sup> Trend test.

gestational age at delivery was found to be associated with decreased odds of Caesarean section in two of the analyses presented here (all Caesareans compared with all vaginal deliveries and elective Caesarean section compared with attempted vaginal delivery). This result is consistent with clinical practice. It is generally decided before term by obstetricians and women if they require elective delivery. If elective Caesarean section is indicated then it will usually be performed before 40 weeks; therefore it is unsurprising that the odds of Caesarean delivery decrease as gestational age increases, as the majority of women who had Caesarean sections (59%) underwent elective procedures.

The second analysis investigated the associations between prenatal factors and elective Caesarean section. The findings are consistent with the published literature with regard to diabetes mellitus, non-cephalic fetal presentation, and previous Caesarean section having increased odds of elective Caesarean delivery. Again, increasing gestational age was associated with decreased odds of Caesarean delivery. Most interestingly, increasing maternal age was once again found to be independently associated with elective Caesarean section. These factors were all identified in the first analysis. However, unlike the first analysis, fetal measurements (namely birthweight and head circumference) do not appear to increase the risk of

elective Caesarean delivery. This suggests that, in this cohort, clinicians were not performing elective Caesarean delivery for suspected macrosomia. In addition, the outcome of the last pregnancy was not included in the final model. This suggests that women with previous poor obstetric outcomes (stillbirth, miscarriage, infant death) are not planning different modes of delivery compared with women with a good outcome or no previous pregnancy. Rather, the suggestion is that differences arise once labour has commenced. This is supported by the third analysis, which indicates increased rates of emergency Caesarean section in women with a poor recent obstetric history. It is likely that there is a complex relationship between pregnancy outcome and mode of delivery for women who are at an increased risk of poor obstetric outcomes. Smith *et al.* found that delivery by Caesarean section may increase subsequent stillbirth.<sup>24</sup>

The final analysis considered the prenatal factors associated with emergency Caesarean section. The findings are consistent with the published literature with regard to previous Caesarean section and non-cephalic presentation. As in the first analysis fetal measurements (birthweight and head circumference) appear to increase the odds of emergency Caesarean section. Maternal age was once again found to be independently associated with an increased risk of emergency Caesarean

delivery. Increasing parity was found to be associated with decreased odds of emergency Caesarean, which is consistent with observations in clinical practice. We found a strong association with epidural analgesia and emergency Caesarean section in this analysis, in contrast to two meta-analyses.<sup>25,26</sup> Some studies have looked at the clinical management of the epidural (the timing of catheter insertion and the timing and frequency of boluses).<sup>27,28</sup> These studies found that rates of Caesarean section were connected to clinical epidural management. These data were not available in the current dataset used. There are no similar results with regard to being in a preferred position in labour in the published literature. Some studies have considered ambulation in labour, although an association with emergency Caesarean was not observed.<sup>29,30</sup>

### Clinical implications

These analyses indicate the different prenatal factors that are associated with different types of Caesarean delivery. The majority of the factors identified are not amenable to change (such as, maternal age, fetal measurements, past medical, and obstetric history). However, two factors associated with emergency Caesarean section (epidural use and being in a preferred labour position) are potentially modifiable. In view of this, it is apparent that to reduce the Caesarean section rates a range of strategies will need to be adopted. For example, it may be possible to incorporate the identified factors into classifications currently used to audit Caesarean section to establish trends with greater validity.<sup>31</sup> It may also be possible to develop interventions based on the identified variables, which may reduce the Caesarean section rate, especially for primiparous women. The negative findings between significant clinical problems (such as, slipped disc and hernia repair) and Caesarean section are also interesting and may potentially help clinicians advise patients.

### Future research

These analyses have found independent associations that are worthy of further investigation in other datasets. They may help us to explore the reasons behind escalating rates of Caesarean section, and perhaps more importantly provide possible explanations for the marked variation between individual clinicians, institutions, and different countries. It is noteworthy that of the wide range of variables considered only a few would

need to be taken into account as potential confounders in comparing Caesarean section in different centres, or in one centre over time.

It is important to understand the relationship between increasing maternal age and both elective and emergency Caesarean section—in particular whether this is driven by women or by clinicians. With the ageing maternity population this could be important in influencing national rates. Identification of the variables in all analyses also provides strong evidence for a comprehensive group of confounders that should be considered when investigating health consequences of Caesarean section for both the mother and the baby.

## Conclusions

In summary, these analyses have confirmed several important associations between prenatal factors and Caesarean section and revealed further interesting ones. The information in this study is potentially important for those who wish to reduce Caesarean section rates, since it allows early identification of women at an increased risk.

## Supplementary Material

Supplementary Material is available at *IJE* Online.

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### KEY MESSAGES

- Caesarean section rates may be amenable to change, especially amongst primiparous women.
- Increasing maternal age is an independent risk factor for Caesarean section.
- Epidural analgesia is associated with emergency Caesarean section.
- Identification of risk factors for Caesarean section allows investigation of the change in rates over time within a unit and between units.

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