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Caesarean Section Rates in England and Wales

Investigating variation between maternity units

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Abstract

Title: Caesarean Section Rates in England and Wales:
Investigating variation between maternity units

In England and Wales, the Caesarean section (CS) rate is 21.5%, ranging from 6% to 66% between maternity units. The impact of a high CS rate on women's health and NHS resources is not clear. Case-mix differences should be taken into account to enable valid comparisons and exploration of factors contributing to this variation. An understanding of these factors is important to ensure quality of obstetric care.

The aim of this thesis was to explore the variation in CS rates between maternity units and evaluate the impact of (i) case-mix and (ii) women's birth preferences using National Sentinel Caesarean Section Audit (NSCSA) data.

Summary of NSCSA data:
Phase 1 (01.05.2000 to 31.07.2000)

- Information on 150,139 women giving birth in 216 maternity units in England and Wales. Variables collected include age, ethnicity, parity, number of previous CS, mode of onset of labour, gestation, presentation, mode of delivery and birth weight.

Phase 2 (01.12.2000 to 31.01.2001)

- Survey of 2,475 pregnant women from 40 selected maternity units. Variables include preferred type of birth. Case-mix data were also collected for all 32,536 women giving birth in these maternity units.

The relationship between case-mix variables and CS (i) before labour and (ii) during labour was demonstrated using logistic regression. Using these results, standardised CS rates were calculated for individual maternity units. Using meta-analytical techniques, the amount of variation in CS rates explained by case-mix adjustment was quantified. Data on preferred type of birth were available for 7% of women in Phase 2. Therefore various techniques for handling 'missing data' including multiple imputations were researched and applied to these data.

Key findings:

- The association between CS and case-mix variables vary for CS before labour and CS during labour. The odds of CS (before and in labour) increase with maternal age. Women from ethnic minority groups have lower odds of CS before labour, and increased odds of CS in labour. Women with a previous vaginal delivery have lower odds of CS, although the magnitude of this for CS before and in labour is markedly different.
- Adjustment for case-mix explained 34% of the variance in CS rates between maternity units.
- Adjustment for case-mix differences and women's birth preferences explained 45% of the variance in CS rates between maternity units in England and Wales.

Table of contents

Abstract 2
1 Background 17
1.1 CS rates 18
1.2 National Sentinel CS Audit data 21
1.2.1 Phase 1 (1 May to 31 July 2000) 22
1.2.2 Phase 2 (1 December 2000 to 28 February 2001) 23
1.3 Aim and objectives of the PhD 26
1.3.1 Aim 26
1.3.2 Objectives 26
2 Literature review 30
2.1 Methods for comparing CS rates 30
2.1.1 Exclusion 30
2.1.2 Stratification 31
2.1.3 Standardisation 32
2.2 Factors associated with CS rates 34
2.2.1 Demographics 34
2.2.2 Clinical features 36
2.2.3 Women's views 40
2.2.4 Organisational factors specific to maternity units 42
2.2.5 Views of obstetricians within a maternity unit 44
3 Demographic and clinical characteristics of women in the NSCSA 46
3.1 Mode of delivery 46
3.2 Age 46
3.3 Ethnicity 48
3.4 Parity and previous CS 48
3.5 Gestation and number of babies born 50
3.6 Onset of labour 52
3.7 Presentation 56
3.8 Birth weight 58
4 Factors associated with delivery by CS for individual women 60
4.1 Univariate and multiple logistic regression models 64
4.1.1 Methods 64
4.1.2 Results 65
4.2 Investigating interactions between case-mix variables 79
4.2.1 Choice of interaction terms between case-mix variables 80
4.2.2 Methods 83
4.2.3 Goodness of fit 87
4.2.4 Distribution of expected probabilities 93
4.2.5 Results from the final logistic regression models that include interaction terms between variables 102
4.2.6 Calculating odds ratios for women who differ from the reference group by more than two factors 120
4.3 Discussion 122

4.3.1 General 122
4.3.2 Woman's age 126
4.3.3 Previous vaginal deliveries 127
4.3.4 Previous CS 128
4.3.5 Ethnicity 130
4.3.6 Gestation 133
4.3.7 Presentation 134
4.3.8 Induction of labour 135
4.3.9 Birth weight 137
5 CS rates standardised for case-mix differences 140
5.1 Methods 140
5.2 Results 143
5.2.1 CS before labour 143
5.2.2 CS in labour 146
5.2.3 Overall CS rates 149
5.2.4 Proportion of variance explained by case-mix 152
5.2.5 Ranking 153
5.3 Discussion 160
5.3.1 Amount of variation explained by case-mix differences 164
5.3.2 Ranking of maternity units 165
5.3.3 Reliability of data used for case-mix adjustment 166
5.4 Conclusions 167
6 Women's preferences and CS 169
6.1 Overview 169
6.2 Comparison of relationships between case-mix variables and risk of CS between phase 1 and phase 2 170
6.2.1 Introduction 170
6.2.2 Data 170
6.2.3 Sampling for phase 2 171
6.2.4 Methods 173
6.2.5 Results 175
6.2.6 Conclusion 195
6.3 Survey of women's views on childbirth 196
6.3.1 Introduction 196
6.3.2 Methods 197
6.3.3 Response rates 199
6.3.4 Results 202
6.3.5 Conclusions 213
7 Analysis of datasets containing missing data – a review of the literature 215
7.1 Types of missing data 215
7.2 Mechanism of missingness 215
7.2.1 MCAR 216
7.2.2 MAR 216
7.2.3 MNAR 217
7.3 Methods of dealing with missing data 217
7.3.1 Case deletion 217
7.3.2 Single imputation 218

7.3.3 Multiple imputation....220
7.4 Application to data....222
7.4.1 Application of the predictive model based method to a simplified NSCSA dataset....226
7.4.2 Data....228
7.4.3 Model for imputation using discriminant function analysis....230
7.4.4 Imputation using loglinear and logistic regression models....241
7.4.5 Number of imputations....247
8 Women's birth preference and CS as mode of delivery....254
8.1 Introduction....254
8.2 Methods....255
8.2.1 Imputing birth preference....255
8.2.2 Combination of results....256
8.3 Results....257
8.3.1 Preliminary analysis....257
8.3.2 CS before labour....259
8.3.3 CS during labour....276
8.4 Discussion....290
8.4.1 Findings from this analysis....291
8.4.2 Advantages and disadvantages of using multiple imputations....294
9 CS rates standardised for case-mix and birth preference....297
9.1 Methods....297
9.2 Results....298
9.2.1 Proportion of variance explained by case-mix and birth preferences....301
9.3 Discussion....302
10 Summary of work presented in this thesis, further work and overall conclusions....305
10.1 Summary of work presented in this thesis....305
10.1.1 Chapter 1....305
10.1.2 Chapter 2....305
10.1.3 Chapter 3....306
10.1.4 Chapter 4....307
10.1.5 Chapter 5....308
10.1.6 Chapter 6....309
10.1.7 Chapter 7....310
10.1.8 Chapter 8....313
10.1.9 Chapter 9....315
10.2 Further work....316
10.3 Statistical conclusions....316
10.4 Overall conclusions....318
11 References....321
12 Appendix....344

List of tables

Table 3.3.1: Women's ethnicity and CS rate 48
Table 3.4.1: Previous deliveries of women in phase 1 NSCSA (n=150,139) 49
Table 3.5.1: Gestation (all pregnancies) (n=150,138*) 50
Table 3.5.2: Mode of delivery by gestational age categories for singleton pregnancies (n=147,921) 51
Table 3.6.1: Onset of labour according to gestation for singleton pregnancies (n=147,921) 54
Table 3.6.2: Onset of labour according to gestation for multiple pregnancies 55
Table 3.7.1: Gestational age by presentation for singleton pregnancies (n=147,921) 56
Table 3.7.2: Mode of delivery by onset of labour for term singleton cephalic pregnancies (n=132,632) 57
Table 3.8.1: Birth weight categories and mode of delivery for term singleton cephalic pregnancies (n=132,632) 58
Table 4.1.2.1: Univariate association between age in categories and CS before labour (n=146,238) 66
Table 4.1.2.2: Univariate association between number of previous vaginal deliveries and CS before labour (n=146,238) 66
Table 4.1.2.3: Univariate and multivariate associations between each variable and the odds of CS before labour 70
Table 4.2.1.4: Univariate association between ethnicity and CS as mode of delivery for women in labour 72
Table 4.2.1.5: Univariate association between number of previous vaginal deliveries and CS as mode of delivery for women in labour 73
Table 4.2.1.6: Univariate and multivariate associations between each variable and odds of CS as mode of delivery 76
Table 4.2.2.1: Lists of interactions between case-mix variables that were investigated..86
Table 4.2.3.1: Observed and predicted number of CS (from model A) defined by deciles of predicted probabilities 88
Table 4.2.3.2: Observed and predicted number of CS defined by deciles of predicted probabilities (models B and C) 90
Table 4.2.4.1: Distribution of expected probabilities 94
Table 4.2.4.2: Observed and expected probabilities of CS before and during labour for women according to case-mix variables 95
Table 4.2.5.1: Relationship between woman's age, previous vaginal delivery and CS before labour (adjusted for all other casemix variables) 103
Table 4.2.5.2: Relationship between woman's age, previous CS and CS before labour (adjusted for all other casemix variables) 104
Table 4.2.5.3: Relationship between ethnicity, previous vaginal delivery and CS before labour (adjusted for all other casemix variables) 105
Table 4.2.5.4: Relationship between ethnicity, previous CS and CS before labour (adjusted for all other casemix variables) 106
Table 4.2.5.5: Relationship between ethnicity, birth weight and CS before labour (adjusted for all other casemix variables) 106

Table 4.2.5.6: Relationship between previous vaginal delivery, previous CS and CS before labour (adjusted for all other casemix variables)....107
Table 4.2.5.7: Relationship between previous CS, gestation and CS before labour (adjusted for all other casemix variables)....108
Table 4.2.5.8: Relationship between previous CS, presentation and CS before labour (adjusted for all other casemix variables)....109
Table 4.2.5.9: Relationship between previous CS, birth weight and CS before labour (adjusted for all other casemix variables)....110
Table 4.2.5.10: Relationship between previous vaginal delivery, presentation and CS before labour (adjusted for all other casemix variables)....110
Table 4.2.5.11: Relationship between previous vaginal delivery, birth weight and CS before labour (adjusted for all other casemix variables)....111
Table 4.2.5.12: Relationship between gestation, presentation and CS before labour (adjusted for all other casemix variables)....112
Table 4.2.5.13: Relationship between gestation, birth weight and CS before labour (adjusted for all other casemix variables)....113
Table 4.2.5.14: Relationship between woman's age, previous vaginal delivery and CS during labour (adjusted for all other casemix variables)....114
Table 4.2.5.15: Relationship between ethnicity, previous vaginal delivery and CS during labour (adjusted for all other casemix variables)....115
Table 4.2.5.16: Relationship between woman's age, previous CS and CS during labour (adjusted for all other casemix variables)....115
Table 4.2.5.17: Relationship between previous vaginal delivery, previous CS and CS during labour (adjusted for all other casemix variables)....116
Table 4.2.5.18: Relationship between previous CS, onset of labour and CS during labour (adjusted for all other casemix variables)....117
Table 4.2.5.19: Relationship between gestation, onset of labour and CS during labour (adjusted for all other casemix variables)....118
Table 4.2.5.20: Relationship between gestation, presentation and CS during labour....118
(adjusted for all other casemix variables)....118
Table 4.2.5.21: Relationship between ethnicity, birth weight and CS during labour 120
(adjusted for all other casemix variables)....120
Table 5.2.5.1: Agreement between ranks of maternity units using the observed and standardised CS rates....154
Table 6.2.5.1: Distribution of explanatory variables in phase 1 and phase 2....175
Table 6.2.5.2: Multivariate association between each variable and odds of CS before labour. (analysis including allowance for strata except in column two as only one maternity unit within each stratum)....178
Table 6.2.5.2 (cont'd): Multivariate association between each variable and odds of CS before labour. (analysis including allowance for strata except in column two as only one maternity unit within each stratum)....179
Table 6.2.5.3: Relationship between 'phase of study' and age and CS before labour...181
Table 6.2.5.4: Relationship between 'phase of study', ethnicity and CS before labour 182
Table 6.2.5.5: Multivariate association between case-mix variables and odds of CS for women in labour (analysis including allowance for strata except in column two as only one maternity unit within each stratum)....184

Table 6.2.5.5 (cont'd): Multivariate association between case-mix variables and odds of CS for women in labour (analysis including allowance for strata except in column two as only one maternity unit within each stratum) 185
Table 6.2.5.6: Relationship between phase of study, age and CS for women in labour 186
Table 6.2.5.7: Relationship between phase of study, ethnicity and CS for women in labour 187
Table 6.2.5.8: Relationship between phase of study, previous vaginal deliveries and CS for women in labour 187
Table 6.2.5.9: Relationship between phase of study, previous CS and CS for women in labour 188
Table 6.2.5.10: Relationship between phase of study, presentation and CS for women in labour 188
Table 6.2.5.11: Relationship between phase of study, birth weight and CS for women in labour 189
Table 6.2.5.12: Multivariate association between case-mix variables and odds of (i) CS before labour, and (ii) CS for women in labour (analysis on combined phase 1 and phase 2 data, omitting those women with missing data for any of the explanatory variables) 190
Table 6.2.5.13: Relationship between phase of study, ethnicity and CS before labour (analysis omitting those women with missing data for any of the explanatory variables) 192
Table 6.2.5.14: Relationship between phase of study, age and CS for women in labour (analysis omitting those women with missing data for any of the explanatory variables) 193
Table 6.2.5.15: Association between 'phase 2' and presentation and CS for women in labour (analysis omitting those women with missing data for any of the explanatory variables) 194
Table 6.2.5.16: Association between 'phase 2' and birth weight and CS for women in labour (analysis omitting those women with missing data for any of the explanatory variables) 194
Table 6.3.4.1: Distribution of case-mix variables for women with and without data on birth preferences in phase 2 203
Table 6.3.4.2: Maternal age according to antenatal birth preferences (n=1953) 206
Table 6.3.4.3: Previous deliveries according to antenatal birth preferences (n=1953) .. 207
Table 6.3.4.4: Rates of CS before labour and CS in labour according to antenatal birth preferences 208
Table 6.3.4.5: Association between birth preferences, demographic and clinical variables and (i) CS before labour, and (ii) CS in labour (multiple logistic regression) 210
Table 6.3.4.5 (cont'd): Association between birth preferences, demographic and clinical variables and (i) CS before labour, and (ii) CS in labour (multiple logistic regression) 211
Table 7.4.2.1: Description of simplified NSCSA dataset (n=26,166) 229
Table 7.4.3.1: Relative frequency of birth preferences according to previous CS and CS before labour 235
Table 7.4.3.2: Distribution of imputed data using SOLAS – predictive model based method using discriminant multiple imputations 236

Table 7.4.4.1: Distribution of observed and imputed birth preference according to CS before labour and previous CS from a single imputation using (i) logistic regression, and (ii) a loglinear model....245
Table 8.3.1.1: Birth preferences according to ethnicity for women in phase 2 258
Table 8.3.1.2: Birth preferences according to gestational age for women in phase 2....258
Table 8.3.1.3: Birth preferences according to presentation for women in phase 2....259
Table 8.3.2.1: Univariate relationship between birth preferences and CS before labour 260
Table 8.3.2.2: Odds ratios for CS before labour according to birth preferences, adjusted for age, ethnicity, previous deliveries, gestation and birth weight....261
Table 8.3.2.3: Relationship between previous CS, birth preferences and CS before labour (phase 2) (n=1888)....263
Table 8.3.2.4: Relationship between previous CS, imputed birth preferences and CS before labour (phase 1) (n=140,969)....263
Table 8.3.2.5: Odds ratios for CS before labour according to case-mix variables, adjusted for birth preferences....265
Table 8.3.2.6: Standard errors of the log odds ratio of CS before labour according to the different case-mix variables and birth preferences for women in phase 1 and phase 2....270
Table 8.3.3.1: Univariate relationship between birth preferences and CS for women in labour....276
Table 8.3.3.2: Odds ratios for CS during labour according to birth preferences adjusted for age, ethnicity, previous deliveries, gestational age, induction of labour and birth weight....277
Table 8.3.3.3: Relationship between previous CS, birth preferences and CS during labour (phase 2) (n=1684)....279
Table 8.3.3.4: Relationship between previous CS, imputed birth preferences and CS before labour (phase 1) (n=140,969)....279
Table 8.3.3.5: Odds ratios for CS during labour according to case-mix and birth preferences....281
Table 8.3.3.6: Standard errors of the log odds ratio of CS during labour according to the different case-mix variables and birth preferences for women in phase 1 and phase 2....284

Figures

Figure 1.1.1:International CS rates 19
Figure 3.2.1: Women's age and CS rate 47
Figure 4.2.4.1: Predicted probabilities of CS before labour (i) for women in labour, and (ii) women who had CS before labour 98
Figure 4.2.4.2: Predicted probabilities of CS for women in labour (i) women who had vaginal delivery, and (ii) women who had CS 99
Figure 4.2.4.3: Receiver operating curve (ROC) for predicted probabilities of CS before labour 100
Figure 4.2.4.4: Receiver operating curve for predicted probabilities of CS for women in labour 100
Figure 5.2.1.1: Observed and standardised CS before labour rates for maternity units.144
Figure 5.2.1.2: Relationship between difference and mean for observed and standardised CS before labour rates 145
Figure 5.2.1.3: Standardised CS before labour rates (with 95% CI) for maternity units. 146
Figure 5.2.2.1: Observed and standardised CS during labour rates for maternity units 147
Figure 5.2.2.2: Relationship between difference and mean for observed and standardised CS in labour rates 148
Figure 5.2.2.3: Standardised CS during labour rates (with 95% CI) for maternity units 149
Figure 5.2.3.1: Observed and standardised overall CS rates for maternity units 150
Figure 5.2.3.2: Relationship between difference and mean for observed and standardised CS rates 151
Figure 5.2.3.3: Standardised overall CS rates for maternity units (with 95% CI) 152
Figure 5.2.5.1: Maternity units ranked by observed overall CS rates and standardised CS before labour rates 155
Figure 5.2.5.2: Maternity units ranked by observed overall CS rates and standardised CS in labour rates 156
Figure 5.2.5.3: Maternity units ranked by observed overall CS rates and standardised overall CS rates 157
Figure 5.2.5.4 Maternity units ranked by observed CS before labour rates and observed CS in labour rates 158
Figure 5.2.5.5: Maternity units ranked by standardised CS before labour and standardised CS in labour rates 159
Figure 6.3.3.1: Summary of response rates for survey of women's views on childbirth 201
Figure 7.4.1: Summary of NSCSA data 223
Figure 7.4.3.1: Observed and predicted relative frequencies 232
Figure 7.4.3.2: Observed and imputed distribution of birth preference: women with no previous CS, no CS before labour 237
Figure 7.4.3.3: Distribution of observed and imputed birth preferences: women with no previous CS who had CS before labour 238
Figure 7.4.3.4: Distribution of observed and imputed birth preferences: women with at least one previous CS, no CS before labour 239

Figure 7.4.3.5: Distribution of observed and imputed birth preferences: women who had had previous CS and CS before labour 240
Figure 7.4.5.1: Relative efficiency with five imputations according to percentage of missing data 248
Figure 7.4.5.2: Relative efficiency by number of imputations 249
Figure 7.4.5.3: Standard errors obtained for log odds ratio of CS before labour for women with previous CS compared with women with no previous CS according to number of imputations 251
Figure 7.4.5.4: Standard errors obtained for log odds ratio of CS before labour for different women's birth preferences compared with preference for vaginal birth according to number of imputations 252
Figure 8.3.2.1: Between-imputation variability in log odds of CS before labour for women aged 30–34 years compared with women aged 25–29 years 274
Figure 8.3.2.2: Between-imputation variation in log odds of CS before labour for birth weight less than 2500 g compared with 2500–4000 g 275
Figure 8.3.3.1: Between-imputation variability in log odds ratio of CS during labour comparing women with previous CS with women with no previous deliveries 288
Figure 8.3.3.2: Between-imputation variability in log odds ratio of CS during labour comparing women with previous vaginal deliveries with women with no previous deliveries 289
Figure 9.2.1: CS rates: Observed and standardised for case-mix and birth preferences for 216 maternity units 299
Figure 9.2.2: CS rates for maternity units: Difference and mean crude and standardised for case-mix and birth preferences 300
Figure 9.2.3: CS rates standardised for case-mix and birth preferences (with 95% CI) for individual maternity units 301

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Glossary of terms

Caesarean section (CS):	abdominal surgery for delivery of a baby from a pregnant woman
Doula:	woman from the community with or without training in childbirth who provides support to women in labour
FIGO:	Federation of International Obstetricians and Gynaecologists
Gestation:	age of the pregnancy, measured in weeks. The estimated date of delivery marks 40 weeks gestation. From 37 weeks onwards, the baby is considered to be mature enough to be born and pregnancies at 37 weeks onwards are referred to as 'term'
Induction of labour:	an intervention designed to artificially initiate uterine contractions leading to progressive dilatation and effacement of the cervix and birth of the baby. This is indicated when it is concluded that the fetus or the mother will benefit from a higher probability of a healthy outcome if delivery is expedited
Intrapartum:	during labour
Macrosomia:	large fetus, estimated birth weight of at least 4000g
Multiparous:	a woman who has given birth at least once before this index pregnancy
Para/parity:	the number of births a woman has had

Presentation:	the part of the baby that will pass through the birth canal first. This is dependent on the position of the baby in the mother's womb. In most cases, the baby's head is down and this is referred to as cephalic presentation. If the baby's bottom is down this is called breech presentation. Transverse or oblique lie refers to cases where the baby is lying across the womb. In these cases, delivery will have to be by CS
Placenta praevia:	placenta implanted at the bottom of the uterus, over the cervix which in some cases may impede vaginal delivery
Primiparous:	a pregnant woman who has not given birth before
RCT:	randomised controlled trial
Saturated model:	A statistical model that includes all combinations of explanatory variables
SCBU:	special care baby unit
SROM:	spontaneous rupture of membranes (breaking water). In the majority of cases, this occurs during labour, after the onset of contractions
Thrombo-embolism:	surgery (and pregnancy) can predispose to the formation of blood clots, which can be transported through the bloodstream, obstructing blood vessels (e.g. the major arteries supplying the lungs)

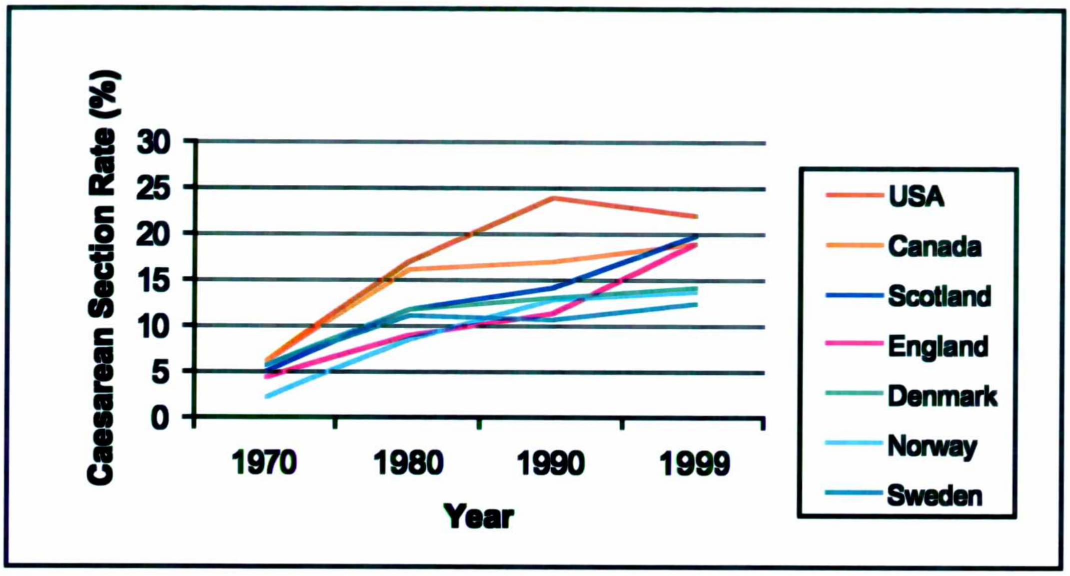
1 Background

Over the last three decades, the proportion of pregnant women having a Caesarean section (CS) has increased[1;2]. The majority of CS are undertaken with the aim of reducing perinatal mortality and morbidity[3]. While there is clear benefit of delivery by CS for the baby in some circumstances[4] (e.g. delivery of the term breech pregnancy), in other circumstances the risks and benefits are less clear (e.g. delivery of the preterm pregnancy)[5]. For the mother, there is a clear maternal health benefit with CS only in a minority of situations (e.g. placenta praevia). The maternal risks associated with CS include haemorrhage[6;7], infection[8;9], thrombo-embolism[10] and there are implications for future pregnancies[11;12]. Hence, there is concern that an increasing number of pregnant women are having major abdominal surgery in childbirth, the longer-term effects of which are not clearly known. The rising CS rate has implications for obstetric health service provision. About 600,000 deliveries take place each year in England[13;14]. The incidence of severe morbidity following childbirth is about 1%; women undergoing emergency CS are up to four times more likely to be affected[15]. A national evidence-based guideline on CS was published in April 2004 outlining the risks and benefits of CS compared with vaginal birth and providing recommendations for the use of CS for women giving birth in England and Wales[16].

1.1 CS rates

Although the increase in CS rates has been a global phenomenon, the timing and rate of increase has differed between countries and marked differences in rates persist. In 1985, WHO issued a consensus statement suggesting there were no additional health benefits associated with CS rates above 10–15%. This was based on an examination of estimates of national CS rates and maternal and perinatal mortality rates from various countries. However, the majority of perinatal deaths are stillbirths or deaths due to prematurity and therefore not related to mode of delivery. Perinatal deaths due to congenital abnormalities are also unrelated to mode of delivery. Therefore crude analysis of perinatal mortality rates is unlikely to be informative about what the optimum CS rate should be. Figure 1.1.1 shows CS rates for different countries over the last 30 years.

Figure 1.1.1:International CS rates



(figure drawn using point estimates to show change in time; not to imply continuity)

In England, there was a doubling of CS rates in the 1970s from 4% in 1970 to 9% in 1980. The increase was less marked during the 1980s. Rates appeared to almost double again during the 1990s, with estimated rates of 16% in 1995[17], and 19% by 1999[14;18], for the first time indicating that CS rates in England had surpassed those recommended by WHO. The most recent estimate of CS rates for England and Wales for 2002–2003 was 22%[19]. A similar pattern of increase was observed in Scotland[20;21]. In the Nordic countries (Norway, Finland, Sweden and Denmark) the pattern of increase was similar to that observed in England up to 1990[21;22]. However, the period of rapid increase observed in England and Scotland during the 1990s did not occur in Nordic countries, where the national rates remained at 12–14%[23]. In the USA, rates nearly tripled during the 1970s and continued to rise steeply throughout the 1980s[24]. Rates increased from 6% in 1970 to 17% in 1980[21] and to 24% in 1990[22;25]. Through the 1990s, rates stabilised and even fell marginally to 22% in 1999[26]. The CS rate in the USA was 26% in 2002[27]. This pattern was mirrored in Canada[21;28].

Within the UK there has been concern that CS rates vary between maternity units, and that this variation is not accounted for by differences in population demographics and clinical characteristics alone. An unpublished survey by the English Nursing Board showed that in 1996, 9% of maternity services had CS rates between 20% and 30% compared with 25% in 1999. Also in 1999, a further 2% of services had CS rates in excess of 30%.

Deriving a complete picture of CS rates in England and Wales is hampered by the lack of comprehensive data: national estimates in 1999 were based on only 67% of maternities in 2000[14] and 72% in 2002–2003[19]. Such deficiencies in the completeness and quality of national maternity data in England and Wales have been documented[17].

The Department of Health has been aware of potentially wide variations in the CS rate between maternity units in England and Wales and has sought to evaluate the role of population, clinical and organisational factors. The National Sentinel CS Audit[1] (NSCSA) (2000–2001) was designed to determine the frequency of CS in all maternity units, as well as to evaluate the demographic, clinical and organisational factors associated with variations in CS rate. The results of the audit have been published[1]. The CS rate for England and Wales was 21.3% in 2000, based on complete data from all 216 maternity units over a 3-month period (May–July 2000). This ranged from 6% to 66% between maternity units (Inter quartile range (IQR): 18%, 23%). However, differences in population characteristics and case-mix between maternity units need to be accounted for before valid comparisons can be made. The work undertaken in this thesis focuses on using the NSCSA data to (i) adjust CS rates for individual maternity units taking into account differences in population characteristics to enable valid comparisons between maternity units, and (ii) quantify the amount of variation in CS rates between maternity units that can be explained by differences in population characteristics.

The following section describes the NSCSA, the databases available for analysis and my involvement with the project. This is followed by a description of the aims and objectives of the PhD in section 1.3.

1.2 National Sentinel CS Audit data

The National Sentinel CS Audit (2000–2001) was designed to determine the frequency of CS in all maternity units, and to evaluate the demographic, clinical and organisational factors associated with variations in CS rate[1]. The quality of clinical care was assessed against agreed standards derived from published literature. In addition, maternal request and clinicians' preference for CS were explored.

The audit was developed by multiprofessional and lay groups drawn principally from the Royal Colleges of Obstetricians and Gynaecologists, Midwives, Anaesthetists and the National Childbirth Trust.

There were two phases of data collection.

1.2.1 Phase 1 (1 May to 31 July 2000)

Aims:

- To determine the frequency of CS
- To evaluate the demographic, clinical and organisational factors associated with variations in CS rate
- To assess the quality of clinical care against agreed standards derived from published literature

All NHS and private maternity units in England and Wales (n=216) took part. During the study period data were collected prospectively on all births that took place in each maternity unit. These were called denominator data; a full list of variables is given in Appendix 1. In addition, clinical data forms were completed for all CS that took place during the study period. These clinical data contain detailed information covering demographic characteristics, details of the index pregnancy, previous obstetric history, the decision-making process leading to CS and an assessment of quality of care against pre-defined standards. In addition, there were supplementary surveys covering midwifery, obstetric and anaesthetic issues and each 'delivery suite' was asked to keep a 2-week diary to validate staffing provision.

The databases from this phase of the study are as follows.

1. Information on population and clinical characteristics, as well as on mode of delivery for 150,139 women giving birth in 216 maternity units in England and Wales between 1 May and 31 July 2000 (99% of all births that took place during this period).

2. Detailed information on decision-making, urgency and quality-of-care issues for all CS that took place during this period (32,082 cases).

3. Unit-level information on organisational factors such as staffing levels and the facilities available in each of these maternity units.

1.2.2 Phase 2 (1 December 2000 to 28 February 2001)

Aims:

- To determine the frequency of maternal request for CS and explore women's views about childbirth.
- To explore clinicians' attitudes towards CS and the variation in agreement to CS in different clinical situations.

Forty units took part in this phase of the audit. The sampling process for selection of units involved creating a sampling frame that stratified hospitals in England, Wales and Northern Ireland by region, size, CS rate (based on preliminary data from phase 1) and type of hospital (district general or teaching hospital). One hospital was selected from each stratum.

The population surveyed was women booked into these maternity units (to receive either community or primary care) with an estimated date of delivery in January 2001. A survey exploring clinicians' attitudes toward, and threshold for, CS was also undertaken among all consultant obstetricians employed in these maternity units.

The databases from this phase of the study are as follows.

1. Survey of consultant obstetricians practising at 40 randomly selected maternity units in England and Wales, stratified by geography and size of hospital. All consultant obstetricians (n=224) at these maternity units were invited to take part. At least one consultant from each of these maternity units responded (n=172, response rate 77%, number of responses per maternity unit ranged from 1 to 11). Information was collected about their views on childbirth in general and their attitudes toward CS. This was carried out in January 2001.

2. Survey of pregnant women with an estimated date of delivery in January 2001 that were booked to deliver in the 40 randomly selected maternity units described in 1 above. Invitations to participate in the survey were sent out to 7873 women, 2942 women (37%) responded to this invitation and were sent a questionnaire. Completed questionnaires were received from 2475 women (response rate: 31% of women who were invited to participate, range

between maternity units 5% - 47%). Information was collected about their birth preferences, their attitudes to childbirth in general and their preferred mode of delivery in the index pregnancy. This was carried out between December 2000 and February 2001.

3. Information on population and clinical characteristics as well as on mode of delivery for 32,536 women giving birth in the 40 maternity units, including those who responded to the survey of pregnant women detailed above. In addition, detailed information on all CS that took place in these units was collected (7,325 cases).

As a research fellow working on the NSCSA, I was responsible for:

- setting up all the databases for the NSCSA
- data cleaning, management and linking of databases
- data analysis
- sampling for phase 2.

I was also directly involved with preparing, drafting and piloting the questionnaires for the survey of women's views of childbirth and the survey of obstetricians' views of childbirth.

The findings of the NSCSA were published in a report that I co-authored[1]. This thesis includes further analysis of the NSCSA databases that was undertaken under supervision, with the aim and objectives outlined in the following section.

I also worked on the national evidence-based guideline for Caesarean section that was published in April 2004[16].

1.3 Aim and objectives of the PhD

1.3.1 Aim

Although there is insufficient information from previous years to investigate the factors that have led to the increase in CS rates in England and Wales, it is possible to use data from the NSCSA to explore the variation between maternity units and to evaluate the impact of various factors on the CS rate.

In this thesis, the aim is to quantify the amount of variation in CS rates between maternity units that is attributable to differences in demographic and clinical factors (case-mix) and women's birth preferences.

1.3.2 Objectives

1. To build an explanatory statistical model that describes the relationship between various demographic and clinical factors (case-mix) and CS for individual women with singleton pregnancies according to current practice in England and Wales
2. To quantify the variation in CS rates between maternity units that is explained by case-mix adjustment

3. To examine the contribution of women's preference for CS to the variation in CS rates between maternity units

In order to meet these objectives, the large NSCSA databases were used to develop statistical models for the relationships between case-mix, birth preferences and CS for individual women.

In chapter 2, the methods available for comparing CS rates are reviewed. This is followed by a review of the factors associated with CS rates to determine which factors should be included in an explanatory statistical model that describes the relationship between case-mix and CS for individual women.

In chapter 3, the demographic and clinical characteristics of women who gave birth during phase 1 of the NSCSA are described, together with CS rates according to these characteristics.

A novel two-stage modelling process was used to describe the relationship between casemix and (i) CS before labour, and (ii) CS during labour in chapter 4. In order to compute CS rates adjusted for these demographic and clinical characteristics (standardised CS rates), the expected number of CS was compared with the observed number of CS that took place within a maternity unit. The calculation of expected probabilities of CS for individual women is also described in chapter 4.

In chapter 5, maternity units are ranked according to standardised CS rates to highlight the extent to which some have significantly higher or lower rates compared with the national average. The amount of variation in CS rates explained by case-mix adjustment is quantified using techniques analogous to those in meta-analysis.

Chapter 6 addresses women's birth preferences and their association with CS as mode of delivery using data from phase 2 of the NSCSA. The sampling approach used during the second period of data collection (40 maternity units in England and Wales) had to be taken into account in order to ensure that the results obtained would be applicable to the general population of England and Wales.

Data on women's birth preferences were available for a small proportion of women in phase 2. Therefore, various techniques for handling 'missing data', including multiple imputations, were researched and their potential for application to the NSCSA data explored in chapter 7.

Chapter 8 describes the relationship between women's birth preference and CS as mode of delivery (following adjustment for case-mix variables), using phase 1 data with imputed birth preferences. Multiple imputations were used to deal with the missing data on birth preferences and the advantages and disadvantages of this approach are discussed.

The results obtained in chapter 8 were then used in chapter 9 to calculate standardised CS rates for individual maternity units. Using meta-analytical techniques, the amount of variation in CS rates explained by case-mix adjustment and women's birth preferences was quantified.

Suggestions for further work and the overall conclusions from this work are given in chapter 10.

2 Literature review

In this chapter, the methods available for comparing CS rates are reviewed. This is followed by a review of the various demographic, clinical, organisational and attitudinal factors associated with CS rates that have been reported in the literature.

2.1 Methods for comparing CS rates

It is generally accepted that case-mix adjustment is necessary to enable valid comparisons of CS rates between maternity units[29]. In general, there are three methods that have been used and reported in the literature: exclusion, stratification and standardisation (direct and indirect).

2.1.1 Exclusion

The simplest method is exclusion, where comparisons are made only on women who fulfil specific criteria and all other women are excluded. One example of this is the comparison of maternity units' CS rates among women who have the characteristics of a 'standard primip' (White women, age 20–34 years, over 155 cm tall, term singleton cephalic pregnancies, who deliver at the maternity unit where they were booked, excluding those who have complications of pregnancy)[30]. However, evaluation of this method for comparing CS rates showed that the definition of a standard primip only includes 43% of the population on average and less in regions that are more ethnically diverse[31]. Therefore, the authors of this evaluation recommended that this method be extended to be more inclusive[31]. Another method that uses the concept of exclusion has been used for comparing CS rates in the

USA; this involves the calculation of 'labour-adjusted CS rates' for individual obstetricians, having excluded women with known high-risk factors for CS such as placenta praevia, placental abruption and breech presentation[32]. The authors of this method refer to these 'high-risk factors' as indications for which all obstetricians would perform a CS[32]. However, there is often more than one indication for a CS and there may not be consistency in deciding the primary indication between obstetricians[1]. The excluded groups within both of the methods described so far contribute substantially to the overall CS rate[1]. The main drawback of their exclusion is that variation in these groups will not be captured.

2.1.2 Stratification

Women giving birth can be stratified into groups depending on their characteristics or risk factors. One example of stratification is the use of Robson groups[33;34], where women are assigned to one of ten groups based on parity, presentation, gestation, spontaneous onset of labour or otherwise, presence or absence of a uterine scar, and singleton or multiple pregnancy. CS rates are then calculated for women within each of the ten groups. Maternal age and ethnicity are not taken into account. This method places women who have either induction of labour or CS before labour within the same group. Women with previous CS who have multiple pregnancies or breech presentation are categorised into the multiple pregnancy or breech presentation group, respectively. Therefore, while this method allows for comparing group-specific CS rates between maternity units, it does not directly allow for comparing rates of primary and repeat CS, or rates of CS before and during labour. Neither does it produce an overall adjusted rate that can be compared between maternity units. However, there is potential to take this method one step further for use in direct standardisation, where the observed rate within groups for one maternity unit is applied to a reference population[35;36].

2.1.3 Standardisation

Direct

Direct standardisation refers to the application of observed risks or rates in the study population to a reference population. Two studies[35;36] in the USA used this method to compare CS rates between teaching and community-based hospitals[36]. Women giving birth were stratified into groups (six groups)[35] and 18 groups[36] based on parity and clinical factors), the CS rate in each group was compared between the hospitals. The expected CS rate for the teaching hospital, if it had the same case-mix as the community hospital; was then calculated in one study[36]. In the other, the expected rates for the community hospitals were calculated using the teaching hospital as the standard reference population[35]. In both studies, no significant difference in CS rate was found between the hospitals following this method of case-mix adjustment. The advantage of this method over the methods described so far is that it is all-inclusive and allows for comparison of an overall adjusted rate. This method is probably useful for comparing rates between small numbers of maternity units. For comparisons between larger numbers of maternity units it is probably not as practical as it would be necessary to determine which maternity unit should be used as the standard reference population for comparisons.

Indirect

Indirect standardisation refers to the application of observed risks in a reference population to the study population. This method has been used for comparing CS rates in some studies[29;37-40]. The advantages of this method are that (i) it is all-inclusive, (ii) it does not require the selection of any particular maternity unit profile for use as the standard reference population, and (iii) it allows for comparisons of an overall CS rate that is adjusted for case-mix. The expected number of CS for individual maternity units is calculated and compared with the observed number of CS to produce a standardised CS rate.

In order to calculate the expected number of CS, it is possible to develop and fit a statistical model to obtain the expected probabilities of CS for individual women according to their characteristics. The expected number of CS would then be the sum of these expected probabilities within a maternity unit. Expected probabilities of CS for individual women only reflect current practice and do not provide information about the appropriateness or effectiveness of the CS for individual women. However, they are useful to account for differences in case-mix across maternity units. Therefore, this method was chosen for use in the analysis of the NSCSA data in this thesis.

2.2 Factors associated with CS rates

Observational studies in different countries have examined the determinants of the CS rate[3;41-43]. The determinants of the CS rate have been described in terms of reasons for performing CS and demographic or clinical characteristics of the population that are associated with a higher likelihood of CS. The main reasons for performing CS have not changed over the last two decades internationally. These remain fetal distress, failure to progress in labour, repeat CS and breech presentation[1;3;41-43]. The demographic (such as maternal age, ethnicity and parity) and clinical (such as gestational age, presentation and birth weight) population characteristics associated with CS are reviewed in detail in sections 2.2.1 and 2.2.2. Women's birth preferences have an impact on their mode of delivery and hence these will also impact on the CS rate[44-49]. A review of women's views on childbirth is presented in section 2.2.3.

In addition, organisational factors (such as staffing, and size of maternity unit)[50-53] and the attitudes of obstetricians[54-56] towards childbirth have also been shown to impact on CS rates. These are reviewed in sections 2.2.4 and 2.2.5.

2.2.1 Demographics

Maternal age

Overall fertility rates have declined and this decline is most marked in women under 30 years, as women choose both to delay childbirth and to have fewer children[25;57]. In 1975, 6% of women giving birth were over 35 years old; in 1995, 11% were in this category[13]. CS rates have been observed to increase with maternal age in a variety of populations with different overall CS rates[23;28;42;43;58-70]. Complications of pregnancy increase with maternal age. However, these alone may not account for all the increases in CS rates observed. It has been suggested that other physical factors such as age-related physiological changes[64] and changes in maternal or clinician preference[71] may also contribute. One study in the U.S. reported that changes in the demographic characteristics of the population accounted for 18% of the increase in primary CS rates in Washington state between 1970 and 1987[67]. However, Nordic countries have experienced similar demographic transitions but have not had the rapid increases in CS rate[23].

Ethnicity

Several population studies report that CS rates vary between some ethnic groups. Higher rates of CS have been reported in non-White women[30;58;72;73]. Some complications of pregnancy are more prevalent in Black women (e.g. diabetes, hypertensive disorders) or in specific ethnic groups (e.g. HIV is more prevalent amongst Black African women)[74] and may contribute to the observed association. A higher prevalence of CS for fetal reasons has also been reported among non-White women compared with White women[75].

Other demographic factors

CS rates have been reported to be higher among women with higher socio-economic status[25] and among women living in urban areas compared with rural areas[62;76]. Maternal education has also been shown to affect CS rates[77;78]. Women with a college education are reported to be 10–40% more likely to have a CS[29;77] although this association is reduced after adjusting for maternal age and birth weight. Sociocultural factors also play a role. For example, it is reported that the acceptance of pain during labour varies between societies, affecting requests for pain relief or epidural analgesia. Such differences may affect CS rates in more interventionist settings, where obstetricians have lower thresholds for performing CS[42].

Male sex of the infant is also reported to be associated with up to a 50% increase in risk of CS[75]. The underlying mechanism for this is not known; it was hypothesized that male babies weigh more and have greater production of corticosteroids and oestrogen precursors that affect the onset of labour[75]. However it has been shown that the association between male fetal sex and increased risk of CS is not explained by differences in birthweight[79].

2.2.2 Clinical features

Parity and previous CS

The risk of a CS in a first pregnancy differs from that for subsequent pregnancies[24]. The CS rate is lowest in women who have only ever had vaginal births previously[34;62;67;77]. It is increased in women who have had a previous CS[34]. Therefore, an increase in the proportion of women who have had a previous CS in a population will result in a disproportionate increase in the overall CS rate[24;25,27;58;80]. Several studies have reported that the risk of a repeat CS is reduced in women who have had a previous vaginal delivery in addition to their previous CS[81-85].

Gestation and birth weight

The incidence of low birth weight (< 2500 g) was about 6% in Scotland and 8% in England in 1998[86;87]; it was 6% in the USA in 1999[58]. The proportions of low birth weight babies and preterm babies have increased[88]. This may reflect the increases in multiple pregnancies, the increases in obstetric intervention, the greater registration of births at lower gestation and the increased use of ultrasound estimates of gestational age. The CS rate for preterm singleton cephalic infants is higher than for term infants[1]. Prematurity and restricted fetal growth are risk factors for poor neonatal outcome[89-91]. However, the optimal mode of delivery for the small or immature baby is not clear[5;92]. The evidence that CS improves the outcome is also not conclusive[5;92]. Survival rates for babies born between 27 and 28 weeks gestation have improved, with 88% surviving for 28 days after delivery[91]. This is double the rate of 15 years ago. The prevalence of breech presentation is higher among preterm births compared to births at term and this contributes to the increased risk of CS for preterm births.

Population studies indicate that the risk of stillbirth increases from 1 per 3000 continuing pregnancies at 37 weeks to 3 per 3000 continuing pregnancies at 42 weeks and 6 per 3000 continuing pregnancies at 43 weeks[93].

It has been demonstrated that there is a U shaped relationship between birthweight risk of emergency CS, with increased risk of CS for very large and very small babies when standardised to a given week of gestation[79]. Overall, perinatal mortality rates are lower for larger babies compared to smaller babies however, the risk of death from intrapartum-related factors is higher for large babies than for small babies[94]. It has been postulated that CS could improve the outcome for suspected fetal macrosomia. However, in order for a policy to be effective, fetal size needs to be estimated accurately – all methods currently used to estimate fetal size are poorly predictive, especially for large fetuses[95].

Induction of labour

This is a common procedure within obstetric practice. Overall, in England and Wales, for the period 1980–95, the induction of labour rate varied between 17% and 21%. For women who are healthy and who have an uncomplicated pregnancy, a policy of active induction of labour after 41 weeks compared with expectant management reduces perinatal mortality and results in a reduction in the CS rate[96]. In the USA, higher rates of CS have been observed among women who have induction of labour and this increases with age[65]. However, there was a higher proportion of elective inductions among older women within the study population[65].

Breech presentation

Breech presentation is associated with an increased risk of both cerebral palsy and death[97;98]. This is independent of mode of delivery and gestation. The prevalence of breech reduces with increasing gestational age, with most fetuses turning to cephalic presentation spontaneously. About 3–4% of all pregnancies reach term with a fetus in the breech presentation. A recent randomised controlled trial (RCT) and systematic review provide information on the risks and benefits of planned CS compared with planned vaginal breech delivery[4;99]. The composite measure of perinatal mortality, neonatal mortality or serious neonatal morbidity was lower for planned CS compared with planned vaginal breech delivery (the number of CS needed to prevent one adverse event was 29).

Other clinical features

Maternal height and weight have also been reported to influence risk of CS[31;38;75]. One study reported a 40% decrease in risk of CS for every 10 cm increase in height and a 25% increase in risk of CS for every 10 kg increase in pre-pregnancy weight[75]. The effect of increasing age on risk of CS is also reported to vary with height; the effect of increasing age on CS rates is most apparent among the tallest women[75].

Several studies have demonstrated an increased risk of CS for obese women (maternal pre-pregnancy body mass index more than 30 kg/m^2)[100-106]. One study in the U.S.A. reported that between 1980 and 1999, the proportion of CS that were attributable to obesity had tripled from 3.9% to

11.6%[102]. Regional differences in prevalence of obesity could contribute to some of the observed variation in CS rates.

2.2.3 Women's views

The Changing Childbirth report[107] explicitly conveyed the right of women to be involved in decisions and to have a choice in childbirth. However, there are varying degrees to which individual women want to be actively involved in decision-making. Not all women will want equal partnerships in the decision to deliver by CS, but they should have the opportunity to be involved[108].

It has been proposed that maternal request for CS has been a factor contributing to the observed increases in CS rates. One systematic review of observational studies[44] and seven further studies published since the review examined rates of maternal request for CS[1;45-49;109].

The systematic review included 12 studies with a total of 13,285 pregnant women in Australia[110-112], the Republic of Ireland[113], Sweden[114] and the UK[108;115-118] between 1993 and 2001. The studies used structured questionnaires, structured interviews or reviews of clinical case notes. The rate of maternal request for CS ranged from 1.5%[113] to 28%[111] of all CS. The reported rates of maternal request for elective CS ranged from 5% [108] to 48%[112]. The rate of maternal request for CS in the absence of known current or previous obstetric complications was 0–1%. The predominant reason expressed for wanting a CS was concerns about safety for themselves and the baby. There are a number of explanations for the wide range in rates reported. The timing of data collection varied between studies and women's expectations change over time. Furthermore, there may be recall bias and post hoc rationalisation within retrospective studies. Studies varied in the extent to which they explored other possible reasons for maternal request, either clinical or psychosocial factors such as anxiety surrounding previous birth experiences, safety, psychological trauma or sexual abuse. The studies that were included in the review did not address the quality or amount of information women were given about CS. It is difficult to ascertain the extent to which each request was primarily the woman's decision or how much it was influenced by the attending obstetrician.

Since publication of the review, a further seven studies examining maternal preferences for birth have been published. These were well-conducted prospective studies carried out in Australia[109], the UK[1;46;49], Sweden[47] and Brazil[45;48]. A total of 8,675 pregnant women were surveyed antenatally about their preferences for birth. The largest of these studies were a survey of women attending antenatal clinics in Sweden (n=3061)[47] and a survey of women's views of childbirth carried out within the National Sentinel CS Audit (n=2475)[1]. The rates of preference for CS expressed by the women surveyed in UK, Australia and Sweden ranged from 5% to 8%[1;46;47;109]. In Brazil, where CS rates are higher (30% in public sector, 70% in private sector; 25% of all births are in the private sector), about 10% of women expressed a preference for CS in the antenatal period[48]. Another study[119] showed that in Brazil, rates of preference for CS varied according to socio-economic status, with rich women more likely to have a CS. Fear of substandard care was the reason for many requests for CS. It has also been reported that the concept of 'keeping the anatomy intact' and the desire for sterilisation at the time of CS also contribute to more acceptance of CS among women in Brazil[42]. Another factor that may contribute to some women's preference for CS is the reduced risk of urinary incontinence associated with planned CS[1;120].

Within these studies[1;47;109] there was a consistent relationship between women's preference for CS and previous CS, previous negative birth experience, a complication in the current pregnancy, or a fear of giving birth. The main reason given for preference for CS was that it was perceived to be safest for the baby. The main reason given by those who expressed a preference for vaginal birth was the experience of a natural event.

2.2.4 Organisational factors specific to maternity units

A number of organisational and staffing factors are known to be associated with both the CS rate and the quality of care that women receive. The organisational factors that have been evaluated with respect to their association with CS rate include[38;50;121;122]:

- size of maternity unit as assessed by the annual delivery rate
- presence of a neonatal intensive care unit (NICU) or perinatal services
- being a tertiary referral centre

- affiliation with a medical school
- 24-hour availability of an anaesthetist.

These factors are not independent of each other or of the clinical characteristics of the population for which they provide care, i.e. hospitals with Neonatal Intensive Care Units (NICU) tend to have higher annual delivery rates and care for women at higher risk of an adverse outcome.

In the USA, lower CS rates have been reported for hospitals with residency programmes compared with those that do not[123]. Obstetricians in the USA are also up to three times more likely to deliver women by CS compared with family physicians[124]. CS rates in the private sector have also been reported to be much higher compared with the public sector[78]. The type of medical insurance cover in the USA[69;73;125] and Brazil[70] has also been evaluated as a factor associated with CS rates.

Evidence from a systematic review of RCTs has shown that continuous support of women in labour reduces the CS rate and the use of analgesia in labour[51-53]. Continuous support within these trials was provided by both healthcare professionals and lay people (trained 'doulas', friends or family members). The importance of one-to-one support during labour has been highlighted in the national evidence-based guideline for CS[16].

A study of maternity units in London (Thames region) between 1994 and 1996 showed that higher levels of junior doctor staffing on maternity units were associated with lower CS rates[126].

2.2.5 Views of obstetricians within a maternity unit

Surveys have shown that obstetricians express a higher rate of preference for CS for themselves or their partners compared with other groups. Surveys in the UK and in Brazil have concluded that doctors underappreciate their influence on women's decision-making[55;56]. An evaluation of differences between maternity units with low CS rates and those with higher rates revealed that a belief and pride in a low CS rate and a culture of birth as a normal physiological process were important attitudinal factors[127]. CS rates and intrapartum-management strategies have been shown to vary between clinicians[128-130]. In addition, there are inconsistencies in decision-making between clinicians and, given the same information at different times, the same clinician may not act consistently[25;131]. Such variation in practice may reflect clinical uncertainty about the magnitude and direction of risk–benefit of CS in different clinical situations.

A number of studies have evaluated the effect of specific characteristics of clinicians (gender, experience, type of practice, academic interest) to see if these were associated with differences in CS rate[130;132-138]. Some factors (e.g. age) have not been consistently shown to be associated with higher CS rates. Recent medico legal claims have been associated (though not consistently) with higher CS rates[25;139]. It has been postulated that guidelines, training, continuous education and intraprofessional monitoring can help foster less dependence on CS as a 'litigation-proof' choice over vaginal birth[25]. Other factors such as being less experienced and male gender (of the obstetrician) are more consistently associated with a higher rate of CS[130;135].

The Federation of International Obstetricians and Gynaecologists (FIGO) has reviewed maternal request as an indication for CS and has concluded that, because no net benefit exists, performing a CS for non-medical reasons is not justified[140]. However, a survey of consultants' response to maternal request for CS suggests that two out of three would agree to perform a CS for this indication[141]. The national evidence-based guideline for CS states that maternal request is not, on its own, an indication for CS and recommends that specific reasons for the request should be explored and discussed[16].

3 Demographic and clinical characteristics of women in the NSCSA

This chapter provides a description of the data on women who gave birth during phase 1 of the NSCSA. The overall distribution of demographic and clinical characteristics of women in England and Wales is presented, together with CS rates according to these characteristics. Regional distributions have been published in the NSCSA report[1].

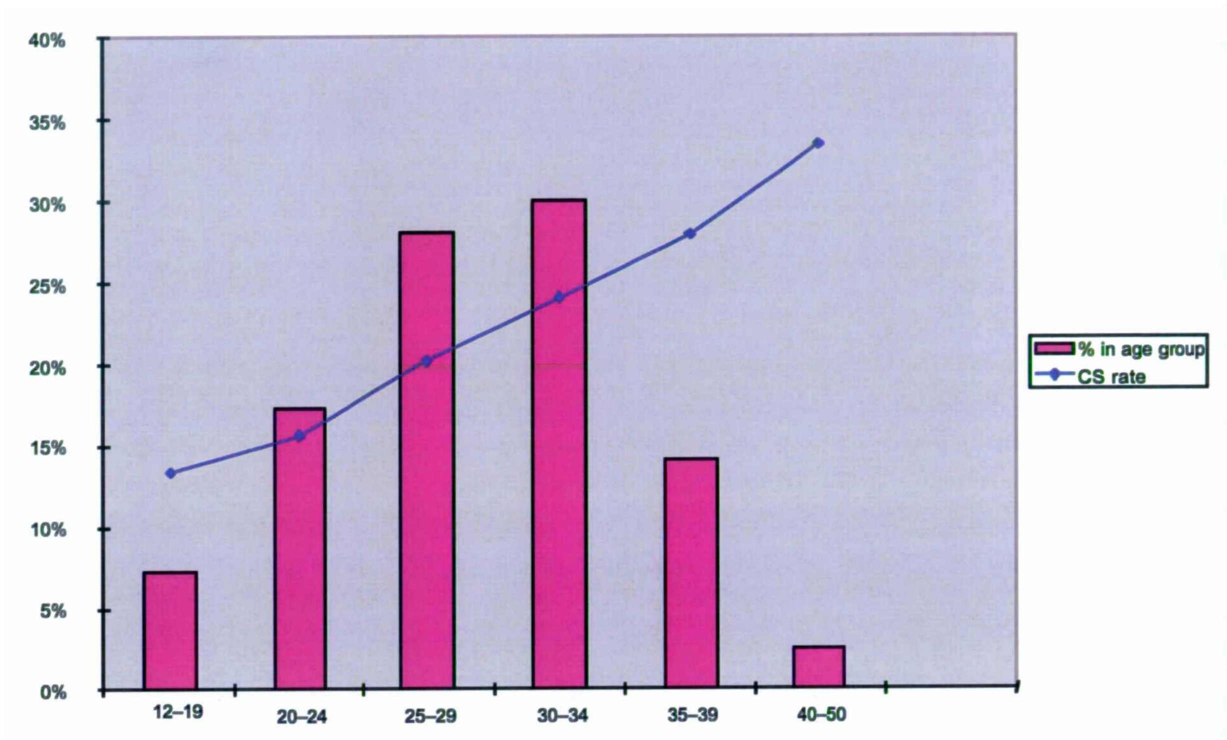
3.1 Mode of delivery

During phase 1, 21% of pregnancies in England and Wales were delivered by CS. This is almost double the rate that was observed a decade ago in England and Wales[13]. Eleven percent of women had instrumental vaginal deliveries, of which 3.5% were with forceps and 7.4% were Ventouse deliveries. Although the rate of Ventouse deliveries has been increasing over the last decade, between 1994 and 1995 there were still more deliveries carried out with forceps than using ventouse[13]. These findings indicate a substantial change in practice compared with previous findings[1;87].

3.2 Age

Data on women's age at childbirth followed an approximate normal distribution with mean 29 years (standard deviation (sd) 5.9 years). The following figure shows the distribution of women according to age categories and the CS rate within each category.

Figure 3.2.1: Women's age and CS rate



The average age of women giving birth (29 years) was consistent with the trend of increasing age at childbirth over the last decade (the average age in 1988 was 27.2 years, rising to 28.9 years in 1999)[14;142]. However, there is geographical variation in this. Women in Southern regions of England were slightly older (30 years) compared with an average age of 28 years for women in Northern regions of England and in Wales[1]. The CS rate was higher for women who were older; it was 13% for women under 20 years of age and 33% for women between 40 and 50 years.

3.3 Ethnicity

The majority of women in England and Wales were reported to be White, 3% were Pakistani, 2% were Indian, 2% were Black African and 1% were Black Caribbean as shown in table 3.31. These proportions varied with region, for example, greater ethnic diversity was observed in London[1]. The CS rate varied between ethnic groups, from 18% among Pakistani women to 31% among Black African women. Ethnicity was not known for less than 1% of women in the dataset.

Table 3.3.1: Women's ethnicity and CS rate

Women's ethnicity	N=150,139 (%)	CS rate (%)
White	84.3	21.3
Black African	2.0	31.3
Black Caribbean	1.3	24.2
Black Other	0.9	23.6
Bangladeshi	0.7	18.7
Indian	2.5	22.7
Pakistani	3.1	18.1
Chinese	0.8	18.8
Asian Other	1.4	23.7
Other	2.1	21.1
Not Known	0.2	16.2
Missing	0.7	17.5

3.4 Parity and previous CS

Forty-one percent of women had no previous pregnancies. The mean age at first pregnancy was 27 years (SD: 5.9 years). Average age at second pregnancy was 29 years (SD: 5.4 years) and 31 years (SD: 5.2 years) at third pregnancy. Of the 3680 women who were between 40 and 50 years of age, 22% were in their first pregnancy.

Sixteen percent of women who were reported to be in their second pregnancy had had a previous CS. Of women who were reported to be in their third pregnancy, 10% had had one previous CS and 6% had had two previous CS. Nine percent of women had had at least three previous pregnancies of whom the majority (83%) had no previous CS. Table 3.4.1 shows the proportion of women according to previous deliveries.

Table 3.4.1: Previous deliveries of women in phase 1 NSCSA (n=150,139)

Previous deliveries	Proportion of all women (%)	CS rate (%)
None	41.4	24.2
Vaginal births only	48.6	10.3
CS only	6.6	74.6
Vaginal births and CS	2.7	49.3
Not known	0.6	19.1

Ten percent of all women had CS before labour (8% of women with no previous deliveries, 5% of women with previous vaginal deliveries only, 54% of women with previous CS only, and 36% of women with previous vaginal births and previous CS).

Twelve percent of women in labour had CS (18% of women with no previous deliveries, 5% of women with previous vaginal deliveries only, 44% of women with previous CS only, and 21% of women with previous vaginal births and previous CS).

3.5 Gestation and number of babies born

The majority of pregnancies (n=137,493; 92%) were singleton of at least 37 weeks gestation as shown in table 3.5.1. About 1.5% of all pregnancies were multiple, including 59 sets of triplets and one set of quadruplets. About 52% of twin pregnancies delivered before 37 weeks gestation, and 92% had delivered before 39 weeks. Thirteen percent of twin and 36% of triplet pregnancies compared with less than 2% of singleton pregnancies were delivered before 33 weeks gestation. This means that of the 3,124 babies who potentially required special care baby unit (SCBU) facilities, 661 (21.2%) were from multiple pregnancies.

Table 3.5.1: Gestation (all pregnancies) (n=150,138*)

Gestation (weeks)	< 28	28–32	33–36	37–42	> 42	Missing	Total
Singleton pregnancies	751 (0.51%)	1712 (1.16%)	7552 (5.11%)	137414 (92.90%)	79 (0.05%)	413 (0.28%)	147921 (100%)
Twin pregnancies	75 (3.48%)	224 (10.38%)	828 (38.37%)	1024 (47.45%)	0	7 (0.32%)	2158 (100%)
Triplet pregnancies	4 (6.78%)	17 (28.81%)	38 (64.41%)	0	0	0	59 (100%)

*excludes the single quadruplet pregnancy

Table 3.5.2: Mode of delivery by gestational age categories for singleton pregnancies (n=147,921)

Mode of delivery	Spontaneous vaginal	CS	Ventouse	Forceps	Vaginal breech	Missing	Total
Gestation (weeks)							
< 28	370	227	4	9	125	16	751
	(49.27%)	(30.23%)	(0.53%)	(1.20%)	(16.64%)	(2.13%)	(100%)
28–32	677	916	18	32	55	14	1712
	(39.54%)	(53.50%)	(1.05%)	(1.87%)	(3.21%)	(0.82%)	(100%)
33–36	4222	2719	250	249	77	35	7552
	(55.91%)	(36.00%)	(3.31%)	(3.30%)	(1.02%)	(0.46%)	(100%)
37–42	94056	26948	10610	4860	311	629	137414
	(68.45%)	(19.61%)	(7.72%)	(3.54%)	(0.23%)	(0.46%)	(100%)
> 42	61	11	4	3	0	0	79
	(77.22%)	(13.92%)	(5.06%)	(3.80%)			(100%)
Missing data	282	82	27	20	0	2	413
	(68.28%)	(19.85%)	(6.54%)	(4.84%)		(0.48%)	(100%)

For singleton pregnancies, the CS rate was higher for pregnancies delivered by CS at gestation less than 37 weeks compared with pregnancies of at least 37 weeks gestation (see table 3.5.2). For pregnancies less than 37 weeks, the CS rate was lower with increasing gestation (53.5% for 28–32 weeks gestation, 36.0% for 33–36 weeks gestation).

Fifty-five percent of all twin pregnancies were delivered by CS. CS was performed for delivery of second twin in 3.5% of twin pregnancies. Fifty-four of the 59 sets of triplets were delivered by CS. All three babies in three sets were delivered vaginally, the second and third triplet were delivered by CS in one set following a spontaneous vaginal delivery for the first triplet. Mode of delivery was missing for one set of triplets. There were no instrumental vaginal deliveries for triplet pregnancies.

3.6 Onset of labour

Onset of labour was induced for 22% of pregnancies (18% were inductions without spontaneous rupture of membranes (SROM), 4% with SROM). The majority of inductions without SROM (95%) took place when gestational age was at least 37 weeks. Four percent of these inductions took place at 33 – 36 weeks gestation. Of these 1101 pregnancies, 5% were induced before 34 weeks, 11% between 34 and 35 weeks, 36% between 35 and 36 weeks and 48% between 36 and 37 weeks gestation. The majority of inductions with pre-labour SROM took place at 37 – 42 weeks and 10% occurred at 33–36 weeks gestation.

Forty-two percent of twin pregnancies had spontaneous onset of labour. Fewer than 50% of triplet pregnancies were in labour prior to delivery. Median gestational age for twin pregnancies delivered by CS prior to labour onset was 37 weeks (IQR: 35, 38 weeks). For triplet pregnancies, the median gestational age was 34 weeks (IQR: 33, 34 weeks). The only quadruplet pregnancy in this dataset was delivered by CS prior to onset of labour at 33 weeks gestation. Tables 3.6.1 and 3.6.2 give information on onset of labour according to gestational age for singleton and multiple pregnancies.

Table 3.6.1: Onset of labour according to gestation for singleton pregnancies (n=147,921)

Singleton pregnancies						
	Labour onset					
Gestation (weeks)	Spontaneous	Induction not SROM	Induction with SROM	CS before labour	Missing	Total
< 28	417	158	24	142	10	751
	(55.53%)	(21.04%)	(3.20%)	(18.91%)	(1.33%)	(100%)
28–32	810	133	62	698	9	1712
	(47.31%)	(7.77%)	(3.62%)	(40.77%)	(0.53%)	(100%)
33–36	4317	985	538	1662	50	7552
	(57.16%)	(13.04%)	(7.12%)	(22.01%)	(0.66%)	(100%)
37–42	93709	25777	4909	12242	777	137414
	(68.19%)	(18.76%)	(3.57%)	(8.91%)	(0.57%)	(100%)
> 42	44	27	3	5	0	79
	(55.70%)	(34.18%)	(3.80%)	(6.33%)		(100%)
Unknown	286	53	19	41	14	413
	(69.25%)	(12.83%)	(4.60%)	(9.93%)	(3.39%)	(100%)

Table 3.6.2: Onset of labour according to gestation for multiple pregnancies

Twin pregnancies n=2158						
	Labour onset					
Gestation (weeks)	Spon	Induction not SROM	Induction with SROM	CS before labour	Missing	Total
< 28	59 (78.67%)	3 (4.00%)	3 (4.00%)	8 (10.67%)	2 (2.67%)	75 (100%)
28–32	143 (63.84%)	6 (2.68%)	7 (3.13%)	65 (29.02%)	3 (1.34%)	224 (100%)
33–36	407 (49.15%)	14 (13.77%)	24 (2.90%)	275 (33.21%)	8 (0.97%)	828 (100%)
37–42	285 (27.83%)	338 (33.01%)	31 (3.03%)	362 (35.35%)	8 (0.78%)	1024 (100%)
Unknown	3 (42.86%)	1 (14.29%)	0	3 (42.86%)	0	7 (100%)
Triplet pregnancies n=59						
	Labour onset					
Gestation (weeks)	Spon	Induction not SROM	Induction with SROM	CS before labour	Missing	Total
< 28	3 (75.00%)	0	1 (25.00%)	0	0	4 (100%)
28–32	10 (58.82%)	0	0	6 (35.29%)	1 (5.88%)	17 (100%)
33–36	8 (21.05%)	2 (5.26%)	0	28 (73.68%)	0	38 (100%)

Spon, spontaneous

Of all singleton pregnancies delivered by CS, 48% were delivered prior to onset of labour, 20% following induced labour with or without SROM and 31% following spontaneous onset of labour. Of the CS carried out prior to onset of labour, 83% were 37–42 weeks gestation and 11% were 33–36 weeks gestation. Nineteen percent of term singleton pregnancies that were induced had a caesarean delivery

3.7 Presentation

Ninety-six percent of singleton pregnancies of at least 37 weeks gestation were cephalic presentation, 3% presented with a breech. The next table shows presentation by gestational age for singleton pregnancies.

Table 3.7.1: Gestational age by presentation for singleton pregnancies (n=147,921)

Gestation (weeks)	< 28	28–32	33–36	37–42	> 42	Missing	Total
Presentation							
Cephalic	500	1351	6899	132557	75	397	141779
	(0.35%)	(0.95%)	(4.87%)	(93.50%)	(0.05%)	(0.28%)	(100%)
Breech	230	311	571	4293	4	11	5420
	(4.24%)	(5.74%)	(10.54%)	(79.21%)	(0.07%)	(0.20%)	(100%)
Transverse/oblique	15	43	76	447	0	1	582
lie	(2.58%)	(7.39%)	(13.06%)	(76.80%)		(0.17%)	(100%)
Missing	6	7	6	117	0	4	140
	(4.29%)	(5.00%)	(4.29%)	(83.57%)		(2.86%)	(100%)

A higher proportion of pregnancies presenting with a breech were delivered before 36 weeks gestation (21%) compared with 6% of pregnancies with cephalic presentation.

Table 3.7.2: Mode of delivery by onset of labour for term singleton cephalic pregnancies (n=132,632)

Mode of delivery	Spontaneous vaginal delivery	CS	Ventouse	Forceps	Missing data	Total
Labour onset						
Spontaneous	73374 (79.49%)	7612 (8.25%)	7506 (8.13%)	3354 (3.63%)	458 (0.50%)	92304 (100%)
Induction not SROM	17083 (66.71%)	4736 (18.49%)	2472 (9.65%)	1215 (4.74%)	101 (0.39%)	25607 (100%)
Induction with SROM	3136 (64.62%)	925 (19.06%)	517 (10.65%)	252 (5.19%)	23 (0.47%)	4853 (100%)
CS before labour		9127 (100%)				9127 (100%)
Missing	524 (70.72%)	107 (14.44%)	78 (10.53%)	26 (3.51%)	6 (0.81%)	741 (100%)

For term singleton cephalic pregnancies, CS rates were 8% for women who had spontaneous onset of labour, and 18.5% for women who had induction of labour. Rates of ventouse delivery were 8% for women who had spontaneous onset of labour and 10% for women who had induction of labour. The rates of delivery with forceps were lower at 5% for women who had induction of labour (see table 3.7.2).

Ninety-one percent of singleton term breech pregnancies were delivered by CS. Seventy-one percent of these deliveries occurred prior to onset of labour, 25% following a spontaneous onset of labour, 4% following an induction of labour either with or without SROM.

3.8 Birth weight

Nearly 3% of term singleton pregnancies delivered a baby weighing not more than 2500 g, 84% weighed 2501–4000 g and 13% weighed more than 4000 g (see Table 3.8.1). Thirty-four percent (n=1357) of the 4019 pregnancies delivered by CS with birth weight greater than 4000 g were delivered prior to onset of labour.

Table 3.8.1: Birth weight categories and mode of delivery for term singleton cephalic pregnancies (n=132,632)

Mode of delivery	Spontaneous vaginal delivery	CS	Ventouse	Forceps	Missing data	Total
Birth weight categories						
≤ 2500 g	2218 (2.36%)	776 (3.45%)	242 (2.29%)	83 (1.71%)	8 (1.34%)	3327 (2.51%)
2501–4000 g	80139 (85.15%)	17830 (79.25%)	9013 (85.25%)	3998 (82.48%)	499 (83.72%)	11479 (84.05%)
> 4000 g	11113 (11.81%)	3677 (16.34%)	1252 (11.84%)	724 (14.94%)	85 (14.26%)	16851 (12.71%)
Missing data	647 (0.69%)	216 (0.96%)	66 (0.62%)	42 (0.87%)	4 (0.67%)	975 (0.74%)
Total	94117 (100%)	22499 (100%)	10573 (100%)	4847 (100%)	596 (100%)	132632 (100%)

Among babies delivered from women with term singleton cephalic pregnancies who had spontaneous onset of labour, 11% of those weighing 2501–4000 g were delivered by CS compared with 12% of those weighing more than 4000 g. Among pregnancies where labour was induced (without SROM), the CS rate was 21% for babies weighing 2501–4000 g compared with 24% for babies weighing more than 4000 g. However, instrumental vaginal delivery rates were similar for both weight categories (12% in those with spontaneous onset of labour and 14% in those who had labour induced).

4 Factors associated with delivery by CS for individual women

It is known that some of the variation in CS rates between maternity units can be attributed to differences in population and clinical characteristics. For example, CS rates increase with maternal age, and age at childbirth varies between regions. Therefore, CS rates need to be adjusted for demographic and clinical characteristics (case-mix) before valid comparisons can be made between maternity units[29;63;143].

This chapter describes the development of a statistical model to obtain expected probabilities of CS for individual women. The primary purpose of this model is to explain the relationships between various characteristics and odds of CS for individual women. The expected number of CS (derived from the sum of expected probabilities of CS obtained from the model) is then compared with the observed number of CS that took place within a maternity unit in order to calculate standardised CS rates for individual maternity units (see chapter 5).

This analysis was restricted to singleton pregnancies (n=147,087) as the mode of delivery for multiple pregnancies is dependent on several additional factors such as presentation of each baby in the pregnancy, and each baby within a multiple pregnancy is not independent of the others. A two-stage modelling process using logistic regression was adopted. First, a logistic regression model was developed to investigate the relationship between the case-mix variables and odds of CS before labour for all women. A second logistic regression model was then developed to investigate the relationship between the case-mix variables and odds of CS for women in labour. The rationale for this is explained below.

Ten percent of women in phase 1 had CS before the onset of labour. This varies between maternity units (IQR: 8%, 10%; range: 4 – 59%). Among the remaining women who went into labour, the CS rate was 12% (between maternity units IQR: 10%, 14%; range: 0.9 – 21%). Preliminary analysis of these NSCSA data showed that the relationship between previous CS and odds of CS in the index pregnancy is different for women who had CS before labour and those who had CS during labour. A two-stage modelling process using logistic regression was therefore adopted to allow for differences in the relationship between the case-mix variables and (i) CS before labour, and (ii) CS during labour. As the CS before labour rate varies between maternity units, it is important to model the two outcomes (CS before labour and CS during labour) separately and then combine predicted probabilities to obtain overall expected numbers for each maternity unit. The use of a statistical model that does not distinguish between CS before and during labour will produce coefficients that vary between maternity units according to the proportion of women who have CS before labour or CS during labour within the unit.

The demographic and clinical explanatory variables (case-mix) that were included in the analysis were:

- women's age
- ethnicity

- previous vaginal deliveries
- previous CS
- gestational age
- induction of labour (only for women in labour)
- presentation
- birth weight.

As shown in chapter 3, CS rates vary according to each of these explanatory variables. For example, women who were older, those with previous CS and those giving birth before 37 weeks gestation had higher CS rates. CS rates were also higher for women who had induction of labour and those who delivered babies that weighed over 4000 g. Although, as described in chapter 2, there are other demographic and clinical factors (such as socio-economic status and body mass index) that have been shown to be associated with risk of CS, these data were not collected in the NSCSA for all women giving birth. Data on body mass index are available only for women who had CS.

The primary aim of this work is to adjust the CS rates of maternity units for case-mix. The logistic regression models described in this chapter have limited value in terms of predicting CS for individual women as not all of the variables used (e.g. birth weight) are known before delivery. The results presented in this chapter are not suitable for use in an antenatal setting to predict an individual woman's risk of CS in an ongoing pregnancy because it is not possible to predict birth weight. Ideally, to assess the impact of other risk factors one would want to adjust for the size of the baby at a standard gestational age. However, since such a measure is not available, there is a case for using a surrogate for this such as birth weight and gestational age. Therefore, these results that are adjusted for birth weight are useful in explaining current practice in England and Wales, with regard to the relationship between case-mix variables and CS. This gives an understanding of how the different case-mix factors affect an individual woman's odds of CS and subsequently impact on the CS rate.

Section 4.1 describes the univariate relationship between case-mix variables and CS before and during labour. These results were used to determine how some of the variables were categorised in subsequent models. The change in these relationships after adjusting for other variables in a multiple logistic regression model is also presented.

Clinically, it is possible that there are interactions between some of the case-mix variables included in the logistic regression models for CS before and during labour. For example, the relationship between maternal age and CS may vary according to the number of previous vaginal deliveries. In section 4.2, the strategy for choosing interactions for inclusion is described. Assessment of the goodness of fit of these models helped to inform the choice of the interaction terms in the final explanatory logistic regression models for CS before and during labour (see section 4.2.2). To further investigate the fit of the model and to judge the overall discriminatory power of the model, the expected probabilities obtained from the models for CS before labour and CS during labour were examined (section 4.2.3). The results of the final logistic regression models for CS before and during labour are presented in section 4.2.4.

The relationships between the explanatory variables and CS before and during labour are discussed in section 4 .3.

In chapter 5, the information from both models is combined to derive expected numbers of CS for individual maternity units, in order to compute a standardised CS rate.

4.1 Univariate and multiple logistic regression models

In this section, firstly the univariate relationships between case-mix variables and (i) CS before labour, and (ii) CS during labour are presented. The change in these relationships after adjusting for other variables in a multiple logistic regression model (on a logit scale) is also presented.

4.1.1 Methods

For a) all women, and b) women who went into labour, logistic regression models were first fitted univariately, with a) CS before labour, and b) CS among women in labour as outcome variables, to investigate the main effect of each of the case-mix variables. For some variables (e.g. previous vaginal deliveries and gestational age) the univariate relationships determined the way in which the variable was used in the final logistic regression models.

A multiple logistic regression model that included all the demographic and clinical explanatory variables was then fitted to investigate the main effect of each of these variables having adjusted for the others. Robust standard errors were obtained to account for clustering within maternity units[144].

4.1.2 Results

CS before labour (univariate and adjusted odds ratios)

Women's age and CS before labour

The odds of CS before labour increased with age, those who were in age categories less than 25 years were 32–52% less likely to deliver by CS before labour while those in age categories above 29 years were more likely to deliver by CS before labour (see table 4.1.2.1). To investigate the linearity of this relationship, a model that included age as a continuous variable (centred on 30 years) as well as in categories was compared with a similar model that excluded age in categories. The Wald test showed that the inclusion of age in categories improved the fit of the model to the data, although this was of borderline statistical significance ($\chi^2(5)=11.00$, $p=0.05$). However, as there was no practical departure from (log) linearity, age was included in the multiple regression model as a continuous variable. For every 1-year increase in age, there was a 7% increase in odds of CS before labour (odds ratio (OR): 1.07 95% confidence interval (CI): 1.07, 1.08).

After adjusting for ethnicity, previous vaginal delivery, previous CS, gestation, presentation and birth weight, the association between age and odds of CS before labour was marginally reduced (see table 4.1.2.3).

Table 4.1.2.1: Univariate association between age in categories and CS before labour (n=146,238)

Age (years)	Odds ratio	95% CI
12–19	0.48	0.43, 0.53
20–24	0.69	0.65, 0.73
25–29	1.00	
30–34	1.40	1.34, 1.47
35–39	1.84	1.74, 1.94
40–50	2.62	2.38, 2.89
Missing data	1.34	1.11, 1.62

Previous vaginal deliveries and CS before labour

The following table shows how the odds of CS before labour vary with the number of previous vaginal deliveries.

Table 4.1.2.2: Univariate association between number of previous vaginal deliveries and CS before labour (n=146,238)

Number of previous vaginal deliveries	Odds ratio	95% CI
0	1.00	
1	0.46	0.44, 0.48
2	0.40	0.37, 0.43
> 3	0.43	0.40, 0.46
Missing data	0.71	0.54, 0.93

A history of at least one previous vaginal delivery had a protective effect against CS before labour in the current pregnancy, and the additional impact of a second or third previous vaginal delivery was negligible. Therefore, this variable was re-categorised as a binary variable with either no previous vaginal deliveries or at least one previous vaginal delivery. In univariate analysis, the 'protective' effect of a previous vaginal delivery was a 56% decrease in odds of CS before labour. After adjusting for other variables including previous CS, women who had had at least one previous vaginal delivery had a 42% decrease in odds of delivery by CS before labour in the index pregnancy, compared with women who did not have previous vaginal deliveries or previous CS. This difference is explained by the fact that the comparator group in the univariate analysis is women who did not have a previous vaginal delivery, including some women who had a previous CS.

Previous CS and CS before labour

The odds of CS before labour in the index pregnancy for women who had had one previous CS was about 12 times higher in univariate and multivariate analyses compared with women who had not had a previous CS (see table 4.1.2.3). The magnitude of this odds ratio was quite large, as 6% of women who had not had a previous CS compared with 43% and 83% of women who had had one or at least two previous CS respectively had CS before labour in this pregnancy.

Ethnicity and CS before labour

The results of univariate analysis show that women who were reported to be Black African had a 23% increase in odds of CS before labour compared with women reported to be White. For Bangladeshi, Pakistani and Chinese women, the odds of CS before labour were reduced by 26%, 20% and 36% (see table 4.1.2.3).

However, 9% of White women compared with 16% of Black African women had had a previous CS. Women who had had a previous CS were more likely to deliver by CS in the index pregnancy. Hence, multivariate analysis showed that after adjustment for previous CS, Black African women were less likely to deliver by CS before labour compared with White women (see table 4.1.2.3). Black Caribbean, Indian and Other Asian women were also less likely to have CS before labour. For Bangladeshi and Chinese women, the magnitudes of odds ratios were only marginally reduced following adjustment for other variables; for Pakistani women, there was a 20% decrease in odds of CS before labour in univariate analysis; and a 32% decrease in odds of CS before labour (compared with White women) following adjustment for other characteristics.

Gestation, presentation and CS before labour

In univariate analysis, the odds of CS before labour for pregnancies above 42 weeks gestation was not significantly increased when compared with pregnancies delivered at 37–42 weeks gestation (OR: 0.68; 95% CI: 0.80, 1.70). Hence, to simplify the model, the reference group (37–42 weeks gestation) was recoded to include pregnancies delivered after 42 weeks gestation.

The odds ratios for gestational age categories were much lower after adjusting for presentation compared with those in univariate analysis (see table 4.1.2.3). For example, the odds ratio for delivery by CS before labour for gestational age category 28–32 weeks was 7.14 (95% CI: 6.48, 7.87) in univariate analysis and

4.51 (95% CI: 3.76, 5.42) in multivariate analysis (reference group at least 37 weeks gestation). This is because the prevalence of breech presentation is higher at lower gestational ages, and the majority of breech babies (60%) were delivered by CS before labour.

Birth weight and CS before labour

In univariate analysis, babies who weighed less than 2500 g were three times more likely to be delivered by CS before labour. After adjustment for gestational age, there was an 80% increase in odds of CS before labour for these babies (see table 4.1.2.3).

Table 4.1.2.3: Univariate and multivariate associations between each variable and the odds of CS before labour

Variable	Univariate odds ratio	95% CI	Multivariate odds ratio (n=144,993)	95% CI
Mother's age (years) (n=144,993)				
	1.07	1.07, 1.08	1.06	1.05, 1.06
Mother's ethnicity (n=146, 238)				
White (n=12330)	1.00		1.00	
Black African (n=2872)	1.23	1.09, 1.39	0.85	0.73, 0.99
Black Caribbean (n=1898)	0.92	0.78, 1.08	0.75	0.62, 0.92
Black Other (n=1367)	1.00	0.81, 1.23	1.00	0.82, 1.23
Bangladeshi (n=1091)	0.74	0.62, 0.89	0.75	0.60, 0.94
Indian (n=3643)	0.91	0.79, 1.06	0.82	0.70, 0.97
Pakistani (n=4557)	0.80	0.72, 0.90	0.68	0.59, 0.79
Chinese (n=1101)	0.64	0.50, 0.81	0.63	0.45, 0.88
Asian Other (n=2034)	0.89	0.76, 1.04	0.78	0.63, 0.96
Other (n=3039)	0.84	0.72, 0.97	0.79	0.67, 0.93
Not Known (n=355)	0.66	0.43, 1.01	0.70	0.45, 1.09
Missing data (n=961)	0.74	0.57, 0.97	0.72	0.54, 0.97
Number of previous vaginal deliveries (n=146,238)				
0 (n=70041)	1.00		1.00	
≥ 1 (n=75138)	0.44	0.42, 0.46	0.58	0.55, 0.61
Missing data (n=1059)	0.71	0.55, 0.93	0.88	0.44, 1.78
Number of previous CS (n=146,238)				
0 (n=131550)	1.00		1.00	
1 (n=11563)	11.69	11.03, 12.39	12.96	12.10, 13.89
≥ 2 (n=2195)	77.30	68.80, 86.84	88.23	77.53, 100.42
Missing data (n=930)	1.93	1.46, 2.55	1.67	0.78, 3.60
Gestation (weeks) (n=146,238)				
< 28 (n=724)	2.47	2.04, 3.00	0.41	0.27, 0.63
28–32 (n=1688)	7.14	6.48, 7.87	4.51	3.76, 5.42
33–36 (n=7464)	2.89	2.72, 3.08	2.32	2.10, 2.55
≥ 37 (n=135964)	1.00		1.00	
Missing data (n=398)	1.16	0.80, 1.70	1.07	0.69, 1.66

Table 4.1.2.3 (cont'd): Univariate and multivariate associations between each variable and the odds of CS before labour

Presentation (n=146,238)				
Cephalic (n=140201)	1.00		1.00	
Breech (n=5337)	18.08	16.85, 19.39	26.34	24.08, 28.81
Transverse (n=577)	22.29	18.74, 26.53	21.87	17.05, 28.05
Missing data (n=123)	7.45	5.25, 10.58	7.10	4.40, 11.45
Birth weight (g) (n=146,238)				
≤ 2500 (n=8522)	3.00	2.81, 3.19	1.81	1.63, 2.01
2501–4000 (n=118695)	1.00		1.00	
> 4000 (n=17166)	0.86	0.80, 0.92	0.99	0.92, 1.06
Missing data (n=1855)	2.31	1.98, 2.68	1.79	1.42, 2.27

CS during labour (univariate and adjusted odds ratios)

Woman's age and CS during labour

For women in labour, the odds of having a CS increased with age: those who were in age categories less than 25 years were 20–25% less likely to deliver by CS while those in age categories above 29 years were more likely to deliver by CS. The results were largely unaltered after adjusting for ethnicity, previous vaginal delivery, previous CS, gestation, onset of labour, presentation and birth weight. As described in the analysis for CS before labour, a model that included age as a continuous variable as well as age in categories was compared with a similar model that excluded age in categories, to investigate the linearity of this relationship. The Wald test showed that the model that included age in categories provided a statistically significantly better fit to the data ($\chi^2(5)=20.17$, p<0.01). However, the departure from linearity was minor. When age was included as a continuous variable centred on 30 years, there was a 5% increase in odds of CS for every 1-year increase in age (OR: 1.05; 95% CI: 1.04, 1.06).

Ethnicity and CS during labour

Table 4.2.1.4: Univariate association between ethnicity and CS as mode of delivery for women in labour

Women's ethnicity (n=131,479)	Odds ratio	95% CI
White	1.00	
Black African	1.99	1.80, 2.20
Black Caribbean	1.36	1.18, 1.56
Black Other	1.24	1.08, 1.42
Bangladeshi	0.99	0.78, 1.26
Indian	1.20	1.04, 1.39
Pakistani	0.86	0.76, 0.98
Chinese	1.04	0.88, 1.23
Asian Other	1.37	1.19, 1.57
Other	1.13	1.00, 1.27
Not Known	0.77	0.50, 1.19
Missing	0.81	0.65, 1.02

Univariate analysis showed that women in labour who were reported to be Black African were twice as likely to have a CS compared with women reported to be White. Women who were reported to be Black Caribbean or Black Other had about 36–24% higher odds of having a CS.

Having adjusted for age, previous vaginal deliveries, previous CS and clinical characteristics such as gestation, presentation, mode of onset of labour and birth weight, the odds ratio of CS for Black African women in labour was double that for White women. For Black Caribbean women in labour the odds ratio was increased by 67%. For Bangladeshi, Indian and Pakistani women in labour it was increased by 26%.

Previous vaginal delivery, previous CS and CS during labour

The following table shows how the odds of having a CS varied according to the number of previous vaginal deliveries.

Table 4.2.1.5: Univariate association between number of previous vaginal deliveries and CS as mode of delivery for women in labour

Number of previous vaginal deliveries (n=131,479)	Odds ratio	95% CI
0	1.00	
1	0.27	0.26, 0.28
2	0.22	0.20, 0.24
≥3	0.25	0.23, 0.27
Missing data	0.40	0.31, 0.52

The magnitudes of odds ratios according to number of previous vaginal deliveries were similar, suggesting that a history of at least one previous vaginal delivery had a protective effect against a CS in the current pregnancy, and the additional impact of a second or third previous vaginal delivery is negligible. Therefore, as in the analysis for CS before labour, this variable was recategorised as a binary variable (no previous vaginal deliveries, at least one previous vaginal delivery). After adjusting for other variables including previous CS, women in labour who had at least one previous vaginal delivery were 79% less likely to deliver by CS in their current pregnancy.

The odds ratio of delivering by CS in the current pregnancy for women in labour who had one previous CS compared with women with no previous CS was four-fold higher in univariate analysis; for women who had at least two previous CS, it was 19 times higher. These odds ratios were similar after adjusting for other variables including previous vaginaldelivery.

Gestation, presentation and CS during labour

The odds ratios presented for gestational age categories are much lower after adjusting for presentation compared with those in univariate analysis. For example, the odds ratio of delivery by CS for gestation category 33–36 weeks was 1.63 (95% CI: 1.51, 1.76) in univariate analysis and 1.21 (95% CI: 1.09, 1.35) in multivariate analysis (reference group gestation 37–42 weeks). This is because the prevalence of breech presentation is higher at lower gestational ages, and the majority of breech babies are delivered by CS.

Induction of labour and CS during labour

The magnitude of odds ratios in univariate and multivariate analyses was similar when comparing inductions of labour with or without SROM with spontaneous onset of labour. Women who had labour induced were twice as likely to deliver by CS compared with women who had spontaneous onset of labour.

Birth weight

In univariate analysis, babies who weighed less than 2500 g had a 78% increase in the odds ratio of CS compared with babies who weighed between 2501 and 4000 g. After adjusting for gestational age, there was a 22% increase in the odds ratio of CS for delivery of these babies. For women who had babies weighing over 4000 g, the odds of CS during labour were double when compared with women whose babies weighed between 2501 and 4000 g.

Table 4.2.1.6: Univariate and multivariate associations between each variable and odds of CS as mode of delivery

Variable	Univariate OR	95% CI	Multivariate OR (n=131,281)	95% CI
Mother's age (years) (n=131,479)				
12–19 (n=10310)	0.75	0.69, 0.81	0.54	0.50, 0.59
20–24 (n=23851)	0.80	0.75, 0.84	0.72	0.68, 0.77
25–29 (n=37470)	1.00		1.00	
30–34 (n=38502)	1.10	1.06, 1.15	1.21	1.15, 1.26
35–39 (n=17400)	1.22	1.16, 1.29	1.48	1.40, 1.58
40–50 (n=2843)	1.37	1.23, 1.52	1.73	1.53, 1.96
Missing (n=1103)	0.81	0.64, 1.03	0.86	0.67, 1.11
Mother's ethnicity (n=131,479)				
White (n=110674)	1.0		1.00	
Black African (n=2518)	1.99	1.80, 2.20	2.30	2.08, 2.55
Black Caribbean/Black Other (n=2945)	1.31	1.18, 1.45	1.67	1.50, 1.86
Bangladeshi/Indian/ Pakistani (n=8479)	1.00	0.92, 1.10	1.26	1.16, 1.38
Chinese (n=1026)	1.04	0.88, 1.23	1.07	0.89, 1.29
Asian Other (n=1847)	1.37	1.19, 1.57	1.58	1.36, 1.83
Other (n=3990)	1.03	0.92, 1.15	1.11	0.99, 1.25
Number of previous vaginal deliveries (n=131,479)				
0 (n=60338)	1.00		1.00	
≥1 (n=70191)	0.25	0.24, 0.27	0.21	0.20, 0.22
Missing data (n=950)	0.40	0.31, 0.52	0.75	0.44, 1.28
Number of previous CS (n=131,479)				
0 (n=123659)	1.00		1.00	
1 (n=6622)	4.11	3.90, 4.33	3.49	3.28, 3.70
≥ 2 (n=370)	19.94	15.46, 25.72	18.10	12.99, 25.23
Missing data (n=828)	0.75	0.56, 1.00	0.44	0.24, 0.78

Table 4.2.1.6 (cont'd): Univariate and multivariate associations between each variable and odds of CS as mode of delivery

Gestation (weeks) (n=131,479)				
< 28 (n=582)	1.23	0.97, 1.56	0.11	0.07, 0.19
28–32 (n=990)	2.04	1.76, 2.37	0.84	0.65, 1.09
33–36 (n=5805)	1.63	1.51, 1.76	1.22	1.10, 1.35
37–42 (n=123671)	1.00		1.00	
> 42 (n=74)	0.66	0.29, 1.52	0.39	0.16, 0.94
Missing data (n=357)	0.86	0.61, 1.24	0.94	0.65, 1.37
Onset of labour (n=131,479)				
Spontaneous (n=98952)	1.00		1.00	
Induction (no SROM) (n=26998)	2.18	2.09, 2.27	2.46	2.36, 2.57
Induction with SROM (n=5529)	2.37	2.15, 2.62	2.34	2.12, 2.59
Presentation (n=131,281*)				
Cephalic (n=129115)	1.00		1.00	
Breech (n=2091)	19.99	17.85, 22.38	35.93	31.57, 40.89
Transverse (n=198)	*		*	
Missing data (n=75)	10.86	6.23, 18.93	8.26	4.21, 16.23
Birthweight (g) (n=131,479)				
≤ 2500 (n=6522)	1.79	1.67, 1.92	1.22	1.11, 1.35
2501–4000 (n=107678)	1.00		1.00	
> 4000 (n=15778)	1.64	1.57, 1.72	1.96	1.86, 2.07
Missing data (n=1501)	1.51	1.30, 1.75	1.43	1.18, 1.73

*n=131,281 as all pregnancies with transverse lie delivered by CS

Summary

In this section the findings of univariate analysis and results from the multiple logistic regression models are summarised particularly in reference to how these relationships determined the way in which certain variables were used in the final logistic regression models.

There was no practical departure from (log) linearity in the relationship between age and odds of CS before and during labour. Therefore, age was included in the final logistic regression models as a continuous variable.

For both CS before and during labour, a history of at least one previous vaginal delivery had a protective effect against CS before or during labour, and the additional impact of more previous vaginal deliveries was negligible. Therefore, previous vaginal delivery was included as a binary variable with either no previous vaginal deliveries or at least one previous vaginal delivery.

For both CS before and during labour, the adjusted odds ratios were similar for Bangladeshi, Indian and Pakistani women. Therefore, these groups were combined in order to simplify the final logistic regression models. The groups 'Not Known', 'Other' and 'Missing data' were also combined because for each of these three categories there is no useful information on ethnicity. For CS before labour, the adjusted odds ratios for Black African and Black Caribbean were similar and these categories were combined. For CS during labour, Black African was kept as a separate category distinct from Black Caribbean and Black Other because these odds ratios were of very different magnitudes.

The odds of CS before and during labour for pregnancies above 42 weeks gestation were not significantly increased when compared with pregnancies delivered at 37–42 weeks. Hence to simplify the model, the reference group was recoded to include pregnancies delivered above 42 weeks gestation in the final logistic regression models.

4.2 Investigating interactions between case-mix variables

Clinically, it is possible that the effect of some case-mix variables on CS as mode of delivery may vary according to other case-mix variables. However, the NSCSA database includes a large number of women, and there is potentially enough statistical power to include many statistically significant high-level interactions between the case-mix variables. Such interactions would be of limited interest clinically and increase the complexity for interpretation. Therefore, it was decided that initially a set of interactions that were considered clinically relevant would be included. In order to determine at what stage to stop investigating complex interactions, the fit of the logistic regression models for (a) CS before labour, and (b) CS during labour could be assessed by examining the predicted probabilities for both CS before labour and CS among women in labour for individual women

The choice of interactions between case-mix variables to be included in the logistic regression models for CS before and during labour is described below. In section 4.2.1, the methods that were used to build the final logistic regression models that include interactions between case-mix variables are described. Section 4.2.2 describes the goodness of fit of the logistic regression models that were fitted to illustrate the choice of the interaction terms between case-mix variables that were included in the final models. The results from these final models are then presented in section 4.2.3.

4.2.1 Choice of interaction terms between case-mix variables

Initially, ten two-way interactions between case-mix variables were selected for inclusion in the logistic regression models for (i) CS before labour and (ii) CS during labour with the following reasons:

1. Woman's age and previous vaginal delivery

The odds of CS (before and during labour) increases with age but is reduced for women who had had previous vaginal deliveries. It is possible that women who are older are also more likely to have had previous vaginal deliveries. Therefore, this interaction term was included to investigate if the protective effect of a previous vaginal delivery on odds of CS varies according to a woman's age.

2. Woman's age and previous CS

Older women and those who have had a previous CS have higher odds of CS when compared with younger women with no previous deliveries. The majority of older women have had previous pregnancies and possibly also a previous CS. Therefore, this interaction term was included to investigate if the effect of a previous CS on odds of CS varied according to a woman's age.

3. Ethnicity and previous vaginal delivery

Compared with White women, Bangladeshi, Pakistani and Chinese women were less likely to have CS before labour, and Black women were more likely to have CS during labour. This suggests that the type of previous deliveries could vary according to ethnicity and hence the effect of a previous vaginal delivery may vary according to ethnicity.

4. Ethnicity and previous CS

As above, it is possible that the type of previous delivery varies with ethnicity, for example a higher proportion of Black women have had a previous CS[75;145]. Therefore, this interaction term was included to investigate the effect of a previous CS according to ethnicity.

5. Ethnicity and birth weight

It has been reported that birth weight varies according to ethnicity[146-148]. Therefore this interaction term was included to investigate the effect of birth weight on mode of delivery according to ethnicity.

6. Previous vaginal delivery and previous CS

While women who have had a previous vaginal delivery are less likely to have CS, women with a previous CS are more likely to have a repeat CS[1;85]. Therefore, this interaction term was included to investigate the effect of a previous vaginal delivery on odds of CS in the index pregnancy, according to whether or not a woman has had a previous CS.

7. Gestation and presentation

Babies born before 37 weeks gestation had higher odds of CS compared with babies born at term (at least 37 weeks gestation). It is known that the prevalence of breech presentation is higher in preterm pregnancies[1], and breech pregnancies are more likely to be delivered by CS[4]. This interaction term was included to investigate the effect of gestational age on odds of CS according to presentation of the baby.

8. Previous CS and induction of labour (CS during labour only)

The risk of uterine rupture with induction of labour for women who have had a previous CS is increased[149]. Therefore, it is possible that the effect of induction of labour on odds of CS varies according to whether or not a woman has had a previous CS.

9. Gestation and induction of labour (CS during labour only)

The majority of inductions of labour are performed for pregnancies that are over 40 weeks gestation. Babies at lower gestational ages are smaller and therefore it is possible that the effect of induction of labour on odds of CS varies according to gestational age.

10. Birth weight and induction of labour (CS during labour only)

Babies that weighed over 4000 g had higher odds of CS. The majority of inductions of labour are performed for pregnancies that are over 40 weeks gestation and these babies are more likely to be heavier. Therefore, this interaction term was included to investigate the effect of birth weight on odds of CS according to mode of onset of labour.

It is possible that there are other interactions between these case-mix variables that have not been listed above. For example, as there is a strong association between 'previous CS' and CS (before and during labour), it is possible that the strength of this association varies according to other clinical variables such as gestational age, presentation and birth weight. Similarly, while a previous vaginal delivery has a protective effect against CS, this association may vary according to other clinical variables such as gestational age, presentation and birth weight. In addition, it is possible that the effect of birth weight on delivery by CS varies according to gestational age. These additional interactions between case-mix variables were added to the model if, when assessed, the goodness of fit of the model to the data was judged to be inadequate.

4.2.2 Methods

Multiple logistic regression models were fitted separately for CS before and during labour, with the addition of one interaction term at a time, in the order presented in the table below. Initially only seven interaction terms were included in the model for CS before labour and ten were included in the model for CS during labour (model A). These were clinically driven and the reasons for their inclusion have been outlined in the previous section. As in previous analyses, robust standard errors were obtained to account for the clustering of women within maternity units. The Wald test was used to assess the statistical significance of each interaction term, $p < 0.05$ was considered to be statistically significant.

The goodness of fit of these logistic regression models was assessed as described in the following section. If the fit of the model was judged to be adequate, no further interaction terms between case-mix variables were added. If the fit of the model was judged to be inadequate, a further seven two-way interactions between variables were added (one at a time) to the model (see model B in table 4.2.2.1). The rationale for these additional interactions has been described in the previous section. As the variables previous CS, previous vaginal delivery, gestational age and presentation were involved in more than one interaction and previous CS in particular has a strong association with delivery by CS, three-way interactions were also included (see model C in table 4.2.2.1).

Assessing goodness of fit

The fit of the logistic regression models for (a) CS before labour and (b) CS during labour was examined. Predicted probabilities for both CS before labour and CS among women in labour were obtained for individual women. The sum of the predicted probabilities defined by deciles of the distribution of predicted probabilities for women who had (a) CS before labour and (b) CS in labour was compared with the observed number of CS that occurred (Hosmer and Lemeshow method)[150]. This method of checking goodness of fit does not allow for the clustering of women within maternity units. Therefore, 'maternity unit' was included in the model described above for CS before labour, as a 'fixed effect' solely for the purpose of checking the goodness of fit of the model.

Table 4.2.2.1: Lists of interactions between case-mix variables that were investigated

	Model A	Model B	Model C
Age & previous vaginal delivery	✓	✓	✓
Age & previous CS	✓	✓	✓
Ethnicity & previous vaginal delivery	✓	✓	✓
Ethnicity & previous CS	✓	✓	✓
Ethnicity & birth weight	✓	✓	✓
Previous vaginal delivery & previous CS	✓	✓	✓
Gestation & presentation	✓	✓	✓
Previous CS & induction of labour (CS during labour only)	✓	✓	✓
Gestation & induction of labour (CS during labour only)	✓	✓	✓
Birth weight & induction of labour (CS during labour only)	✓	✓	✓
Previous CS & gestation		✓	✓
Previous CS & presentation		✓	✓
Previous CS and birth weight		✓	✓
Previous vaginal delivery & gestation		✓	✓
Previous vaginal delivery & presentation		✓	✓
Previous vaginal delivery & birth weight		✓	✓
Gestation and birth weight		✓	✓
Previous CS, previous vaginal delivery & gestational age			✓
Previous CS, previous vaginal delivery & presentation			✓
Previous CS, gestational age & presentation			✓

Distribution of expected probabilities

In order to (i) further investigate the fit of the models for CS before and during labour to the data and (ii) judge the overall discriminatory power of the model, the observed and expected probabilities of (a) CS before labour and (b) CS in labour were examined according to the various demographic and clinical variables. Also, histograms of expected probabilities by mode of delivery and receiver operating curves for the predicted probabilities were constructed.

4.2.3 Goodness of fit

In this section, the goodness of fit of the logistic regression models that were fitted for (i) CS before labour and (ii) CS during labour is shown to illustrate the choice of the final logistic regression models for CS before and during labour.

Table 4.2.3.1 shows the sum of the predicted probabilities defined by deciles of the distribution of predicted probabilities for women who had (a) CS before labour and (b) CS during labour compared with the observed number of CS that occurred. The models (models A, B and C) that were fitted vary in the number of interaction terms between case-mix variables that were included and are described in full in section 4.2.2 (see table 4.2.2.1).

Model A was fitted for both CS before and during labour as described in section 4.2.2. For CS during labour, the interaction terms between (i) ethnicity and previous CS (Wald test statistic = 15.64 ~ $\chi^2(18)$, p = 0.62); and (ii) birth weight and onset of labour (Wald test statistic = 1.64 ~ $\chi^2(2)$, p = 0.44) did not improve the fit of the model to the data and were therefore excluded.

Table 4.2.3.1: Observed and predicted number of CS (from model A) defined by deciles of predicted probabilities

	CS before labour		CS for women in labour	
Centile of distribution of predicted probabilities	Observed	Expected	Observed	Expected
0th–10th	176	245	331	332
10th–20th	259	321	382	374
20th–30th	262	337	338	352
30th–40th	343	405	627	641
40th–50th	455	486	822	840
50th–60th	510	592	1145	1112
60th–70th	459	531	1440	1483
70th–80th	719	746	1896	1955
80th–90th	2858	2349	3004	2941
90th–100th	8466	8494	5573	5527
Total	14506	14506	15558	15558

The results in table 4.2.3.1 show that the observed and expected number of CS for women in labour is similar within each decile of the distribution of predicted probability of CS for women in labour, suggesting adequate fit of the model to the data.

For CS before labour, the expected numbers of CS before labour appear to be systematically higher than the observed numbers up to the 80th centile of the distribution of predicted probabilities of CS before labour. Between the 80th and 90th centile, the observed number of CS before labour exceeds the expected number by 509. In the top 10th decile, the observed and expected numbers are similar.

One of the reasons for the poor fit could be that this method of checking goodness of fit does not allow for the clustering of women within maternity units. Therefore, 'maternity unit' was included in the model described above for CS before labour, as a 'fixed effect'. However, this did not result in much improvement in the fit of the model to the data.

It was possible that there were more interactions between variables that had not been included in the model. Therefore models B and C (described in section 4.2.2) were fitted and the goodness of fit was assessed as shown in table 4.2.3.2. The interaction term between previous vaginal delivery and gestation did not significantly improve the fit of the model to the data and was excluded (Wald test statistic = 3.72 ~ $\chi^2(3)$, p = 0.29).

Table 4.2.3.2: Observed and predicted number of CS defined by deciles of predicted probabilities (models B and C)

	CS before labour Model including additional two-way interactions and maternity units as fixed effects (model B)		CS before labour Model including three-way interactions and maternity units as fixed effects (model C)	
Centile of distribution of predicted probabilities	Observed	Expected	Observed	Expected
0^{th}–10^{th}	132	163	136	166
10^{th}–20^{th}	195	230	201	234
20^{th}–30^{th}	253	281	243	285
30^{th}–40^{th}	331	334	324	338
40^{th}–50^{th}	375	393	388	397
50^{th}–60^{th}	444	462	452	466
60^{th}–70^{th}	587	561	578	566
70^{th}–80^{th}	812	757	806	763
80^{th}–90^{th}	2763	2699	2770	2696
90^{th}–100^{th}	8605	8613	8609	8595
Total	14497	14497	14507	14507

Comparison of these expected and observed numbers of CS before labour showed that the model with the additional two-way interactions and the inclusion of maternity unit as a 'fixed effect' provided a better fit of the model to the data. However, there were still some discrepancies between the observed number of CS and sum of predicted probabilities, particularly in the first three deciles of the distribution of predicted probability of CS before labour. The inclusion of three-way interactions did not appear to further improve the fit of the model. Given the complexities of interpretation, a decision was taken to use the model with two-way interactions (model B).

Although the general Hosmer and Lemeshow approach was used to assess model fit, with comparison of observed and expected numbers of CS defined by deciles of risk, the Hosmer and Lemeshow $\chi 2$ test was however not carried out for three reasons:

1. The Hosmer and Lemeshow statistic only approximates to a $\chi 2$ distribution with (number of categories – 2) degrees of freedom. The extent to which the approximation holds is dependent upon the number of different covariate patterns in the data [150]. With the NSCSA data, since 7 of the 8 variables are categorical the number of different covariate patterns is substantially less than the number of observations which may make the assumption invalid.

2. A perfect fit of the models to the data was not expected. Robust standard errors were adopted to deal with the clustered nature of the data. This clustered nature of the data would also render conclusions from the Hosmer and Lomeshow test suspect.

3. With large datasets whenever a model is fitted there is almost always statistically significant evidence of lack of fit. Unless many high order interaction terms are incorporated it is unlikely that this statistically significant evidence will ever be eliminated. It was felt that preserving a degree of simplicity was important.

Therefore the approach that was adopted (fitting a model with one set of clinically motivated interactions, looking at agreement between observed numbers of CS with expected numbers of CS within deciles of the distribution of the expected probabilities of CS, then fitting a model with a second set of clinically motivated interactions if the goodness of fit was judged to be inadequate) was thought to be a reasonable approach.

Therefore, the final logistic regression models included the following two-way interactions:

a) CS before labour

- Maternal age and previous vaginal delivery
- Maternal age and previous CS
- Ethnicity and previous vaginal delivery
- Ethnicity and previous CS
- Ethnicity and birth weight
- Previous vaginal delivery and previous CS
- Previous CS and gestation
- Previous CS and presentation
- Previous CS and birth weight

- Previous vaginal delivery and presentation
- Previous vaginal delivery and birth weight
- Gestation and presentation
- Gestation and birth weight

b) CS for women in labour

- Woman's age and previous vaginal delivery
- Woman's age and previous CS
- Ethnicity and previous vaginal delivery
- Ethnicity and birth weight
- Previous vaginal delivery and previous CS
- Previous CS and induction of labour
- Gestation and induction of labour
- Gestation and presentation

4.2.4 Distribution of expected probabilities

In this section the distribution of expected probabilities obtained from the models for CS before labour and CS in labour are examined in order to (i) further investigate the fit of the models for CS before and duri ng labour to the data, and (ii) judge the overall discriminatory power of the model.

The distribution of expected probabilities from the two models is shown in table 4.2.4.1. The variance within the distribution of expected probabilities for CS before labour is larger compared with that for CS among women in labour. The observed rate of CS before labour was 10%, while the CS rate for women in labour was 12%.

Table 4.2.4.1: Distribution of expected probabilities

	Mean	SD	Median	IQR
CS before labour	0.10	0.18	0.03	0.02, 0.05
CS among women in labour	0.12	0.13	0.07	0.03, 0.14

The observed CS rate and average expected probability for women who had CS before labour and women in labour who had CS was examined according to the various demographic and clinical variables (see table 4.2.4.2).

Table 4.2.4.2: Observed and expected probabilities of CS before and during labour for women according to case-mix variables

	CS before labour		CS among women in labour	
	Observed CS	Mean expected probability of CS	Observed CS	Mean expected probability of CS
Mother's age (years)				
12–19	0.04	0.04	0.09	0.09
20–24	0.06	0.06	0.10	0.10
25–29	0.09	0.09	0.12	0.12
30–34	0.12	0.12	0.13	0.13
35–39	0.15	0.15	0.14	0.14
40–50	0.20	0.19	0.16	0.16
Mother's ethnicity				
White	0.10	0.10	0.12	0.12
Black African	0.12	0.12	0.21	0.21
Black Caribbean	0.09	0.10	0.15	0.15
Black Other	0.10	0.10	0.14	0.14
Bangladeshi	0.08	0.08	0.12	0.10
Indian	0.09	0.09	0.14	0.13
Pakistani	0.08	0.09	0.10	0.11
Chinese	0.07	0.07	0.12	0.12
Asian Other	0.09	0.09	0.15	0.15
Other	0.09	0.08	0.13	0.12
Not known	0.07	0.07	0.09	0.12
Missing	0.08	0.08	0.10	0.12
Number of previous vaginal deliveries				
0	0.14	0.14	0.19	0.19
≥ 1	0.06	0.06	0.06	0.06
Number of previous CS				
0	0.06	0.06	0.11	0.11
1	0.43	0.43	0.33	0.33
≥ 2	0.83	0.83	0.71	0.70

Table 4.2.4.2 (cont'd): Observed and expected probabilities of CS before and during labour for women according to casemix variables

Gestation (weeks)				
< 28	0.20	0.19	0.14	0.13
28–32	0.41	0.41	0.21	0.20
33–36	0.22	0.22	0.18	0.17
≥ 37	0.09	0.09	0.12	0.12
Missing data	0.10	0.10	0.10	0.09
Onset of labour				
Spontaneous	-	-	0.10	0.10
Induction	-	-	0.19	0.19
CS before labour	-	-	-	-
Presentation				
Cephalic	0.08	0.08	0.11	0.11
Breech	0.61	0.61	0.71	0.71
Transverse lie	0.65	0.65	-	-
Missing data	0.39	0.36	0.57	0.57
Birthweight (g)				
≤ 2500	0.23	0.23	0.18	0.18
2501–4000	0.09	0.09	0.11	0.11
> 4000	0.08	0.08	0.17	0.17
Missing data	0.19	0.19	0.16	0.15

Overall, the results in table 4.2.4.2 show that the mean expected probability of CS is very similar to the observed CS rate within groups of women. For example, the observed CS before labour rate among women with breech presentation was 61%, and the mean expected rate in this group was also 61%. In most categories, the mean expected probabilities were within 1% of the observed proportions.

The following histograms show the predicted probabilities for the groups of women who had CS and those who had a vaginal delivery.

Figure 4.2.4.1: Predicted probabilities of CS before labour (i) for women in labour, and (ii) women who had CS before labour

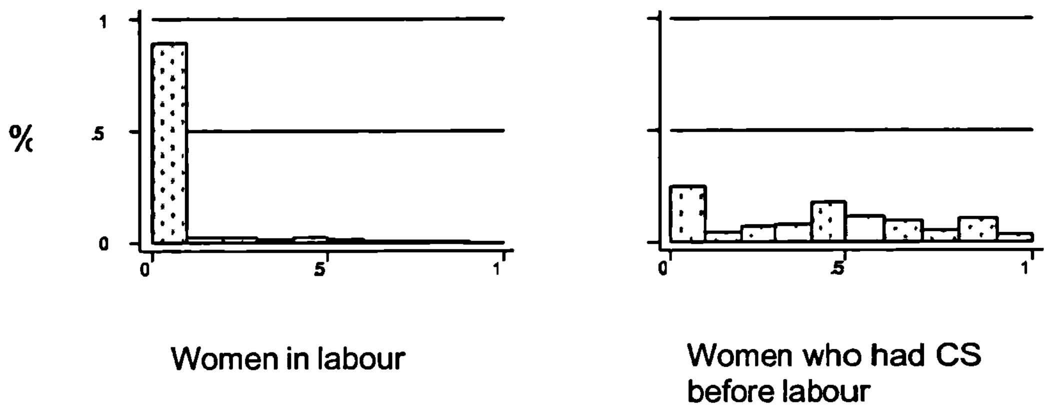
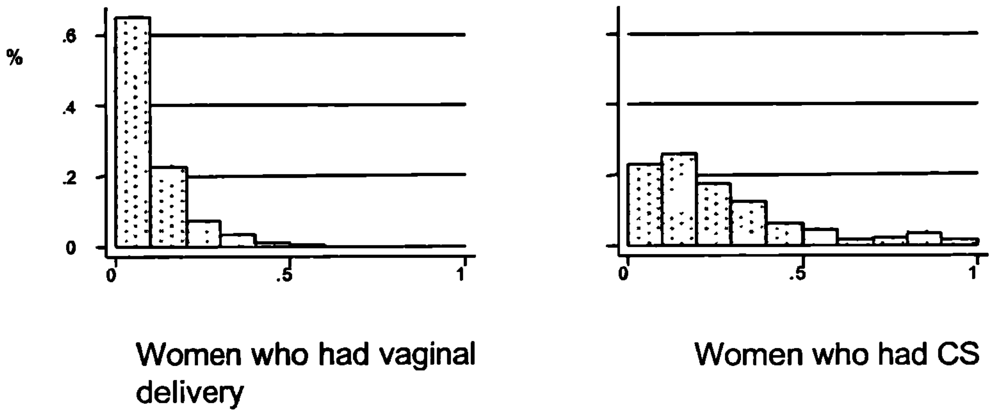


Figure 4.2.4.2: Predicted probabilities of CS for women in labour (i) women who had vaginal delivery, and (ii) women who had CS



Figures 4.2.4.3 and 4.2.4.4 show the receiver operating curves for the predicted probabilities for CS before labour and CS for women in labour.

Figure 4.2.4.3: Receiver operating curve (ROC) for predicted probabilities of CS before labour

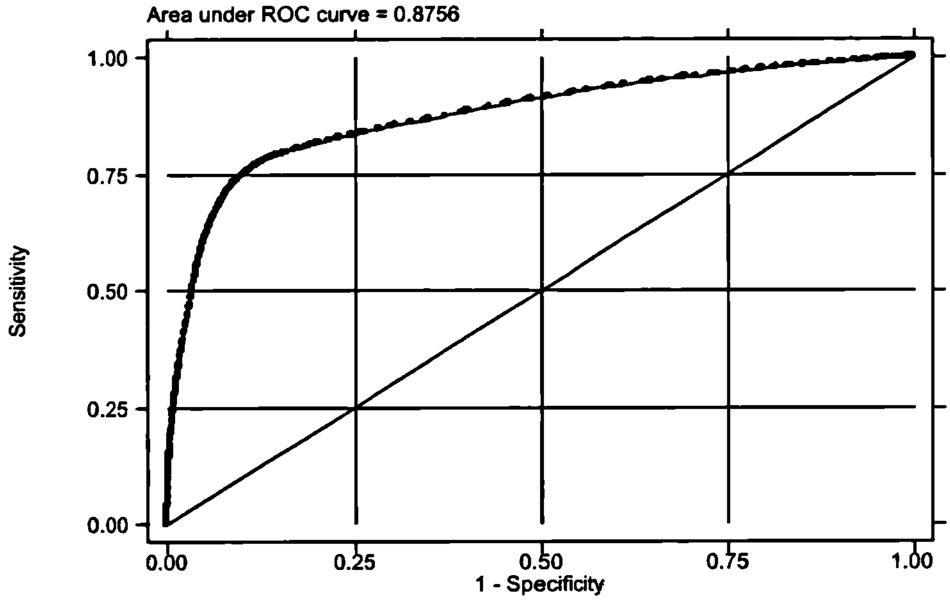


Figure 4.2.4.4: Receiver operating curve for pred'cted probabilities of CS for women in labour

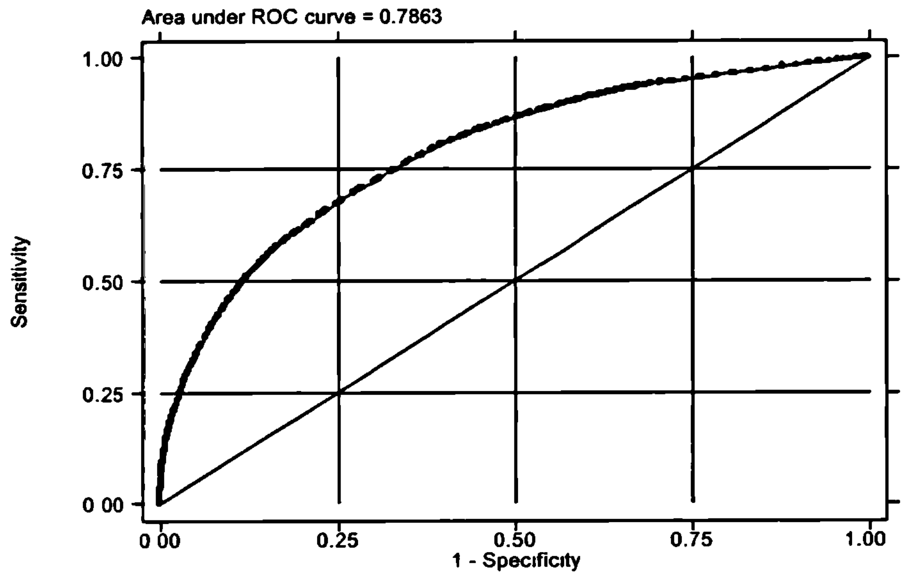


Figure 4.2.4.1 shows that the distribution of predicted probabilities of CS before labour are heavily skewed towards the lower extreme of values; 75% of women who did not have CS before labour had predicted probabilities of CS before labour of 15% or less. For women who had CS before labour, at least 50% of the expected probabilities for CS before labour were greater than 30%. For women who had CS following onset of labour, at least 50% of the expected probabilities for CS were greater than 20% (see figure 4.2.4.2). These findings are also shown in figures 4.2.4.3 and 4.2.4.4, illustrating that discrimination is not perfect. The models are better at distinguishing CS before labour, than CS in labour. This is probably because there may be other factors (such as duration of labour) that have not been accounted for in the model that was used to predict probability of CS for women in labour.

4.2.5 Results from the final logistic regression models that include interaction terms between variables

As the final models for both CS before and during labour included many interactions, with some variables involved in more than one interaction, a reference group was chosen and the results presented here describe how the odds of (i) CS before labour and (ii) CS during labour vary when pairs of factors differ from those in the reference group. This reference group includes women with characteristics that are most common:

- 30 years of age
- White
- no previous deliveries (vaginal or CS)
- at least 37 weeks gestation (term)
- cephalic presentation
- birth weight 2501–4000 g
- spontaneous onset of labour (for CS during labour only)

CS before labour: Interactions between variables

The following tables show the differences between the reference group of women (described above) and groups differing from this reference group in pairs of factors. For example, women who have similar characteristics as those in the reference group except that they are 40 years of age and have had a previous vaginal delivery have a 32% increase in odds of CS before labour when compared with women in the reference group (OR: 1.32; 95% CI: 1.22, 1.44) (table 4.2.5.1).

Age and previous vaginal delivery

Table 4.2.5.1: Relationship between woman's age, previous vaginal delivery and CS before labour (adjusted for all other casemix variables)

	Woman aged 30 years odds ratio (95% CI)	Woman aged 35 years odds ratio (95% CI)	Woman aged 40 years odds ratio (95% CI)
No previous vaginal deliveries	1.00	1.41 (1.37, 1.46)	2.00 (1.87, 2.13)
At least one previous vaginal delivery	0.73 (0.68, 0.79)	0.98 (0.91, 1.06)	1.32 (1.20, 1.44)

There was a minor quantitative interaction between age and previous vaginal deliveries. The odds of CS before labour increased with age and decreased with history of a previous vaginal delivery (see table 4.2.5.1). For women in their first pregnancy, the odds of CS before labour was 41% higher for women aged 35 years, while for women aged 40 years it was twice as high when compared with women aged 30 years. The relative 'protection' of a previous vaginal delivery increases slightly with age; with odds of CS before labour reduced by 27%, 30% and 34% for women aged 30, 35 and 40 years, respectively.

Age and previous CS

Table 4.2.5.2: Relationship between woman's age, previous CS and CS before labour (adjusted for all other casemix variables)

	Mother aged 30 years odds ratio (95% CI)	Mother aged 35 years odds ratio (95% CI)	Mother aged 40 years odds ratio (95% CI)
No previous CS	1.00	1.41 (1.37, 1.46)	2.00 (1.87, 2.13)
One previous CS	23.16 (21.31, 25.17)	27.39 (25.06, 29.95)	32.40 (28.93, 36.28)
At least two previous CS	193.00 (159.05, 234.21)	226.63 (182.63, 281.23)	266.11 (195.72, 361.81)

Women who had a previous CS were more likely to have a CS before labour (see table 4.2.5.2). However, as age increased, the relative effect of a previous CS decreased. The relative effect of 1 previous CS is a 23-fold increase in odds of CS before labour for women aged 30 years; for women aged 35 and 40 years the odds are 19 and 16 times higher, respectively. The relative effect of at least two previous CS also decreased as age increased.

Ethnicity and previous vaginal delivery

Among women with no previous deliveries, compared with White women, Chinese women had odds of CS before labour of about a half. Women of other ethnic groups had similar odds of CS before labour when compared with White women.

The protective effect of a previous vaginal delivery varied with ethnicity as shown in table 4.2.5.3. The relative effect of a previous vaginal delivery was about a 26% reduction in odds of CS before labour for White, Black African and Black Caribbean women. For Bangladeshi, Indian, Pakistani and Asian women, the relative effect of a previous vaginal delivery was about a 45% reduction in odds of CS before labour. For Chinese women, it was a 39% reduction in odds of CS before labour.

Table 4.2.5.3: Relationship between ethnicity, previous vaginal delivery and CS before labour (adjusted for all other casemix variables)

Ethnicity	No previous vaginal deliveries odds ratio (95% CI)	At least one previous vaginal delivery odds ratio (95% CI)
White	1.00	0.73 (0.68, 0.79)
Black African/Black Caribbean	0.92 (0.71, 1.19)	0.69 (0.57, 0.83)
Black Other	0.95 (0.61, 1.49)	0.68 (0.47, 0.98)
Indian/Pakistani/Bangladeshi	0.95 (0.79, 1.14)	0.52 (0.43, 0.61)
Chinese	0.54 (0.31, 0.95)	0.33 (0.17, 0.67)
Asian Other	1.31 (0.96, 1.77)	0.59 (0.42, 0.83)
Not Known	0.80 (0.62, 1.03)	0.57 (0.44, 0.73)

Ethnicity and previous CS

There was also an interaction between 'previous CS' and ethnicity (see table 4.2.5.4). While the relative effect of one previous CS was about a 20-fold increase in the odds of CS before labour for White and some Black women; for Black Caribbean, Black African, Bangladeshi, Indian, Pakistani and other Asian women it was about a 12–14-fold increase; for Chinese women it was increased over 30 fold.

Table 4.2.5.4: Relationship between ethnicity, previous CS and CS before labour (adjusted for all other casemix variables)

Ethnicity	No previous CS (and no previous vaginal delivery) odds ratio (95% CI)	One previous CS odds ratio (95% CI)	At least two previous CS odds ratio (95% CI)
White	1.00	23.16 (21.31, 25.17)	193.00 (159.05, 234.21)
Black African/ Black Caribbean	0.92 (0.71, 1.19)	13.26 (10.56, 16.66)	110.39 (68.05, 179.06)
Black Other	0.95 (0.61, 1.49)	19.49 (13.51, 28.11)	166.09 (56.80, 485.63)
Indian/Pakistani/ Bangladeshi	0.95 (0.79, 1.14)	12.07 (9.58, 15.21)	104.27 (71.66, 151.73)
Chinese	0.54 (0.31, 0.95)	21.36 (11.91, 38.29)	44.45 (14.43, 136.92)
Asian Other	1.31 (0.96, 1.77)	15.18 (10.94, 21.08)	164.49 (62.60, 432.20)
Not Known	0.80 (0.62, 1.03)	15.06 (11.45, 19.82)	135.18 (73.76, 247.72)

Ethnicity and birth weight

Table 4.2.5.5: Relationship between ethnicity, birth weight and CS before labour (adjusted for all other casemix variables)

	Birth weight		
Ethnicity	≤ 2500 g	2501–4000 g	> 4000 g
White	1.96 (1.65, 2.33)	1.00	1.15 (1.01, 1.31)
Black African / Black Caribbean	2.29 (1.61, 3.28)	0.92 (0.71, 1.19)	1.02 (0.65, 1.58)
Black Other	1.73 (0.90, 3.30)	0.95 (0.61, 1.49)	2.50 (1.09, 5.72)
Indian/Pakistani/Bangladeshi	2.57 (1.98, 3.35)	0.95 (0.79, 1.14)	1.67 (1.09, 2.57)
Chinese	1.49 (0.63, 3.49)	0.54 (0.31, 0.95)	0.72 (0.21, 2.41)
Asian Other	1.55 (0.86, 2.81)	1.31 (0.96, 1.77)	1.43 (0.64, 3.19)
Not Known	1.74 (1.12, 2.72)	0.80 (0.62, 1.03)	1.01 (0.58, 1.73)

Table 4.2.5.5 shows the relationship between ethnicity, birth weight and CS before labour. Women who had babies weighing less than 2500 g (having adjusted for gestational age) were more likely to be delivered by CS before labour.

The relative effect of birth weight less than 2500 g was a two-fold increase in odds of CS before labour for women from all ethnic groups except for Chinese women who had a two and a half fold increase.

Previous vaginal delivery and previous CS

Table 4.2.5.6: Relationship between previous vaginal delivery, previous CS and CS before labour (adjusted for all other casemix variables)

	No previous vaginal deliveries odds ratio (95% CI)	At least one previous vaginal delivery odds ratio (95% CI)
No previous CS	1.00	0.73 (0.68, 0.79)
One previous CS	23.16 (21.31, 25.17)	10.76 (9.57, 12.10)
At least two previous CS	193.00 (159.05, 234.21)	153.42 (115.10, 204.48)

Women in their second pregnancy (who were delivered by CS in their first pregnancy) were 23 times more likely to deliver by CS before labour in their index pregnancy when compared with women who did not have any previous deliveries. Women who had at least two previous pregnancies and one previous CS were 11 times more likely to have CS before labour, while multiparous women with no previous CS had a 27% reduction in odds of CS before labour. Women with at least two previous CS had very high odds of a CS before labour in the index pregnancy.

The relative protective effect of a previous vaginal delivery was a 54% reduction in odds of CS before labour for women who had had one previous CS. However, for women who had had two previous CS, it was about a 21% reduction in odds of CS before labour.

Previous CS and gestation

Table 4.2.5.7: Relationship between previous CS, gestation and CS before labour (adjusted for all other casemix variables)

	< 28 weeks	28–32 weeks	33–36 weeks	> 37 weeks
No previous CS	1.37	8.44	4.23	1.00
	(0.23, 7.95)	(4.90, 14.53)	(3.78, 4.73)	
One previous CS	8.28	52.24	33.70	23.16
	(1.13, 60.57)	(27.45, 99.41)	(27.24, 41.69)	(21.31, 25.17)
At least two previous	23.11	49.75	49.66	193.00
CS	(2.68, 199.12)	(19.25, 128.58)	33.31, 74.04)	(159.05, 234.21)

For women with no previous deliveries, the odds of CS before labour were about eight times higher between 28 and 32 weeks gestation and about four times higher between 33 and 36 weeks gestation when compared with term pregnancies. For term pregnancies, the relative effect of one previous CS is over a 20-fold increase in odds of CS before labour. For pregnancies under 33 weeks gestation, the relative effect of a previous CS was about a six-fold increase in odds of CS before labour, between 33 and 36 weeks gestation it was about an eight-fold increase. A similar pattern was seen for women who had at least two previous CS, those with pregnancies at term had much higher odds of CS before labour, while at lower gestational ages, the relative effect of at least two previous CS was less.

Previous CS and presentation

Table 4.2.5.8: Relationship between previous CS, presentation and CS before labour (adjusted for all other casemix variables)

	Cephalic presentation odds ratio (95% CI)	Breech presentation odds ratio (95% CI)	Transverse presentation odds ratio (95% CI)
No previous CS	1.00	53.91 (48.75, 59.63)	35.70 (24.58, 51.84)
One previous CS	23.16 (21.31, 25.17)	257.97 (190.64, 349.08)	168.20 (101.79, 277.94)
At least two previous CS	193.00 (159.05, 234.21)	980.01 (433.39, 2216.08)	726.19 (178.84, 2948.69)

For women with no previous deliveries, the odds of CS before labour was over 50 times higher for pregnancies with breech presentation. The relative effect of one previous CS for pregnancies with breech presentation was a five-fold increase in odds of CS before labour; the relative effect of at least two previous CS was an 18-fold increase. The relative effect of previous CS was similar for pregnancies with transverse presentation.

Previous CS and birth weight

Table 4.2.5.9: Relationship between previous CS, birth weight and CS before labour (adjusted for all other casemix variables)

	Birth weight		
	≤ 2500g	2501–4000 g	> 4000 g
No previous CS	1.96 (1.65, 2.33)	1.00	1.15 (1.01, 1.31)
One previous CS	25.47 (20.10, 32.27)	23.16 (21.31, 25.17)	23.10 (20.17, 26.44)
At least two previous CS	257.28 (151.53, 436.84)	193.00 (159.05, 234.21)	98.59 (67.94, 143.07)

There was a minor quantitative interaction between previous CS and birth weight. While the relative effect of one previous CS was an increase over 20-fold in the odds of CS before labour for babies weighing between 2501 and 4000 g, for babies under 2500 g it was a 13-fold increase. For babies weighing over 4000 g, the relative effect of a previous CS was similar to that for babies weighing between 2501 and 4000 g.

Previous vaginal delivery and presentation

Table 4.2.5.10: Relationship between previous vaginal delivery, presentation and CS before labour (adjusted for all other casemix variables)

	Cephalic presentation odds ratio (95% CI)	Breech presentation odds ratio (95% CI)	Transverse presentation odds ratio (95% CI)
No previous vaginal delivery	1.00	53.91 (48.75, 59.63)	35.70 (24.58, 51.84)
At least one previous vaginal delivery	0.73 (0.68, 0.79)	36.01 (31.30, 41.44)	34.24 (25.75, 45.53)

There was a minor quantitative interaction between previous vaginal deliveries and presentation. Women who had had at least one previous vaginal delivery had a 30% reduction of odds of CS before labour for pregnancies with breech presentation. This compares with a 27% reduction in odds of CS before labour for pregnancies with cephalic presentation. For pregnancies with transverse presentation, the odds of CS before labour were about 30-fold higher irrespective of whether or not a woman had previous vaginal deliveries.

Previous vaginal delivery and birth weight

Table 4.2.5.11: Relationship between previous vaginal delivery, birth weight and CS before labour (adjusted for all other casemix variables)

	Birth weight		
	≤ 2500 g	2501–4000 g	> 4000 g
No previous vaginal delivery	1.96 (1.65, 2.33)	1.00	1.15 (1.01, 1.31)
At least one previous vaginal delivery	1.30 (1.09, 1.54)	0.73 (0.68, 0.79)	0.69 (0.60, 0.78)

For babies weighing less than 4000 g, there was about a 30% reduction in odds of delivery by CS before labour for women who had had a previous vaginal delivery. For babies weighing over 4000 g, the relative effect of the mother having had a previous vaginal delivery was a 40% reduction in odds of CS before labour.

Gestation and presentation

Table 4.2.5.12: Relationship between gestation, presentation and CS before labour (adjusted for all other casemix variables)

	Cephalic presentation odds ratio (95% CI)	Breech presentation odds ratio (95% CI)	Transverse presentation odds ratio (95% CI)
< 28 weeks	1.37 (0.23, 7.95)	3.02 (0.49, 18.62)	3.25 (0.30, 35.46)
28–32 weeks	8.44 (4.90, 14.53)	18.66 (10.28, 33.87)	20.54 (8.28, 50.92)
33–36 weeks	4.23 (3.78, 4.73)	16.54 (13.16, 20.81)	29.39 (15.23, 56.71)
≥ 37 weeks	1.00	53.91 (48.75, 59.63)	35.70 (24.58, 51.84)

Table 4.2.5.12 shows how the effect of gestation on odds of delivery by CS before labour varied with presentation. For term pregnancies, those with breech presentation or transverse lie were more likely to be delivered by CS before labour compared with cephalic presentation. Before 37 weeks, pregnancies with cephalic presentation were more likely to be delivered by CS before labour compared with cephalic pregnancies at term. The relative effect of breech presentation is a two- to four-fold increase in odds of CS before labour at gestations below 37 weeks. For term pregnancies, the odds of CS before labour are over 50 times higher when compared with pregnancies at similar gestation with cephalic pregnancies.

Gestation and birth weight

Table 4.2.5.13: Relationship between gestation, birth weight and CS before labour (adjusted for all other casemix variables)

	Birth weight		
	≤ 2500 g	2501–4000 g	> 4000 g
< 28 weeks	3.37 (1.76, 6.44)	1.37 (0.23, 7.95)	5.46 (0.46, 64.49)
28–32 weeks	18.45 (15.81, 21.52)	8.44 (4.90, 14.53)	5.24 (0.93, 29.62)
33–36 weeks	9.45 (8.25, 10.83)	4.23 (3.78, 4.73)	10.17 (5.70, 18.15)
≥ 37 weeks	1.96 (1.65, 2.33)	1.00	1.15 (1.01, 1.31)

There was a minor quantitative interaction between gestational age and birth weight. The relative effect of lower birth weight on babies at lower gestational ages was an increase in odds of delivery by CS before labour; the magnitude of this increase was similar to that for babies with birth weight between 2501 and 4000 g.

CS for women in labour: interactions between variables

The following tables show the differences between the reference group of women (defined in earlier in this section) and groups differing from this reference group in pairs of factors. Calculation of odds ratios when more than two factors differ from those in the reference group are described in section 4.2.5.

Age, previous vaginal delivery, ethnicity and previous CS

In this model which allows for an interaction between age and previous vaginal delivery, there was no evidence that the relationship between age and odds of having a CS for women in labour was non linear (χ^2 (5)=5.69, p=0.34). Age was therefore included in the model as a continuous variable, centred on 30 years. For every 1 year increase in age there was a 6% (95% Ct 5.7%, 6.7%) increase in odds of delivering by CS.

Table 4.2.5.14: Relationship between woman's age, previous vaginal delivery and CS during labour (adjusted for all other casemix variables)

	Mother aged 30 years odds ratio (95% CI)	Mother aged 35 years odds ratio (95% CI)	Mother aged 40 years odds ratio (95% CI)
No previous vaginal deliveries	1.00	1.36 (1.33, 1.39)	1.86 (1.77, 1.94)
At least one previous vaginal delivery	0.20 (0.19, 0.21)	0.22 (0.21, 0.24)	0.25 (0.23, 0.27)

These results show that for women who did not have any previous vaginal deliveries, the odds of having a CS increased with age. The odds of delivery by CS were 36% and 86% higher for women aged 35 years and 40 years, respectively, when compared with women aged 30 years. The protective effect of a previous vaginal delivery increased slightly with age. The effect of having had at least one previous vaginal delivery was an 80% decrease in the odds of delivering by CS if a woman was 30 years old; 84% and 86% as age increased to 35 and 40 years.

The protective effect of a previous vaginal delivery varied with ethnicity as shown in table 4.2.5.15. For women reported to be White, Black African, Black Caribbean and Chinese, the relative effect of a previous vaginal delivery was a 76–80% reduction in odds of CS in labour. For Bangladeshi, Indian, Pakistani and other Asian women, the relative effect was an 82–84% reduction in odds of CS in labour.

Table 4.2.5.15: Relationship between ethnicity, previous vaginal delivery and CS during labour (adjusted for all other casemix variables)

Ethnicity	No previous vaginal deliveries odds ratio (95% CI)	At least one previous vaginal delivery odds ratio (95% CI)
White	1.00	0.20 (0.19, 0.21)
Black African	2.11 (1.81, 2.46)	0.50 (0.42, 0.60)
Black Caribbean/ Black Other	1.67 (1.45, 1.93)	0.37 (0.30, 0.46)
Indian/Pakistani/Bangladeshi	1.41 (1.25, 1.50)	0.22 (0.19, 0.25)
Chinese	0.93 (0.71, 1.25)	0.20 (0.14, 0.29)
Asian Other	1.69 (1.40, 2.04)	0.31 (0.24, 0.40)
Not Known	1.11 (0.96, 1.29)	0.27 (0.23, 0.33)

Table 4.2.5.16: Relationship between woman's age, previous CS and CS during labour (adjusted for all other casemix variables)

	Mother aged 30 odds ratio (95% CI)	Mother aged 35 odds ratio (95% CI)	Mother aged 40 odds ratio (95% CI)
No previous CS	1.00	1.36 (1.33, 1.39)	1.86 (1.77, 1.94)
One previous CS	3.46 (4.08, 4.87)	4.46 (4.08, 4.87)	5.74 (5.03, 6.55)
At least two previous CS	16.22 (11.45, 22.97)	15.81 (10.88, 22.97)	15.40 (9.20, 25.77)

The relative effect of one previous CS was about a three-fold increase in odds of CS for women in labour aged 30, 35 and 40 years. The relative effect of at least two previous CS, however, decreased as age increased. For women in labour aged 30 years, the relative effect of at least two previous CS was a 16-fold increase in odds of CS during labour, for women in labour aged 35 and 40 years the odds of CS increased by 11 and 8 fold, respectively.

Table 4.2.5.17: Relationship between previous vaginal delivery, previous CS and CS during labour (adjusted for all other casemix variables)

	No previous vaginal deliveries odds ratio (95% CI)	At least one previous vaginal delivery odds ratio (95% CI)
No previous CS	1.00	0.20 (0.19, 0.21)
One previous CS	3.46 (3.21, 3.72)	0.95 (0.85, 1.07)
At least two previous CS	16.22 (11.45, 22.97)	11.02 (6.68, 18.19)

Women in labour who were in their second pregnancy (delivered by CS in their first pregnancy) were three and a half times more likely to deliver by CS in their index pregnancy when compared with women who had no previous deliveries. However, women in labour who had had at least two previous pregnancies and one previous CS had similar odds of delivery by CS in their index pregnancy as women with no previous deliveries, while the odds for delivery by CS for multiparous women in labour who had had no previous CS was 80% lower. Women in labour who had had at least two previous CS were over ten times more likely to be delivered by CS whether or not they had a previous vaginal delivery.

Women who had had at least one previous vaginal delivery were less likely to have CS during labour even if they had had a previous CS. There is some similarity in the relative magnitude of effect of at least one previous vaginal delivery for women who had no previous CS and women who had had only one previous CS. For these two groups of women, the effect of a history of at least one previous vaginal delivery was around a 75% reduction in odds of having a CS in the index pregnancy. However, for women who had at least two previous

CS, the effect of at least one previous vaginal delivery was only a 30% reduction in odds of a CS during labour in the current pregnancy.

Table 4.2.5.18: Relationship between previous CS, onset of labour and CS during labour (adjusted for all other casemix variables)

	Spontaneous onset of labour odds ratio (95% CI)	Induction of labour odds ratio (95% CI)
No previous CS	1.00	2.56 (2.45, 2.68)
One previous CS	3.46 (3.21, 3.72)	6.36 (5.64, 7.19)
At least two previous CS	16.22 (11.45, 22.97)	6.68 (3.54, 12.62)

Women with no previous deliveries, who had induction of labour were two and a half times more likely to deliver by CS compared with women who had spontaneous onset of labour at term. Similarly, women who had had one previous CS were twice as likely to have another CS if labour was induced when compared with women who had spontaneous onset of labour. However, only a small proportion of women who had more than one previous CS had induction of labour. Hence, there is a wider confidence interval surrounding the estimated effect of induction of labour on the odds of having a CS during labour for this group of women.

Gestation, onset of labour and presentation

Table 4.2.5.19: Relationship between gestation, onset of labour and CS during labour (adjusted for all other casemix variables)

	Spontaneous onset of labour odds ratio (95% CI)	Induction of labour odds ratio (95% CI)
< 28 weeks	0.73 (0.44, 1.23)	0.19 (0.08, 0.45)
28–32 weeks	1.45 (1.13, 1.86)	0.94 (0.51, 1.71)
33–36 weeks	1.17 (1.03, 1.33)	3.48 (2.96, 4.09)
≥ 37 weeks	1.00	2.56 (2.45, 2.68)

Table 4.2.5.20: Relationship between gestation, presentation and CS during labour (adjusted for all other casemix variables)

	Cephalic presentation odds ratio (95% CI)	Breech presentation odds ratio (95% CI)
< 28 weeks	0.73 (0.44, 1.23)	3.32 (1.96, 5.61)
28–32 weeks	1.45 (1.13, 1.86)	18.89 (12.24, 29.15)
33–36 weeks	1.17 (1.03, 1.33)	32.67 (23.78, 44.89)
≥ 37 weeks	1.00	46.44 (40.08, 53.81)

Table 4.2.5.19 shows the relationship between gestation and onset of labour (for pregnancies with cephalic presentation) and odds of delivery by CS. Singleton pregnancies with cephalic presentation (spontaneous onset of labour, 33-36 weeks gestation) had a 17% increase in odds of being delivered by CS compared with similar pregnancies at term. Induction of labour between 33 and 36 weeks gestation was associated with more than a three-fold increase in odds of CS compared with singleton cephalic pregnancies at term with spontaneous onset of labour. The relative effect of induction of labour on these

pregnancies after 32 weeks gestation was a two-fold increase in odds of delivery by CS.

Table 4.2.5.20 shows how the effect of gestation on odds of delivery by CS for women in labour varied with presentation. The huge odds ratios seen for breech pregnancies generally reflect the fact that 88% of breech pregnancies in the dataset were delivered by CS. Before 28 weeks gestation, the odds ratio of delivery by CS for pregnancies with breech presentation was about three-fold higher compared with pregnancies with cephalic presentation. After 28 weeks gestation there was a marked increase in odds of delivering by CS when compared with cephalic pregnancies. The magnitude of this increase is dependent on gestational age. For example, between 28 and 32 weeks gestation, the odds of CS for delivery of pregnancies presenting with a breech were 13 times higher than that for pregnancies with cephalic presentation of the same gestational age. Similarly, it is 28 and 47 times higher respectively at 33 to 36 weeks and at term (at least 37 weeks).

Ethnicity and birth weight

Table 4.2.5.21: Relationship between ethnicity, birth weight and CS during labour (adjusted for all other casemix variables)

	Birth weight		
Ethnicity	≤ 2500 g	2501–4000 g	> 4000 g
White	1.37 (1.23, 1.53)	1.00	1.93 (1.82, 2.05)
Black African	2.10 (1.35, 3.28)	2.11 (1.81, 2.46)	6.04 (4.61, 7.91)
Black Caribbean/ Black Other	1.38 (0.96, 1.99)	1.67 (1.45, 1.93)	3.48 (2.36, 5.15)
Indian/Pakistani/Bangladeshi	1.22 (0.94, 1.56)	1.41 (1.25, 1.50)	4.02 (2.96, 5.46)
Chinese	0.97 (0.37, 2.53)	0.93 (0.71, 1.25)	3.84 (2.24, 6.60)
Asian Other	0.88 (0.56, 1.37)	1.69 (1.40, 2.04)	5.10 (3.18, 8.19)
Not Known	0.67 (0.41, 1.08)	1.11 (0.96, 1.29)	2.31 (1.56, 3.42)

The odds of delivering by CS varied with birth weight. However, the extent of the variation was dependent on ethnicity. White women with babies weighing more than 4000 g had a 93% increase in odds of CS compared with those with babies weighing between 2501 and 4000 g. For women reported to be Black African, the odds of CS were three times higher if the baby weighed more than 4000 g compared with birth weights of 2500–4000 g. This was also the case for Indian/Pakistani/Bangladeshi, and other Asian women. For Black Caribbean women the odds of CS were twice as high if birth weight was over 4000 g compared with 2500–4000 g. For Chinese women it was four times higher.

4.2.6 Calculating odds ratios for women who differ from the reference group by more than two factors

The above results are descriptions of odds ratios for women who differ from the reference group in pairs of factors. These results can also be used to calculate odds ratios of CS before labour for women who differ from the reference group by more than two factors. This calculation is illustrated firstly using a simple example that only differs from the reference population in two factors. This is followed by a more complex example that differs from the reference group in three factors, where there is an interaction term between two of these factors.

Example 1

The odds ratio (of CS before labour) for a 35-year-old Black African mother with no previous deliveries, whose other characteristics are the same as those in the reference group, can be calculated directly from the tables presented in the results section. It is the product of the odds ratio for Black African women with no previous vaginal deliveries (0.92 – see table 4.2.5.3), and the odds ratio associated with 35 years of age and no previous vaginal deliveries (1.41 – see table 4.2.5.1). This result of this calculation is an odds ratio of 1.31 (95% CI: 1.01, 1.68). It is not possible to calculate the confidence intervals solely from the information in the tables presented here as additional information such as variances and covariances are also required. Therefore these were obtained using the 'lincom' command in STATA.

Example 2

The odds ratio for women who have similar characteristics as the reference group except that they are Black African, with at least one previous vaginal delivery and breech presentation in the index pregnancy is the product of the odds ratios associated with the following characteristics:

- Black African: 0.92 (table 4.2.5.3)

- previous vaginal delivery: 0.73 (table 4.2.5.3)
- breech presentation: 53.91 (table 4.2.5.10)
- interaction term between Black African and previous vaginal delivery: 0.69/(0.92 x 0.73)
- Interaction term between breech presentation and previous vaginal delivery: 36.01/(53.91 x 0.73)
- There is no interaction term between ethnicity and presentation.

The product of these estimates simplifies to (36.01 x 0.69)/0.73, which is equal to 34.04. Therefore the odds ratio of CS before labour for this group of women (compared with women in the reference group) is 34.04 (95% CI: 26.9, 43.0).

4.3 Discussion

4.3.1 General

The primary aim of this chapter was to obtain expected probabilities of CS (before and during labour) for individual women according to their demographic and clinical characteristics. The variables available for analysis were maternal age, ethnicity, type of previous deliveries, gestational age, mode of onset of labour, presentation and birth weight. Other factors that have been shown to be associated with CS rates such as maternal socio-economic status and body mass index were not included in this analysis as these data were only available for women who had CS and not all women who gave birth during the NSCSA study period. Most other studies in the literature have included either parity or previous CS as explanatory variables and not both previous CS and previous vaginal deliveries as in the analysis presented here.

This analysis of the NSCSA data makes the distinction between CS before and during labour, using a novel two-stage modelling method that allows the relationships between case-mix variables and (i) CS before labour, and (ii) CS during labour to vary. Most studies (with the exception of one[38]) did not make this distinction between CS before and during labour. Furthermore, these studies do not take into account clustering of women within maternity units. Therefore the assessment of demographic and clinical (case-mix) factors associated with CS (before and during labour) presented in this chapter may not be directly comparable with those reported in the literature. The exception to this is a study that was carried out in France[38] that calculated expected CS rates for 149 maternity units based on 40,512 singleton births that took place over a 4-year period (1994–1998) using logistic regression. The variables included in their analysis were maternal age, height, parity, previous CS, presentation, gestation, induction of labour, fetal and maternal indications for CS, pre-existing maternal morbidity and complications of pregnancy and labour. In this study, the overall CS rate was 15% (CS before labour rate was 8%). These are lower than the rates from the NSCSA (overall CS rate 21%; CS before labour rate 10%). However, the authors acknowledged that their sample of maternity units may not have been representative of the overall distribution of maternity unit characteristics in France. The estimated odds ratios for the various characteristics associated with CS reported in this study are discussed with the results from analysis of the NSCSA data in the relevant following sections.

The models used in the analysis of this NSCSA data are explanatory and are not intended for use in predicting risk of CS for individual women in an ongoing pregnancy. They have limited value in terms of prediction of risk of CS for individual women as not all of the variables used (e.g. birth weight) are known before delivery. However, the motivation was to obtain case-mix adjusted CS rates to enable comparisons between maternity units and, therefore, variables such as birth weight were included in the analysis. It has been reported that birth weight is higher now compared with 20 years ago; demographic changes in the population (including birth weight) have contributed to increases in the CS rate over the last 20 years and comparisons of CS rates should allow for at least maternal age, birth weight and parity[63;67]. However one study has demonstrated that nearly half of the observed increases in birthweight can be explained by changes in maternal age, height and parity[151]. Another study has shown that over a 15 year period, adjustment for birthweight did not significantly alter the population attributable fraction of CS related to year of delivery, suggesting no evidence that increasing birthweights have contributed to increasing rates of CS[79].

It has also been argued that case-mix adjustment should only include variables that are beyond the control of women or their health care professionals (e.g. maternal age, parity), and not include variables that may be practice-driven (e.g. induction of labour)[36;143;152]. However, in England and Wales, a national evidence-based guideline recommends induction of labour for healthy pregnant women after 41 weeks, and a policy of induction of labour has not been shown to be associated with increased CS rates in RCTs[153]. The increased risk of CS with induction of labour that is reported in observational studies is probably due to the higher likelihood of CS that is associated with the reason for intervening with induction of labour rather than the intervention itself[65]. It is possible that the inclusion of breech presentation as an explanatory variable could mask variation in practice between maternity units with regard to the use of external cephalic version (ECV) to reduce the prevalence of breech presentation at term. However, current evidence suggests that for term breech pregnancies, the risk of perinatal mortality is lower with delivery by planned CS and this is reflected in current practice in England and Wales. The prevalence of breech presentation was consistent across maternity units at about 3–4%. Within the NSCSA data, the rate of ECV availability and uptake was not known.

In this analysis, logistic regression was used to obtain odds ratios. The magnitude of effect reported as an odds ratio can be much greater than the corresponding relative risk. This approach was chosen because the primary aim was to obtain predicted probabilities of CS for individual women based on their case-mix characteristics and this is easily calculated from fitting a logistic regression model.

In the following sections, the similarities and differences in the way the various demographic and clinical characteristics are associated with CS before labour and CS for women in labour are discussed in the context of clinical practice, factors considered when making decisions about mode of delivery and findings from other studies.

4.3.2 Woman's age

Age is associated with both CS before labour and also CS for women in labour. The magnitude of this association is similar; there is a 6–7% increase in odds of CS for every 1-year increase in maternal age. Higher CS rates for older women have been consistently reported in the literature[59], ranging from a 24– 60% increase in risk of CS for women over 35 years compared with those under 35 years of age[29;38;60], to a risk of CS that is three times higher for women over 40 years of age compared with those under 20 years of age[70;77;154]. One study in the UK reported a linear association between maternal age and risk of CS (for women with term singleton cephalic pregnancies): for every 1 year increase in age there was a 16% increase in risk of planned CS and an 8% increase in risk of emergency CS[64]. These estimates are not adjusted for other confounding factors such as ethnicity and previous deliveries and hence are larger than those obtained from the analysis of the NSCSA data that is presented here. It is reported that there is a higher rate of complications (such as diabetes, hypertension, pre-eclampsia, chromosomal abnormalities and stillbirth) among older women[60;64;66]. Most studies have reported that for women with complications of pregnancy, labour and delivery, there is a limited effect of increasing maternal age on risk of CS, but for women with no complications, the risk of CS increases with age[61;67;68;77]. It has been observed that older women in labour have a longer length of second stage of labour, higher rates of failure to progress in labour, higher rates of instrumental vaginal deliveries and are at increased risk of post partum haemorrhage, suggesting deteriorating myometrial function with increasing age[64;65]. One study in the USA reported higher rates of malpresentation and previous myomectomy among older women resulting in a higher CS before labour rate, when compared with younger women[65].

For both CS before labour and CS during labour, the protective effect of a previous vaginal delivery increases as age increases. While the effect of a previous CS is an increase in odds of both CS before labour and CS during labour, the relative effect of this decreases as women's age increases. This finding has not been reported in other studies but is consistent with findings from a survey of obstetricians' views on childbirth[1], which suggested that obstetricians were less likely to agree requests for CS for older multiparous women. Possible reasons for this include the higher rate of postoperative complications such as thrombo-embolism[6] among older women.

4.3.3 Previous vaginal deliveries

Having had at least one previous vaginal delivery confers a 'protective effect' against delivery by CS. The magnitude of this effect, however, is not the same for CS before labour and CS for women in labour. Women who have had at least one previous vaginal delivery are about 27% less likely to have a CS before labour, for women in labour the 'protective' effect of a previous vaginal delivery is much greater (about 80% reduction in odds of CS). One possible explanation for this could be that the decision for CS before labour is due to clinical factors that require delivery to be expedited. However, women in labour with uncomplicated pregnancies who had had a previous vaginal delivery are more likely to have another vaginal delivery.

For both CS before labour and CS in labour, there is a minor quantitative interaction between previous vaginal deliveries and maternal age – as age increases, the protective effect of a previous vaginal delivery also increases slightly.

The effect of a previous vaginal delivery on CS before labour and CS during labour also varies with ethnicity and previous CS; these will be discussed in the following sections. The effect of a previous vaginal delivery on CS before labour also varies with presentation and birth weight. These will also be discussed in the following sections.

4.3.4 Previous CS

For women who had had one previous CS, the adjusted OR for CS before labour was 23.16 (95% CI: 21.31, 25.17), for women in labour it was 3.46 (95% CI: 4.08, 4.87). A possible explanation for this difference may be that women with one previous CS were more likely to request a CS in their index pregnancy i.e. CS before labour. This is consistent with findings from a survey of women's views on childbirth, where 20% of pregnant women surveyed who had had a previous CS expressed a wish to have a caesarean birth in their index pregnancy[1].

The magnitudes of odds ratios in this analysis of NSCSA data were much higher for women with more than one previous CS, reflecting the fact that the majority of women in this category had a CS in the index pregnancy either before labour or after the onset of labour. As discussed above, the relative effect of previous CS on the odds of CS either before or during labour decreases as age increases.

These estimates are lower than estimates from a French study that reported odds of CS before labour that were about 40 times higher and odds of CS during labour that were about 13 times higher for women with previous CS compared with women with no previous CS[38]. However the effect of previous vaginal deliveries was not taken into account and this may explain some of the discrepancy.

The effect of a previous CS on CS either before or during labour varies according to whether or not a woman had a previous vaginal delivery. The relative effect of one previous CS for women who had at least one previous vaginal delivery is a 14-fold increase in odds of CS before labour, and a five-fold increase in odds of CS for women in labour. The relative effect of a history of more than one previous CS is a more than 200-fold increase in odds of CS before labour and a 55-fold increase in odds of CS for women in labour. This is consistent with findings from a systematic review of 29 observational studies that reported women in labour with previous CS who also had previous vaginal deliveries were twice as likely to have a vaginal birth after CS (OR 2.1 95% CI:

1.7, 2.5); while women with more than one previous CS had a 30% decrease in odds of vaginal birth after CS (OR 0.7; 95% CI: 0.5, 0.9)[85].

For CS before labour, there is also a minor quantitative interaction between previous CS and the mother's ethnicity, which is probably not clinically significant. This will be discussed in the following section. The effect of previous CS also varies with clinical factors such as gestation, presentation and birth weight as will be discussed in the following sections.

The risks and benefits of a planned CS compared with vaginal birth after CS have been outlined in the national evidence-based guideline for CS, and these would have been taken into account by individual women and their health care professionals when planning the mode of delivery. Although the absolute risks are small, the increased relative risk of an unexplained stillbirth for women with previous CS compared with those with previous vaginal deliveries[12] and the increased risk of uterine rupture[149;155] and perinatal death[156] associated with planned vaginal birth after CS compared with planned repeat CS may influence some of the decision-making according to women's preferences and priorities.

4.3.5 Ethnicity

Chinese women (with no previous deliveries) are statistically significantly less likely to have CS before labour compared with similar White women. For women from other ethnic minorities, the odds of CS before labour are not statistically significantly different from those for White women. Black and Asian women in labour, however, have statistically significantly higher odds of CS when compared with similar White women. In the literature, CS rates have been reported to be increased by 24–40% for Black women compared with White women even after adjustment for socio-economic factors[145]. It is also reported that the prevalence of CS for fetal reasons is higher among Black women[75].

The relative protective effect of a previous vaginal delivery on CS before labour varies with ethnicity. It is higher for Chinese, Bangladeshi, Indian and Pakistani women (about 40%) compared with White women (about 26%). The magnitude of the protective effect of a previous vaginal delivery on CS for women in labour also varied slightly with ethnicity, but was in the same direction and of the same order (about 80%) as the main effect.

The relative effect of a previous CS on CS before labour also varies with ethnicity. For White women, it is more than a 20-fold increase in odds of CS before labour, while for Black and Asian women it is about 12-fold higher. The relative effect of a previous CS did not vary significantly with ethnicity for women in labour.

While White women are more likely to have CS before labour, Black and Asian women in labour have higher odds of delivery by CS when compared with White women in labour. This is consistent with a study of 16,718 pregnancies over a 5-year period in London that reported lower rates of emergency CS and higher rates of elective CS among Bangladeshi women compared with White women[157]. There are two possible reasons for this.

Firstly, the prevalence for CS for maternal request is higher among White women. Unpublished data from the NSCSA showed that, regardless of ethnicity, previous CS is the primary indication for about 20–30% of women who have CS before labour. Maternal request was the primary indication for 13% of White women who had CS before labour, 12% of Indian women and fewer than 10% of Black African, Black Caribbean, Bangladeshi and Pakistani women. However, there are limited conclusions that can be drawn from this, as there is inconsistency in the use of indications for CS by clinicians. There are no data for the prevalence of maternal request for CS among all women who gave birth in this 3-month study period, between May – July 2000.

Secondly, women from ethnic minorities may not be accessing antenatal care. It has been reported that women from ethnic minorities made 9% fewer antenatal visits compared with White British women, following adjustment for clinical variables[158], and were two to four times more likely to have booked for antenatal care after 18 weeks gestation[159]. As a result, it could be that those with problems in their pregnancy requiring delivery by CS present later, possibly after the onset of labour. In the NSCSA, maternal medical disease was the primary indication for CS before labour in 3% of White women compared with 3% to 10% of women from other ethnic groups. Among women in labour, it was the primary indication for less than 1% of White women compared with 1–2% of women from other ethnic groups.

4.3.6 Gestation

Pregnancies between 28 and 32 weeks gestation had significantly higher odds of delivery by CS. The magnitude of the main effect of lower gestational age was much higher for CS before labour. The odds of delivery by CS before labour were four to eight times higher for pregnancies between 28 and 32 weeks gestation compared with term pregnancies. This is consistent with findings from a French study that reported odds of CS before labour that were about four times higher for pregnancies under 37 weeks gestation compared with those of at least 37 weeks gestation[38]. During labour, the odds of CS were 17–45% higher for pregnancies between 28 and 32 weeks gestation compared with term pregnancies. These findings are consistent with higher odds of CS at lower gestational age when compared with term pregnancies that are reported in the literature[29].

Preterm birth may result from spontaneous onset of preterm labour or because delivery at early gestation is thought to be beneficial to the woman (such as in cases of severe pre-eclampsia) or the baby (such as in cases of presumed fetal compromise). The prevalence of breech presentation and multiple pregnancies is higher at lower gestational ages, and this will also influence decisions that are made about mode of delivery. A trial of labour may not be seen as the most suitable course of action and delivery may be more likely to be expedited by CS before labour. The impact of delivery by CS on neonatal outcomes for small babies is uncertain. RCTs that have attempted to evaluate this were discontinued due to difficulties in recruitment[5].

The effect of gestational age on CS before labour varies according to whether or not a woman had had a previous CS. Although the magnitude of the effect of lower gestational ages is smaller for women who had had a previous CS, it is in the same direction as that observed for women with no previous deliveries. This interaction between gestational age and previous CS was not investigated for women in labour.

The results also show that the effect of gestational age varies with presentation and birth weight. These will be discussed in the following sections.

4.3.7 Presentation

The results show that having adjusted for demographic, clinical characteristics and interactions between these variables, the odds ratio for CS before labour and CS for women in labour are about 50 times higher for pregnancies with breech presentation compared with cepha lic presentation.

The relative effect of breech presentation on CS before labour varies with gestational age. For term pregnancies it is about 50-fold increase in odds of CS either before or during labour whereas at gestational ages less than 37 weeks it is about a three- to nine-fold increase in odds of CS before labour, and a 5- to 30- fold increase in odds of CS during labour.

A recent RCT[4] has shown that delivery by CS reduces perinatal mortality and morbidity in term breech pregnancies. As a result, the majority of term pregnancies with breech presentation are delivered by CS, and the observed odds ratios for CS before and during labour are 40–50 times higher compared with term pregnancies with cephalic presentation. The use of external cephalic version for breech presentation is recommended after 36 weeks to reduce the prevalence of breech presentation and the need for CS[16]. The evidence for the benefit of delivery by CS for preterm pregnancies is less conclusive. The results show that for pregnancies with breech presentation, the relative effect of lower gestational age is a reduction in odds of delivery by CS compared with term pregnancies. In the CESDI Project 27/28 report, survival rates (86%) were higher for breech babies between 26 and 29 weeks gestation that were delivered by CS compared with vaginal birth (77%)[160].

For CS before labour, there are also minor quantitative interactions between presentation and 'previous CS' and 'previous vaginal delivery'. However, the effect of these is in the same direction as that of the main effect. For CS in labour, interactions between 'presentation' and 'previous CS' and 'previous vaginal delivery' were not investigated.

Pregnancies with transverse lie have to be delivered by CS and in some cases this occurs before onset of labour. All women in labour who presented with transverse lie had CS.

4.3.8 Induction of labour

Mode of onset of labour was used as an explanatory variable in the model for women in labour. Women who had no previous deliveries, who had induction of labour had odds of CS that were about two to three times higher than those who had spontaneous onset of labour. This is consistent with results from observational studies that show an increased likelihood of CS in pregnancies where labour was induced[38;65]. However, RCTs that compared policies of induction of labour versus expectant management have not shown an increase in CS rates[96]. The explanation for this is probably that the reason for the intervention itself (i.e. induction of labour) is probably associated with a higher likelihood of delivery by CS. In England and Wales, a national evidence-based guideline for induction of labour was published in 2001, and recommends that induction of labour should only be considered when vaginal birth is felt to be the most appropriate mode of delivery, and women with no pregnancy complications should be offered induction of labour after 41 weeks because of the risk of stillbirth associated with prolonged pregnancy[153].

The effect of induction of labour varies according to whether women had had a previous CS. For women who had had only one previous CS, the relative effect of induction of labour is about a two-fold increase in odds of CS, for women who had had at least two previous CS, however, the relative effect is a 60% reduction in odds of CS in index pregnancy as the majority of women with two previous CS in labour had spontaneous onset of labour and a third CS. For women with previous CS, compared with women who had planned repeat CS, the risk of uterine rupture is increased with induction of labour[149] (without prostaglandins risk ratio (RR): 4.9, 95% CI: 2.4, 9.7; with prostaglandins RR: 15.6, 95% CI: 8.1, 30.0).

The effect of induction of labour also varies with gestational age. Before 32 weeks, the relative effect of induction of labour is a reduction in odds of CS, after 32 weeks gestation, however, induction of labour is associated with a two-to three-fold increase in odds of CS.

The effect of induction of labour on CS rates has been reported in other studies to vary according to age, with higher rates of CS among older women who have induction of labour[65;66]. However, in both these studies there was also a larger proportion of elective inductions among older women before 41 weeks. The effect of induction of labour according to age was not investigated in this analysis of the NSCSA data.

4.3.9 Birth weight

Babies that weighed less than 2500 g at birth, having adjusted for gestational age, had 37% increase in odds of delivery by CS during labour, and 96% increase in odds of CS before labour. This is consistent with the finding that babies at lower gestational ages were more likely to be delivered by CS before labour, as discussed above. Babies who weighed more than 4000 g had a 93% increase in odds of CS during labour, but there was no difference in odds of CS before labour. Higher CS rates for babies who weighed over 4000 g have not been shown to be associated with lower neonatal mortality or morbidity[161]. The increase in odds of CS was only apparent for women in labour in the NSCSA data, suggesting that it may be related to cephalopelvic disproportion during labour.

The effect of birth weight varies slightly according to the mother's ethnicity; however, this is a minor quantitative interaction that is in the same direction and of the same order of the main effect of birth weight.

For CS before labour there are also minor quantitative interactions between birth weight and 'previous CS' and 'previous vaginal delivery' and gestational age; these are in the same direction as the main effect of the variables. These interactions were not included in the model for CS in labour.

Although gestational age and birthweight are continuous variables they were categorised in this analysis. It is known that although convenient, categorisation of continuous variables can result in loss of information. However, categorisation enabled the use a category for women with missing data on these variables so that they could be included in the analysis. Gestational age and birthweight are highly correlated variables. An alternative approach to include this information in the analysis would have been to use growth centiles, however this was not explored in this analysis. In the multiple logistic regression models without interaction terms, the odds ratios obtained for the different gestational age categories do not allow for the effect of birthweight to differ at different gestational ages. For example, a 2000g fetus at 34 weeks would be normally grown with low likelihood of delivery by CS whereas a fetus with similar weight at 40 weeks gestation would be severely growth restricted and have higher likelihood of delivery by CS. The final model with interaction terms for CS before labour included an interaction term between gestational age and birthweight (both in categories). The pattern of odds ratios obtained from this model for CS before labour are consistent with the U shaped relationship between birthweight and risk of CS for babies at 40 weeks gestation as has been previously described[79]. A limitation of this analysis is that the interaction term between gestational age and birthweight was not included in the model for CS during labour, as it is inevitable that gestational age and birthweight will interact.

However the list of interactions to be investigated and strategy for their inclusion was drawn up and discussed prospectively. The strategy was as follows: A model was fitted including the interactions described in model A (Table 4.2.2.1). As described in section 4.2.1 these interactions were clinically motivated. The goodness of fit was then assessed by comparing observed numbers of CS with expected numbers of CS within deciles of the distribution of the expected probabilities of CS. If the goodness of fit was judged to be inadequate as was the case for CS before labour, a further set of interactions was included (model B – which includes an interaction term between gestation and birthweight). Goodness of fit was judged to be adequate using model A for CS during labour. With hindsight, an interaction term between birthweight and gestational age could have been included in model A.

5 CS rates standardised for case-mix differences

In this chapter, standardised CS rates (SCR) that are adjusted for case-mix variables (age, ethnicity, previous deliveries, gestational age, mode of onset of labour, presentation and birth weight) are calculated for each maternity unit. The aim is to quantify the amount of variation in CS rates between maternity units that can be explained by case-mix differences.

For each maternity unit, the observed rates of CS before labour and CS during labour are compared separately with the respective standardised rates. Overall standardised CS rates are then calculated for each maternity unit and compared with the respective observed CS rates. Maternity units are then ranked according to standardised CS rates to highlight the extent to which some have significantly higher or lower rates compared with the national average. Outlying maternity units are identified. Meta-analytical techniques are used to examine the change in the between maternity units component of variance, before and after standardisation, in order to quantify the amount of variation between maternity units that can be explained by case-mix adjustment.

5.1 Methods

For each maternity unit, the expected number of CS (before or during labour) is the sum of the expected probabilities of CS (before or during labour respectively) for individual women within the unit, as predicted by the logistic regression models (for CS before labour and CS among women in labour respectively) that included case-mix variables only (model B for CS bfore labour and model A for CS during labour as described in chapter 4). The expected number of total CS for a particular maternity unit is the sum of the expected number of CS before labour and the expected number CS during labour for that maternity unit.

For (i) CS before labour, and (ii) CS in labour, standardised rates were calculated by comparing the observed number of CS (before and during labour respectively) that took place within a maternity unit with the expected number of CS (before and during labour respectively) for that maternity unit, and multiplying this by the overall rate for England and Wales (10% for CS before labour and 12% for CS during labour).

The overall standardised CS rate was calculated as the sum of the total number of observed CS (before and during labour) divided by the sum of expected number of CS (before and during labour) within each maternity unit, multiplied by the overall CS rate for all maternity units (20.5%).

For example, calculation of the standardised CS rate for maternity unit A is as follows:

1. Fitted probabilities of CS before labour and CS for women in labour are obtained for women who attended maternity unit A, using the logistic regression models for CS before labour and CS among women in labour

(model B for CS before labour and model A for CS during labour as described in chapter 4). The sum of these fitted probabilities represent the total number of expected CS for maternity unit A (E).

2. The observed number of CS (O) that took place within maternity unit A is then divided by the expected number of CS (E), and multiplied by 20.5%.

Discrepancies between observed and expected CS rates (for CS before labour, CS during labour and overall CS rates) were assessed by identifying maternity units that had observed rates that were outside the fitted 95% reference range calculated from the expected proportion of CS (p) in that unit ($p \pm 1.96[p(1-p)/n]^{0.5}$).

Assuming that the expected values are error-free and that the observed proportions follow a binomial distribution, standard errors for these SCRs were calculated using the normal approximation to the binomial distribution.

Each of these standardised rates (standardised CS before labour rate, standardised CS during labour rate, overall standardised CS rate) for maternity units were then ranked.

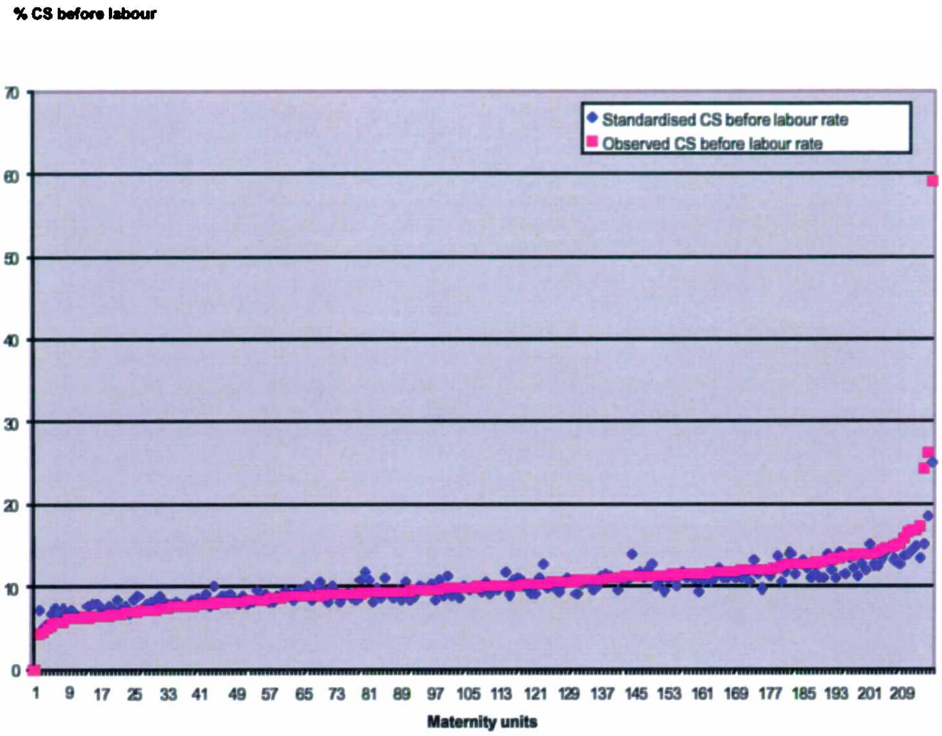
A random effects meta-analysis of CS rates was carried out to investigate the heterogeneity between maternity units before and after this standardisation process. The Q test statistic and I^2 tests were used to assess heterogeneity in CS rates between maternity units[162;163].

5.2 Results

5.2.1 CS before labour

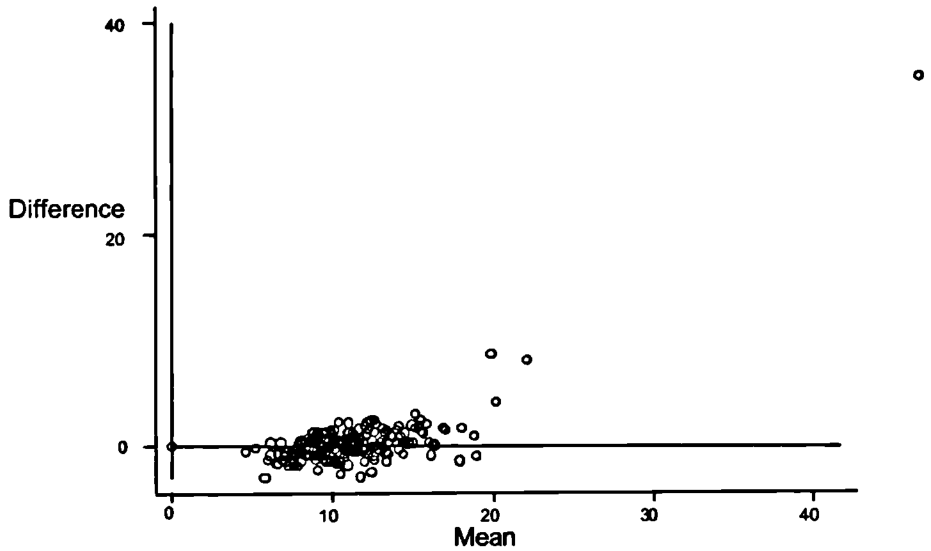
The overall CS before labour rate was 10%. For the 216 maternity units, the median observed CS before labour rate was 10% (IQR: 8%, 12%). One maternity unit did not perform any CS before labour. The range of observed rates excluding this maternity unit was 4%–59%. The range for standardised CS before labour rates was 5%–25%. Figure 5.2.1.1 shows the observed and standardised CS before labour rates for the 216 maternity units, ordered by their observed CS before labour rates. Figure 5.2.1.2 shows the relationship between the difference and mean for observed and standardised CS before labour rates.

Figure 5.2.1.1: Observed and standardised CS before labour rates for maternity units



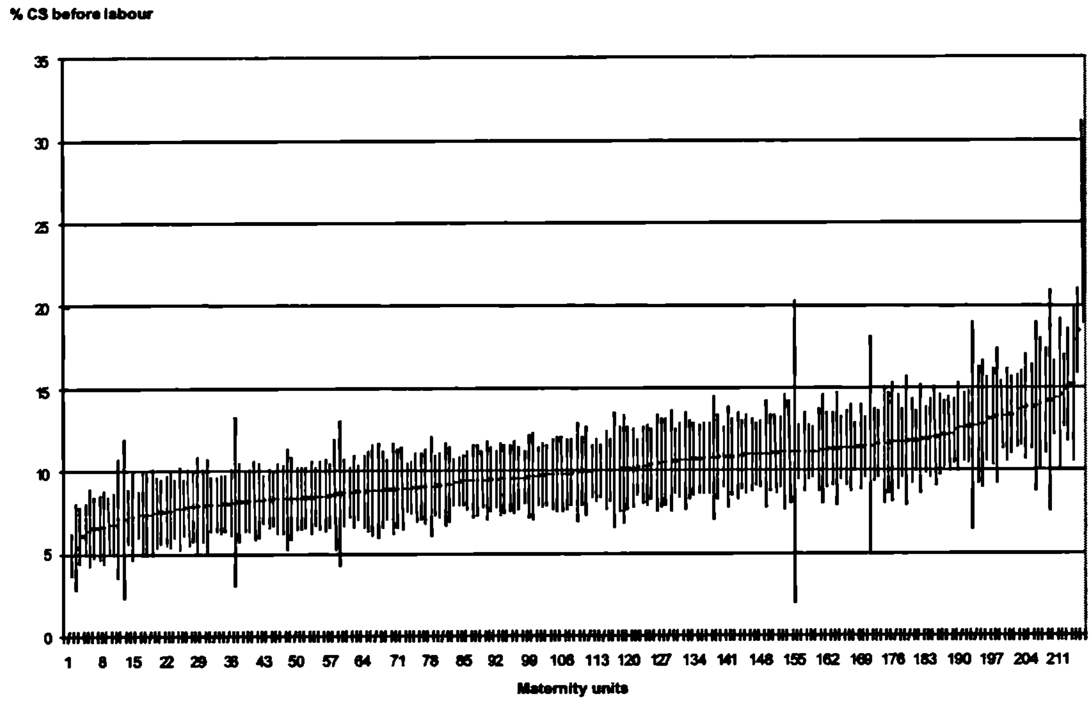
Nineteen maternity units had observed CS before labour rates that were below the lower limit of the 95% reference range of their expected CS before labour rates. Twenty-eight maternity units had observed CS before labour rates that were above the upper limit of the 95% reference range of their expected CS before labour rates.

Figure 5.2.1.2: Relationship between difference and mean for observed and standardised CS before labour rates



The mean difference between observed and standardised CS before labour rates was –0.08%. The median difference was –0.33% (IQR: –1.08%, 0.36%). As shown in figure 5.2.1.2 above, there are three outlying maternity units. All three are private maternity units, with observed CS before labour rates of 24%, 26% and 59% and standardised rates of 16%, 18% and 25%, respectively. The variance of the difference between observed and standardised CS before labour rates was reduced from 7.2% to 1.8% when these outlying maternity units were excluded. This graphical display also suggests a linear relationship between the observed and standardised rates, as would be expected as the standardised rates are dependent on the observed rate. The process of adjusting for case-mix results in lower standardised rates for units with higher observed rates, and higher standardised rates for units with lower observed rates.

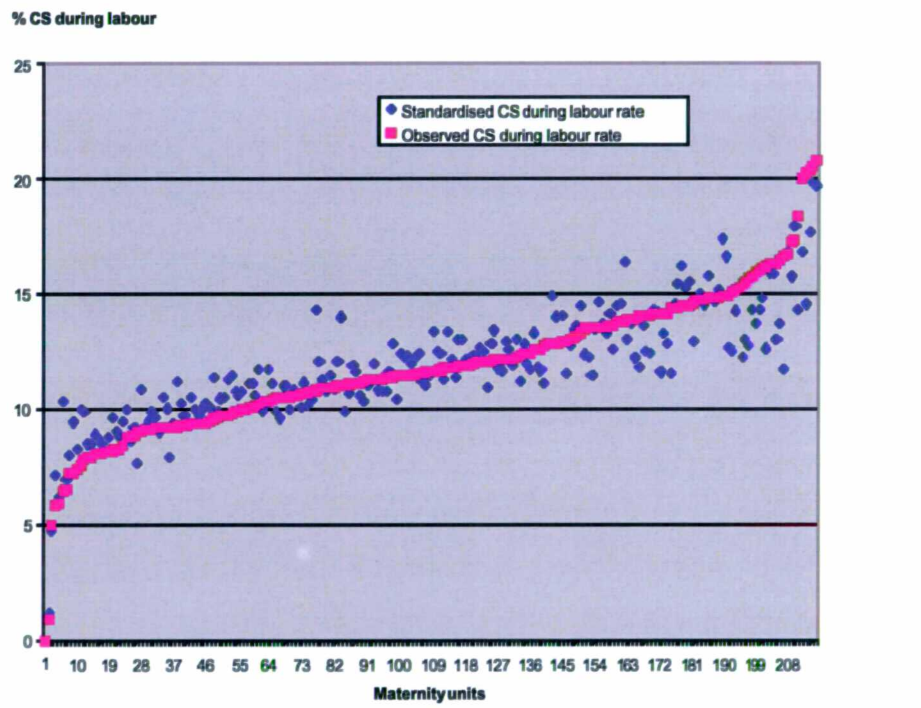
Figure 5.2.1.3: Standardised CS before labour rates (with 95% CI) for maternity units.



5.2.2 CS in labour

The overall CS rate among women in labour was 12%. The median observed CS rate among women in labour for the 216 maternity units was 12% (IQR: 10%, 14%). One maternity unit only performed CS before labour and therefore had no CS among women in labour. The range of observed CS during labour rates excluding this latter maternity unit was 0.9–21%. The range of standardised CS during labour rates was 1%–19%. Figure 5.2.2.1 shows the observed and standardised CS rates for women in labour for the 216 maternity units, ordered by their observed CS rates for women in labour. Figure 5.2.2.2 shows the relationship between the difference and mean for observed and standardised CS in labour rates. Figure 5.2.2.3 shows the standardised CS in labour rates with 95% CI for maternity units.

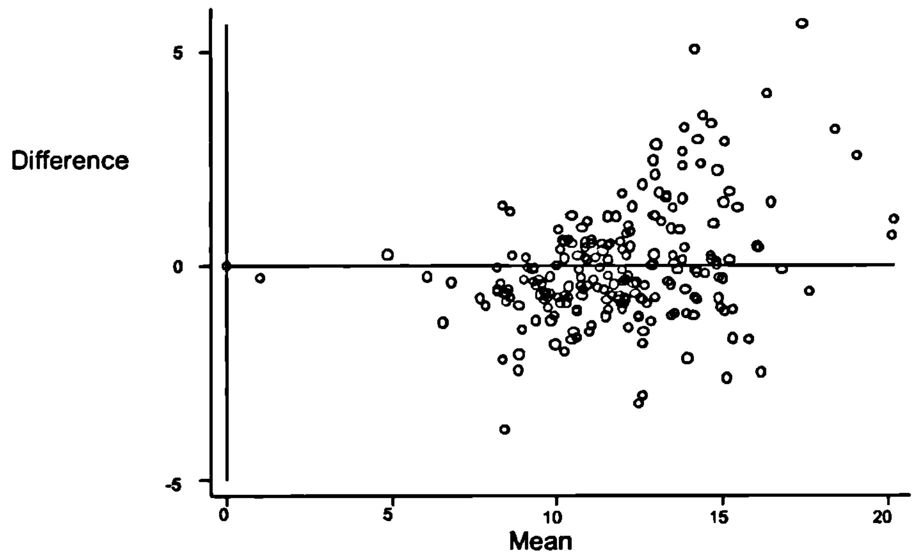
Figure 5.2.2.1: Observed and standardised CS during labour rates for maternity units



Twenty-four maternity units had observed CS during labour rates that were lower than the lower limit of the 95% reference range of the expected CS during labour rate. Of these, five also had observed CS before labour rates that were below the lower limit of the 95% reference range of their expected CS before labour rates. Two of these maternity units had observed CS before labour rates that were above the upper limit of the 95% reference of their expected CS before labour rates.

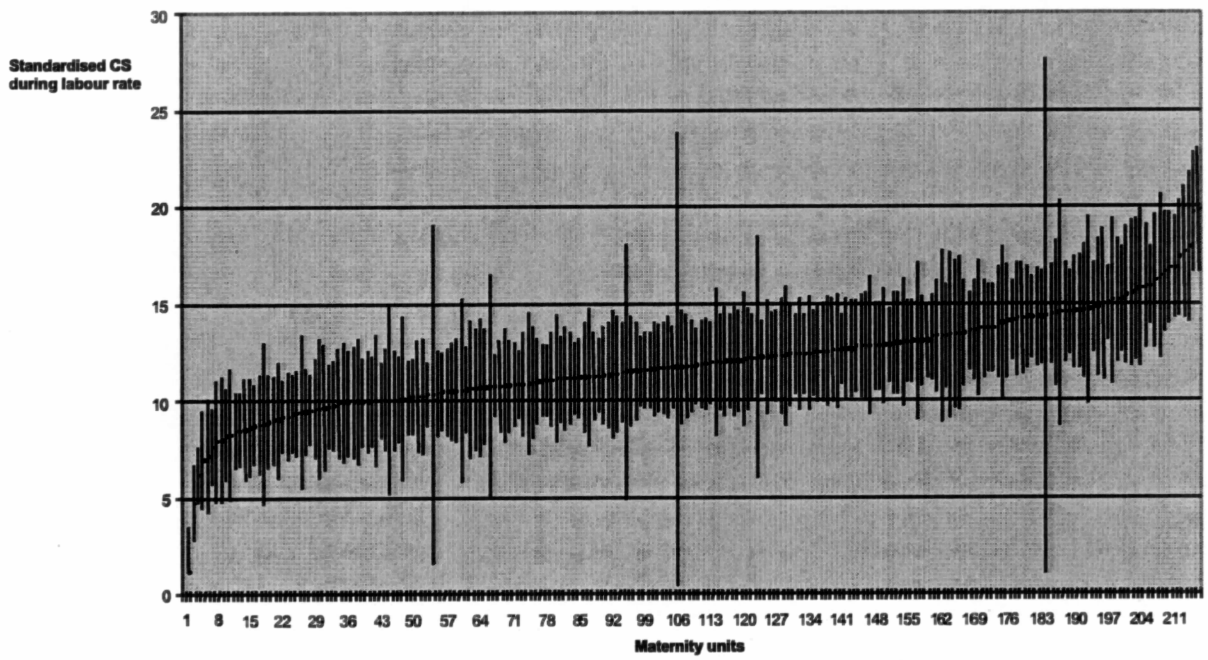
Thirty-two maternity units had observed CS during labour rates that were more than the upper limit of the 95% reference range of the expected CS during labour rate. Of these, 11 also had observed CS before labour rates that were above the upper limit of the 95% reference range of their expected CS before labour rates. One of these maternity units had an observed CS before labour rate that was below the lower limit of the 95% reference range of its expected CS before labour rate.

Figure 5.2.22: Relationship between difference and mean for observed and standardised CS in labour rates



The mean difference between observed and standardised CS in labour rates was 0.13% (SD: 1.36%). The median difference was –0.13% (IQR: –0.63%, 0.67%).

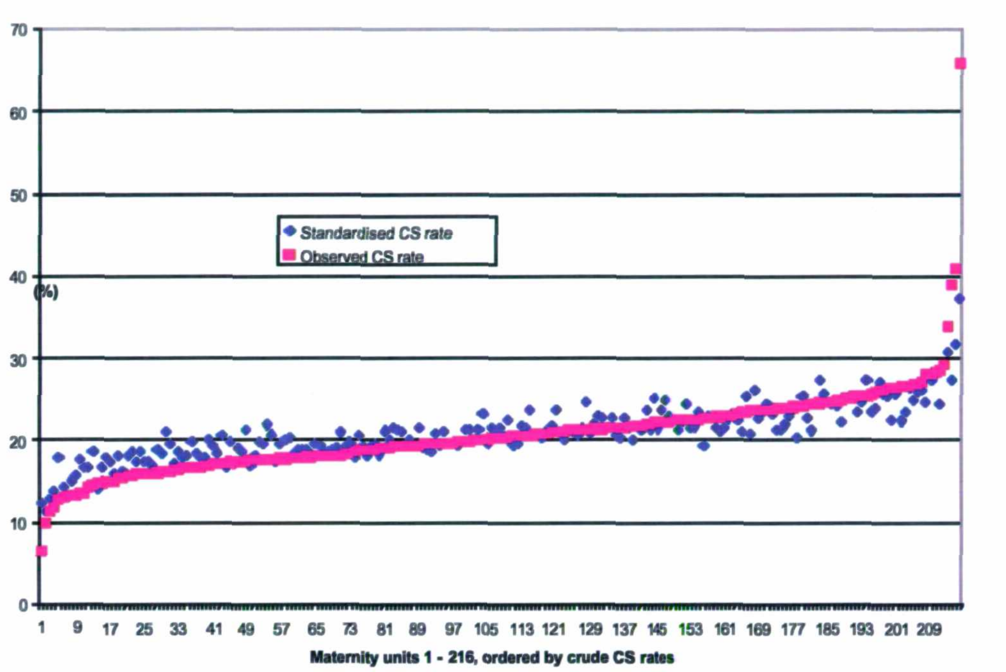
Figure 5.2.2.3: Standardised CS during labour rates (with 95% CI) for maternity units



5.2.3 Overall CS rates

The overall CS rate was 21%. The median observed CS rate for the 216 maternity units was 20.7% (IQR 17.9%, 23.5%). Figure 5.2.3.1 shows the observed and standardised CS rates for the 216 maternity units, ordered by their observed CS rates. Figure 5.2.3.2 shows the relationship between the difference and mean for observed and standardised CS rates (standardised for case-mix differences). Figure 5.2.3.3 shows the standardised CS rate (SCR) with 95% CI for maternity units.

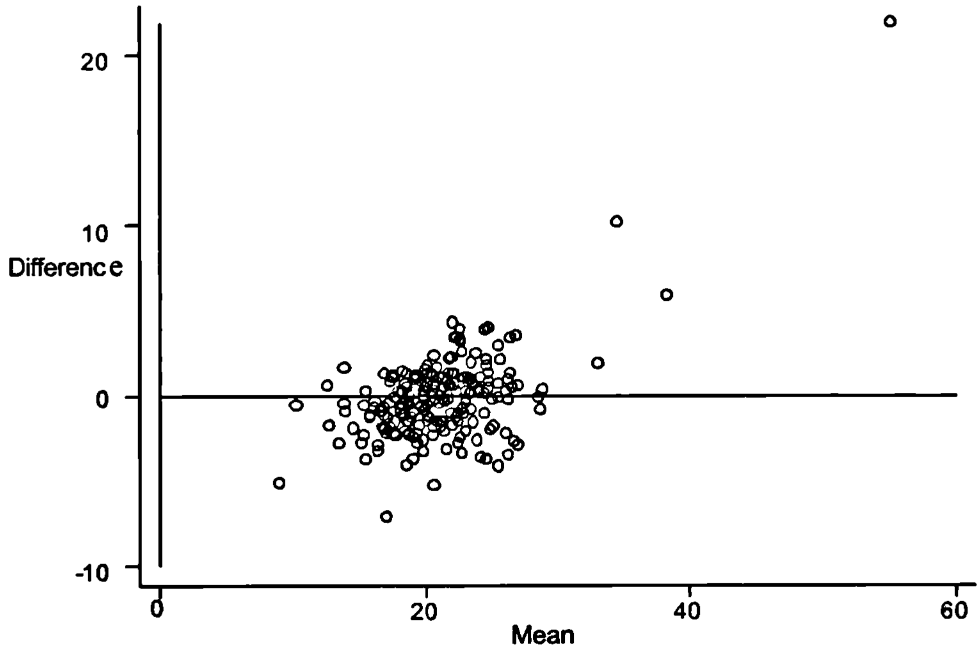
Figure 5.2.3.1: Observed and standardised overall CS rates for maternity units



Thirty-one maternity units had observed CS rates that were below the lower limit of the 95% reference range of their overall expected CS rates. Of these, four had significantly lower CS before labour and CS during labour rates, ten were highlighted to have lower CS before labour rates and eight were highlighted to have lower CS during labour rates in the previous sections.

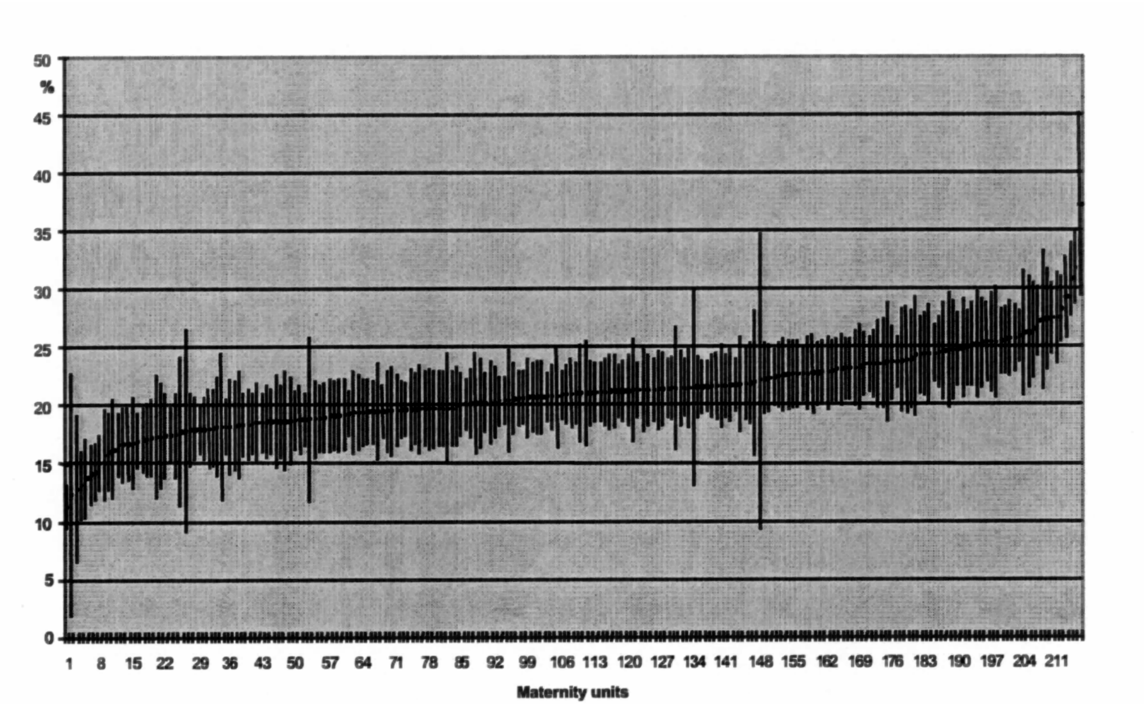
Thirty-seven maternity units had observed CS rates that were above the upper limit of the 95% reference range of their expected CS rate. Of these, nine were highlighted to have both high CS before and during labour rates, 12 were highlighted to have higher CS before labour rates and 12 were highlighted to have higher CS during labour rates in the previous sections.

Figure 5.2.3.2: Relationship between difference and mean for observed and standardised CS rates



The mean difference between observed and standardised CS rates was 0.31% (SD: 2.54%). The median difference was 0.18% (IQR: –1.01%, 1.44%). As shown in figure 5.2.3.2 above, there are three outlying maternity units. These are the same private maternity units that were discussed in the previous section for CS before labour, with an observed CS rate of 29%, 41% and 66% and standardised rates of 29%, 34% and 43%, respectively. The variance of the difference between observed and standardised overall CS rates was reduced from 6.4% to 4.1% when these outlying maternity units were excluded.

Figure 5.2.3.3: Standardised overall CS rates for maternity units (with 95% CI)



5.2.4 Proportion of variance explained by case-mix

A random effects meta-analysis was carried out to look at the change in the between maternity units component of variance, before and after standardisation of overall CS rates. There was statistically significant heterogeneity ($p<0.0001$) in observed CS rates between maternity units. The I^2 statistic showed that only 15% of this variation could be attributed to chance with the true between unit standard deviation estimated to be 3.7% (moment-based estimate of variance between maternity units was 13.87). Following adjustment for case-mix variables, the heterogeneity in CS rates between maternity units was still statistically significant ($p<0.0001$), the true between-unit standard deviation for observed rates was reduced to 3.0% (moment-based estimate of variance between maternity units was 9.11); equating to a 34% reduction in true between-unit variance. These results remained similar when the three outlying maternity units were excluded.

5.2.5 Ranking

Maternity units were ranked separately based on their observed overall CS rates, standardised CS before labour, standardised CS in labour and standardised overall CS rates. The following comparisons of ranks were then made:

- observed overall CS rates and standardised CS before labour rates
- observed overall CS rates and standardised CS in labour rates
- observed overall CS rates and standardised overall CS rates
- observed CS before labour rates and observed CS in labour rates
- standardised CS before labour rates and standardised CS in labour rates.

The agreement of ranks within these comparisons was assessed by examination of (i) Spearman rank correlation coefficient between the ranks obtained using each of the two methods, and (ii) the differences between the ranks obtained using each of the two methods.

Table 5.2.5.1: Agreement between ranks of maternity units using the observed and standardised CS rates

Comparison	Spearman rank correlation coefficient between ranks	95% reference range for difference between ranks
Observed overall CS and standardised CS before labour	0.64, p<0.01	–103, 103
Observed overall CS and standardised CS in labour	0.76, p<0.01	–84, 84
Observed overall CS and standardised overall CS	0.88, p<0.01	–59, 59
Observed CS before labour and observed CS in labour	0.39, p<0.01	–135, 135
Standardised CS before labour and standardised CS in labour	0.31, p<0.01	–144, 144

The following graphs show the spread of results for these comparisons.

Figure 5.2.5.1: Maternity units ranked by observed overall CS rates and standardised CS before labour rates

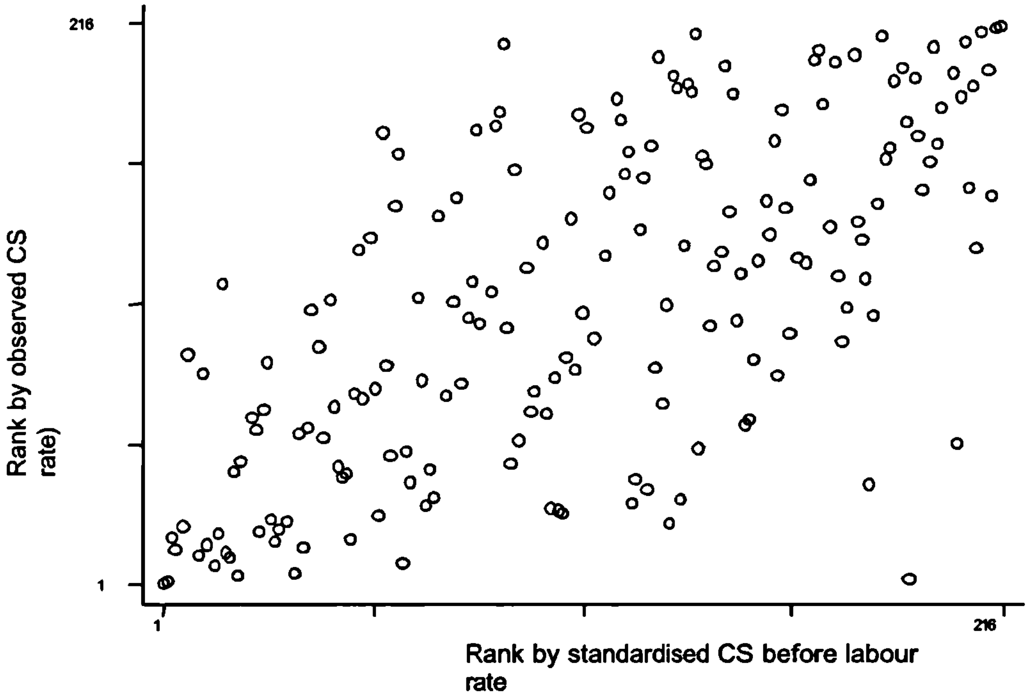


Figure 5.2.5.2: Maternity units ranked by observed overall CS rates and standardised CS in labour rates

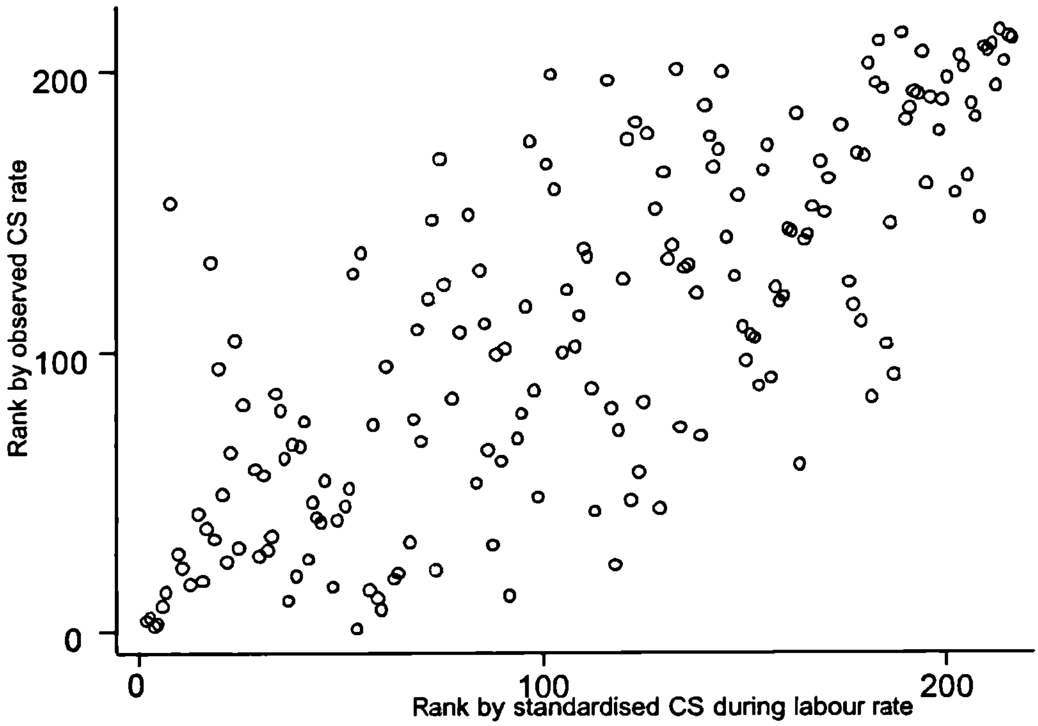


Figure 5.2.5.3: Maternity units ranked by observed overall CS rates and standardised overall CS rates

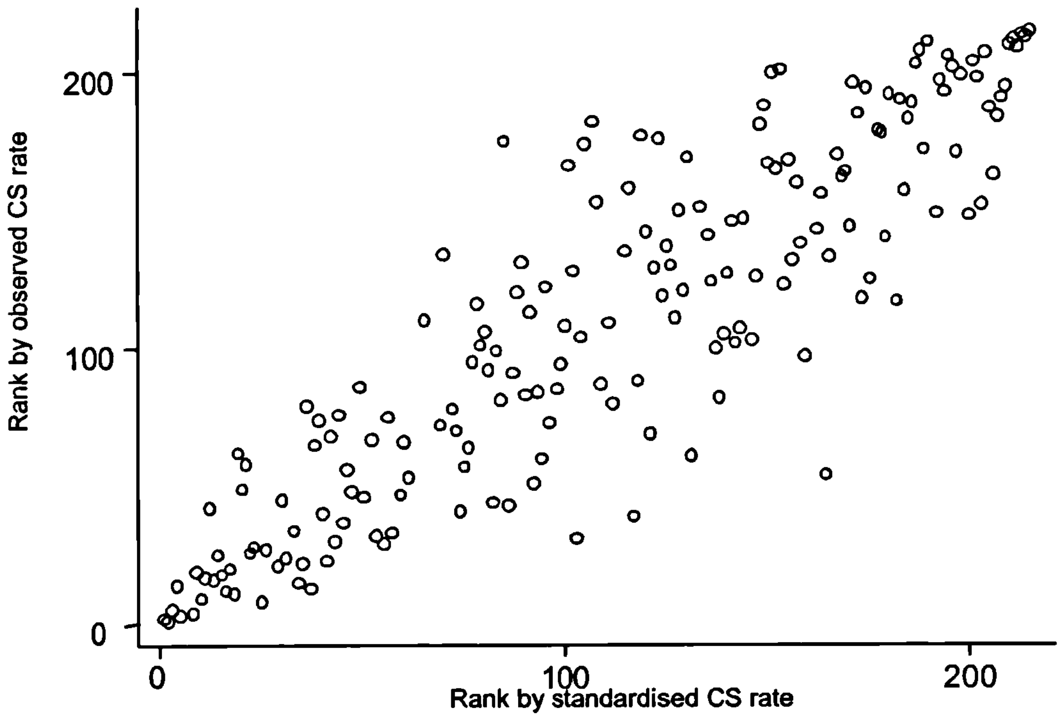


Figure 5.2.5.4 Maternity units ranked by observed CS before labour rates and observed CS in labour rates

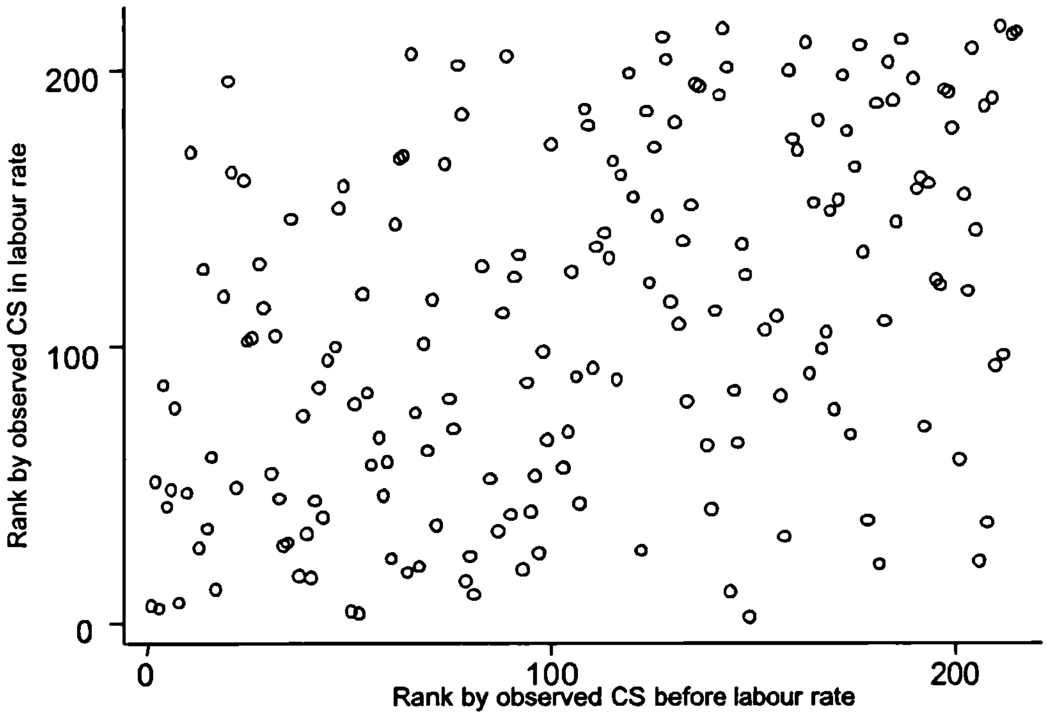
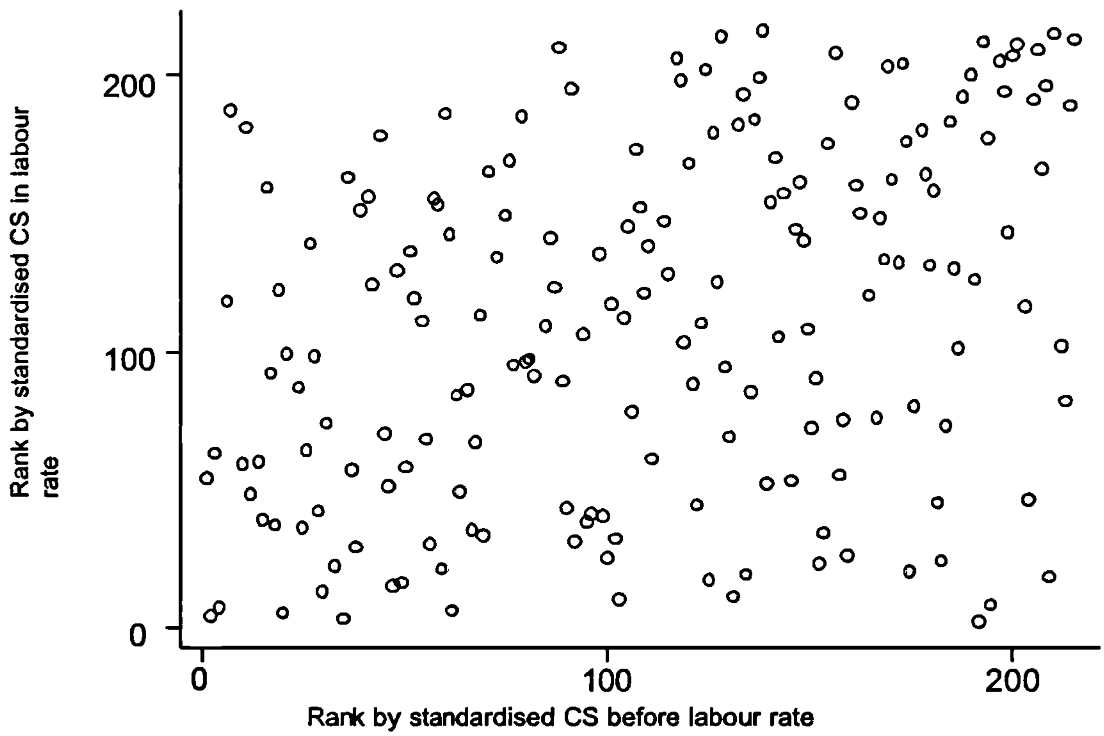


Figure 5.2.5.5: Maternity units ranked by standardised CS before labour and standardised CS in labour rates



These results show that, overall, there is a wide reference range for the difference in rank of maternity units according to their observed and standardised CS rates (see table 5.2.5.1). Although in general, maternity units with higher observed CS rates also have (i) higher standardised CS before labour and (ii) higher standardised CS in labour rates, the rank assigned to these maternity units within each of these comparisons can change by over 84 places. The change in rank when observed CS rates were compared with standardised CS rates was about 59 places. The spread of results was much wider when comparisons were made between observed and standardised CS before and in labour rates (figures 5.2.5.4 and 5.2.5.5). The product moment correlation coefficient between (i) observed CS before labour and observed CS in labour rates and (ii) standardised CS before labour and standardised CS in labour rates was much lower (about 0.3). The change in rank for these comparisons is over 135 places. This is also illustrated by the overlapping confidence intervals for standardised CS before labour, CS during labour and overall CS rates shown in figures 5.2.1.3, 5.2.2.3 and 5.2.3.3.

5.3 Discussion

It is generally accepted that case-mix adjustment is necessary to enable valid comparisons of CS rates between maternity units[29]. As discussed in chapter 4, the variables that should be included in case-mix adjustment need to be determined. The inclusion of too many variables carries the risk of over adjustment. However, the primary aim in this analysis was to explain variation in CS rates and hence it is important to maximise discrimination (the correct prediction of women who have CS based on probabilities obtained from the fitted model).

The method used for comparing CS rates between maternity units in this analysis was indirect standardisation. This refers to the application of observed risks in a reference population to the study population. This method was used in this analysis, with the sophistication of a two-stage prediction model. The expected CS rates for maternity units were based on average practice for England and Wales; they were derived from expected probabilities of CS for individual women obtained from logistic regression models that were fitted to the whole dataset, whilst accounting for clustering of women within maternity with the use of robust standard errors as described in chapter 4. The advantages of this method are that (i) it is all-inclusive, (ii) it does not require the selection of any particular maternity unit for use as the standard reference population, and (iii) it allows for comparisons of an overall CS rate that is adjusted for case-mix. Expected probabilities of CS for individual women only reflect current practice and do not provide information about the appropriateness or effectiveness of the CS for individual women. These expected probabilities are based on variables that were measured in the NSCSA and therefore do not take into account other factors associated with risk of CS such as body mass index. Therefore it is possible that some of the unexplained variation in CS rates between maternity units is due to residual confounding by variables that were not measured in the NSCSA.

In this analysis of the NSCSA data, the ranges of observed CS before and CS during labour rates were 4%–59%, and 0.9%–21%, respectively. The ranges for standardised rates were 5%–25% and 1%–19%, respectively. The range for observed overall CS rates was 6%–66%, while for standardised overall CS rates it was 10%–43%. For CS before labour and overall CS rates, three outlying maternity units were identified; all three were private maternity units. It is unlikely that these maternity units were outliers because of random variation but rather their position probably reflects differences in practice within these units.

In order to assess the impact of case-mix adjustment on CS rates, observed CS rates were compared with the calculated expected CS rates and their 95%

reference range. For CS before labour, 49 maternity units had observed rates that were significantly lower (19 maternity units) or higher (28 maternity units) compared with their calculated expected rates. For CS during labour, 56 maternity units had observed rates that were significantly lower (24 maternity units) or higher (32 maternity units) compared with their calculated expected rates.

For overall CS rates, 68 maternity units had observed CS rates that were significantly higher or lower compared with their expected rates. Four had lower observed CS before labour and CS during labour rates, ten had lower observed CS before labour rates and eight had lower observed CS during labour rates, nine had higher observed rates for both CS before and during labour, 12 had higher observed CS before labour rates and 12 had higher observed CS during labour rates when compared with their calculated expected rates. Therefore, following case-mix adjustment 31% (n=68) of maternity units were highlighted to have significantly higher or lower observed CS rates when compared with their calculated expected CS rates. By chance alone it is expected that there would be a change in CS rates following adjustment for at least 11 maternity units.

Five studies have also used indirect standardisation to compare CS rates[29;37-40]. The population studied and factors adjusted for in case-mix adjustment varied across the studies, but the concept was similar in that a statistical model was fitted to the data to obtain probabilities of CS for individual women which were then summed within maternity units to calculate a unit-specific expected number of CS. Most studies considered either the overall CS rate or the primary CS rate and reported substantial differences between observed rates and calculated expected rates. This affirms the importance of case-mix adjustment for more valid comparisons of CS rates between maternity units. One study made the distinction between CS before and during labour[38], but did not report the range of expected rates that were calculated, nor did they assess the impact of risk adjustment on observed rates. The findings from the other four studies are summarised below.

A study of CS rates across 21 hospitals (26,000 women) in the USA[37] reported observed CS rates ranging from 6% to 26%. Following adjustment for 39 risk factors (demographic and clinical, including pregnancy and labour complications) standardised rates ranged from 8% to 22%. They reported that a third of the 21 hospitals were classified as outliers based on the unadjusted rate, and that adjustment changed outlier status for five hospitals.

Two studies[29;40] reported on risk adjustment for primary CS rates. These studies excluded women with previous CS because it was thought that decision-making for primary CS is different from repeat CS. The first study included 160,753 women in 154 hospitals in the USA[29]. Observed CS rates ranged from 6% to 30%, and expected CS rates ranged from 9% to 24%. They reported that 65 (42%) of the 154 maternity units had observed CS rates that were different from their expected rates. The second study[40] focused on comparing rates between managed care (insurance) plans in the USA.

Another study[39] used very similar methods to those used in this analysis of NSCSA data to highlight outlying maternity units that had adjusted CS rates that were significantly higher or lower than other maternity units in the region. The analysis was based on 8,229 women giving birth in 16 hospitals in the USA. The average observed CS rate was 22%. Of the five hospitals with the lowest observed CS rates, only two had observed rates that were significantly lower than their expected rates, while three of the five hospitals with the highest observed rates had observed rates that were significantly higher than their expected rates.

5.3.1 Amount of variation explained by case-mix differences

In this analysis, random effects meta-analysis was used to estimate the change in the between maternity units component of variance, before and after standardisation of overall CS rates. Adjustment for case-mix factors resulted in a 34% reduction in the between-units variance. Similar findings were reported in a study that used the R-squared statistic to describe the amount of variance in the data that can be accounted for by case-mix variables (maternal age, parity, presentation, birth weight, birth interval, male sex, pre-pregnancy weight gain, pre-existing maternal morbidity and complications of pregnancy and labour) in an explanatory linear regression model[152]. In this study, 35% of the variation in the data was explained by a minimal set of case-mix variables (maternal age, placenta praevia or abruption, cord problems, herpes, amnionitis, birth weight and male sex). This increased to 37% when the full complement of available case-mix variables was used[152].

5.3.2 Ranking of maternity units

Maternity units in England and Wales were ranked based on their observed and standardised rates for CS before and during labour and overall. There was not much consistency in the rank assigned to these maternity units using the different measures of CS rate. In figures 5.2.1.3, 5.2.2.3 and 5.2.3.3, maternity units were ordered according to their standardised rates for CS before labour, during labour and overall. The 95% CI for the standardised CS during labour rates overlap between the majority of maternity units, illustrating the unreliability of ranking maternity units. These findings are consistent with other studies that have investigated the use of ranks for comparison of hospital performance based on statistics such as the CS rate. Two studies reported substantial changes in the rank of hospitals when comparing observed with case-mix-adjusted CS rates, with moderate correlation between unadjusted and adjusted ranks[37;164]. In contrast, another study reported that adjustment did not greatly alter the ranking of hospitals[152].

One study[165] compared four different systems for risk adjustment, ranked 15 hospitals using each system, and then used Spearman's correlation to assess the consistency of rankings across systems. There was some consistency in the relative ranking of hospitals across the systems. The maximum number of difference in ranks was three, with five hospitals ranked consistently across the systems. There were also some inconsistencies; for example, hospitals that experienced the biggest change within one system were unaffected in another.

Ranking can overestimate the magnitude of difference between maternity units; for example, if the rates of five maternity units were 20.1, 20.2, 20.3, 20.4, 20.5; ranked one to five, there is a difference of four in rank which corresponds to a 0.4% difference in rate.

One study[166] ranked maternity units based on 'prophylactic CS rates' and focused on the estimation of credible intervals for each maternity unit rank using Bayesian methodology. Their results showed that the use of ranks to compare maternity units is misleading such that none of the maternity units could be confidently placed in the upper or lower quartiles. Similar findings were highlighted in an assessment of league tables to evaluate performance of fertility clinics[167]. This study highlighted the unreliability of ranks placed in the middle of the ranked league table. Precision of ranks is linked to the sample size involved, but whilst increasing the sample size improves precision, the instability of ranks persists for smaller units and those ranked in the middle.

5.3.3 Reliability of data used for case-mix adjustment

Most studies that have studied case-mix adjustment for CS rates have relied on routinely collected data such as birth certificate data. It is reported that the method of data collection for birth certificate data is not standardised across hospitals and this can lead to inconsistencies in the data. One study[168] compared the discrimination of risk-adjustment models for primary CS using data abstracted from medical records, with the same models using birth certificate data, to determine if the two sources of data would yield similar profiles of hospital risk-adjusted CS rates. This was a large study that included

29,234 women without previous CS who gave birth between 1993 and 1995 in 20 hospitals in the USA. Thirty-nine risk factors were accounted for in the risk-adjustment process. The results showed that there were differences in the discriminatory power of the models fitted depending on the source of data, but these differences were less pronounced when using variables that were common to both sources of data or where there was high agreement between the two sources of data. The results suggested that many variables in birth certificate data may not be suitable for use in case-mix adjustment but using a set of variables that are reliable is reasonable. Furthermore, hospitals that were identified as statistical outliers differed depending on the risk-adjustment model used.

One of the strengths of the NSCSA data is that they were collected prospectively and contemporaneously and there were several measures in place to ensure reliability. Validation against birth registration data from the Office for National Statistics showed that there was good coverage (99% of all births that occurred in England and Wales during the study period were included in the dataset)[1]. However, these issues highlight the need for a standardised maternity dataset for England and Wales and the tools for data collection and methodology employed in the NSCSA are useful to inform this process.

5.4 Conclusions

In this analysis, average national practice for England and Wales was used as the reference population in standardising CS rates for comparison between maternity units. While this may not be a true measure of quality of care, it enables more valid comparison of rates between maternity units, highlights maternity units that are outliers and is the first step in understanding variation in CS rates between maternity units.

There is a need to compare CS rates across populations but currently a variety of methods are being used for case-mix adjustment, utilising various sources of data and accounting for different risk factors. This highlights the need for a standard risk-adjustment methodology that utilises data collected routinely in a uniform manner across different maternity units, using consistent definitions of data items collected. There is also a need for consensus on which risk factors should be included in case-mix adjustment. It is possible that inclusion or exclusion of some risk factors can overestimate or underestimate case-mix-adjusted CS rates.

Within the framework of clinical governance, standardised CS rates are useful as they enable maternity units to compare their practice with average national practice to monitor and potentially improve their practice over time. It can also be useful in the evaluation of the effectiveness of interventions that have been used to reduce CS rates or to improve quality of care provided to women giving birth.

6 Women's preferences and CS

6.1 Overview

The aim of this chapter is to examine the contribution of women's birth preferences to variation in CS rates.

As data on women's birth preferences were only collected during phase 2 of the NSCSA, in the first instance phase 2 data are described and compared with phase 1 data to investigate whether or not the relationships between case-mix variables and risk of CS varies between phases. Phase 1 data give greater precision around the estimates obtained because of the larger number of women involved. However, there is no information on birth preferences for these women who gave birth during the phase 1 study period. If there is no 'time period effect' between the two phases, it is possible to use the information from the survey of women's views on childbirth carried out during phase 2 to 'predict' these 'missing data' on birth preferences for the women in phase 1. This is discussed in section 6.2.

Data on women's preferences is only available for 7% of all women who gave birth during the phase 2 study period. Therefore, a description of the survey methodology and characteristics of women who responded and those for whom there are no data available on their preferences is given in section 6.3. These 'missing data' on women's preferences had to be taken into account in the analysis so as to enable the results to be generalisable for all women giving birth in England and Wales. Therefore, a review of the methods available for handling missing data and their applicability to the NSCSA is given in chapter 7. A simplified data subset from the NSCSA containing only three variables was used to illustrate the use of these methods for handling missing data and this is also described in chapter 7.

The full analysis that shows the relationship between case-mix variables, women's birth preferences and risk of CS is given in chapter 8. These results were then used in chapter 9 to examine the contribution of women's birth preferences to variation in CS rates using meta-analytical techniques.

6.2 Comparison of relationships between case-mix variables and risk of CS between phase 1 and phase 2

6.2.1 Introduction

Data on women's preferences were collected during phase 2 of the NSCSA. As phase 2 was carried out 6 months after phase 1 it was necessary to investigate if there was a time-period effect in the relationships between case-mix variables and risk of CS. Any differences between the two phases would have to be considered when making inferences about the relationship between women's preferences and risk of CS for all women giving birth in England and Wales.

6.2.2 Data

Phase 1 data were collected from all maternity units (216) in England and Wales for the period May to July 2000. This database contains information for

150,139 women. The relationships between various demographic and clinical characteristics and (i) CS before labour, and (ii) CS during labour were assessed as reported in chapter 4.

Phase 2 took place between December 2000 and February 2001; the aims of this phase of the study included surveying women's views about childbirth and clinicians' attitudes towards, and threshold for, CS.

Forty maternity units in England, Wales and Northern Ireland were selected to participate. The sampling method used to select these maternity units is described in detail below. A survey of pregnant women's views on childbirth as well as obstetricians' views on CS was to be undertaken in the selected maternity units. In addition, data on demographic and clinical characteristics (case-mix variables) as well as mode of delivery were to be collected for all women giving birth in these maternity units during a 3-month period, using the same data-collection tools as in phase 1. These denominator data were collected so that by linking the survey data on women's views to the denominator dataset, outcome data for women who responded to the survey would be available.

6.2.3 Sampling for phase 2

The aim was to choose 40 maternity units in England and Wales, stratified by region, size of hospital and whether the CS rate based on preliminary data was high or low.

To create a sampling frame, all eight regions in England and Wales were conflated to five regions:

- North Eastern and North Western
- East Midlands and West Midlands
- Wales and South West
- London
- Eastern and South East.

All 216 maternity units in England and Wales were then stratified by region (five regions), size of maternity unit (annual delivery rate of at least 2,500, or greater than 2,500) and CS rate based on preliminary data (<16%, 16–20%, 20–24%, > 24%). Thus, there were eight strata for each of the five regions. In regions where there was only one teaching hospital, this was automatically selected. One maternity unit was then randomly selected from each stratum, such that in total 40 maternity units in England and Wales were selected whilst ensuring that at least one teaching hospital was selected from each region. Sampling with probability proportional to size (PPS) was not used.

However, one maternity unit from the England and Wales sampling frame was unable to gain ethical approval in time for the start of data collection for phase 2, and withdrew participation. Thus, in total there were 39 maternity units selected from England and Wales.

All 12 maternity units in Northern Ireland were participating in the NSCSA for the first time during phase 2, and one was randomly selected to participate in the survey of women's views on childbirth. The methodology that relates to the survey on women's preferences is described in section 6.3.2.

6.2.4 Methods

The analysis had to take into account the sampling method that was used. Firstly, as PPS was not used, women attending different maternity units had unequal probabilities of selection. Therefore, the data were weighted in the analysis to remove bias caused by unequal probabilities of selection. As the unit of analysis was the individual women and not maternity units, the weights were based on the number of women (weight w_j for the j^{th} woman means that the j^{th} woman represents w_j women in the population from which the sample was drawn).

There was no sampling involved in data collection from Northern Ireland. Hence, these women were given a weight of 1. Women who delivered during phase 1 in England and Wales were given weight of 1 as data were collected on nearly all women who gave birth in England and Wales during that 3-month study period, validation of data against birth registration data from the Office for National Statistics showed that the phase 1 database included 99% of all birth registration for that study period.

The stratification (five regions, size of hospital and CS rate) used in sampling was also taken into account in the analysis. For phase 1 and phase 2 data combined, there are 228 maternity units within 40 strata. Estimations were made within each stratum, and a stratified estimate for the whole population was calculated by weighting the stratum estimates by the population size in each stratum. Robust standard errors were obtained to account for the clustering of women within maternity units.

Logistic regression models (without interaction terms between case-mix variables) that were built to investigate the association between demographic and clinical variables and (i) CS before labour, and (ii) CS for women in labour (as reported in chapter 4) were fitted to phase 2 data separately. The phase 1 and phase 2 datasets were then combined and the same analysis was carried out including a dummy variable which took the value '0' for phase 1 data and '1' for phase 2 data. Interaction terms between case-mix variables and phase of study were explored by choosing the phase 1 baseline reference group as the reference category for phase 2. Interaction terms were then tested simultaneously, using the Wald test.

As the results suggested that the pattern of missing data was different in the two phases of the study, further 'sensitivity' analysis was undertaken by fitting the logistic regression models described above having omitted women who had 'missing data' for any of the variables used in the analysis.

6.2.5 Results

Distribution of data

The following table shows the distribution of case-mix variables in phase 1 and phase 2.

Table 6.2.5.1 : Distribution of explanatory variables in phase 1 and phase 2

Variable	Phase 1 (%)	Phase 2 (%)	Phase 2 (weighted) (%)	P value for comparison between phase 1 and phase 2
Mother's age (years):				
< 20	7.37	8.06	8.15	
20–24	17.39	18.87	18.74	
25–29	28.08	27.61	27.41	
30–34	29.88	28.31	28.19	
35–39	14.00	13.75	14.14	
> 40	2.44	2.76	2.90	
Missing data	0.85	0.64	0.47	< 0.01
Mother's ethnicity:				
White	84.31	85.81	81.49	
Black African	1.97	1.10	1.67	
Black Caribbean	1.30	1.04	2.08	
Black other	0.94	0.64	0.86	
Bangladeshi	0.74	1.90	0.87	
Indian	2.48	2.15	2.75	
Pakistani	3.11	3.30	3.84	
Chinese	0.76	0.64	1.35	
Asian Other	1.39	1.46	2.51	
Other	2.08	1.33	1.86	
Not known	0.24	0.08	0.13	
Missing data	0.67	0.55	0.60	< 0.01

Table 6.2.5.1 (cont'd): Distribution of explanatory variables in phase 1 and phase 2

Number of previous vaginal deliveries				
0	47.89	47.99	48.71	
> 1	51.36	51.42	50.92	
Missing data	0.75	0.59	0.37	0.79
Number of previous CS				
0	89.93	89.53	89.96	
1	7.91	8.18	8.02	
> 2	1.50	1.78	1.74	
Missing data	0.66	0.51	0.28	<0.01
Gestation (weeks)				
< 28	0.50	0.46	0.56	
28–32	1.15	1.23	1.29	
33–36	5.11	5.33	5.53	
> 37	92.96	92.73	92.38	
Missing data	0.28	0.26	0.24	0.22
Presentation				
Cephalic	95.87	95.90	95.70	
Breech	3.65	3.53	3.56	
Transverse lie	0.39	0.33	0.28	
Missing data	0.09	0.25	0.45	0.14
Birth weight (g)				
< 2500	5.83	6.15	6.76	
2500–4000	81.17	82.01	81.85	
> 4000	11.72	11.02	10.52	
Missing data	1.28	0.82	0.87	<0.01

Inspection of the age distribution between phase 1 and phase 2 shows that there is a slightly higher proportion of women under the age of 20 years in phase 2 (8.15%), compared with phase 1 (7.37%) and a slightly higher proportion of women for whom there are missing data on age in phase 1 (0.85%), compared with phase 2 (0.47%). There is a slightly higher proportion of Black African women in phase 1, and a higher proportion of Bangladeshi women in phase 2. The distribution of other case-mix variables was similar for both phase 1 and phase 2.

CS before labour

In phase 1, 10.09% of women had CS before labour. In phase 2 it was 10.76%. The weighted proportion in phase 2 was 10.62%.

Table 6.2.5.2 below shows that the odds ratios for most explanatory variables are similar in phase 1 and phase 2. However, there are some differences. Women for whom there were no data on age had a 50% increase in odds of CS before labour in phase 1. In phase 2, they had a 60% reduction in odds of CS before labour.

Table 6.2.5.2: Multivariate association between each variable and odds of CS before labour. (analysis including allowance for strata except in column two as only one maternity unit within each stratum)

Characteristic	Phase 1 (n=146,238)	Phase 2 (n=31,094)	Phases 1 and 2 (n=173, 332)
Mother's age (years):			
< 20	0.54 (0.49, 0.61)	0.60 (0.44, 0.81)	0.57 (0.48, 0.67)
20–24	0.77 (0.72, 0.82)	0.76 (0.58, 0.99)	0.76 (0.66, 0.87)
25–29	1.00	1.00	1.00
30–34	1.30 (1.23, 1.37)	1.29 (1.10, 1.51)	1.30 (1.19, 1.41)
35–39	1.60 (1.48, 1.72)	1.68 (1.38, 2.04)	1.63 (1.47, 1.82)
> 40	2.34 (2.08, 2.65)	1.88 (1.15, 3.05)	2.11 (1.64, 2.71)
Missing data	**1.53 (1.24, 1.88)**	**0.43 (0.20, 0.91)**	1.11 (0.85, 1.44)
Mother's ethnicity:			
White	1.00	1.00	1.00
Black African	**0.84 (0.72, 0.97)**	**1.30 (1.05, 1.62)**	1.02 (0.86, 1.21)
Black Caribbean	0.76 (0.62, 0.92)	0.88 (0.63, 1.23)	0.84 (0.70, 1.00)
Black other	1.00 (0.83, 1.22)	0.70 (0.33, 1.50)	0.86 (0.61, 1.21)
Bangladeshi	0.73 (0.58, 0.91)	0.35 (0.16, 0.79)	0.51 (0.34, 0.78)
Indian	0.82 (0.70, 0.95)	1.00 (0.65, 1.52)	0.90 (0.71, 1.14)
Pakistani	0.66 (0.57, 0.77)	0.98 (0.64, 1.50)	0.84 (0.62, 1.13)
Chinese	0.63 (0.44, 0.89)	0.64 (0.32, 1.29)	0.63 (0.40, 0.98)
Asian Other	**0.79 (0.64, 0.99)**	**0.46 (0.33, 0.63)**	0.57 (0.44, 0.74)
Other	0.78 (0.64, 0.98)	0.55 (0.15, 2.01)	0.67 (0.38, 1.18)
Not known	0.73 (0.46, 1.14)	1.19 (0.07, 19.45)	0.86 (0.29, 2.52)
Missing data	0.73 (0.54, 0.98)	1.12 (0.43, 2.88)	0.91 (0.58, 1.41)
Number of previous vaginal deliveries			
0	1.00	1.00	1.00
≥ 1	0.58 (0.56, 0.62)	0.68 (0.58, 0.78)	0.63 (0.58, 0.68)
Missing data	0.86 (0.42, 1.78)	0.55 (0.15, 1.98)	0.67 (0.35, 1.34)

Table 6.2.5.2 (cont'd): Multivariate association between each variable and odds of CS before labour. (analysis including a llowance for strata except in column two as only one maternity unit within each stratum)

Number of previous CS			
0	1.00	1.00	1.00
1	13.08 (12.23, 14.00)	13.54 (11.49, 15.95)	13.22 (12.22, 14.43)
≥ 2	88.40 (77.51, 100.81)	84.81 (64.20, 112.03)	85.83 (73.36, 100.42)
Missing data	1.71 (0.80, 3.66)	4.13 (0.95, 17.95)	2.50 (1.23, 5.07)
Gestation (weeks)			
< 28	0.42 (0.27, 0.64)	0.17 (0.04, 0.64)	0.29 (0.15, 0.55)
28–32	4.53 (3.77, 5.44)	3.97 (2.55, 6.16)	4.27 (3.33, 5.48)
33–36	2.33 (2.12, 2.57)	2.10 (1.36, 3.24)	2.21 (1.78, 2.73)
≥ 37	1.00	1.00	1.00
Missing data	**1.14 (0.74, 1.76)**	**0.17 (0.04, 0.74)**	0.66 (0.40, 1.09)
Presentation			
Cephalic	1.00	1.00	1.00
Breech	26.43 (24.24, 28.82)	22.53 (17.93, 28.30)	24.50 (21.70, 27.66)
Transverse lie	22.20 (17.42, 28.29)	27.70 (8.96, 85.65)	23.79 (15.83, 35.75)
Missing data	7.21 (4.48, 11.59)	6.83 (4.68, 9.97)	6.93 (5.14, 9.33)
Birth weight (g)			
< 2500	1.80 (1.62, 2.00)	2.28 (1.77, 2.94)	2.02 (1.73, 2.36)
2500–4000	1.00	1.00	1.00
> 4000	0.99 (0.92, 1.07)	1.02 (0.76, 1.38)	1.01 (0.87, 1.16)
Missing data	1.78 (1.39, 2.26)	3.37 (1.55, 7.34)	2.21 (1.59, 3.08)
Phase 1	N/A	N/A	1.00
Phase 2	N/A	N/A	1.07 (0.97, 1.17)

The most strikingly discrepant odds ratios between phase 1 and phase 2 are highlighted in bold in the first two columns

Black African women in phase 1 had a 16% reduction in odds of CS before labour while in phase 2 there was a 30% increase in the odds of CS before labour. There were also discrepancies in the odds of CS before labour for 'Other Asian' women and women where the gestational age at birth was not known. These are the odds ratios that are most strikingly discrepant between phase 1 and phase 2 and are highlighted in bold in the table 5.2.5.2 above.

CS before labour: investigating interactions between case-mix variables and phase of study

In order to investigate a 'period' effect, interaction terms between phase and each predictor variable were included in the model. Simultaneous testing of all these interaction terms showed that their inclusion significantly improved the fit of the model to the data ($p<0.0001$). When these terms were tested singularly, only the interaction terms between phase and age ($p=0.03$), and phase and ethnicity ($p<0.0001$) were statistically significant at the 5% level.

The following tables show how the association between CS before labour and (i) age, and (ii) ethnicity vary according to phase of the study. The baseline group for the odds ratios shown in these tables includes women who gave birth during phase 1 with the following characteristics: White, age 25–29 years, no previous births, cephalic presentation, at least 37 weeks gestation, birth weight 2501 – 4000 g.

Table 6.2.53: Relationship between 'phase of study' and age and CS before labour

Mother's age (years):	Phase 1	Phase 2
< 20	0.54 (0.49, 0.61)	0.59 (0.46, 0.77)
20–24	0.77 (0.72, 0.82)	0.75 (0.60, 0.95)
25–29	1.00	0.99 (0.86, 1.14)
30–34	1.30 (1.23, 1.37)	1.28 (1.09, 1.50)
35–39	1.60 (1.48, 1.72)	1.67 (1.42, 1.96)
> 40	2.34 (2.08, 2.65)	1.86 (1.19, 2.91)
Missing data	1.53 (1.24, 1.88)	0.42 (0.20, 0.90)

Compared with women with baseline characteristics who gave birth in phase 1, the odds of CS before labour were similar for the various age categories in phase 1 and phase 2. However, the odds of CS before labour for women for whom age was not known was about 50% higher in phase 1 whereas in phase 2 it was reduced by about 60%.

Table 6.2.5.4: Relationship between 'phase of study', ethnicity and CS before labour

Mother's ethnicity:	Phase 1	Phase 2
White	1.00	0.99 (0.86, 1.14)
Black African	0.84 (0.72, 0.97)	1.29 (1.08, 1.56)
Black Caribbean	0.76 (0.62, 0.92)	0.88 (0.62, 1.24)
Black other	1.00 (0.83, 1.22)	0.70 (0.31, 1.59)
Bangladeshi	0.73 (0.58, 0.91)	0.35 (0.16, 0.76)
Indian	0.82 (0.70, 0.95)	0.99 (0.61, 1.59)
Pakistani	0.66 (0.57, 0.77)	0.98 (0.61, 1.57)
Chinese	0.63 (0.44, 0.89)	0.63 (0.34, 1.18)
Asian Other	0.79 (0.64, 0.98)	0.45 (0.32, 0.63)
Other	0.78 (0.66, 0.93)	0.54 (0.16, 1.82)
Not known	0.73 (0.46, 1.14)	1.18 (0.08, 16.30)
Missing data	0.73 (0.54, 0.98)	1.11 (0.43, 2.84)

Compared with women with baseline characteristics who gave birth in phase 1, the odds of CS before labour were similar for the various ethnic groups irrespective of phase of study. However, the direction of effect for Black African women was different. In phase 1 there was a 16% reduction, but in phase 2 there was a 29% increase in odds of CS in labour when compared with the baseline group. For 'Other Asian' women, there was a reduction in odds of CS before labour in both phases of the study; however, the magnitude of this effect was greater in phase 2.

CS in labour

In phase 1, 12.13% of women had CS before labour, in phase 2 it was 12.36%. The weighted proportion in phase 2 was 12.70%.

Multivariate analysis showed that although the odds of CS in labour for most explanatory variables were similar in phase 1 and phase 2 (compared with baseline groups within phase 1 and phase 2), there were some differences. For women with one previous CS, the direction of effect was similar in phase 1 and phase 2 but the magnitude of odds ratios was greater in phase 1. For breech presentation, birthweight < 2500 g, > 4000 g the direction of effect was the same but the magnitude of effect was greater in phase 2. In phase 1 women aged 30–34 years had a significant increase in odds of CS during labour but this was not seen in phase 2. Chinese women and women for whom the number of previous vaginal deliveries was not known had significant reductions in odd of CS in labour in phase 2 but this was not seen in phase 1. Women with missing data on number of previous CS were significantly less likely to have CS in labour in phase 1 but this effect was not observed in phase 2. The association between women's age and CS was statistically significant when age was treated as a continuous variable (Phase 1 OR: 1.05 (95%CI 1.04, 1.06), Phase 2 OR 1.06 (95%CI 1.05, 1.07), Phase 1 and 2 OR 1.05 (95%CI 1.04, 1.06).

Table 6.2.5.5: Multivariate association between case-mix variables and odds of CS for women in labour (analysis including allowance for strata except in column two as only one maternity unit within each stratum)

Characteristic	Phase 1 (n=131,281)	Phase 2 (n=27,583)	Phases 1 and 2 (n=158,864)
Mother's age (years):			
< 20	0.54 (0.50, 0.59)	0.49 (0.38, 0.64)	0.52 (0.46, 0.59)
20–24	0.72 (0.68, 0.77)	0.63 (0.54, 0.73)	0.68 (0.63, 0.73)
25–29	1.00	1.00	1.00
30–34	**1.21 (1.15, 1.26)**	**1.03 (0.90, 1.18)**	1.12 (1.05, 1.20)
35–39	1.48 (1.39, 1.58)	1.42 (1.15, 1.75)	1.45 (1.31, 1.60)
> 40	1.73 (1.52 (1.97)	2.32 (1.67, 3.23)	2.04 (1.66, 2.51)
Missing data	0.86 (0.67, 1.12)	1.06 (0.52, 2.16)	0.94 (0.68, 1.29)
Mother's ethnicity:			
White	1.00	1.00	1.00
Black African	2.30 (2.07, 2.54)	1.99 (1.68, 2.36)	2.15 (1.97, 2.35)
Black Caribbean	1.66 (1.42, 1.94)	1.68 (1.38, 2.05)	1.69 (1.47, 1.95)
Black other	1.68 (1.44, 1.96)	1.19 (0.72, 1.97)	1.43 (1.10, 1.85)
Bangladeshi	1.51 (1.15, 1.98)	1.83 (1.12, 3.00)	1.68 (1.24, 2.27)
Indian	1.34 (1.16, 1.56)	1.24 (0.87, 1.76)	1.29 (1.07, 1.54)
Pakistani	1.14 (0.99, 1.30)	0.88 (0.63, 1.23)	1.00 (0.84, 1.21)
Chinese	**1.07 (0.89, 1.29)**	**0.65 (0.53, 0.79)**	0.80 (0.64, 1.01)
Asian Other	1.57 (1.36, 1.83)	0.93 (0.50, 1.75)	1.15 (0.83, 1.58)
Other	1.24 (1.10, 1.41)	1.28 (0.75, 2.18)	1.27 (1.01, 1.58)
Not known	0.83 (0.51, 1.36)	0.49 (0.04, 5.81)	0.70 (0.33, 1.51)
Missing data	0.84 (0.63, 1.11)	1.21 (0.47, 3.09)	0.97 (0.64, 1.48)
Number of previous vaginal deliveries			
0	1.00	1.00	1.00
≥ 1	0.21 (0.20, 0.22)	0.22 (0.20, 0.24)	0.21 (0.20, 0.22)
Missing data	**0.76 (0.43, 1.32)**	**0.04 (0.00, 0.43)**	0.31 (0.12, 0.80)

Table 6.2.5.5 (cont'd): Multivariate association between case-mix variables and odds of CS for women in labour (analysis including allowance for strata except in column two as only one maternity unit within each stratum)

Number of previous CS			
0	1.00	1.00	1.00
1	**3.49 (3.29, 3.70)**	**2.50 (2.13, 2.93)**	2.99 (2.68, 3.32)
≥ 2	18.19 (13.04, 25.38)	23.18 (10.99, 48.88)	20.92 (13.60, 32.17)
Missing data	**0.44 (0.24, 0.80)**	**8.04 (0.63, 102.36)**	1.04 (0.39, 2.76)
Onset of labour			
Spontaneous	1.00	1.00	1.00
Induction	2.44 (2.34, 2.55)	2.45 (2.21, 2.71)	2.44 (2.30, 2.58)
Gestation (weeks)			
< 28	0.11 (0.07, 0.19)	0.28 (0.09, 0.91)	0.14 (0.08, 0.24)
28–32	0.84 (0.66, 1.08)	1.11 (0.46, 2.69)	0.94 (0.59, 1.50)
33–36	1.22 (1.09, 1.35)	1.00 (0.74, 1.37)	1.10 (0.93, 1.29)
≥ 37	1.00	1.00	1.00
Missing data	0.95 (0.65, 1.38)	0.83 (0.20, 3.41)	0.84 (0.43, 1.66)
Presentation			
Cephalic	1.00	1.00	1.00
Breech	**35.89 (31.64, 40.71)**	**52.08 (37.42, 72.51)**	41.33 (35.61, 47.97)
Transverse lie	8	8	8
Missing data	8.29 (4.17, 16.45)	48.04 (6.28, 367.25)	23.83 (5.84, 97.14)
Birth weight (g)			
< 2500	**1.22 (1.11, 1.35)**	**1.75 (1.40, 2.19)**	1.47 (1.29, 1.67)
2500–4000	1.00	1.00	1.00
> 4000	**1.96 (1.86, 2.07)**	**2.19 (1.95, 2.45)**	2.06 (1.94, 2.18)
Missing data	1.43 (1.18, 1.72)	0.53 (0.08, 3.45)	1.19 (0.82, 1.73)
Phase 1	N/a	N/a	1.00
Phase 2	N/a	N/a	1.05 (0.98, 1.13)

The most strikingly discrepant odds ratios between phase 1 and phase 2 are highlighted in bold in the first two columns

CS in labour: Investigating interactions between case-mix variables and phase of study

In order to investigate a 'period' effect, interaction terms between phase and each predictor variable were included in the model. Simultaneous testing of all these interaction terms showed that their inclusion significantly improved the fit of the model to the data ($p<0.0001$). When these terms were tested one by one, the following interaction terms were statistically significant at the 5% level: phase and age ($p=0.0001$), phase and ethnicity ($p<0.0001$), phase and previous vaginal deliveries ($p=0.03$), phase and previous CS ($p=0.0001$), phase and presentation ($p=0.02$), phase 2 and birth weight ($p=0.0001$).

Table 6.2.5.6: Relationship between phase of study, age and CS for women in labour

Woman's age (years)	Phase 1	Phase 2
< 20	0.54 (0.50, 0.59)	0.56 (0.44, 0.71)
20–24	0.72 (0.68, 0.77)	0.71 (0.60, 0.84)
25–29	1.00	1.13 (0.98, 1.30)
30–34	1.21 (1.15, 1.26)	1.16 (1.03, 1.30)
35–39	1.48 (1.39, 1.58)	1.61 (1.33, 1.94)
> 40	1.73 (1.52, 1.97)	2.63 (2.02, 3.43)
Missing data	0.86 (0.67, 1.12)	1.20 (0.63, 2.28)

When compared with women with baseline characteristics in phase 1, the 95% CI for phase 2 data are wider than those in phase 1, but they include the upper and lower limits of the 95% CI for phase 1 data.

Table 6.2.5.7: Relationship between phase of study, ethnicity and CS for women in labour

Mother's ethnicity	Phase 1	Phase 2
White	1.00	1.13 (0.98, 1.30)
Black African	2.30 (2.07, 2.54)	2.25 (1.82, 2.78)
Black Caribbean	1.66 (1.42, 1.94)	1.90 (1.53, 2.36)
Black other	1.68 (1.44, 1.96)	1.34 (0.79, 2.28)
Bangladeshi	1.51 (1.15, 1.98)	2.07 (1.28, 3.35)
Indian	1.34 (1.16, 1.56)	1.40 (0.97, 2.01)
Pakistani	1.14 (0.99, 1.30)	1.00 (0.68, 1.47)
Chinese	1.07 (0.89, 1.29)	0.73 (0.60, 0.89)
Asian Other	1.57 (1.36, 1.83)	1.05 (0.59, 1.87)
Other	1.24 (1.10, 1.41)	1.44 (0.82, 2.54)
Not known	0.83 (0.51, 1.36)	0.55 (0.05, 6.24)
Missing data	0.84 (0.63, 1.11)	1.36 (0.54, 3.43)

When compared with women with baseline characteristics in phase 1, the odds ratios and 95% CI for the various categories of ethnicity in phase 1 are comparable with those in phase 2.

Table 6.2.5.8: Relationship between phase of study, previous vaginal deliveries and CS for women in labour

Number of previous vaginal deliveries	Phase 1	Phase 2
0	1.00	1.13 (0.98, 1.30)
≥ 1	0.21 (0.20, 0.22)	0.25 (0.21, 0.29)
Missing data	0.76 (0.43, 1.32)	0.04 (0.00, 0.45)

For women with no data on the number of previous vaginal deliveries, the relative odds ratio of CS in labour was 95% lower in phase 2 compared with phase 1.

Table 6.2.5.9: Relationship between phase of study, previous CS and CS for women in labour

Number of previous CS	Phase 1	Phase 2
0	1.00	1.13 (0.98, 1.30)
1	3.49 (3.29, 3.70)	2.82 (2.29, 3.48)
≥ 2	18.19 (13.04, 25.37)	26.19 (13.25, 51.77)
Missing data	0.44 (24.10, 0.80)	9.08 (0.76, 108.47)

The relative odds of CS for women with one previous CS was 19% lower in phase 2 compared with phase 1. For women with at least two previous CS, the odds ratios of CS in labour were similar in phase 1 and phase 2. For women with no data on the number of previous CS, the odds ratio was over 20-fold higher in phase 2 compared with phase 1.

Table 6.2.5.10: Relationship between phase of study, presentation and CS for women in labour

Presentation	Phase 1	Phase 2
Cephalic	1.00	1.13 (0.98, 1.30)
Breech	35.89 (31.64, 40.71)	58.85 (43.61, 79.42)
Transverse lie	8	8
Missing data	8.29 (4.18, 16.44)	54.28 (7.84, 375.67)

The relative odds of CS was about 64% higher for women with breech presentation in phase 2 when compared with phase 1.

Table 6.2.5.11: Relationship between phase of study, birth weight and CS for women in labour

Birth weight (g)	Phase 1	Phase 2
< 2500	1.22 (1.11, 1.34)	1.98 (1.56, 2.51)
2500–4000	1.00	1.13 (0.98, 1.30)
> 4000	1.96 (1.86, 2.07)	2.47 (2.08, 2.94)
Missing data	1.43 (1.18, 1.72)	0.60 (0.09, 3.90)

The relative odds of CS in labour for women who delivered babies weighing less than 2500 g was 62% higher in phase 2 compared with phase 1. For women who delivered babies weighing over 4000 g, it was about 26% higher in phase 2 compared with phase 1.

Analysis excluding missing data

The results presented so far suggest that the pattern of missing data is different in the two phases of the study. The total number of women with 'missing data' for any of the variables in this analysis is 7299 (4.1%). As this is a relatively small proportion, the analysis was repeated omitting those women who had 'missing data' for any of the variables used in the analysis. These results for CS before labour and CS for women in labour are presented in the table below.

Table 6.2.5.12: Multivariate association between case-mix variables and odds of (i) CS before labour, and (ii) CS for women in labour (analysis on combined phase 1 and phase 2 data, omitting those women with missing data for any of the explanatory variables)

Characteristic	CS before labour Phases 1 and 2 (n = 171,095)	CS in labour Phases 1 and 2 (n=153,530)
Mother's age (years)		
< 20	0.56 (0.47, 0.67)	0.51 (0.46, 0.58)
20–24	0.77 (0.67, 0.88)	0.68 (0.63, 0.73)
25–29	1.00	1.00
30–34	1.31 (1.20, 1.42)	1.12 (1.05, 1.19)
35–39	1.63 (1.46, 1.82)	1.46 (1.33, 1.61)
> 40	2.14 (1.67, 2.75)	2.07 (1.69, 2.54)
Mother's ethnicity		
White	1.00	1.00
Black African	1.07 (0.88, 1.30)	2.18 (1.99, 2.39)
Black Caribbean	0.79 (0.66, 0.96)	1.65 (1.44, 1.90)
Black Other	0.81 (0.57, 1.16)	1.45 (1.11, 1.90)
Bangladeshi	0.46 (0.30, 0.71)	1.69 (1.23, 2.32)
Indian	0.93 (0.74, 1.18)	1.29 (1.08, 1.54)
Pakistani	0.82 (0.61, 1.11)	1.04 (0.88, 1.24)
Chinese	0.61 (0.39, 0.95)	0.79 (0.63, 1.00)
Asian Other	0.57 (0.43, 0.74)	1.18 (0.86, 1.60)
Other	0.68 (0.39, 1.20)	1.28 (1.02, 1.62)
Not known	0.86 (0.27, 2.69)	0.70 (0.31, 1.55)
Number of previous vaginal deliveries		
0	1.00	1.00
≥ 1	0.63 (0.58, 0.68)	0.21 (0.20, 0.22)
Number of previous CS		
0	1.00	1.00
1	13.50 (12.26, 14.87)	2.95 (2.64, 3.30)
≥ 2	92.99 (79.51, 108.75)	26.05 (14.76, 45.97)
Onset of labour		
Spontaneous	N/A	1.00
Induction	N/A	2.49 (2.35, 2.63)

Table 6.2.5.12 (cont'd): Multivariate association between case-mix variables and odds of (i) CS before labour, and (ii) CS for women in labour

Gestation (weeks)			
	< 28	0.13 (0.04, 0.45)	0.46 (0.18, 1.17)
	28–32	3.93 (3.00, 5.16)	1.18 (0.78, 1.79)
	33–36	2.19 (1.76, 2.72)	1.13 (0.96, 1.33)
	≥ 37	1.00	1.00
Presentation			
	Cephalic	1.00	1.00
	Breech	25.97 (23.26, 28.98)	45.58 (39.49, 52.61)
	Transverse lie	25.34 (16.46, 39.01)	8
Birth weight (g)			
	< 2500	2.07 (1.77, 2.41)	1.37 (1.20, 1.57)
	2500–4000	1.00	1.00
	> 4000	1.01 (0.88, 1.16)	2.07 (1.94, 2.20)
	Phase 1	1.00	1.00
	Phase 2	1.07 (0.98, 1.17)	1.05 (0.98, 1.12)

Interaction terms between each predictor variable and phase of study were also included within each model and simultaneously tested for statistical significance using the Wald test as described previously.

For CS before labour, the inclusion of all these interaction terms significantly improved the fit of the model to the data ($p<0.0001$). However, on testing each of these interaction terms separately, only the interaction term between ethnicity and phase 2 was statistically significant ($p<0.0001$). This result is shown in the following table.

Table 6.2.5.13: Relationship between phase of study, ethnicity and CS before labour (analysis omitting those women with missing data for any of the explanatory variables)

Mother's ethnicity	Phase 1	Phase 2
White	1.00	1.01 (0.87, 1.16)
Black African	0.84 (0.72, 0.98)	1.42 (1.19, 1.70)
Black Caribbean	0.73 (0.60, 0.88)	0.83 (0.58, 1.20)
Black other	0.97 (0.79, 1.20)	0.64 (0.26, 1.61)
Bangladeshi	0.64 (0.51, 0.81)	0.33 (0.15, 0.75)
Indian	0.83 (0.71, 0.97)	1.05 (0.67, 1.64)
Pakistani	0.65 (0.56, 0.76)	0.98 (0.61, 1.56)
Chinese	0.62 (0.43, 0.88)	0.62 (0.33, 1.14)
Asian Other	0.79 (0.63, 0.99)	0.46 (0.33, 0.65)
Other	0.78 (0.65, 0.93)	0.57 (0.17, 1.92)
Not known	0.71 (0.45, 1.13)	1.20 (0.09, 16.78)

Compared with women in phase 1 with baseline characteristics, Black African women in phase 1 had a 16% reduction in odds of CS before labour. However, in phase 2, the odds were about 42% higher. For women in other ethnic groups, the odds ratios for CS before labour are similar for phase 1 and phase 2. The odds ratios for Black African women differ in the two phases of the study but there is no clear explanation for this. For 'Other Asian' women compared with White women, the odds of CS before labour is reduced in both studies although the magnitude of this reduction is greater in phase 2. The results presented in this table are similar to those shown in table 6.2.5.4, which includes women with missing data on ethnicity.

For CS in labour, the inclusion of all interaction terms between explanatory variables and phase of study significantly improved the fit of the model to the data (p<0.0001). However, on testing each of these interaction terms separately, the interaction terms between phase of study and the following explanatory variables were statistically significant at the 5% level: age (p=0.0005), ethnicity (p=0.0003), previous CS (p<0.0001), presentation (p=0.01) and birth weight (p=0.007). These results are shown in the following tables.

Table 6.2.5.14: Relationship between phase of study, age and CS for women in labour (analysis omitting those women with missing data for any of the explanatory variables)

Woman's age (years):	Phase 1	Phase 2
< 20	0.54 (0.50, 0.59)	0.55 (0.44, 0.70)
20–24	0.72 (0.68, 0.76)	0.72 (0.61, 0.85)
25–29	1.00	1.14 (1.00, 1.30)
30–34	1.21 (1.15, 1.26)	1.16 (1.04, 1.31)
35–39	1.48 (1.39, 1.58)	1.64 (1.36, 1.98)
> 40	1.75 (1.53, 2.00)	2.68 (2.04, 3.52)

For women in labour, compared with women in phase 1 with baseline characteristics, the relative increase in odds of CS was 53% for women aged 40 years or more in phase 2. This is a minor quantitative interaction as the odds ratios are in the same direction and only differ slightly in magnitude. For women in the other age categories the odds for CS in labour are similar for phase 1 and phase 2. The results presented in this table are similar to those shown in table 6.2.5.6, whichincludes women with missing data on presentation.

Odds ratios for CS in labour for the various ethnic groups and number of previous CS were similar in both phase 1 and phase 2 with overlap of the 95% CI.

Table 6.2.5.15: Association between 'phase 2' and presentation and CS for women in labour (analysis omitting those women with missing data for any of the explanatory variables)

Presentation	Phase 1	Phase 2
Cephalic	1.00	1.14 (1.00, 1.30)
Breech	38.85 (34.08, 44.29)	66.81 (50.70, 88.03)
Transverse lie	8	8

For women in labour, compared with women in phase 1 with baseline characteristics, there was a relative increase of 72% in phase 2 for breech presentation. This is probably following publication of results from the term breech trial which showed that perinatal mortality is reduced for breech babies delivered by CS compared with vaginal birth. However, whilst the magnitude of the effect is greater, it is in the same direction in both phases of the study. The results presented in this table are similar to those shown in table 6.2.5.10, which include women with missing data on presentation.

Table 6.2.5.16: Association between 'phase 2' and birth weight and CS for women in labour (analysis omitting those women with missing data for any of the explanatory variables)

Birth weight (g)	Phase 1	Phase 2
< 2500	1.17 (1.06, 1.30)	1.82 (1.44, 2.30)
2500–4000	1.00	1.14 (1.00, 1.30)
> 4000	1.97 (1.86, 2.09)	2.49 (2.10, 2.95)

There is a minor quantitative interaction between birth weight and time period of the study. While the odds ratio for delivery by CS was 55% higher for women who delivered babies under 2500 g in phase 2 compared with phase 1, it was 21% lower in phase 2 for women who delivered babies weighing more than 4000 g. These odds ratios are similar to those shown in table 6.2.5.11, which include women with missing data on birth weight.

6.2.6 Conclusion

Phase 2 of data collection took place five months after phase 1. Although this is a short time period, it was thought that for completeness there should be some investigation of a time period effect between the two phases. However, the criteria for judging the presence of a period effect were not set in advance. The results indicate that the interactions between explanatory variables and phase for both models (CS before labour and CS in labour) are, in general, minor quantitative interactions, despite statistical significance at the 5% level. However with the large number of observations in the dataset there is enough power to detect minor interactions. Therefore the decision as to whether or not there was a time period was based on examination of how much the relationship between casemix variables CS (before and during labour) varied between the two phases of data collection. The odds ratios for CS in labour for Black African women varied between the two phases in magnitude and direction of effect but there is no clear explanation for this. The odds ratios for the other case-mix variables, however, are similar. As a result it was thought that it would be acceptable to ignore a time-period effect.

This assumes that the relationship between case-mix variables and CS are similar in phase 1 and phase 2. Therefore, by using the phase 1 data, precision around the estimates is gained because of the larger number of women involved. However, there is no information on birth preferences for these women who gave birth duri ng the phase 1 study period but there is potential for using the information from the survey of women's views on childbirth carried out during phase 2 to 'predict' these 'missing data' on birth preferences for the women in phase 1.

6.3 Survey of women's views on childbirth

6.3.1 Introduction

The aim of this survey was to document the frequency of maternal request for CS and explore women's views about childbirth. t included an exploration of the sources of information women use when they are forming their views about how they wish to have their baby, as well as determining women's perception of the risks and benefits of different modes of delivery. A full description of results from this survey has been published in the NSCSA report. In this thesis, the survey data are linked to denominator data (case-mix variables and mode of birth) and the aim of analysis is to evaluate the contribution of women's birth preferences and case-mix variables to the variation in CS rates. This section specifically gives a description of the data with respect to (i) responders, and non-responders to the survey, and (ii) relationships between case-mix variables, women's birth preferences and CS.

6.3.2 Methods

Survey methodology

The population to be surveyed included women booked in to 40 selected maternity units as described in section 6.2.3 (both to receive community or primary care), with an estimated date of delivery in January 2001. Local hospital facilitators compiled lists of eligible women. Variation in patient information systems meant that not all centres could easily identify such women directly. Therefore, in some centres, indirect methods were used; for example, identifying women from appointment diaries of the ultrasound department or antenatal clinic. Because of ethical reasons and data confidentiality, lists of eligible women included in the sample were kept by the local facilitators and were not available to Royal College of Obstetricians and Gynaecologists Clinical Effectiveness Support Unit (RCOG CESU). In order to estimate response rates, the numbers of invitations sent out were reported back to the RCOG CESU.

To try to ensure that women who had experienced an adverse event (e.g. preterm birth or neonatal death) were not included in the survey, local facilitators cross checked this information against an appropriate local source. In the event that a woman was inadvertently sent a questionnaire, the local facilitator contacted the woman's GP and the person responsible for her maternity care to inform them of this. Where appropriate, they were also sent a letter of apology from the RCOG CESU.

The RCOG CESU prepared and dispatched the survey materials to the facilitators for distribution. Local facilitators sent the eligible women an information leaflet, an invitation to participate in the survey, patient address labels and a prepaid response envelope. The enclosures also included an endorsement from the maternity unit, but it was made clear that all responses to the survey were confidential and would not be available to women's health care professionals.

Women who wished to take part in the study were required to send their address label in the prepaid response envelope to the RCOG CESU. The questionnaire, a pen and a further prepaid return envelope were then dispatched by return. Women were required to return completed questionnaires to the RCOG CESU. The time interval between the initial invitation and dispatching the questionnaire was kept as short as possible to reduce the risk of an interim adverse event.

The questionnaires were only available in English, and consisted of 37 closed questions about socio-demographic characteristics, previous and current obstetric history, antenatal care, amount and sources of information received during the pregnancy about various topics such as 'what to expect with induction of labour' and birth preferences including the question 'how would you prefer to give birth to this baby?'. There were five options in response to this last question:

- I would prefer to give birth vaginally

- I would prefer to have a planned CS
- I do not have a preference
- My preference is dictated by medical reasons
- I don't know

This last variable is referred to in this thesis as 'women's birth preference' and is used in the analysis in this thesis.

Data on the women's date of birth and maternity unit code were used to link survey data to denominator data.

Statistical analysis

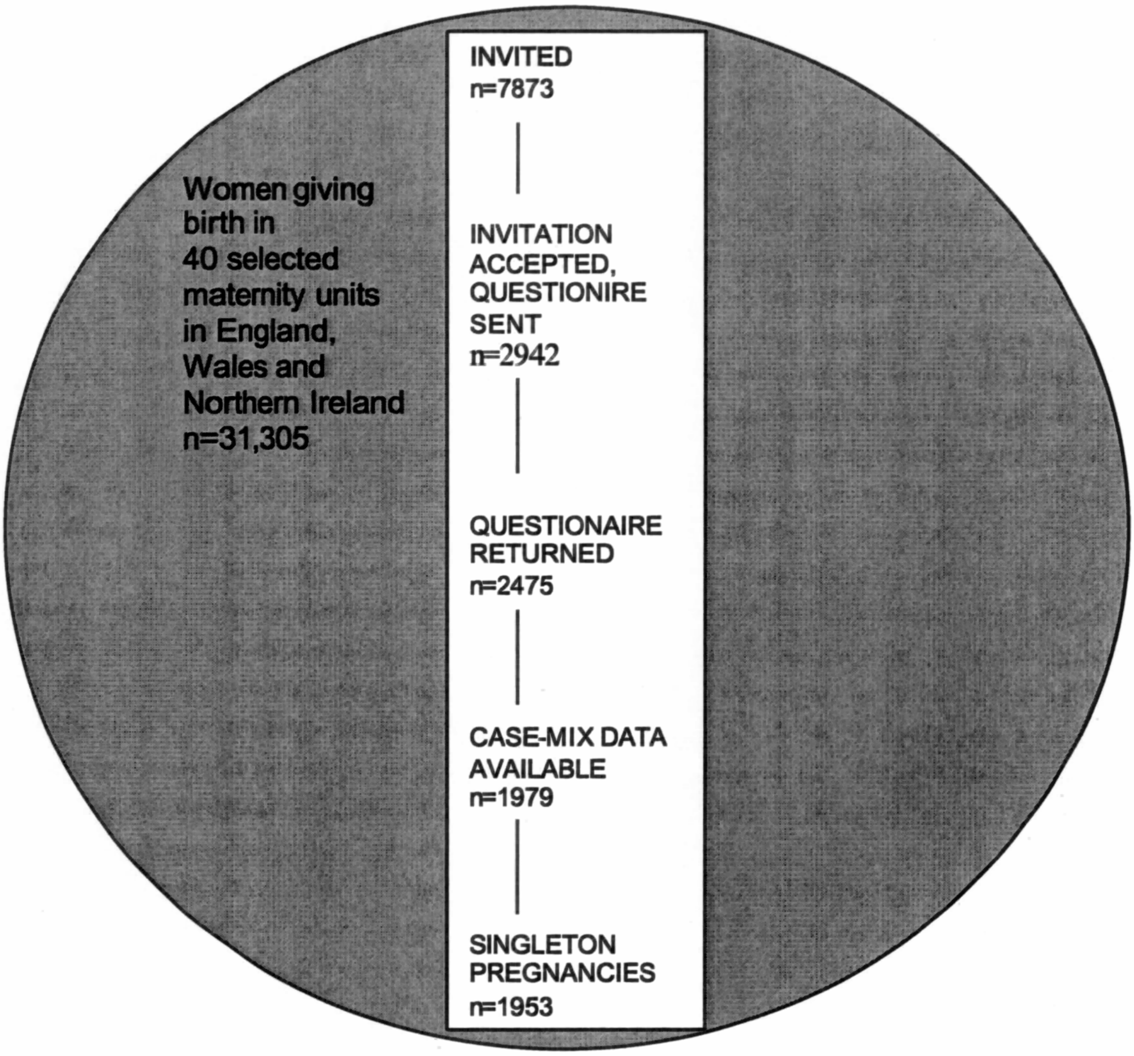
Logistic regression models for (i) CS before labour, and (ii) CS in labour were fitted separately. The explanatory variables used were as described in previous sections (i.e. age, ethnicity, number of previous vaginal deliveries, number of previous CS, gestation, presentation, birth weight and mode of onset of labour for CS in labour model). In addition, women's birth preferences as expressed in the antenatal survey of women's views was included in each of these two models as an explanatory variable.

6.3.3 Response rates

Invitations were sent out to 7,873 pregnant women; 2,942 (37.4%) women responded to the invitation and were sent questionnaires. Of these, 2,475 women (31.4% of the total group) completed and returned questionnaires. It was inevitable that, for a proportion of women whose due dates were in January, delivery would occur either earlier or later than anticipated. Because of ethical reasons and data confidentiality, the patient identifiers for all women who were sent invitations but did not respond are not known to RCOG CESU. Based on the women's date of birth and maternity unit code, it was possible to link survey data to denominator data for 1979 women (80%). Of these, 1953 (99%) had singleton pregnancies. The majority of these women gave birth in January 2001, 14% gave birth in December 2000 and another 14% gave birth in February 2001.

The following figure summarises the response rates.

Figure 6.3.3.1: Summary of response rates for survey of women's views on childbirth



6.3.4 Results

Table 6.3.4.1 shows the distribution of case-mix variables for the 1953 women with singleton pregnancies for whom there were data on birth preferences as well as women for whom these data were not available. It was not possible to separate the data according to invitation to participate as there are no patient identifiers for all women who were sent invitations but did not respond.

Table 6.3.4.1: Distribution of case-mix variables for women with and without data on birth preferences in phase 2

Demographic variables	Women with data on birth preferences (n=1953)	Women for whom there are no data on birth preferences (n=29,352)	P value for comparison between responders and non-responders based on the χ^2 test
Mother's age (years):			
< 20	80 (4.1%)	2444 (8.3%)	
20–24	200 (10.2%)	5708 (19.4%)	
25–29	544 (27.8%)	8100 (27.6%)	
30–34	658 (33.7%)	8204 (27.9%)	
35–39	385 (19.7%)	3919 (13.3%)	
> 40	86 (4.4%)	777 (2.6%)	
Missing data	0 (0%)	200 (0.7%)	<0.01
Mother's ethnicity:			
White	1840 (94.2%)	25024 (85.2%)	
Black African	5 (0.3%)	340 (1.2%)	
Black Caribbean	18 (0.9%)	308 (1.0%)	
Black other	7 (0.4%)	192 (0.6%)	
Bangladeshi	2 (0.1%)	593 (2.0%)	
Indian	22 (1.1%)	651 (2.2%)	
Pakistani	14 (0.7%)	1020 (3.5%)	
Chinese	18 (0.9%)	182 (0.6%)	
Asian Other	5 (0.3%)	451 (1.5%)	
Other	16 (0.8%)	399 (1.4%)	
Not known	1 (0.1%)	25 (0.1%)	
Missing data	5 (0.3%)	167 (0.6%)	<0.01
Clinical variables			
Number of previous vaginal deliveries			
0	458 (23.4%)	5565 (19.0%)	
> 1	1495 (76.5%)	19637 (66.9%)	
88	0 (0%)	4150 (14.1%)	0.22

Table 6.3.4.1 (cont'd): Distribution of case-mix variables for women with and without data on birth preferences in phase 2

Number of previous CS	Women with data on birth preferences (n=1953)	Women for whom there are no data on birth preferences (n=29,352)	P value for comparison between responders and non-responders based on the χ^2 test
0	1758 (90.0%)	26269 (89.5%)	
1	158 (8.1%)	2402 (8.2%)	
> 2	27 (1.4%)	531 (1.8%)	
Missing data	10 (0.5%)	150 (0.5%)	0.81
Gestation (weeks)			
< 28	0 (0%)	143 (0.5%)	
28–32	3 (0.1%)	382 (1.3%)	
33–36	66 (3.4%)	1601 (5.4%)	
> 37	1880 (96.3%)	27,150 (92.5%)	
Missing data	4 (0.2%)	76 (0.3%)	<0.01
Onset of labour			
Spontaneous	1249 (63.9%)	18747 (63.9%)	
Induction	478 (24.5%)	7273 (24.8%)	
CS before labour	214 (11.0%)	3131 (10.7%)	
Missing data	12 (0.6%)	201 (0.7%)	0.48
Presentation			
Cephalic	1874 (95.9%)	28148 (95.9%)	
Breech	69 (3.5%)	1034 (3.5%)	
Transverse lie	4 (0.2)	98 (0.3%)	
Missing data	6 (0.3%)	72 (0.2%)	0.64
Birth weight (g)			
< 2500	63 (3.2%)	1861 (6.3%)	
2500–4000	1617 (82.8%)	24056 (82.0%)	
> 4000	262 (13.4%)	3188 (10.9%)	
Missing data	11 (0.6%)	247 (0.8%)	<0.01

There was a higher proportion of older women among those for whom there was data on birth preferences compared to those with no data on birth preferences (4.4% of women with data on birth preferences were over 40 years of age compared to 2.6% of women with no data on birth preferences). There was also a lower proportion of women under 20 years of age among those with data on birth preferences (4.1%) compared with women with no data on birth preferences (8.3%).

Over 90% of women who responded to the survey were White. About 6% of these women were from other ethnic groups compared with about 15% of all other women who gave birth during the phase 2 study period. The distribution of clinical variables (number of previous vaginal deliveries, number of previous CS, mode of onset of labour and presentation) among these women was similar to that for all women who gave birth during the phase 2 study period. As expected, the proportion of women who gave birth at term and the proportion of babies weighing between 2500 g and 4000 g were slightly higher among those who responded to the survey.

The overall CS rate for women who responded to the survey was 23% compared with 22% for women for whom there were no data on birth preferences. The CS before labour rate was similar for both groups (11%). For women in labour, the CS rate was higher among those women who had responded to the survey (13%) compared with 12% among women for whom there were no data on birth preferences.

The majority of pregnant women expressed a preference for a vaginal birth during the antenatal period (76%); about 5% of women expressed a preference for a planned CS. Seven percent of women reported that they had no preference, 8% reported that their 'preference was dictated by medical reasons' and 3% responded 'don't know'.

The following tables show birth preferences and women's characteristics such as age, ethnicity and number of previous vaginal deliveries and previous CS.

Table 6.3.4 2: Maternal age according to antenatal birth preferences (n=1953)

	Number of women expressing birth preference (%)					
Woman's age (years)	'I would prefer to give birth vaginally'	'I would prefer to have a planned CS'	'I do not have a preference'	'My preference is dictated by medical reasons'	'Don't know'	Missing data
< 20	65 (81.2%)	2 (2.5%)	4 (5.0%)	2 (2.5%)	7 (8.7%)	0
20–24	155 (77.5%)	17 (8.5%)	13 (6.5%)	8 (4.0%)	6 (2.0%)	1 (0.5%)
25–29	423 (77.8%)	26 (4.8%)	41 (7.5%)	36 (6.6%)	12 (2.2%)	6 (1.1%)
30–34	493 (74.9%)	31 (4.7%)	50 (7.6%)	64 (9.7%)	12 (1.8%)	8 (1.2%)
35–39	286 (74.3%)	21 (5.4%)	19 (4.9%)	46 (11.9%)	9 (2.3%)	4 (1.0%)
> 40	62 (72.1%)	7 (8.1%)	4 (4.6%)	10 (11.6%)	3 (3.5%)	0
All women	1484 (76.0%)	104 (5.3%)	131 (6.7%)	166 (8.5%)	49 (2.5%)	19 (1.0%)

The majority (at least 70%) of women in all age categories expressed a preference for a vaginal birth during the antenatal period. The majority of women who expressed a preference for a planned CS were over 30 years of age. The distribution of these birth preferences were similar among White and non-White women with the majority (over 75%) expressing a preference for a vaginal birth and about 5% expressing a preference for a planned CS during the antenatal period. Table 5.3.4.3 shows the distribution of birth preferences according to previous modes of deliveries.

Table 6.3.43: Previous deliveries according to antenatal birth preferences (n=1953)

	Number of women with specific previous deliveries (%)				
	No previous births	At least one previous vaginal birth, no previous CS	At least one previous CS, no previous vaginal births	Previous vaginal births and previous CS	Missing data on previous deliveries
'I would prefer to give birth vaginally'	655 (76.6%)	743 (82.4%)	56 (39.7%)	20 (45.4%)	10 (90.0%)
'I would prefer to have a planned CS'	31 (3.6%)	38 (4.2%)	28 (19.9%)	6 (13.6%)	1 (9.1%)
'I do not have a preference'	83 (9.7%)	39 (4.3%)	9 (6.4%)	0	0
'My preference is dictated by medical reasons'	54 (6.3%)	59 (6.5%)	39 (27.7%)	14 (31.82%)	0
'Don't know'	28 (3.3%)	15 (1.7%)	6 (4.3%)	3 (6.8%)	0
Missing data	4 (0.5%)	8 (0.9%)	3 (2.1%)	1 (2.3%)	0

The majority of women who were in their first pregnancy and those who had had only previous vaginal deliveries expressed a preference for a vaginal birth. About 40% of women who had had a previous CS expressed a preference for vaginal birth, 20% expressed a preference for a planned CS and 28% reported that their preference was dictated by medical reasons. Among women who had had both previous vaginal deliveries and previous CS, 45% expressed a preference for vaginal birth, 14% expressed a preference for a planned CS and 32% reported that their preference was dictated by medical reasons.

Table 6.3.4.4: Rates of CS before labour and CS in labour according to antenatal birth preferences

	All women (n=1953)	CS before labour (n=1932*)		CS during labour (n=1718)	
Birth preference	Number (%)	Number (%)	Univariate OR (95% CI)**	Number (%)	Univariate OR (95% CI)**
'I would prefer to give birth vaginally'	1484 (76.0%)	81 (5.5%)	1.00	156 (11.3%)	1.00
'I would prefer to have a planned CS'	104 (5.3%)	48 (46.1%)	14.64 (9.49, 22.01)	14 (25.0%)	2.62 (1.52, 4.52)
'I do not have a preference'	131 (6.7%)	9 (6.9%)	1.27 (0.66, 2.43)	26 (21.5%)	2.15 (1.31, 3.54)
'My preference is dictated by medical reasons'	166 (8.5%)	61 (37.0%)	10.02 (7.19, 13.97)	28 (26.9%)	2.90 (1.75, 4.81)
'Don't know'	49 (2.5%)	8 (16.3%)	3.58 (1.91, 6.68)	6 (14.6%)	1.53 (0.61, 3.86)
Missing data	19 (0.9%)	7 (36.8%)	10.25 (3.54, 29.64)	3 (25.0%)	1.97 (0.40, 9.60)

*n=1932 as mode of onset of labour and/or mode of delivery not known for 21 women

**standard errors adjusted for clustering of women within maternity units

CS rates before and in labour were generally lower among women who expressed a preference for vaginal birth compared with those who expressed a preference for CS. While about 5% of women who reported a preference for vaginal birth had CS before labour, 46% of those who reported a preference for planned CS had a CS before labour (univariate OR: 14.64; 95% CI: 9.49, 22.01) (see table 6.3.4.4). Compared with women who expressed a preference for vaginal birth, the odds of CS before labour was higher for women who reported that their preference was dictated by medical reasons. Among women in labour, 11% of those who reported a preference for vaginal birth compared with 25% of those who reported a preference for CS had a CS (univariate OR: 2.62; 95% CI: 1.52, 4.52). The magnitude of the univariate odds ratios for CS in labour are similar for those women who did not express a preference for vaginal birth in the antenatal period.

Table 6.3.4.5 shows the association between birth preferences, demographic and clinical variables and (i) CS before labour, and (ii) CS in labour in separate multiple logistic regression models.

Table 6.3.4.5: Association between birth preferences, demographic and clinical variables and (i) CS before labour, and (ii) CS in labour (multiple logistic regression)

Explanatory variable	CS before labour (n=1874)*	CS in labour (n=1689)**
Preference for mode of delivery		
Vaginal birth	1.00	1.00
CS	15.79 (8.75, 28.49)	3.02 (1.50, 6.08)
Preference dictated by medical reasons	0.90 (0.32, 2.50)	1.70 (1.07, 2.69)
No preference	5.93 (4.05, 8.67)	2.55 (1.38, 4.71)
Don't know	3.84 (1.81, 8.14)	1.46 (0.60, 3.53)
Missing data	6.73 (3.20, 14.16)	2.61 (0.40, 17.08)
Mother's age (years)		
< 20	0.64 (0.16, 2.62)	0.34 (0.12, 0.99)
20 – 24	0.55 (0.24, 1.29)	0.30 (0.15, 0.63)
25 – 29	1.00	1.00
30 – 34	1.46 (0.90, 2.35)	0.92 (0.62, 1.35)
35 – 39	1.41 (0.77, 2.56)	1.11 (0.69, 1.79)
> 40	1.22 (0.48, 3.10)	1.12 (0.47, 2.68)
Mother's ethnicity		
White	1.00	1.00
Black African	*	1.38 (0.78, 2.45)
Black Caribbean	2.44 (0.68, 8.74)	2.96 (0.71, 12.39)
Black other	*	**
Bangladeshi	*	53.83 (6.59, 439.81)
Indian	2.18 (0.53, 9.04)	1.14 (0.18, 7.30)
Pakistani	4.42 (1.38, 14.13)	1.36 (0.12, 14.89)
Chinese	*	1.18 (0.28, 4.91)
Asian Other	*	0.22 (0.04, 1.11)
Other	0.42 (0.12, 1.50)	2.70 (0.72, 10.15)
Not known	*	**
Missing data	*	**

Table 6.3.4.5 (cont'd): Association between birth preferences, demographic and clinical variables and (i) CS before labour, and (ii) CS in labour (multiple logistic regression)

Number of previous vaginal deliveries			
	0	1.00	1.00
	≥ 1	0.59 (0.37, 0.93)	0.17 (0.11, 0.28)
	Missing data	*	**
Number of previous CS			
	0	1.00	1.00
	1	10.73 (7.38, 15.61)	2.28 (1.26, 4.16)
	≥ 2	66.44 (16.87, 261.65)	85.03 (6.91, 1046.82)
	Missing data	*	**
Onset of labour			
	Spontaneous	n/a	1.00
	Induction	n/a	3.20 (2.14, 4.80)
Gestation (weeks)			
	< 28 weeks	*	**
	28–32	0.79 (0.14, 4.25)	**
	33–36	3.90 (0.92, 16.59)	1.37 (0.54, 3.48)
	> 37	1.00	1.00
	Missing data	*	**
Presentation			
	Cephalic	1.00	1.00
	Breech	66.92 (38.98, 114.89)	61.89 (19.30, 198.55)
	Transverse lie	*	-
	Missing data	*	1.81 (0.04, 71.50)
Birth weight (g)			
	< 2500	1.30 (0.28, 5.99)	1.12 (0.53, 2.40)
	2500–4000	1.00	1.00
	> 4000	1.57 (0.89, 2.79)	1.97 (1.35, 2.89)
	Missing data	1.59 (0.40, 6.32)	**

*Data on mode of onset of labour was only known for 1932 women. None of the women in the following categories had CS before labour: Black African (n=5), other Black women (n=7), Bangladeshi (n=2), Chinese (n=18), Other Asian women (n=5), ethnicity not known (n=1), missing data on ethnicity (n=3), missing data on number of previous vaginal deliveries (n=1), missing data on gestational age (n=3), transverse lie (n=4), missing data on presentation (n=2). There were also missing data on number of previous CS for seven women, six of these expressed a preference for vaginal birth and none of these had CS before labour; one expressed a preference for CS and had CS before labour, these women were also excluded as convergence could not be achieved with their inclusion.

**None of the women in the following categories had CS: Other Black women (n=7), ethnicity not known (n=1), missing data on ethnicity (n=3), missing data on number of previous vaginal deliveries (n=1), gestation 28–32 weeks (n=2), missing data on gestational age (n=3), missing data on birth weight (n=4). There were also missing data on number of previous CS for six women, all expressed a preference for vaginal birth and none of these had CS before labour; one had CS while the others had vaginal delivery; however, because of other characteristics (e.g. missing data on ethnicity), these women were also excluded as convergence could not be achieved with their inclusion.

Having adjusted for demographic and clinical characteristics, women who expressed an antenatal preference for planned CS had a 16-fold increase in odds of CS before labour compared with women who expressed an antenatal preference for vaginal birth. Those who responded 'no preference' or 'don't know' also had higher odds of CS before labour. For women in labour, the odds ratio of CS was three-fold higher for women who expressed an antenatal preference for planned CS and about two-fold higher for women who reported either 'no preference' or that their 'preference was dictated by medical reasons'. The inclusion of 'birth preferences' did not change the magnitude of odds ratios for demographic and clinical variables. The magnitude of odds ratios for the demographic and clinical variables are similar to those obtained from analysis of phase 1 data, although the precision of estimates is greater from the phase 1 data because of the greater number of women in the dataset. As shown in table 6.3.4.5, it was not possible to estimate odds ratios for some of the categories of some variables in this analysis because of the small number of women involved.

6.3.5 Conclusions

The analysis presented here so far is limited to the group of women for whom there are data on both 'birth preferences', case-mix variables and mode of delivery. These results may be spurious as there may be differences between responders and non-responders and it cannot be assumed that 'non-response' was a random occurrence. Limiting the analysis to cases with completely observed data also meant discarding an unacceptably large portion of data, resulting in a loss of power. Therefore, the challenge was to utilise the information from the large phase 1 database in estimating the association between women's antenatal birth preferences and mode of delivery. Although there are no data on birth preferences for the women in phase 1, this absence could potentially be treated as 'missing data'. There are techniques described in the literature for 'handling' missing data and these are reviewed together with possible application to this dataset in the next chapter (chapter 7). The intention is to utilise the information that is available to try to get more accurate results that will be generalisable for all women giving birth in England and Wales.

The demographic characteristics (age and ethnicity) of women who responded to the survey differed from women for whom there was no data on birth preferences. Women who responded were also more likely to have had term pregnancies. It is possible that these women are therefore not representative of all women who gave birth during phase 2. However by making the assumption that the reasons for non-response are related to observed variables (e.g. women who are younger and those from ethnic minorities who do not speak

English are less likely to respond), it is possible to use mult'ple imputation procedures. This assumption is termed missing at random and is expanded on in the next chapter.

7 Analysis of datasets containing missing data – a review of the literature

7.1 Types of missing data

There are two types of missing data, unit non-response and item non-response[169]. Unit non-response refers to situations where there is a complete absence of information for individuals or cases that are included in a study (e.g. individuals who do not respond or return questionnaires in a survey). Item non-response refers to situations where there is information for some variables but not other variables (e.g. individuals responding to a questionnaire may answer some but not all questions). In longitudinal studies with repeated waves of data collection there may be complete data for individual cohort members for some but not all waves. This may be classified as either unit or item non-response depending on the analytical context.

The 'missing data' may have a univariate pattern (where only one variable within a dataset is affected) or an arbitrary pattern (where any number of variables may be affected for any particular individual within the dataset)[169].

7.2 Mechanism of missingness

The mechanism of missingness has to be taken into account when deciding on the statistical method for dealing with missing data. The mechanism for missingness refers to the possible reasons why the data are missing and hence assumptions about the missing data. There are three mechanisms defined in the literature[169]. These are 'missing completely at random' (MCAR), 'missing at random' (MAR) or 'missing not at random' (MNAR).

7.2.1 MCAR

MCAR refers to situations where the missing data are completely random and are not related to the variables that are being measured. For example, if the reason for non-response in a survey is in no way related to the content of the questionnaire, or that the data are missing by design of the study. MCAR can be tested by examining whether or not responders have similar characteristics to non-responders. The data (Y) can be partitioned into observed (Y_{obs}) and missing (Y_{mis}). The probability of missingness (R) is independent of the data (both Y_{obs} and Y_{mis}).

$$P(R \mid Y) = P(R)$$

7.2.2 MAR

MAR assumes that the missing data may be related to outcomes but only through data that are observed. This is also referred to in the literature as 'ignorable non-response', and it is often the default assumption. For example, in a longitudinal study, it may be reasonable to assume that the probability of an individual not responding at the third wave of data collection is related to the observed data from the first two waves of data collection but conditional on this, is independent of outcomes that would be observed at the third wave. This assumes that the probability of missingness (R) does not depend on the missing data.

$P(R \mid Y) = P(R \mid Y_{obs}, Y_{mis}) = P(R \mid Y_{obs})$

7.2.3 MNAR

MNAR refers to situations where the missingness is related to outcomes to a degree that cannot be fully accounted for by data that are observed. For example, in a longitudinal study, the probability of an individual dropping out at time t depends on the unobserved response at time t. Another example is where there are unmeasured confounders related to both probability of missingness and to the outcome. This is also referred to as 'non-ignorable non-response'[169]. In practice, this type of missing data is not easily dealt with as it requires very strong assumptions to be made about the data. However, it may be possible to use sensitivity analyses.

7.3 Methods of dealing with missing data

7.3.1 Case deletion

This is the approach of analyzing only completely observed data (i.e. all cases or individuals that have data missing for one or more variables are excluded from the analysis). This is probably only acceptable if the quantity of missing data is 'small' and relatively uninfluential. It is reported to yield correct (although not efficient) inferences under MCAR[170]. This method is non-parametric and therefore no assumptions are made about the distribution of the data. However, if the mechanism for missingness is not MCAR, this method introduces bias and is nearly always inefficient[171]. In some cases, an unacceptably large portion of cases may be discarded.

If the MCAR assumption is not valid, it is possible to discard the incomplete cases and then use reweighting so that the complete cases resemble the population more closely. However, this assumes MAR, does not allow for differential responses related to measured or unmeasured variables and may not be efficient[171].

7.3.2 Single imputation

Imputation is the practice of 'filling in' missing data with plausible values. Missing data are replaced with values based on data that are observed. For example, data on 'number of children' or 'height' may be missing for some individuals in a study. These missing data can be replaced by any of the following methods:

- Replace the missing value with a value that is deduced from the values of other observed variables. For example, if there are missing data on the number of children, and the age of the subject under consideration is 5 years old, then the number of children for that subject must be 0. This is known as deductive imputation.

- Replace with the mean height for other study participants for whom data are available (mean substitution).

- Replace each missing value by a randomly drawn observed value (hot decking).
- Replace each missing value by a predicted value from a regression model estimated from the observed data (regression method).
- In longitudinal data, replace missing values with the value from the most recent observed value (last observation carried forward).

The limitations with these methods are documented[169;172-176]. Mean substitution may preserve the mean but distorts the distribution of the data so that while the sample size is increased, the standard errors will be too small. The relationships between variables will also be distorted. Hot-deck imputation preserves the marginal distributions but distorts the relationships between variables. Regression methods will inflate correlations between variables in the data while 'last observation carried forward' ignores regression to the mean and systematic trends within the data.

Therefore, the limitations of single imputations are firstly the potential for bias (as the imputed value is not always related to other values for the particular observation), and secondly the uncertainty of missing data is not reflected in later analyses[173;177]. It overstates the sample size giving confidence intervals that are too narrow with high type 1 error rates. This is reported to be worse when the proportion of missing data is greater than 5% and when more parameters are involved[178;179].

7.3.3 Multiple imputation

Multiple imputation is a simulation-based approach to missing data[180]. A number (m, m>1) of imputations are generated for the missing data, thus producing m datasets with 'complete data'. Each of these m datasets are then analysed by standard complete data methods (such as logistic regression). Variability between the resulting parameter estimates provides a measure of uncertainty due to the missing data. The results from these m analyses are then combined. The main advantage is that by using several plausible imputations for the missing data, the missing data 'uncertainty' can be taken into account in the final analysis. The method for combining results from the m imputed datasets is called the 'repeated-imputation inference method' and has been described by Rubin in 1987[170]. The multiple imputation paradigm does not require or assume that non-response is non-ignorable[171]. The importance of using all the available information as predictor variables in the model for imputations is documented[171]. This means that in situations where only a subset of variables are to be used in the final analysis, these as well as others that may be predictive of them or 'missingness' should be included in the model for imputation. This method is reported to be highly efficient[170;171]. The efficiency is dependent on the number of imputations (m) and the fraction of missing data (lambda). This means that the standard error obtained will be approximately $(1 + \text{lambda}/m)^{0.5}$ times as large as the estimate with an infinite value of m. It is expected that standard errors from multiple imputation will be smaller than those of analysis of completely observed data (e.g. case deletion) but larger than those using single imputation.

Multiple imputations have been used to deal with missing data in a number of areas of medical research including HIV[181-184], cardiovascular disease[185-189], immunology[190], orthopaedics[191], and cancer[192;193]. Two methods for obtaining imputations are described in this section, the propensity score method and the predictive model method[194].

Propensity score method

The propensity score method is based on logistic regression. An indicator r_j for missing variable y_i is regressed on observed covariates within the datasets. The propensity score is the conditional probability of missingness given the vector of observed covariates. Imputations for each missing value $y_{j(miss)}$ are independent random draws from a subset of observed values of $y_{j(obs)}$ with propensity scores close to that assigned to the case with missing data. This method is not recommended for inferences about associations as opposed to marginal distributions as the relationships between variables are not well preserved under this approach. [171;177;195].

Predictive model based method

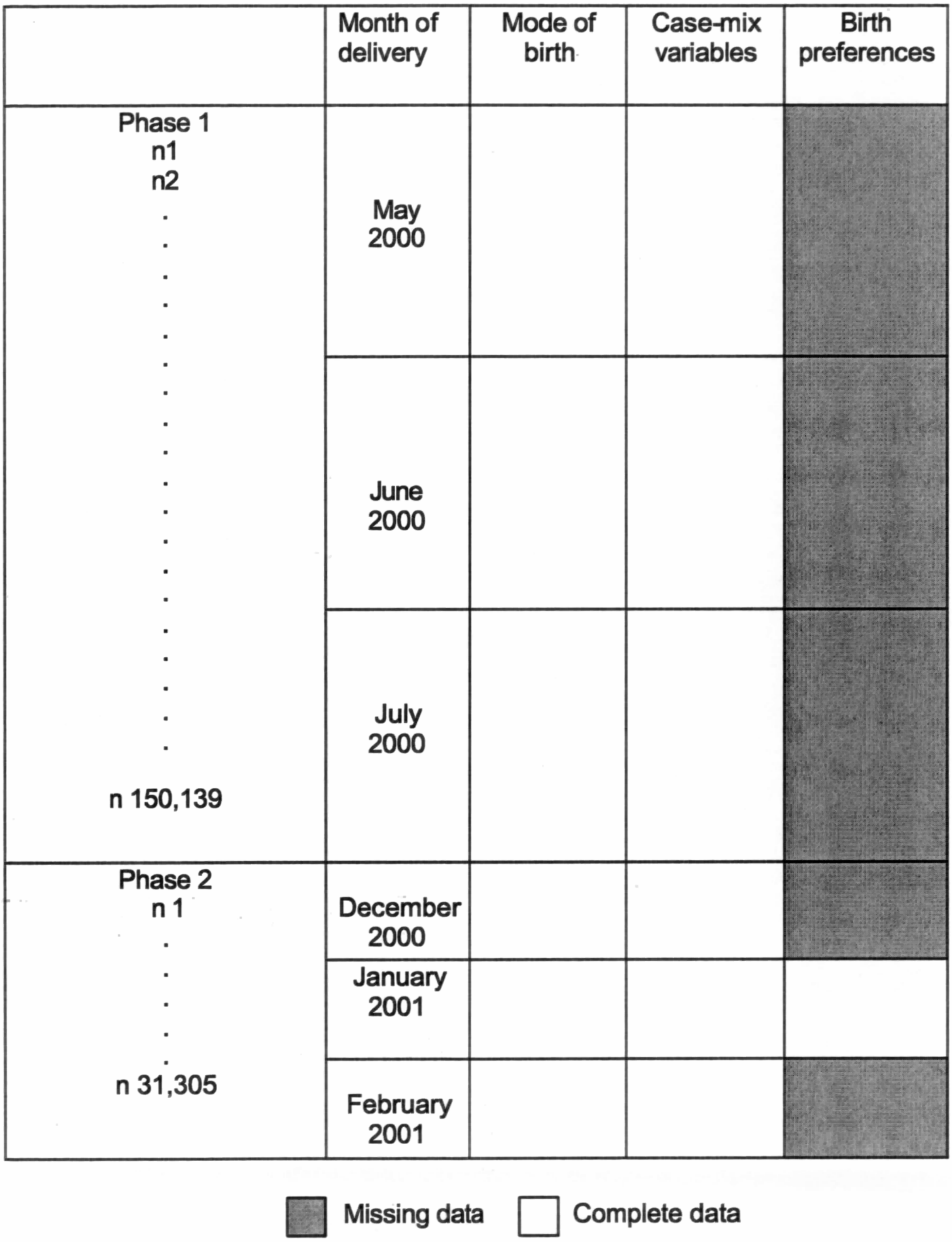
In this method, the relationships between variables within completely observed data are used to predict the missing variable for those cases with missing data. The variable to be imputed is regressed on observed covariates using an appropriate model. For binary or categorical variables, this can be done using discriminant function analysis, logistic regression or a loglinear model. M imputations are independently generated using the values predicted by the regression equation to create m imputed datasets. Each dataset is then analysed separately using standard methods such as logistic regression. The estimates and standard errors from the m datasets are then combined by computing the mean of the m estimates and a variance estimate that includes both a within-imputation and a between-imputation component.

In the following sections (7.4.3 and 7.4.4) the use of discriminant function analysis, logistic regression and a loglinear model for predicting imputations are described using a simplified dataset from the NSCSA.

7.4 Application to data

In the NSCSA data, the missing birth preferences data can be thought of as item non-response with a univariate pattern. This is because information on case-mix variables are available for all women who gave birth in the 216 maternity units during phase 1 and the 'sampled' 40 maternity units that took part in phase 2; while information on their antenatal birth preferences is only available for a small proportion of women that gave birth during phase 2.

Figure 7.4.1: Summary of NSCSA data



The mechanism for missingness in the NSCSA is partly MCAR as only women who were expected to deliver in January were invited to participate in the survey. MCAR would be a reasonable assumption unless the relationships between variables are different in January compared with other months. This is unlikely as previous analysis did not suggest any time period effect on the relationship between case-mix variables and risk of CS. However, non-response to the invitation to participate and to the questionnaire are not MCAR but may be MAR, making the assumption that the relationship between missing data on birth preferences and outcome is similar to that of observed data on birth preferences and outcome.

The limitations of case deletion were illustrated in the analysis of observed data from the NSCSA (see section 6.3.4). There was a loss in the precision of estimates obtained due to loss of power from discarding an unacceptably large portion of data. Furthermore, the MCAR assumption is not valid as discussed above. Re-weighting may be an option. However, as the weights were not used in the sampling for phase 2, the calculation of weights in order to make the results applicable to all women in England and Wales may not be straightforward.

Analysis of these data using multiple imputations to deal with the 'missing data' on birth preferences seemed to be a reasonable option. There are two ways to generate the imputations: the propensity score method and the predictive model based method.

The propensity score method is not suitable for the analysis of NSCSA data. Using this method, the imputations for each missing birth preference are independent random draws from a subset of observed birth preferences with propensity scores close to that assigned to the women with missing data. The main predictor of 'missingness' is month of delivery. However, it would not be reasonable to use this in calculating the propensity score because there are very little data on birth preferences for women who gave birth in December or February and therefore a scarcity of 'similar propensity scores' to draw from. Other predictor variables (case-mix variables) could be used to calculate the propensity score; however, this method will only be valid if the linear combination of variables that predict 'missingness' are also related to preferences. This is not necessarily the case as women with similar probabilities of having 'missing birth preferences' may not necessarily have the same distribution of birth preferences. For example, response to the questiomaire would depend on literacy and familiarity with the English language and, as a result, ethnicity may be a strong predictor of missingness but analysis of the completely observed data suggests that previous CS is the main predictor of birth preference for CS.

The predictive model based method, however, seems a reasonable approach for generating the imputations. The application of this method to the NSCSA data is illustrated in the following sections using a simplified dataset containing only three variables.

7.4.1 Application of the predictive model based method to a simplified NSCSA dataset

The overall aim is to fit a model that relates CS in the index pregnancy to previous CS and birth preference. Previous analysis of these data showed that previous CS is a strong predictor of both birth preference and of CS as an outcome in the index pregnancy. A dataset that contained three variables (previous CS, birth preference and CS before labour) was used to illustrate this method for imputation. In this way, the data can be categorized into four distinct categories:

(i) women with no previous CS who did not have CS before labour in the index pregnancy

(ii) women who had at least one previous CS and who did not have CS before labour in this pregnancy

(iii) women with no previous CS who had CS before labour in this pregnancy

(iv) women with at least one previous CS who had CS before labour in this pregnancy.

The advantage of this dataset is that the imputed distribution can easily be compared with the observed distribution as there are only four distinct categories.

Models were fitted using three different approaches (discriminant function analysis, sequential logistic regression and a loglinear model), to the completely observed data to estimate the relationship between women's preference (dependent variable); and two explanatory variables (previous CS and CS before labour). These estimations are then applied to incompletely observed data to predict 'women's preference' for each individual woman for whom data on preference are not available. This is done m times, to create m imputed datasets. Each dataset is then analysed separately using logistic regression (with CS before labour as the outcome variable and previous CS and preference as explanatory variables). The estimates and standard errors from the m datasets are then combined by computing the mean of the m estimates and a variance estimate that includes both a within-imputation and a between-imputation component.

Firstly, the data that were used to illustrate the application of the predictive model based method are described (section 7.4.2). Secondly, the method using discriminant function analysis (as implemented in SOLAS[194]) is described and illustrated using the simplified dataset (section 7.4.3). The results from this application suggested that this method would not be suitable for use with the NSCSA data and this is discussed in section 7.4.3. Therefore, other methods for creating the imputations using logistic regression or a loglinear model were explored and these are described in section 7.4.4.

7.4.2 Data

The simplified dataset that was used to illustrate these methods for handling missing data was a subset of the phase 2 dataset that included only White women, with three variables:

(i) women's birth preference (five categories)

(ii) previous CS (binary)

(iii) CS before labour (binary).

For simplicity, women who had missing data for any of the case-mix variables were excluded. The following table gives a description of this simplified dataset.

Table 7.4.2.1: Description of simplified NSCSA dataset (n=26,166)

	Numbers of women (%)						
	'I would prefer to give birth vaginally'	'I would prefer to have a planned CS'	'I do not have a preference'	'My preference is dictated by medical reasons'	'Don't know'	Total with observed data on birth preference	Missing data
No previous CS, No CS before labour							
	1232 (5.6%)	49 (0.2%)	109 (0.5%)	84 (0.4%)	39 (0.2%)	1513 (6.8%)	20649 (93.2%)
No previous CS, CS before labour							
	58 (3.9%)	16 (1.1%)	6 (0.4%)	21 (1.4%)	3 (0.2%)	104 (7.0%)	1373 (93.0%)
At least one previous CS, No CS before labour							
	51 (4.4%)	3 (0.3%)	5 (0.4%)	14 (1.2%)	2 (0.2%)	75 (6.5%)	1079 (93.5%)
At least one previous CS, CS before labour							
	19 (1.4%)	28 (2.0%)	2 (0.1%)	38 (2.8%)	4 (0.3%)	91 (6.6%)	1282 (93.4%)
All women							
	1360 (5.2%)	96 (0.4%)	122 (0.4%)	157 (0.6%)	48 (0.2%)	1783 (6.8%)	24383 (93.2%)

The majority of women for whom there was completely observed data expressed a preference for a vaginal birth. Only 3–4% of women who went into labour had expressed a preference for CS during the antenatal period compared with 15–30% of women who had CS before labour. The proportion of women who reported that their preference was dictated by medical reasons was higher among those who had had CS before labour whether or not they had had a previous CS.

7.4.3 Model for imputation using discriminant function analysis

It is reported that a normal distribution can be used to approximate a discrete distribution such that the use of discriminant function analysis for the imputation of categorical variables is justified[194;196]. Discriminant function analysis discriminates between groups of individuals on the basis of a number of predictor variables under the assumption that these variables follow a multivariate normal distribution in each group. In this section, the theory of using discriminant function analysis is explained, followed by an illustration of the use of this method (as implemented in SOLAS)[194] using the simplified NSCSA dataset.

Discriminant function analysis theory

Logistic regression is used to model the dependency of an outcome on a number of predictor variables by assuming that the outcome variable follows a binomial distribution whose expectation is given through a linear relationship between the log odds of the outcome and the predictor variables. In contrast, discriminant function analysis assumes that each of the predictor variables follows a normal distribution (with different means and variances) in each of the outcome groups. It then follows that the relationship between the log odds of the outcome and the predictor variables is quadratic[197]. Furthermore, this relationship is linear if the variances are the same in each outcome group.

For discrete predictor variables, the discriminant function approach will not be appropriate if the relative frequencies of the outcome variable at each level of the predictor are not preserved when the predictor variables are approximated by normal distributions.

To investigate this in a simple situation, suppose that a particular binary predictor has probability p in a particular outcome group. Discriminant function analysis assumes that the predictor is normally distributed with mean p and variance p(1–p) in this group. Hence, the relative frequencies of the two outcomes are as follows:

$$\frac{1}{\sqrt{2\pi p(1-p)}}\exp^{-0.5}\left(\frac{(p-0)^2}{p(1-p)}\right)$$

and

$$\frac{1}{\sqrt{2\pi p(1-p)}}\exp^{-0.5}\left(\frac{(1-p)^2}{p(1-p)}\right)$$

Hence the relative frequency is

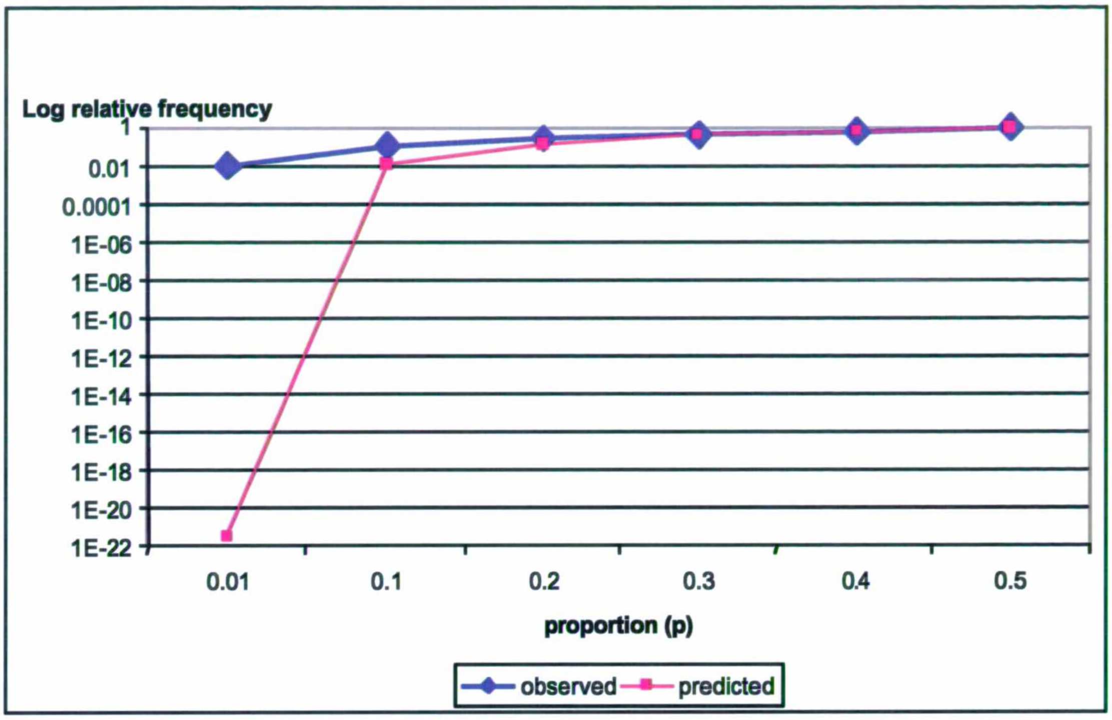
$$\exp^{-0.5}\left(\frac{(1-p)^2-p^2}{p(1-p)}\right) = \exp^{-0.5}\left(\frac{1-2p}{p(1-p)}\right).$$

This approximation will be appropriate if

$\frac{p}{1-p}$ is approximately equal to $\exp^{-0.5}\left(\frac{1-2p}{p(1-p)}\right)$.

The relationship between these two variables is shown in the following figure.

Figure 7.4.3.1: Observed and predicted relative frequencies



This figure shows that when p is at least 0.4, the relative frequency and variance are in good agreement. However, when p is 0.2 or smaller, the relative frequency is substantially smaller than p/(1–p). For example when p is 0.01, p/(1–p) is 0.0101 and the relative frequency obtained by using this normal approximation is 3×10^{-22}. Therefore rare outcomes become even rarer when this approximation is used.

Application of this method to the simplified NSCSA data

SOLAS implements 'discriminant multiple imputations' using discriminant function analysis for imputation of categorical variables. Multiple imputations are generated using a regression model of 'women's preference' on 'previous

CS' and 'CS before labour'. The imputations are generated by randomly drawing regression estimates from the Bayesian posterior distribution based on the cases for which 'women's preference' is observed. Each imputed value is the predicted value from these randomly drawn estimates plus a randomly drawn error term. The randomly drawn error term is added to the imputations to prevent over-smoothing of the imputed data. The regression model estimates are drawn from a Bayesian posterior distribution in order to reflect the extra uncertainty due to the fact that regression estimates can be estimated but not determined from the observed data[194].

To check the validity of this method for the NSCSA data, the distribution of the imputed preference variable was compared with the distribution within the completely observed data. Given the findings described in the previous section, the expected distribution of birth preferences was calculated by computing the probability density functions of the curve when the discrete observed data are approximated by a bivariate normal distribution.

Results

Complete data on preferences were available for 1783 women in phase 2. The majority of women (76%) expressed a preference for vaginal birth. About 9% of women reported that their preference was dictated by medical reasons, 7% expressed 'no preference', 5% expressed a preference for CS, and fewer than 3% responded 'don't know'. The majority of women also did not have previous CS or CS before labour. Therefore, there were very few women in some combinations of birth preference, previous CS and CS before labour (see table 7.4.2.1).

Table 7.4.3.1 that follows illustrates the calculation of relative frequencies of birth preferences. For example, among women who expressed a preference for vaginal birth, the mean for 'previous CS' is 0.05 (SD: $(0.05 \times 0.95)^{0.5} = 0.22$) and the mean for 'CS before labour' is 0.06 (SD: $(0.06 \times 0.94)^{0.5} = 0.23$). This information is used together with the variance covariance matrix for these two variables in order to calculate the relative frequencies in each of the four categories of previous CS and CS before labour.

Table 7.4.3.1: Relative frequency of birth preferences according to previous CS and CS before labour

				Probability density function Relative frequency of birth preference (%)			
	Mean previous CS (SD)	Mean CS before labour in index pregnancy (SD)	Variance covariance matrix	no previous CS, no CS before labour	No previous CS, CS before labour	One previous CS, no CS before labour	One previous CS, CS before labour
Preference: vaginal birth (n=1360)	0.05 (0.22)	0.06 (0.23)	0.05 0.01, 0.05	2.3218 88.5%	0.0003 1.95%	0.0001 1.42%	1.33e-06 0.003%
CS (n=96)	0.32 (0.47)	0.46 (0.50)	0.22 0.14, 0.25	0.0300 1.14%	0.0059 38.41%	0.0012 17.02%	0.0159 42.06%
No preference (n=122)	0.06 (0.23)	0.06 (0.25)	0.05 0.01, 0.06	0.1822 6.95%	0.00009 0.58%	0.00003 0.42%	7.25e-07 0.002%
Medical reasons (n=157)	0.33 (0.47)	0.37 (0.48)	0.22 0.12, 0.24	0.0497 1.89%	0.0088 57.29%	0.0056 79.43%	0.0212 56.08%
Don't know (n=48)	0.12 (0.33)	0.14 (0.36)	0.11 0.07, 0.13	0.0392 1.49%	0.0003 1.95%	0.0001 1.42%	0.0007 1.85%
All women (n=1783)				2.62295 100%	0.01536 100%	0.00705 100%	0.0378 100%

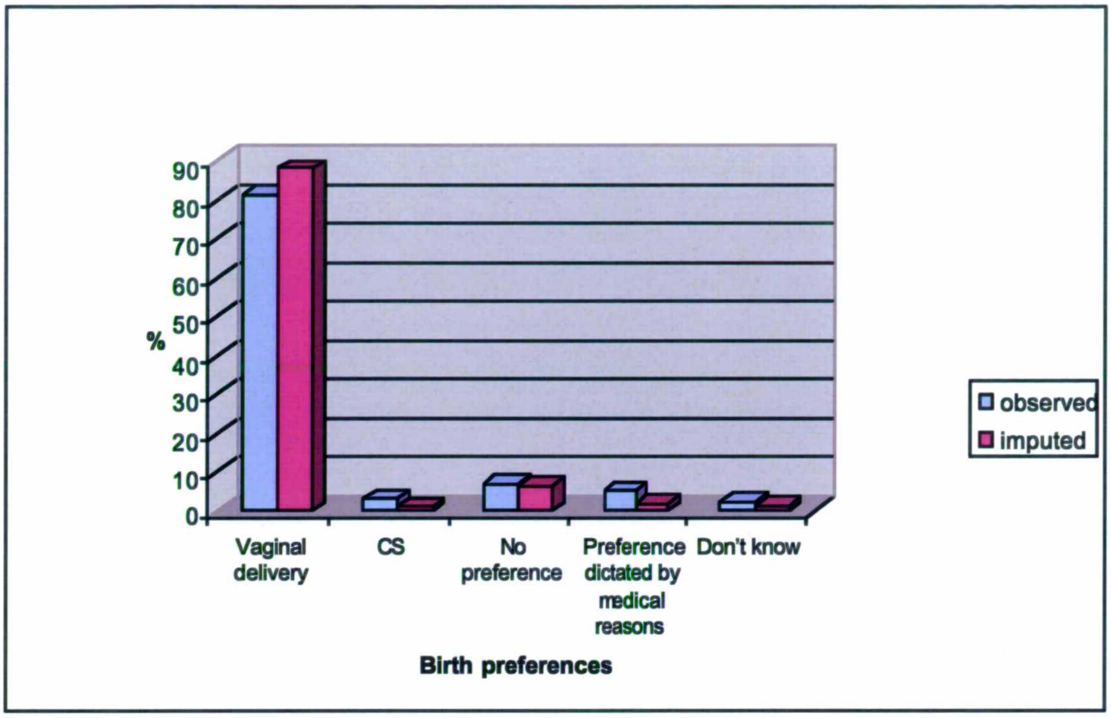
Table 7.4.3.2: Distribution of imputed data using SOLAS – predictive model based method using discriminant multiple imputations

Pref	No previous CS No CS before labour		No previous CS CS before labour		At least one previous CS No CS before labour		At least one previous CS CS before labour	
	Obs	Imp	Obs	Imp	Obs	Imp	Obs	Imp
Vaginal delivery	1232 (81.4%)	18210 (88.2%)	58 (55.8%)	39 (2.8%)	51 (68.0%)	15 (1.4%)	19 (20.9%)	0
CS	49 (3.2%)	244 (1.2%)	16 (15.4%)	449 (32.7%)	3 (4.0%)	248 (23.0%)	28 (30.8%)	587 (45.8%)
No pref	109 (7.2%)	1392 (6.7%)	6 (5.8%)	4 (0.3%)	5 (6.7%)	6 (0.6%)	2 (2.2%)	0
Pref dictated by medical reasons	84 (5.5%)	442 (2.1%)	21 (20.2%)	861 (62.7%)	14 (18.7%)	791 (73.3%)	38 (41.8%)	676 (52.7%)
Don't know	39 (2.6%)	361 (1.7%)	3 (2.9%)	20 (1.5%)	2 (2.7%)	19 (1.8%)	4 (4.4%)	19 (1.5%)
All women	1513 (100%)	20649 (100%)	104 (100%)	1373 (100%)	75 (100%)	1079 (100%)	91 (100%)	1282 (100%)

Pref, preference; Obs, observed; imp, imputed

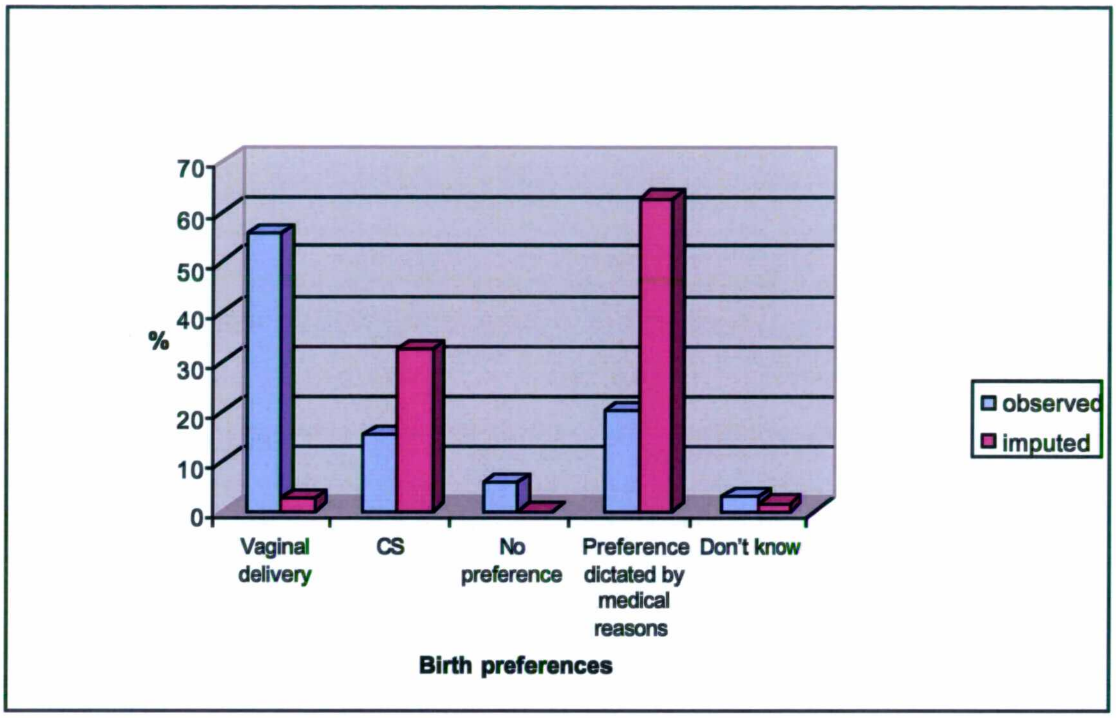
Table 7.4.3.2 shows the distribution of imputed birth preferences according to previous CS and CS before labour for women with missing data on birth preferences using SOLAS[194]. The imputed distribution of birth preferences is similar to the calculated relative frequency shown in table 7.4.3.1. However, there are large discrepancies between the observed and imputed distributions of birth preference particularly in the less prevalent categories of women who had either previous CS or CS before labour. These discrepancies are further illustrated in the following figures.

Figure 7.4.3.2: Observed and imputed distribution of birth preference: women with no previous CS, no CS before labour



For women who had neither a previous CS nor CS before labour in the index pregnancy, there was a higher proportion of women with preference for vaginal birth in the imputed dataset (88%) compared with the observed dataset (81%). The proportion of women with 'no preference' was similar in the two datasets. However, the proportion of women with other birth preferences was lower in the imputed dataset.

Figure 7.4.3.3: Distribution of observed and imputed birth preferences: women with no previous CS who had CS before labour



For women who did not have a previous CS and had a CS before labour in the index pregnancy, approximation with a multivariate normal distribution resulted in only 3% of women in the preference for vaginal birth category in the imputed dataset compared with 56% in the observed dataset. The proportion of women in the 'no preference' and 'don't know' categories were also lower in the imputed dataset. However, the proportions of women in the preference for CS and preference dictated by medical reasons categories were higher (33% and 63%, respectively) when compared with the observed data (15% and 20%). Similar large discrepancies between the observed and imputed datasets were also seen among women who had a previous CS whether or not they had a CS before labour in the index pregnancy (see figures 7.4.3.4 and 7.4.3.5).

Figure 7.4.3.4: Distribution of observed and imputed birth preferences: women with at least one previous CS, no CS before labour

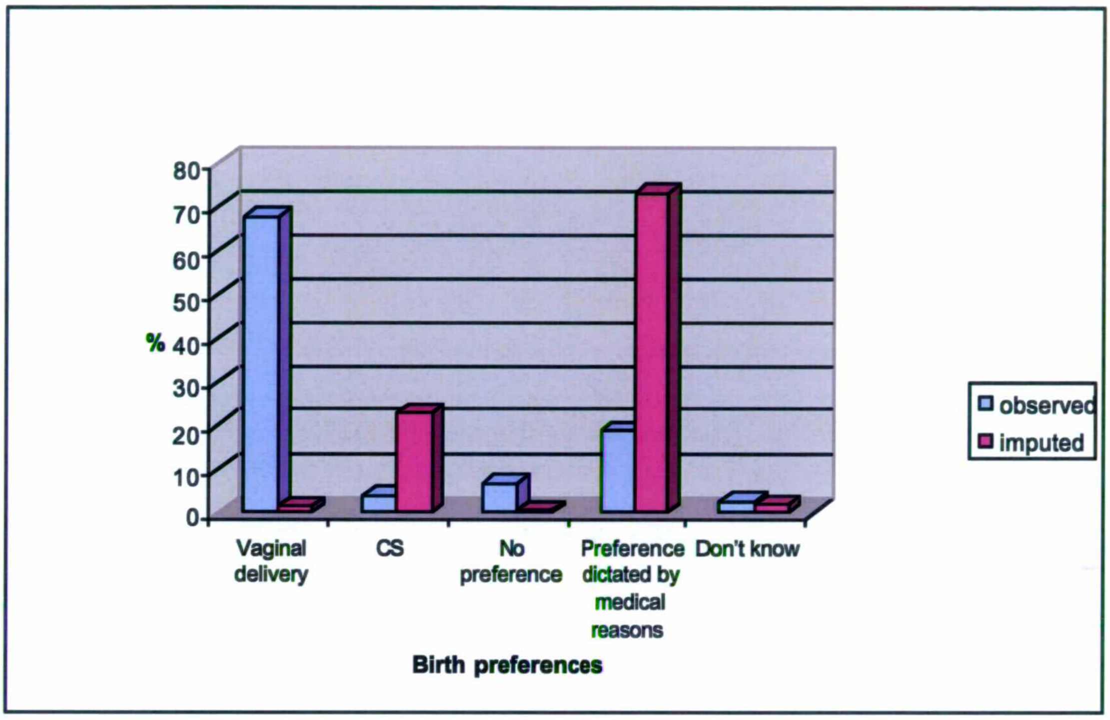
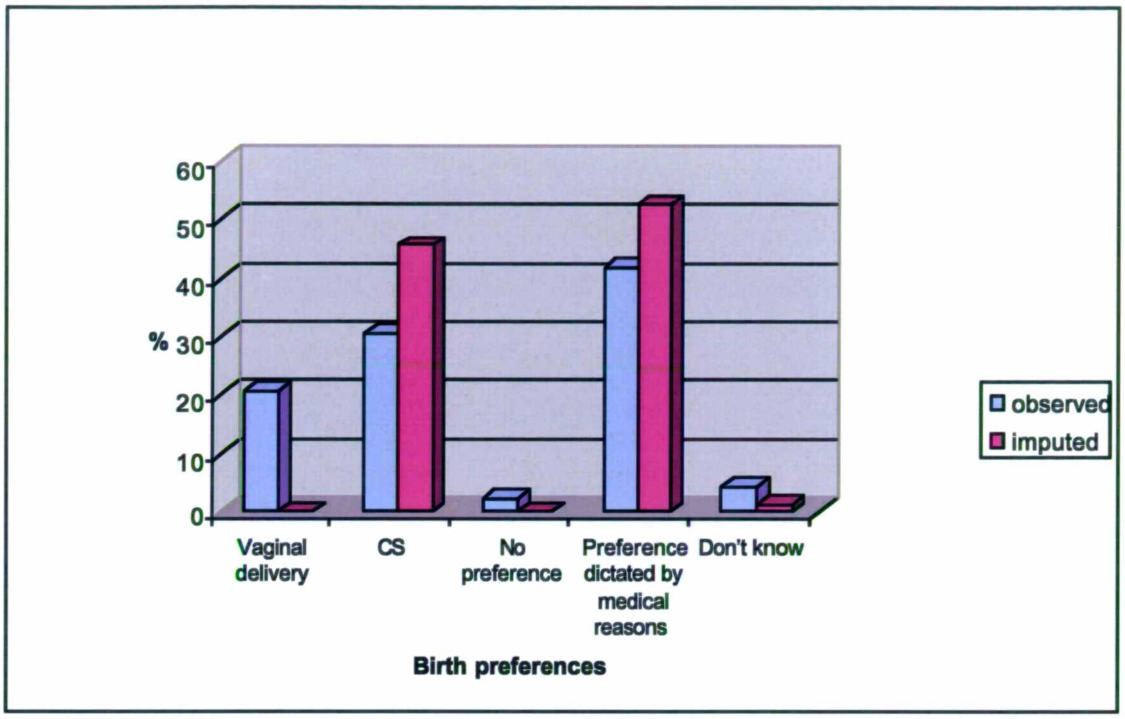


Figure 7.4.3.5: Distribution of observed and imputed birth preferences: women who had had previous CS and CS before labour



Discussion

It is reported that a normal distribution can be used to approximate a discrete distribution such that the use of discriminant function analysis for the imputation of categorical variables is justified[194;196]. However, this is not the case when one (or more) categories of response are rare, as shown above using a univariate example. Furthermore, the results of this analysis show that the relative frequencies obtained by approximating the discrete distribution of the NSCSA data with a bivariate rormal distribution are not in good agreement with the observed relative frequencies. The majority of women (85%) in this dataset had neither a previous CS nor CS before labour in the index pregnancy. For these women, although there were some differences, there was some similarity in the distribution of birth preferences between the imputed and observed data. About 4–6% of all women in the dataset were in the other three categories of previous CS and CS before labour and there were large discrepancies between the distribution of observed and imputed birth preferences.

Although it has been reported in the literature that discriminant function analysis can be used for imputation of categorical variables, there were no applications of this approach reported in the literature for imputation of categorical variables. Two studies[190;193] that used multiple imputations to deal with missing categorical data had used a logistic regression model for imputation of binary variables and a loglinear model for imputation of categorical variables.

7.4.4 Imputation using loglinear and logistic regression models

This section includes an overview of the methods for obtaining imputations for birth preference using (i) logistic regression, and (ii) a loglinear model. The aim is to utilise the relationship between previous CS, CS before labour and birth preference from completely observed data to impute birth preferences for the incompletely observed data. In this way, the relationships between variables in the complete data are preserved and 'carried over' to the incomplete data. As birth preference is an ordinal variable with five categories, the loglinear model can be used to model the cell counts in a contingency table that cross-classifies women according to birth preference, whether or not they had previous CS and whether or not they had CS before labour. However, when there are many explanatory variables it is more difficult to extend this approach to develop a more complex loglinear model that includes interactions between the variables for imputation. Logistic regression would be computationally an easier model to fit. However, in order to predict the preference variable that has five categories, four sequential logistic regression models would be required. Each of these four models would have a binary outcome variable to represent the five categories of birth preference. Both of these methods for imputation of categorical data have been used in the literature[190;193] and are described in detail below using the simplified NSCSA data.

Methods for using logistic regression and loglinear model for imputation

Sequential logistic regression

Four dummy variables were created to represent the five categories of 'birth preferences'. Four logistic regression models were fitted sequentially to the completely observed data to obtain estimates of the regression coefficients for the explanatory variables 'previous CS' and 'CS before labour'. In the first logistic regression model, the outcome variable took the value '1' if birth preference was 'vaginal birth' and '0' otherwise. The next logistic regression model was fit to the data on women who did not have preference for vaginal birth with the outcome variable that took the value '1' if birth preference was 'CS' and '0' otherwise. The third and fourth logistic regression models had outcome variables that took the value '1' if birth preference was 'no preference', '0' otherwise and '1' if birth preference was 'dictated by medical reasons', '0' otherwise respectively.

The cholesky decomposition of the variance covariance matrix (square root of the variance covariance matrix) of each of the four logistic regression models was multiplied independently by a set of random numbers (r) drawn from a normal distribution to introduce variation to the estimates. New coefficients (ß*) for the explanatory variables were then calculated as the sum of the fitted regression coeffcients and the product of the 3 x 3 cholesky decomposition matrix and 3 x 1 matrix of random numbers. Predictions and fitted probabilities were then obtained for the women with missing data on birth preferences using these new coefficients.

Four independent sets of numbers (p1, q1, r1, s1) were generated from a uniform distribution for each woman with missing data on birth preferences. Using the first set of numbers from uniform distribution that was generated (p1 ~ U [0,1]), the predicted preference for vaginal delivery was assigned the value '1' if p1 < fitted probability of 'preference for vaginal birth' and '0' if p1 > fitted probability of preference for vaginal birth. The same process was followed for predicting the other categories of birth preferences, for women who were assigned '0' for the preceding predicted preference.

Loglinear model

A saturated model was fitted to the completely observed data with birth preference (five categories) as the dependent variable and 'CS before labour' and 'previous CS' as explanatory variables'. The variance covariance matrix for this model and its cholesky decomposition was obtained. Twenty random numbers were then generated independently from a normal distribution and used in calculation of new coefficients (ß*) for use in prediction. These new coefficients (ß*) were then multiplied by the design matrix for the saturated loglinear model to obtain predicted counts or each combined category of 'CS before labour', 'previous CS' and 'birth preferences'. Fitted and cumulative probabilities were calculated for each of these categories. A set of random numbers from a uniform d'stribution was generated for women with missing data on birth preferences. Predictions were then made by comparing the random numbers with the cumulative probabilities.

Results

Table 7.4.4.1 shows the distribution of observed and imputed birth preference according to CS before labour and previous CS using (i) logistic regression, and (ii) loglinear models.

Table 7.4.4.1: Distribution of observed and imputed birth preference according to CS before labour and previous CS from a single imputation using (i) logistic regression, and (ii) a loglinear model

	CS before labour=0 Previous CS=0			CS before labour=0 Previous CS=1			CS before labour=1 Previous CS=0			CS before labour=1 Previous CS=1		
Preference	Obs	Imputed logistic	Imputed loglinear	Obs	Imputed logistic	Imputed loglinear	Obs	Imputed logistic	Imputed loglinear	Obs	Imputed logistic	Imputed loglinear
Vaginal	1232	16829	16785	51	762	734	58	720	735	19	247	265
delivery	81.4%	81.5%	81.3%	68.0%	70.6%	68.0%	55.8%	52.4%	53.5%	20.9%	19.3%	20.7%
CS	49	542	612	3	22	26	16	250	256	28	410	388
	3.2%	2.6%	3.0%	4.0%	2.0%	2.4%	15.4%	18.2%	18.6%	30.8%	32.0%	30.3%
No	109	1565	1550	5	50	46	6	37	31	2	30	29
preference	7.2%	7.6%	7.5%	6.7%	4.6%	4.3%	5.8%	2.7%	2.3%	2.2%	2.3%	2.3%
Medical	84	1143	1153	14	231	258	21	324	306	38	564	566
reasons	5.5%	5.5%	5.6%	18.7%	21.4%	23.9%	20.2%	23.6%	22.3%	41.8%	44.0%	44.1%
Don't know	39	570	549	2	14	15	3	42	45	4	31	34
	2.6%	2.8%	2.7%	2.7%	1.3%	1.4%	2.9%	3.1%	3.3%	4.4%	2.4%	2.6%
Total	1513	20649	20649	75	1079	1079	104	1373	1373	91	1282	1282
	(100%)	100%	100%	100%	100%	100%	100%	100%	100%	100%	100%	100%

Obs, observed

In general, the distribution of the imputed variable is similar using both logistic regression and the loglinear model for imputation. There is also, in general, good agreement in the distribution of the imputed data when compared with the distribution of the completely observed data. For some categories there are very few women in the completely observed data and there are minor discrepancies between the observed and imputed distribution of birth preferences. For example, in the observed data on women with previous CS who did not have CS before labour, only five (6.7%) women expressed a preference for CS; the imputation resulted in 4.6% (n=50, using logistic regression) and 4.3% (n=46, using the loglinear model) women expressing a preference for CS.

Discussion

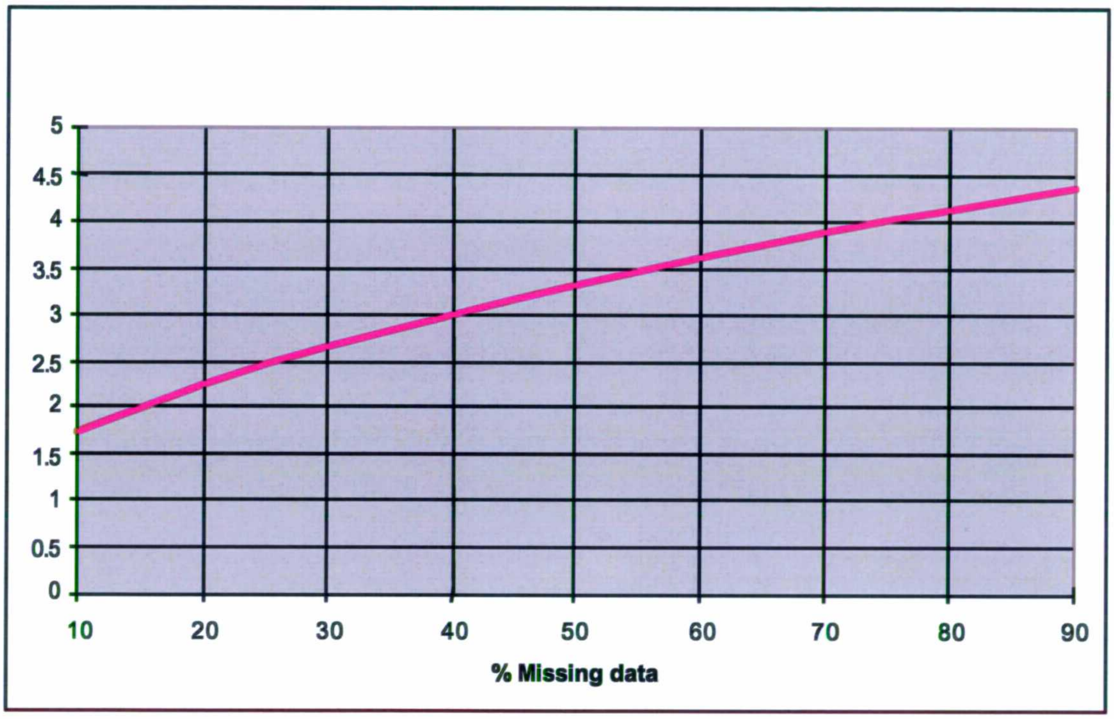
The aim of this section was to decide on the type of model that would be appropriate for imputation of the birth preference variable. As this is a categorical variable with five non-ordered categories, a loglinear model would have been the model of choice. However, in the NSCSA data there are seven explanatory variables (all categorical with two to six categories per variable) for inclusion in the imputation model for birth preference. While it is possible to fit complex loglinear models with two- and three-way interactions between explanatory variables, it is more difficult to use this approach in predicting counts for combined categories with more complex models. This last part of the process is easier to deal with using logistic regression when there are many explanatory variables. However, as birth preference is an ordinal variable it was necessary to use four dummy variables as outcome variables in four logistic regression models fitted sequentially. It was possible that the results obtained using the sequential logistic regression models could vary according to the sequence that was used. Therefore, this was compared with the results from the loglinear model. Both the sequential logistic regression models and a loglinear model seemed to yield similar results. However, generating the imputations using the logistic regression approach is computationally easier to deal with and this method was preferred for imputing the birth preference variable in the NSCSA data.

The next section investigates the number of imputations using sequential logistic regression that would be required as the proportion of missing data on birth preferences is large in the NSCSA.

7.4.5 Number of imputations

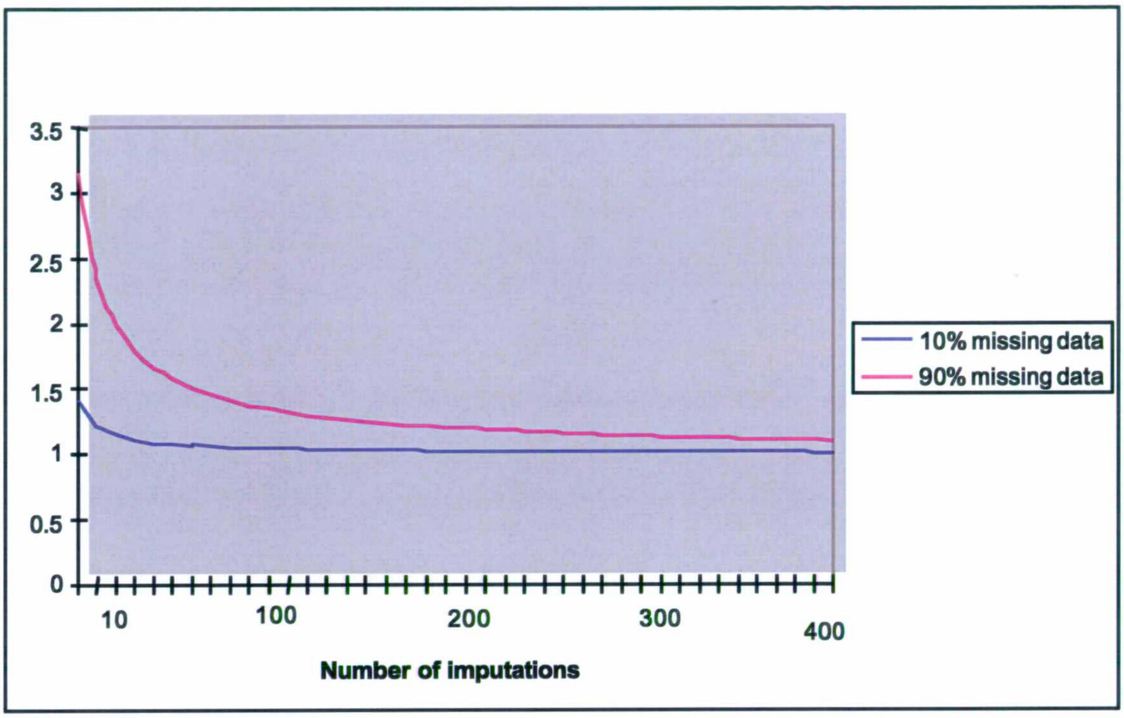
It is necessary to use multiple imputations as opposed to a single imputation in order to allow for the between imputation component of variability, so that the uncertainty around the missing data can be reflected in the estimates obtained in the final analysis. As the proportion of missing data increases, there is more variability around the estimates obtained and it is possible that more imputations would be required. It is reported that the efficiency is dependent on the number of imputations (m) and the fraction of missing data (lambda)[171]. This means that the standard error obtained will be approximately $(1 + \text{lambda/m})^{0.5}$ times as large as the estimate with an infinite number of imputations. It is also reported that 'unless rates of missing information are unusually high there tends to be no practical benefit to using more than five to ten imputations'[171]. The following figure shows the predicted relative efficiency with five imputations with different proportions of missing data. In datasets with 10% missing data, the standard error of estimates obtained are about 1.5 times higher with five imputations compared with an infinite number of imputations. This increases to over four times higher when the proportion of missing data is 90%.

Figure 7.4.5.1: Relative efficiency with five imputations according to percentage of missing data



In the NSCSA the proportion of women with missing data on birth preference is 93%. The following figure shows how the predicted efficiency varies according to number of imputations when 10% and 90% of data are missing. When the proportion of missing data is only 10%, the standard errors obtained with ten imputations are similar to those with an infinite number of imputations. With larger proportions of missing data more imputations will be required. Applying this method of estimating efficiency to the scenario with 90% missing data suggests that standard errors would be triple and twice as large with ten and 20 imputations respectively, but there is not much gain in efficiency with increasing the number of imputations.

Figure 7.4.5.2: Relative efficiency by number of imputations



The method for computing efficiency based on number of imputations and proportion of missing data that has been described in the literature has been used for situations with up to 10% missing data. The number of imputations that would be required in order to obtain efficient estimates in the final analysis for the NSCSA data is investigated empirically in this section to investigate if these predicted results about efficiency also hold with a very high proportion of missing data.

Methods

The sequential logistic regression models described in the previous section were used for imputation. The imputation cycle was repeated 100 times. Each of the imputed datasets were then analysed separately using logistic regression (with CS before labour as the outcome variable and previous CS and birth preference as explanatory variables) and the estimates combined using the implogit command that was written for STATA. This uses the Rubin (1987) corrections of coefficients and standard errors for logistic regressions with data that contain multiple imputations. The gain in efficiency with increasing the number of imputations was investigated by examining the standard errors from combined results of 5–100 imputed datasets.

Results

The following figures show the efficiency of estimates obtained according to the number of imputations. Figure 7.4.5.3 illustrates the reduction in standard error of the log odds of CS before labour for women with previous CS compared with those with no previous CS, from 0.2 in the completely observed dataset (n=1783) to 0.1 in the combined analysis of the 5–100 imputed datasets (n=24,383 in each dataset). This reflects the greater precision of estimates that is obtained from the larger dataset.

Figure 7.4.5.4 shows that between 5 and 15 imputations, there is much variability in the standard errors of the log odds of CS before labour for women who expressed different birth preferences compared with women who expressed a preference for a vaginal birth. However, after 20 imputations, there was not any material reduction in the standard errors obtained.

Figure 7.4.5.3: Standard errors obtained for log odds ratio of CS before labour for women with previous CS compared with women with no previous CS according to number of imputations

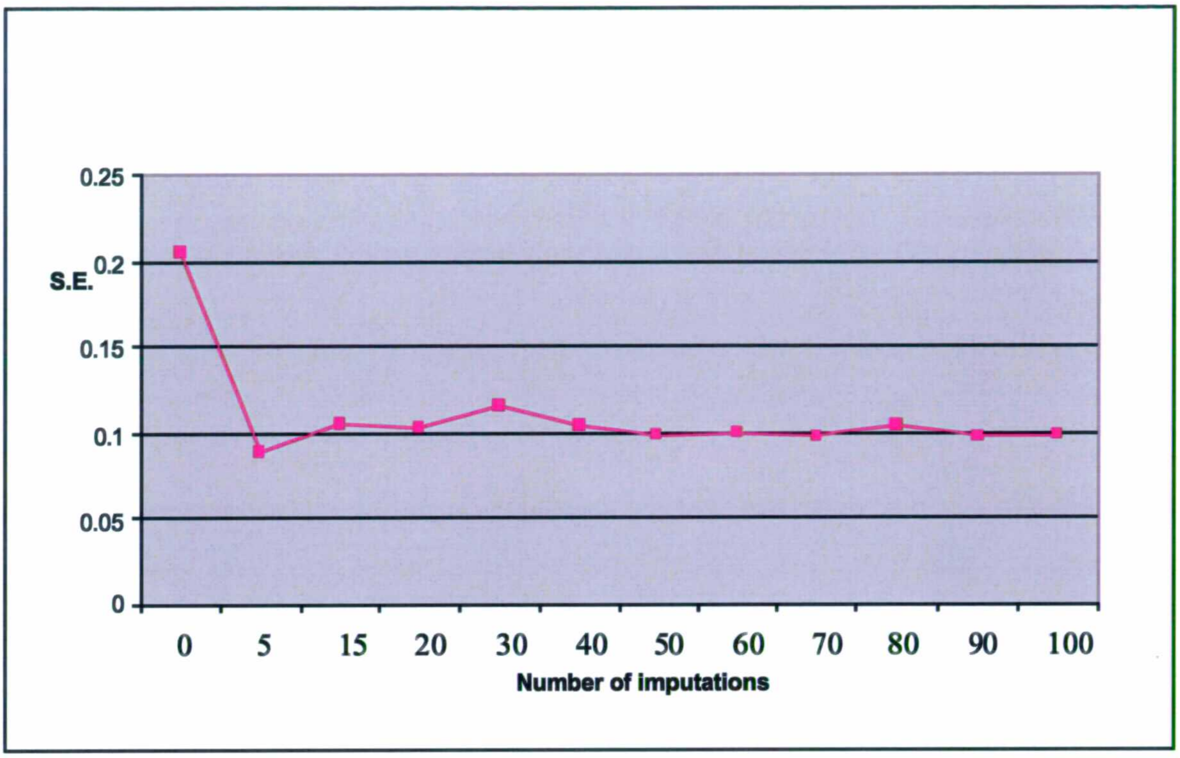
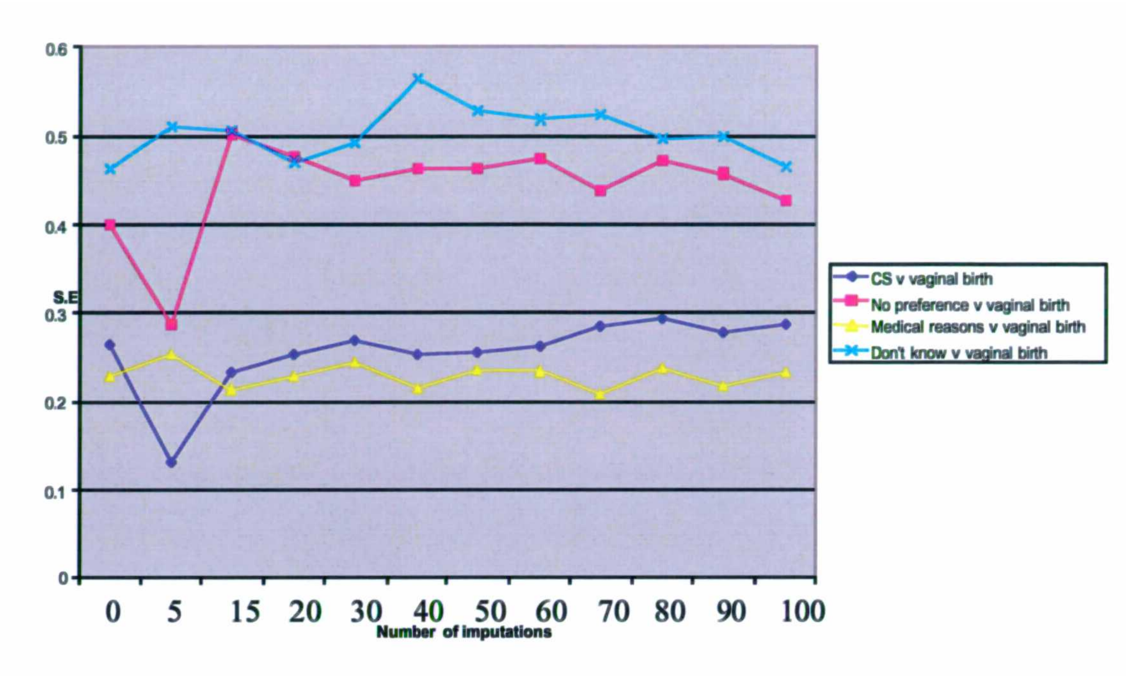


Figure 7.4.5.4: Standard errors obtained for log odds ratio of CS before labour for different women's birth preferences compared with preference for vaginal birth according to number of imputations



Discussion

The use of multiple imputations to deal with missing data allows the utilisation of all the information in the dataset. By increasing the number of observations, greater precision is obtained for estimates such as the effect of previous CS on odds of CS before labour, where the information on previous CS was observed for all women. However, there is not much gain in precision of the estimate for the effect of the birth preference variables on odds of CS before labour. This is because 93% of the information on birth preferences was imputed. The estimates for birth preferences are based on relationships between the variables in the completely observed data and carried over to the incompletely observed data. There was more variability in the standard errors of the estimates obtained for birth preference with fewer than 15 imputations and more consistency after 20 imputations. There was not much gain in efficiency by increasing the number of imputations beyond 20. Therefore it was decided that 20 imputations will be used in the analysis of the NSCSA data. These empirical findings differ from the theoretical results shown earlier in this section. The theoretical results are based on a formula for calculating efficiency reported in the literature that has been used in situations with small proportions of missing data and therefore may not be valid in situations with larger proportions of missing data.

8 Women's birth preference and CS as mode of delivery

8.1 Introduction

This chapter aims to describe the relationship between women's birth preference and CS as mode of delivery, having adjusted for case-mix variables. These results are then used in chapter 9 to evaluate the contribution of women's birth preferences to the observed variation in CS rates between maternity units in England and Wales. This analysis is carried out using phase 1 data with imputed data on birth preferences. The advantage of using phase 1 compared with phase 2 data is that it includes all maternity units in England and Wales, so that the results are applicable to women giving birth in England and Wales. In addition, the phase 1 dataset is large (compared with phase 2 data) and enables more accurate assessment of the confounding effects of case-mix variables in the relationship between birth preferences and CS as mode of delivery. However, adjustment for birth preferences leads to a loss in precision of the estimated relationship between case-mix variables and CS, in both phase 1 and phase 2 data because of inaccurate assessment of the confounding effects of birth preferences. This is because the confounding effects of birth preferences are based on analysis of the smaller phase 2 dataset, and these relationships are simply carried over to the phase 1 dataset with the use of multiple imputations for the birth preference variable. To illustrate these issues, the results of analysis of phase 1 data (with and without imputed birth preferences) are presented together with results from the analysis of phase 2 data. The potential advantages and disadvantages of using multiple imputations for this analysis are also given in this chapter.

Firstly, birth preference was imputed for all women in phase 1 using sequential logistic regression models, separately for (i) all women and (ii) women in labour. The imputed datasets were then analysed separately and the results combined to produce odds ratios for the association between case-mix variables, birth preference and (i) CS before labour, and (ii) CS during labour. These results are presented and compared with results from analysis of phase 2 data with complete data on birth preferences, in sections 8.3.2 and 8.3.3. Also in these sections, the standard errors of the log odds ratios that were obtained from analysis of phase 1 and phase 2 data (with and without imputations) are compared to enable understanding of the within- and between-imputation variability, as well as the gains and losses from using multiple imputations in this analysis. These findings and possible explanations are then discussed in section 8.4.

8.2 Methods

8.2.1 Imputing birth preference

The sequential logistic regression predictive model method was used to impute birth preferences for women in phase 1 from the completely observed data in phase 2. For simplicity, only women who had completely observed data for the case-mix variables (age, ethnicity, previous vaginal deliveries, previous CS, gestation, presentation and birth weight) were included. Twenty imputations were done separately for (i) all women, and (ii) women who were in labour. Therefore, in total, there were 40 imputations.

For each imputation, four sequential logistic regression models were fitted to the completely observed phase 2 data, each using one of the four dummy variables (representing the five categories of birth preference) as the outcome variable. The predictor variables in these models were the case-mix variables and either (i) CS before labour or (ii) CS during labour. Two-way interactions were also included in the model for imputation between (a) previous CS and previous vaginal delivery, and (b) previous CS and either (i) CS before labour or (ii) CS during labour. These interactions were chosen because previous analysis showed that previous CS is the main predictor of CS as an outcome and is also a predictor of women's preference for CS in the antenatal period. The interaction between previous vaginal deliveries and previous CS was also shown to be important in previous analysis. Birth preferences for women in phase 1 were predicted and imputed according to their individual case-mix characteristics as described in section 7.4.4. These steps were repeated 20 times separately for (i) all women, and (ii) women who were in labour.

8.2.2 Combination of results

Each of the imputed datasets was then analysed separately using logistic regression. CS before labour was the outcome variable in analysis of the datasets that included all women and CS during labour was the outcome variable in the datasets that included women in labour. These models included two-way interactions between (i) previous vaginal delivery and previous CS, and (ii) previous CS and birth preference. These were chosen because previous analysis showed that (i) the relationship between previous CS and CS as the outcome of the index pregnancy was dependent on previous vaginal deliveries, and (ii) women with previous CS were more likely to express a preference for CS in the antenatal period. The model for women in labour also included induction of labour as an explanatory variable.

The estimates from the imputed datasets were then combined using the implogit command that was written for STATA. This uses the Rubin (1987) corrections of coefficients and standard errors for logistic regression with data that contain multiple imputations.

8.3 Results

8.3.1 Preliminary analysis

In Phase 1 there were 140,969 women with complete data on case-mix variables. A full description of the demographic and clinical characteristics for these women has been given in previous chapters. In phase 2 there were 1888 women with complete data on case-mix variables and birth preferences. A full description of the demographic and clinical characteristics for these women has been given in chapter 6 (section 6.3.4). The following tables show the distribution of birth preferences according to ethnicity, gestational age and presentation in order to illustrate the reasons for simplifying the categorisation of some of the case-mix variables.

Table 8.3.1.1: Birth preferences according to ethnicity for women in phase 2

	Number of women expressing a preference (%)					
Ethnicity	'I would prefer to give birth vaginally'	'I would prefer to have a planned CS'	'I do not have a preference'	'My preference is dictated by medical reasons'	'Don't know'	Total
White	1360 (76.3%)	96 (5.4%)	122 (6.8%)	156 (8.7%)	48 (2.7%)	1782 (100%)
Black African	25 (86.2%)	1 (3.4%)	1 (3.4%)	2 (6.9%)	0	29 (100%)
Black Caribbean/ Black other	28 (73.7%)	2 (5.3%)	4 (10.5%)	3 (7.9%)	1 (2.6%)	38 (100%)
Bangladeshi /Indian /Pakistani	15 (88.2%)	1 (5.9%)	1 (5.9%)	0	0	17 (100%)
Chinese	4 (80.0%)	1 (20.0%)	0	0	0	5 (100%)
Other	13 (76.5%)	0	2 (11.8%)	2 (11.8%)	0	17 (100%)
Total	1445 (76.5%)	101 (5.3%)	130 (6.9%)	163 (8.65)	49 (2.6%)	1888 (100%)

Table 8.3.1.2: Birth preferences according to gestational age for women in phase 2

	Number of women expressing a preference (%)					
Gestation (weeks)	'I would prefer to give birth vaginally'	'I would prefer to have a planned CS'	'I do not have a preference'	'My preference is dictated by medical reasons'	'Don't know'	Total
28–32	1 (33.3%)	1 (33.3%)	1 (33.3%)	0	0	3 (100%)
33–36	37 (60.7%)	7 (11.5%)	9 (14.7%)	6 (9.8%)	2 (3.3%)	61 (100%)
At least 37	1407 (77.1%)	93 (5.1%)	120 (6.6%)	157 (8.6%)	47 (2.6%)	1824 (100%)

Table 8.3.1.3: Birth preferences according to presentation for women in phase 2

	Number of women expressing a preference (%)					
Presentation	'I would prefer to give birth vaginally'	'I would prefer to have a planned CS'	'I do not have a preference'	'My preference is dictated by medical reasons'	'Don't know'	Total
Cephalic	1400 (77.0%)	95 (5.2%)	125 (6.9%)	150 (8.2%)	49 (2.7%)	1819 (100%)
Breech	45 (65.2%)	6 (8.7%)	5 (7.2%)	13 (18.8%)	0	69 (100%)

The majority (94%) of women for whom there were complete data on case-mix variables and birth preferences were White. As there were very few women from other ethnic groups, in the following analysis ethnicity was categorised as a binary variable (White, non-White). There were no women with pregnancies less than 28 weeks gestation and only three had pregnancies that were between 28 and 32 weeks gestation at the time of delivery. Therefore in this analysis, gestational age was categorised as a binary variable, at least 37 weeks or less than 37 weeks. The majority of women had cephalic pregnancies, 69 were breech and none of these women had pregnancies with a transverse lie. Because of the small number of women with non-cephalic presentation, this variable was excluded from the models for imputation and the final analysis.

8.3.2 CS before labour

Ten percent of women in phase 1 and phase 2 had CS before labour.

Birth preferences and odds of CS before labour

Table 8.3.2.1 shows the univariate relationship between birth preferences and CS before labour.

Table 8.3.2.1: Univariate relationship between birth preferences and CS before labour

	Phase 1 n=140,969 Combined results following 20 imputations	Phase 2 n=1888
Preference for vaginal delivery	1.00	1.00
Preference for CS	8.93 (4.01, 19.87)	14.08 (8.97, 22.11)
No preference	1.59 (0.66, 3.81)	1.25 (0.61, 2.56)
Preference dictated by medical reasons	13.82 (4.90, 38.98)	9.81 (6.65, 14.48)
Don't know	7.00 (1.63, 29.98)	3.28 (1.49, 7.24)

In univariate analysis, compared with women who expressed a preference for vaginal birth, women who expressed a preference for CS or reported that their preference was dictated by medical reasons had higher odds of CS before labour. Women who responded 'don't know' were also more likely to have CS before labour. The direction of these associations was similar in phase 1 and phase 2, though the magnitude varied. For example, compared with women who expressed a preference for vaginal birth, women who had expressed a preference for CS were about nine times more likely to have CS before labour in the phase1 dataset and about 14 times more likely to do so in the phase 2 dataset. This difference in unadjusted odds ratios could be due to difference in prevalence of the case-mix factors between the two datasets.

The following table shows the odds ratios for CS before labour according to birth preferences having adjusted for case-mix variables in phase 1 and phase 2.

Table 8.3.2.2: Odds ratios for CS before labour according to birth preferences, adjusted for age, ethnicity, previous deliveries, gestation and birth weight

Vanable	Phase 1 data (combined results from 20 imputations of birth preference) n=140,969	Phase 2 data n=1888
Birth preference		
Vaginal	1.00	1.00
CS	5.55 (2.86, 10.75)	7.96 (4.26, 14.86)
No preference	1.33 (0.73, 2.41)	0.96 (0.40, 2.30)
Medical reasons	5.78 (1.85, 18.04)	5.21 (3.04, 8.96)
Don't know	2.90 (0.81, 10.41)	1.66 (0.49, 5.61)

The magnitude of these adjusted odds ratios of CS before labour according to birth preferences were smaller when compared with those obtained in univariate analysis. Compared with women who expressed a preference for vaginal birth, women who had expressed a preference for CS in the antenatal period had higher odds of CS before labour in both phase 1 (OR: 5.55; 95% CI: 2.86, 10.75) and phase 2 (OR: 7.96; 95% CI: 4.26, 14.86), following adjustment for case-mix variables. The phase 2 dataset is smaller with only 1888 women, which could result in inaccurate estimation of the confounding effects of the case-mix variables. This could be a reason for the differences in the magnitude of odds ratios obtained when comparing results from phase 1 and phase 2. Women who reported that their preference was dictated by medical reasons also had higher odds of CS before labour (phase 1, OR: 5.78; 95% CI: 1.85, 18.04; phase 2, OR: 5.21; 95% CI: 3.04, 8.96). The odds of CS before labour for women who expressed no preference or responded 'don't know' was not statistically significantly different when compared with women who expressed a preference for vaginal birth. The standard errors for these estimates of the log odds ratio of CS before labour comparing women with different birth preferences with those who expressed preference for vaginal birth are similar in phase 1 and phase 2 as shown in table 8.3.2.6, suggesting (as expected) that there is no material gain or loss in precision of the estimates obtained following multiple imputations of the birth preference variable. However, the estimates from phase 1 are probably less biased because the confounding effects of the case-mix variables will be better assessed in a larger dataset.

Two-way interactions between birth preference and previous CS were included in the model. The following table shows how the odds ratios for CS before labour vary according to birth preference and number of previous CS. Women in the reference group were aged 25–29 years, White, had no previous deliveries, were at at least 37 weeks gestation and had babies that weighed between 2500 and 4000 g and expressed a preference for a vaginal birth in the antenatal period.

Table 8.3.2.3: Relationship between previous CS, birth preferences and CS before labour (phase 2) (n=1888)

	No previous CS	At least one previous CS
Preference for vaginal delivery	1.00	6.90 (3.64, 13.11)
Preference for CS	7.96 (4.26, 14.86)	126.88 (41.16, 391.14)
No preference	0.96 (0.40, 2.30)	7.69 (1.79, 32.98)
Preference dictated by medical reasons	5.22 (3.04, 8.96)	44.28 (20.86, 93.96)
Don't know	1.66 (0.49, 5.61)	49.02 (8.97, 267.97)

Table 8.3.2.4: Relationship between previous CS, imputed birth preferences and CS before labour (phase 1) (n=140,969)

	No previous CS	At least one previous CS
Preference for vaginal delivery	1.00	5.94 (3.59, 9.82)
Preference for CS	4.71 (2.04, 10.87)	115.41 (13.81, 964.77)
No preference	1.08 (0.42, 2.76)	10.76 (0.86, 134.71)
Preference dictated by medical reasons	5.07 (2.31, 11.13)	53.24 (2.68, 1058.43)
Don't know	2.57 (0.96, 6.90)	44.77 (0.99, 2028.29)

Compared with women in this reference group, women who expressed a preference for CS in the antenatal period were more likely to have CS before labour (phase 1, OR: 4.71; 95% CI: 2.04, 10.87; phase 2, OR: 7.96; 95% CI: 4.26, 14.86). The relative effect of a previous CS was an increase in odds of CS before labour for women who expressed a preference for CS, which was 15 times higher in phase 1 and 24 times higher in phase 2. This difference in magnitude of effect between phase 1 and phase 2 could be due to either chance or to the inaccurate assessment of the effects of confounding in the smaller phase 2 dataset as stated earlier.

Women who reported that their preference was dictated by medical reasons also had higher odds of CS before labour compared with women in the reference group (phase 1, OR: 5.07: 95% CI: 2.31, 11.13; phase 2, OR: 5.22; 95% CI: 3.04, 8.96). The relative effect of a previous CS was an increase in the odds of CS before labour (ten times higher in phase 1 and eight times higher in phase 2).

Case-mix factors and odds of CS before labour

The following table shows the combined odds ratios for CS before labour according to case-mix variables for women in phase 1, following 20 imputations of the birth preference variable. Odds ratios including and excluding the birth preference variable for phase 1 and completely observed data in phase 2 are also shown.

Table 8.3.2.5: Odds ratios for CS before labour according to case-mix variables, adjusted for birth preferences

Variable	A Phase 1 data Model fitted **excluding** preference variables n=140,969	B Phase 2 data Model fitted **excluding** preference variables n=1888	C Phase 2 data Model fitted **including** preference variables n=1888	D Phase 1 data Model fitted **including** imputed preference variables (combined results from 20 imputations) n=140,969
Maternal age (years)				
12–19	0.53 (0.47, 0.59)	0.31 (0.07, 1.35)	0.34 (0.08, 1.48)	0.55 (0.40, 0.75)
20–24	0.72 (0.67, 0.77)	0.70 (0.34, 1.43)	0.57 (0.27, 1.23)	0.63 (0.51, 0.76)
25–29	1.00	1.00	1.00	1.00
30–34	1.33 (1.26, 1.40)	1.28 (0.84, 1.96)	1.24 (0.79, 1.94)	1.35 (1.11, 1.65)
35–39	1.66 (1.56, 1.76)	1.12 (0.69, 1.83)	1.10 (0.65, 1.84)	1.69 (1.41, 2.03)
40–50	2.42 (2.18, 2.69)	1.21 (0.55, 2.68)	1.04 (0.44, 2.48)	2.14 (1.57, 2.92)
Ethnicity				
White	1.00	1.00	1.00	1.00
Non-White	0.77 (0.73, 0.82)	0.73 (0.34, 1.58)	0.88 (0.39, 1.98)	0.81 (0.63, 1.06)
Previous deliveries				
No previous vaginal delivery, no previous CS	1.00	1.00	1.00	1.00
At least one previous vaginal delivery, no previous CS	0.59 (0.56, 0.62)	0.64 (0.42, 0.96)	0.60 (0.39, 0.92)	0.59 (0.53, 0.67)

Table 8.3.2.5 (cont'd): Odds ratios for CS before labour according to case-mix variables, adjusted for birth preferences

Variable	A	B	C	D
At least one previous CS, no previous vaginal delivery	15.01 (14.22, 15.85)	14.36 (9.18, 22.46)	6.90 (3.64, 13.11)	5.94 (3.59, 9.82)
At least one previous CS, at least 1 previous vaginal delivery	5.91 (5.47, 6.38)	10.64 (5.30, 21.36)	5.03 (2.06, 12.22)	2.43 (1.40, 4.23)
Gestation				
At least 37 weeks gestation	1.00	1.00	1.00	1.00
Less than 37 weeks gestation	2.60 (2.41, 2.80)	2.31 (1.08, 4.94)	2.56 (1.20, 5.43)	2.93 (2.34, 3.66)
Birth weight (g)				
≤ 2500	2.19 (2.03, 2.37)	1.45 (0.62, 3.42)	1.41 (0.55, 3.62)	2.18 (1.58, 3.00)
2501–4000	1.00	1.00	1.00	1.00
> 4000	0.84 (0.79, 0.90)	1.03 (0.63, 1.68)	1.16 (0.70, 1.93)	0.92 (0.74, 1.14)

Firstly, the results from analysis of phase 1 (column A) and phase 2 (column B) data without adjusting for birth preferences show that compared with women aged 25–29 years, women under 24 years had a 28–47% reduction in odds of CS before labour in phase 1 and a 30–69% reduction in odds of CS before labour in phase 2. Women over 34 years had higher odds of CS before labour in both phase 1 and phase 2. Non-White women had a 23% reduction the odds of CS before labour in phase 1 (27% reduction in phase 2) compared with White women. Compared with women who had no previous deliveries, women with previous vaginal deliveries had a 41% reduction in odds of CS before labour (36% reduction in phase 2), while women with previous CS had odds of CS before labour that were about 14–15 times higher. The relative effect of a previous vaginal delivery for women who had had a previous CS was a 61% reduction in odds of CS before labour in phase 1 (26% reduction in phase 2). In both phase 1 and phase 2 the odds of CS before labour were about two times higher for women who had pregnancies under 37 weeks gestation and those whose babies weighed under 2500 g (in phase1 only) when compared with women with term pregnancies or those with babies weighing 2501–4000 g, respectively. In phase 2, the odds of CS before labour was about 45% higher for women with babies weighing under 2500 g although this was not significant at the 5% level.

Adjustment for birth preferences in phase 1 data resulted in a very small change in the odds ratio of CS before labour comparing non-White women with White women from 0.77 (95% CI: 0.73, 0.82) to 0.81 (95% CI: 0.63, 1.06) after allowing for the effect of birth preferences. A similar change is also seen in phase 2 data. In both phase 1 and phase 2, there was a reduction in the odds of CS before labour for women who had a previous CS and no previous vaginal deliveries compared with those who had no previous deliveries, following adjustment for birth preferences (from OR 15.01 [95% CI 14.22, 15.85] to OR 6.90 [95% CI: 3.64, 13.11] in phase 1, and from OR 14.36 [95% CI 9.18, 22.46] to 5.94 [95% CI: 3.59, 9.82] in phase 2). The odds of CS before labour for women who only had previous vaginal deliveries did not materially change after allowing for the effect of birth preferences in both phase 1 and phase 2. However, there was a reduction in odds of CS before labour for women who had had both previous vaginal deliveries and previous CS compared with women who had no previous deliveries following adjustment for birth preferences in both phase 1 (41% reduction) and phase 2 (47% reduction).

In both phase 1 and phase 2, adjustment for birth preferences resulted in a very small change in odds of CS before labour for women with pregnancies less than 37 weeks gestation compared with women with pregnancies of at least 37 weeks gestation (phase 1 OR not adjusted for birth preference: 2.60; 95% CI: 2.41, 2.80; OR adjusted for birth preference: 2.93; 95% CI: 2.34, 3.66; phase 2 OR not adjusted for birth preference: 2.31; 95% CI: 1.08, 4.94; OR adjusted for birth preference: 2.56; 95% CI: 1.20, 5.43).

In phase 1, women with babies weighing less than 2500 g had odds of CS before labour that were two times higher than women with babies weighing between 2500 and 4000 g. This association did not change following adjustment for birth preferences. In phase 2, there was a 45% and a 41% increase in odds of CS before labour for women with babies weighing less than 2500 g, before and after adjustment for birth preferences, respectively. However, these odds ratios were not statistically significant at the 5% level.

Precision of estimates

In phase 2 data, the standard errors of the log odds ratios of CS before labour associated with case-mix variables were larger in the analysis that included the birth preference variable. There was also a loss in the precision of estimates in phase 1 data following adjustment for birth preferences and this is explored in detail in this section.

The following table (table 8.3.2.6) shows the standard errors of the log odds ratio of CS before labour according to the different case-mix variables and birth preferences for women in phase 1 and phase 2 (columns A–E). The other columns show selected comparisons of these standard errors as ratios. For example, the change in standard errors for estimates of the log odds ratios of CS before labour associated with the different case-mix variables is shown as a ratio of the standard errors of the log odds ratios from the model that included birth preferences divided by the standard errors of the log odds ratios from the model that excluded birth preferences, for each of the case-mix variables (C/B).

Table 8.3.2.6: Standard errors of the log odds ratio of CS before labour according to the different case-mix variables and birth preferences for women in phase 1 and phase 2

	A SE of log odds ratio CS before labour Phase 1 Excluding birth pref n=140,969	B SE of log odds ratio CS before labour Phase 2 Excluding birth pref n=1888	C SE of log odds ratio CS before labour Phase 2 data Including birth pref n=1888	D SE of log odds ratio CS before labour Phase 1 data Including birth pref n=140,969 Single imputation	E SE of log odds ratio CS before labour Phase 1 data Including birth pref n=140969 20 imputations	C/B	D/A	E/A	D/C	E/C
Age (years) (reference group 25–29)										
12–19	0.05	0.74	0.76	0.06	0.15	1.02	1.04	2.73	0.07	0.20
20–24	0.03	0.36	0.39	0.04	0.10	1.07	1.06	2.73	0.09	0.24
30–34	0.03	0.22	0.23	0.03	0.10	1.06	1.07	3.66	0.12	0.42
35–39	0.03	0.25	0.26	0.03	0.09	1.06	1.08	2.87	0.12	0.33
40–50	0.05	0.41	0.44	0.06	0.15	1.09	1.09	2.76	0.13	0.34
Ethnicity (reference group White)										
Non-White	0.03	0.39	0.41	0.03	0.13	1.06	1.09	4.28	0.08	0.30
Previous deliveries (reference group no previous deliveries)										
At least one previous CS	0.03	0.23	0.33	0.03	0.24	1.43	0.93	8.75	0.08	0.74
At least one previous vaginal delivery	0.02	0.21	0.22	0.05	0.06	1.04	1.93	2.28	0.22	0.26
Interaction term between previous CS and previous vaginal delivery	0.05	0.42	0.47	0.06	0.10	1.13	1.17	2.01	0.12	0.20
Gestational age (weeks) (reference group at least 37 weeks)										
< 37	0.04	0.39	0.43	0.04	0.11	1.10	1.07	2.81	0.09	0.25
Birth weight (reference group 2500–4000 g)										
≤ 2500 g	0.04	0.44	0.48	0.04	0.15	1.10	1.07	3.86	0.09	0.32
> 4000 g	0.03	0.25	0.26	0.04	0.10	1.04	1.08	3.02	0.14	0.39

Birth preference (reference group vaginal birth)						
CS	0.32	0.05	0.32		0.16	1.00
No pref	0.45	0.05	0.29		0.11	0.64
Med	0.28	0.10	0.55		0.35	1.97
Don't know	0.62	0.06	0.61		0.09	0.98

Pref, preference; med, medical reasons

In phase 2 data, adjustment for birth preference resulted in an increase in the standard errors of the log odds ratios of CS before labour associated with the case-mix variables (C/B). The largest increase was in the estimate for women who had a previous CS (43%). Adjustment for birth preferences resulted in a 2–13% increase in the standard errors of the log odds ratios of CS before labour comparing women with different case-mix characteristics with women in the reference group. This is an expected result as it has been shown that covariate adjustment in logistic regression does, in general, decrease the precision of the estimated effect, in the absence of strong confounding[198].

In the analysis of phase 1 data (with a single imputation of birth preference), there was a small increase in the standard errors of the log odds ratios of CS before labour for women according to their case-mix characteristics following adjustment for birth preference, compared with analysis that excluded the birth preference variable (see column D/A). This is probably due to the effect of covariate adjustment in logistic regression decreasing the precision of estimated effects in the absence of strong confounding as stated earlier[198]. However, there was a 7% reduction in the estimate for women who had had a previous CS and a 93% increase in the estimate for women who had both a previous CS and a previous vaginal delivery. In the analysis using 20 imputations, adjustment for birth preference resulted in at least a doubling of the standard errors of the log odds ratios of CS before labour for women according to their case-mix characteristics (see column E/A). The standard error of the log odds ratio of CS before labour for women with at least one previous CS was nine times higher when compared with analysis that excluded the birth preference variable. This is probably because the confounding effects of birth preferences are inaccurately assessed as this is derived from the smaller phase 2 dataset with completely observed data. The magnitude of increase in standard errors of the log odds ratios for CS before labour in the analysis using 20 imputations is larger than in the analysis using a single imputation for birth preferences because of the between-imputation variability.

The standard errors of the log odds ratios of CS before labour from phase 1 data with imputed birth preferences (columns D and E) were compared with those obtained from the analysis of completely observed data in phase 2 (column C). The standard errors were smaller in the analysis of phase 1 data with imputed birth preferences compared with those obtained from the completely observed data in phase 2. This is because the confounding effects of the case-mix variables are less accurately assessed in the phase 2 dataset which is smaller (n=1888) compared with the phase 1 dataset (n=140,969). The magnitude of this reduction was greater in the analysis of phase 1 data with one set of imputations compared with the analysis using 20 imputations, reflecting the between-imputation variability from multiple imputations.

The amount of between-imputation variation is illustrated in the following figures for women who were aged 30–34 years (see figure 8.3.2.1) and those who had babies weighing under 2500 g (see figure 8.3.2.2), compared with women in the reference group (age 25–29 years, White, no previous deliveries, at least 37 weeks gestation, birth weight between 2501-4000 g and expressed a preference for a vaginal birth in the antenatal period).

Figure 8.3.2.1: Between-imputation variability in log odds of CS before labour for women aged 30–34 years compared with women aged 25–29 years

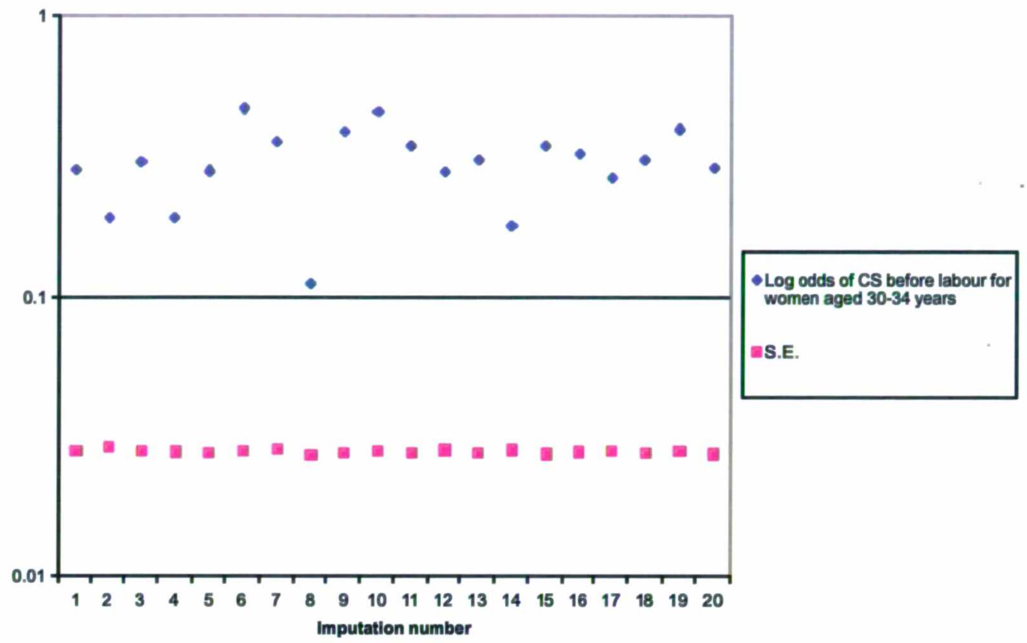
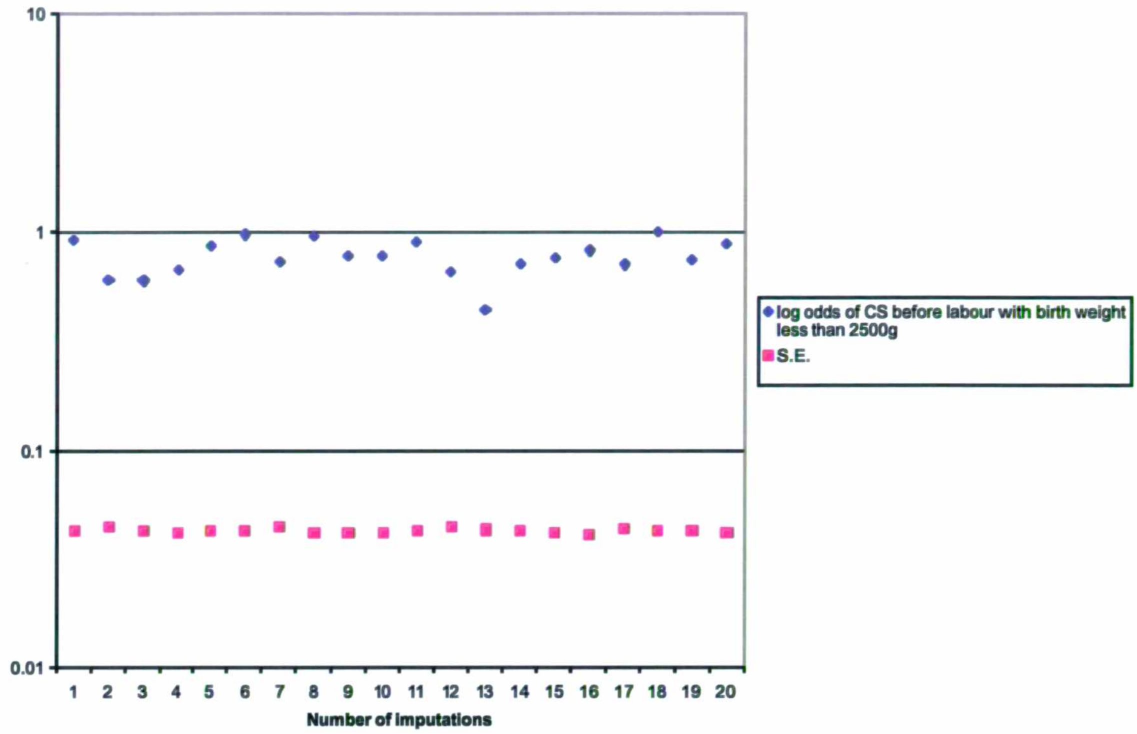


Figure 8.3.2.2: Between-imputation variation in log odds of CS before labour for birth weight less than 2500 g compared with 2500–4000 g



In both of these examples, the within-imputation precision is relatively constant. The standard error of the log odds ratio of CS before labour comparing women aged 30–34 years with those aged 25–29 years was 0.03. However, the estimate of the log odds ratio ranged from 0.2 to 0.5. This is equivalent to a 22–64% increase in odds of CS before labour for women aged 30–34 years compared with those aged 25–29 years. The standard error of the log odds ratio of CS before labour comparing women who had babies weighing less than 2500 g compared with those with birth weight 2501–4000 g was 0.04. The estimates of the log odds ratios ranged from 0.6 to 1.0. This is equivalent to an increase ranging from 82% to 271% in the odds of CS before labour for women who had babies weighing less than 2500 g compared with those with birth weight between 2501 and 4000 g. This explains why the standard errors shown in column E (20 imputations) are much larger than those shown in column D (single imputation) of table 8.3.2.6.

8.3.3 CS during labour

In phase 1, 12.1% of women in labour had CS while 13.5% of women with complete data on birth preferences in phase 2 had CS during labour.

Birth preferences and odds of CS for women in labour

Table 8.3.3.1 shows the univariate relationship between birth preferences and CS for women in labour.

Table 8.3.3.1: Univariate relationship between birth preferences and CS for women in labour

	Phase 1 Combined results following 20 imputations n=126,901	Phase 2 n=1684
Preference for vaginal delivery	1.00	1.00
Preference for CS	2.59 (1.37, 4.89)	2.70 (1.44, 5.07)
No preference	2.05 (1.18, 3.58)	2.17 (1.36, 3.45)
Preference dictated by medical reasons	2.57 (1.27, 5.20)	2.95 (1.85, 4.71)
Don't know	1.58 (0.76, 3.25)	1.36 (0.56, 3.28)

In univariate analysis, women who either expressed a preference for CS or no preference and those who reported that their preference was dictated by medical reasons had odds of CS during labour that were more than two to three times higher compared with women who expressed a preference for vaginal birth. The magnitudes of these odds ratios were similar in phase 1 and phase 2.

The following table shows odds ratios for CS during labour according to birth preferences following adjustment for case-mix variables in phase 1 and phase 2.

Table 8.3.3.2: Odds ratios for CS during labour according to birth preferences adjusted for age, ethnicity, previous deliveries, gestational age, induction of labour and birth weight

Variable	Phase 1 data (combined results from 20 imputations) n=126,901	Phase 2 data n=1684
Birth preference		
Vaginal	1.00	1.00
CS	2.37 (1.24, 4.53)	2.42 (1.12, 5.20)
No preference	1.49 (0.98, 2.27)	1.47 (0.86, 2.50)
Medical Reasons	1.49 (0.78, 2.84)	1.95 (1.07, 3.54)
Don't know	1.31 (0.66, 2.59)	1.06 (0.38, 2.92)

Following adjustment for case-mix variables in both phase 1 and phase 2, there was a reduction in the magnitudes of odds ratios of CS during labour, comparing women with different birth preferences to women who expressed a preference for vaginal birth. The odds of CS during labour was twice as high for women who had expressed a preference for CS in the antenatal period compared with women who expressed an antenatal preference for vaginal birth (phase 1, OR: 2.37; 95% CI: 1.24, 4.53; phase 2, OR: 2.42; 95% CI: 1.12, 5.20. There was no difference in the odds of CS during labour for women who expressed no preference or responded 'don't know'. In phase 2, women who reported that their preference was dictated by medical reasons had a 95% increase in odds of CS during labour (OR: 1.95; 95% CI: 1.07, 3.54) but in phase 1 this was a 49% increase that was not significant at the 5% level (OR: 1.49; 95% CI: 0.78, 2.74). As in the analysis for CS before labour, this difference may reflect the fact that the confounding effects of covariates are less accurately estimated in the smaller phase 2 dataset. Another explanation is that the difference is due to chance as the confidence intervals surrounding these estimates are wide and there is overlap between them. The width of the confidence intervals for the odds of CS during labour, comparing women who either expressed a preference for CS or no preference to women who expressed a preference for vaginal birth, were narrower in the analysis using phase 1 data with 20 imputations for birth preference with the analysis of completely observed data in phase 2. However, for women who either reported that their preference was dictated by medical reasons or responded 'don't know', the widths of confidence intervals for the estimates obtained were similar in phase 1 and phase 2.

Two-way interactions between birth preference and previous CS were included in the model. The following table shows how the odds ratios for CS during labour vary according to birth preference and number of previous CS. Women in the reference group were aged 25–29 years, White, had no previous deliveries, were at least 37 weeks gestation, had spontaneous onset of labour, babies who weighed between 2501 and 4000 g and had expressed a preference for vaginal birth in the antenatal period.

Table 8.3.3.3: Relationship between previous CS, birth preferences and CS during labour (phase 2) (n=1684)

	No previous CS	At least 1 previous CS
Preference for vaginal delivery	1.00	1.12 (0.50, 2.50)
Preference for CS	2.42 (1.12, 5.20)	9.28 (0.85, 100.94)
No preference	1.47 (0.86, 2.50)	9.95 (1.73, 57.17)
Preference dictated by medical reasons	1.95 (1.07, 3.54)	9.17 (2.79, 30.15)
Don't know	1.06 (0.38, 2.92)	10.48 (0.55, 199.17)

Table 8.3.3.4: Relationship between previous CS, imputed birth preferences and CS before labour (phase 1) (n=140,969)

	No previous CS	At least 1 previous CS
Preference for vaginal delivery	1.00	1.49 (0.64, 3.49)
Preference for CS	2.37 (1.24, 4.53)	16.80 (1.79, 157.22)
No preference	1.49 (0.98, 2.27)	10.14 (1.95, 52.80)
Preference dictated by medical reasons	1.49 (0.78, 2.84)	5.79 (0.72, 46.23)
Don't know	1.31 (0.66, 2.59)	7.34 (0.33, 160.59)

The relative effect of a previous CS was an increase in the odds of CS during labour that was seven times higher for women who expressed a preference for CS in phase 1 and four times higher in phase 2. For those who reported that their preference was dictated by medical reasons, the relative effect of a previous CS in both phase 1 and 2 was an increase in the odds of CS during labour that was four times higher. For women who expressed no preference, the relative effect of a previous CS was an increase in the odds of CS during labour that was seven times higher in both phase 1 and phase 2. For women who responded 'don't know', the odds of CS during labour was six times higher in phase 1 for women who had a previous CS compared with women who did not and ten times higher in phase 2. As before, the differences in the magnitude of effect seen between results from phase 1 and phase 2 reflects the inaccurate estimation of the confounding effects of case-mix variables in the smaller phase 2 dataset.

Case-mix factors and odds of CS for women in labour

The following table shows combined odds ratios for CS during labour according to case-mix variables for women in phase 1, following 20 imputations of birth preference for women who did not have CS before labour in phase 1. Odds ratios including and excluding the birth preference variable for phase 1 and completely observed data in phase 2 are also shown.

Table 8.3.3.5: Odds ratios for CS during labour according to case-mix and birth preferences

Variable	Phase 1 data Model fitted **excluding** preference variables n=126,901	Phase2 data Model fitted **excluding** preference variables n=1684	Phase2 data Model fitted **including** preference variables n=1684	Phase 1 data Model fitted **including** imputed preference variables (combined results from 20 imputations) n=126,901
Maternal age (years)				
12–19	0.54 (0.50, 0.58)	0.30 (0.12, 0.74)	0.31 (0.13, 0.78)	0.54 (0.48, 0.62)
20–24	0.70 (0.67, 0.74)	0.30 (0.16, 0.57)	0.30 (0.15, 0.57)	0.68 (0.60, 0.76)
25–29	1.00	1.00	1.00	
30–34	1.22 (1.16, 1.27)	0.89 (0.61, 1.29)	0.88 (0.60, 1.29)	1.22 (1.13, 1.31)
35–39	1.49 (1.40, 1.58)	1.06 (0.69, 1.64)	1.07 (0.69, 1.67)	1.50 (1.36, 1.66)
40–50	1.80 (1.60, 2.02)	1.11 (0.49, 2.49)	1.09 (0.48, 2.45)	1.64 (1.37, 1.96)
White	1.00	1.00	1.00	
Non-White	1.41 (1.34, 1.48)	1.30 (0.69, 2.42)	1.29 (0.68, 2.44)	1.46 (1.27, 1.67)
No previous vaginal delivery, no previous CS	1.00	1.00	1.00	
At least one previous vaginal delivery, no previous CS	0.21 (0.21, 0.22)	0.18 (0.12, 0.26)	0.18 (0.12, 0.26)	0.22 (0.20, 0.24)

Table 8.3.3.5 (cont'd): Odds ratios for CS during labour according to case-mix and birth preferences

At least one previous CS, no previous vaginal delivery	3.39 (3.17, 3.62)	2.35 (1.30, 4.25)	1.12 (0.50, 2.50)	1.49 (0.64, 3.49)
At least one previous CS, at least one previous vaginal delivery	0.93 (0.84, 1.03)	1.08 (0.39, 2.98)	0.76 (0.24, 2.34)	0.64 (0.21, 1.95)
Spontaneous onset of labour	1.00	1.00	1.00	
Induction of labour	2.19 (2.11, 2.27)	2.86 (2.10, 3.89)	2.83 (2.07, 3.87)	2.09 (1.94, 2.26)
At least 37 weeks gestation	1.00	1.00	1.00	
Less than 37 weeks gestation	1.59 (1.47, 1.72)	1.60 (0.69, 3.70)	1.42 (0.60, 3.40)	1.80 (1.55, 2.09)
Birth weight ≤ 2500 g	1.30 (1.20, 1.41)	1.13 (0.50, 2.53)	1.14 (0.50, 2.58)	1.34 (1.16, 1.55)
2501–4000 g	1.00	1.00	1.00	
> 4000 g	1.85 (1.76, 1.95)	2.06 (1.37, 3.12)	2.19 (1.44, 3.32)	1.98 (1.81, 2.16)

The first two columns show the odds ratios of CS during labour in phase 1 and phase 2 without adjustment for birth preferences. Before allowing for the effects of birth preferences, the odds of CS during labour were higher for non-White women compared with White women (phase 1, OR: 1.41; 95% CI: 1.34, 1.48; phase 2, OR: 1.30; 95% CI: 0.69, 2.42). In phase 1, women over 30 years of age who went into labour had a 22–80% increase in odds of CS during labour compared with women aged 25–29 years. In phase 2 there was a 6% and 11%

increase in odds of CS during labour for women aged 35–39 and 40–50 years, respectively. However, this was not statistically significant at the 5% level. There were a smaller number of women in phase 2 and the 95% confidence intervals for these estimates include those obtained from phase 1. In both phase 1 and phase 2 women who had previous CS were more likely to have CS in labour (phase 1, OR: 3.39; 95% CI 3.17, 3.62; phase 2, OR: 2.35; 95% CI: 1.30, 4.25). Women who had had a previous CS and a previous vaginal delivery did not have an increase in odds of CS during labour when compared with women who had no previous births. Women who had induction of labour and those who had babies weighing over 4000 g had odds of CS during labour that were twice as high when compared with women in spontaneous labour and women who had babies weighing between 2501 and 4000 g, respectively. The magnitudes of these odds ratios are comparable in phase 1 and phase 2.

In the analysis of both phase 1 and phase 2 data, adjustment for birth preferences did not have material effects on many of the estimates obtained for case-mix variables. However, there was a reduction in the odds ratio for previous CS from 3.39 (95% CI: 3.17, 3.62) to 1.49 (95% CI: 0.64, 3.49) in phase 1 and from 2.35 (95% CI: 1.30, 4.25) to 1.12 (95% CI: 0.50, 2.50) in phase 2 after adjustment for birth preferences.

Precision of estimates

The following table shows the standard errors of the log odds ratio of CS during labour comparing women with different case-mix characteristics with women in the reference group, in phase 1 and phase 2, as well as comparisons of these standard errors as ratios.

Table 8.3.3.6: Standard errors of the log odds ratio of CS during labour according to the different case-mix variables and birth preferences for women in phase 1 and phase 2

	A SE of log odds ratio CS during labour Phase 1 Excluding birth pref n=126,90 1	B SE of log odds ratio CS during labour Phase 2 Excluding birth pref n=1684	C SE of log odds ratio CS during labour Phase 2 Including birth pref n=1684	D SE of log odds ratio CS before labour Phase 1 Including birth pref n=126,901 Single imputation	E SE of log odds ratio CS before labour Phase 1 Including birth pref n=126,901 20 imputations	C/B	D/A	E/A	D/C	E/C
Age (years) (reference group 25–29)										
12–19	0.04	0.46	0.46	0.04	0.06	1.01	1.02	1.51	0.09	0.13
20–24	0.03	0.33	0.33	0.03	0.06	1.02	1.03	2.04	0.09	0.18
30–34	0.02	0.19	0.19	0.02	0.04	1.02	1.01	1.51	0.12	0.18
35–39	0.03	0.22	0.23	0.03	0.05	1.02	1.01	1.63	0.13	0.21
40–50	0.06	0.41	0.42	0.06	0.09	1.01	1.03	1.47	0.15	0.21
Ethnicity (reference group White)										
Non-White	0.02	0.32	0.33	0.03	0.07	1.03	1.04	2.71	0.08	0.20
Previous deliveries (reference group no previous deliveries)										
At least one previous CS	0.03	0.30	0.41	0.05	0.41	1.35	1.38	11.96	0.11	1.00
At least one previous vaginal delivery	0.02	0.19	0.19	0.02	0.05	1.01	1.01	2.27	0.11	0.26
Interaction term between previous CS and previous vaginal delivery	0.06	0.61	0.67	0.07	0.35	1.10	1.11	5.46	0.11	0.52
Mode of onset of labour (ref group spontaneous onset)										
Induction of labour	0.02	0.16	0.16	0.02	0.04	1.02	1.01	1 89	0.12	0.23
Gestation (reference group at least 37 weeks)										
< 37	0.04	0.43	0.44	0.04	0.07	1.04	1.01	1.74	0.09	0.16
Birth weight (reference group 2501–4000 g)										
≤ 2500 g	0.04	0.41	0.42	0.04	0.07	1.01	1.02	1.63	0.10	0.16
> 4000 g	0.03	0.21	0.21	0.03	0.04	1.02	1.02	1.65	0.12	0.20

Birth preference (reference group vaginal birth)					
CS	0.39	0.03	0.31	0.06	0.67
No pref	0.27	0.07	0.20	0.25	0.52
Med	0.30	0.14	0.31	0.46	1.14
Don't know	0.52	0.10	0.33	0.20	1.08

Pref, preference; med, medical reasons

In both phase 2 and phase 1 (using single and multiple imputations for birth preferences), adjustment for birth preferences resulted in bigger standard errors of the log odds ratio of CS during labour comparing women with different case-mix characteristics with women in the reference group. In phase 2 this was an increase of 1% to 4% for most variables except for previous CS where there was a 35% increase in the standard error following adjustment for birth preferences. The amount of increase in the standard errors following adjustment for birth preferences was similar in ana ysis of phase 1 data using a single imputation for the birth preference variable. Similar to the analysis for CS before labour, for all variables except previous CS, this increase is not unexpected as it has been shown that in logistic regression, covariate adjustment decreases the precision of the estimated effect, in the absence of confounding[198]. Previous CS is the only variable that is materially affected by confounding from birth preferences. In phase 1 data using 20 imputations of the birth preference variable, the standard errors of the log odds ratios were much bigger following adjustment for birth preferences when compared with analysis using a single imputation for birth preferences. For example, in phase 1 data with 20 imputations, the standard error of the log odds ratio of CS during labour comparing women with previous vaginal delivery to women in the reference group was two times larger when compared with analysis that excluded the birth preference variable. In phase 1 data with single imputation for birth preference, this was a 1% increase in the standard error of the log odds ratio of CS during labour comparing women with previous vaginal delivery to women in the reference group. As in the analysis for CS before labour, the greater loss of precision in phase 1 data with 20 imputations compared with phase 1 data with a single imputation reflects the loss of precision from covariate adjustment as well as the between-imputation variability. However, the standard errors of the log odds ratios obtained from phase 1 data using 20 imputations for birth preferences are still generally smaller when compared with those obtained from analysis of completely observed phase 2 data.

The standard errors of the log odds ratios of CS during labour from phase 1 data with imputed birth preferences (single and 20 imputations) were compared with those obtained from the analysis of completely observed data in phase 2. The standard errors were smaller in the analysis of phase 1 data with imputed birth preferences compared with those obtained from the completely observed data in phase 2, reflecting the better assessment of confounding effects in the larger dataset (similar to the findings from analysis of CS before labour). The magnitude of this reduction was greater in the analysis of phase 1 data with one set of imputations compared with the analysis using 20 imputations, reflecting the between-imputation variability.

The amount of between imputation variation is illustrated in the following figures for women who had (i) previous CS (see figure 8.3.3.1), and (ii) previous vaginal deliveries (see figure 8.3.3.2) compared with women with no previous deliveries.

Figure 8.3.3.1: Between-imputation variability in log odds ratio of CS during labour comparing women with previous CS with women with no previous deliveries

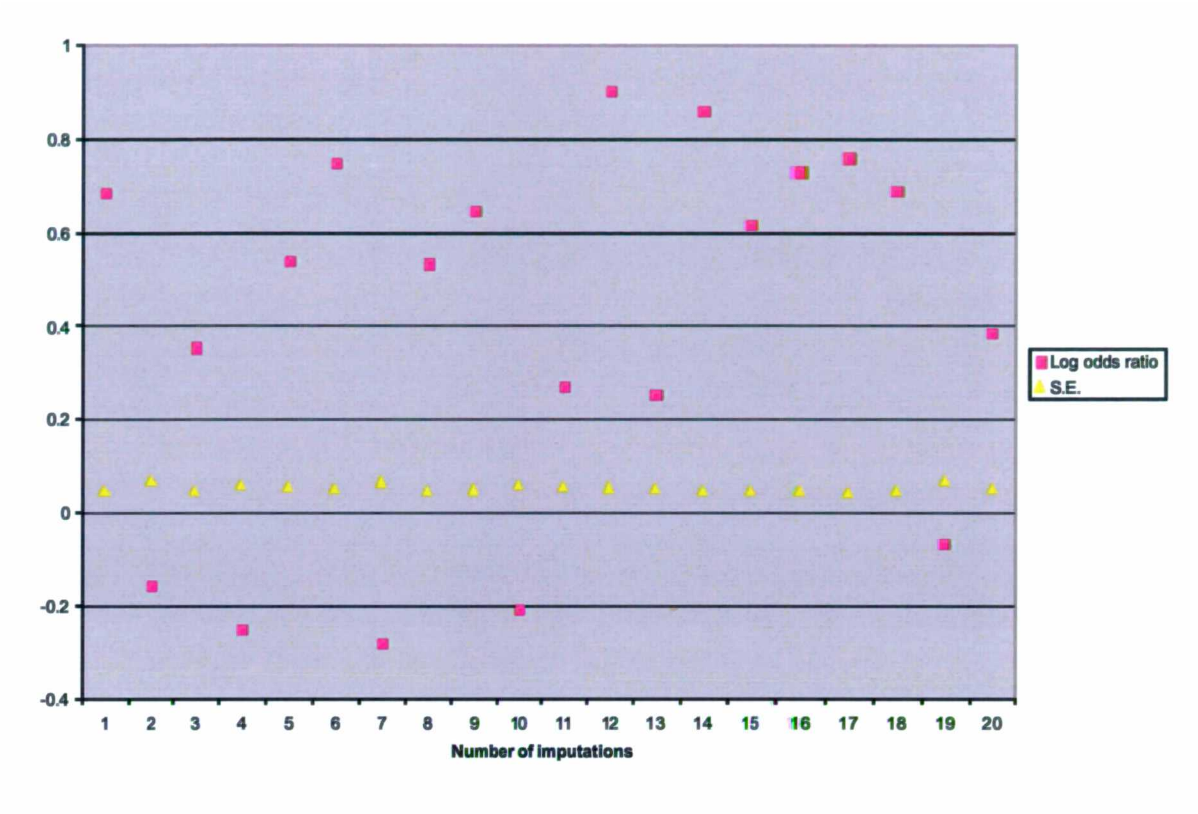
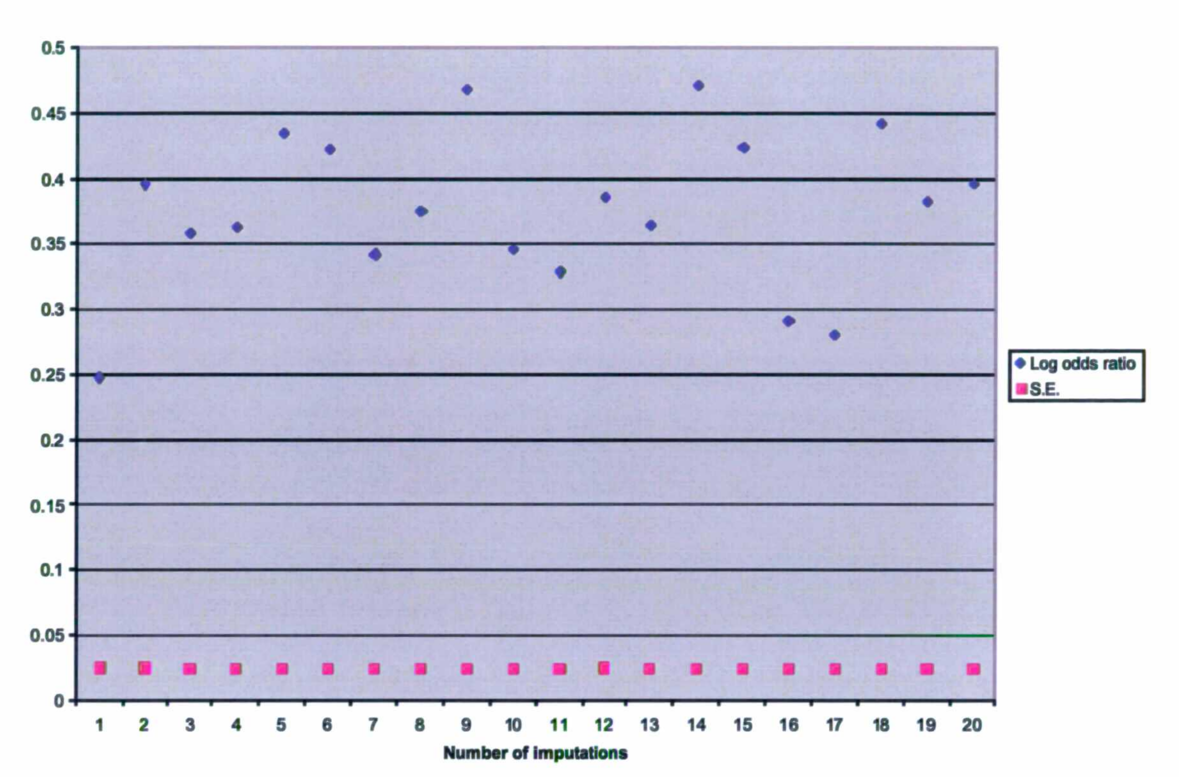


Figure 8.3.3.2: Between-imputation variability in log odds ratio of CS during labour comparing women with previous vaginal deliveries with women with no previous deliveries



In both of the examples above, the standard errors for the estimates of the log odds ratios are similar across the 20 imputations (0.06 for previous CS and 0.02 for previous vaginal deliveries. However, there is variation between the imputations in the estimates of the log odds ratios of CS during labour comparing women with either previous CS or previous vaginal deliveries with women with no previous deliveries. For women with previous CS, the between-imputation variability is particularly large (as illustrated in figure 8.3.3.1), such that the standard error for the log odds ratio of CS during labour comparing women with previous CS with those with no previous deliveries is eight times higher in the analysis of phase 1 data with 20 imputations (0.41) compared with single imputation (0.05). In contrast, the standard error for the log odds ratio of CS during labour comparing women with previous vaginal deliveries with those with no previous deliveries is two and a half times higher in the analysis of phase 1 data with 20 imputations (0.05) compared with single imputation (0.02). This is probably because the effect of previous CS is strongly associated with birth preferences, and the effects of birth preferences are not precisely estimated.

8.4 Discussion

The aim of this analysis was to describe the relationship between women's birth preference and CS as mode of delivery having adjusted for case-mix variables. While phase 1 data included women from all maternity units in England and Wales, there were no data on women's birth preferences. Data on birth preferences were available for 7% of women who delivered in 40 maternity units during phase 2. Analysis of these data was discussed in chapter 6 and the lack of precision around estimates for case-mix variables due to the smaller number of women included was highlighted. In order to utilise the large amount of information in phase 1, birth preferences for women in phase 1 were imputed using the completely observed data in phase 2. As previous analysis showed that there were no large effects of time on the risk of CS between the two phases, it was thought that imputing phase 1 birth preferences from phase 2 data would be appropriate.

The results presented in this section are based on analysis of women with completely observed data on case-mix variables. This is partly because 'sensitivity analysis' in previous sections suggested that the pattern of missing data may be different in the two phases of the study. The other reason for excluding women with incomplete data on case-mix variables was to create a monotone pattern of missingness. This approach resulted in exclusion of 3.6% of women from the phase 1 dataset. Another approach would have been to impute these missing values however this is a small proportion and the mechanism for missingness can reasonably be assumed to be MCAR. Therefore it is unlikely that exclusion of these women would have a big effect on the results reported here.

The sequential logistic regression models for imputation of birth preferences included interactions between previous CS and previous vaginal deliveries; previous CS and the outcome variable in the final analysis (CS before and during labour). This was done in order to preserve the relationships between the variables within completely observed data and carry its effect over to the imputed datasets.

8.4.1 Findings from this analysis

The findings from this analysis show that women who express a preference for CS in the antenatal period are more likely to have CS either before or during labour. In a univariate analysis, women who expressed either a preference for CS or reported that their preference was dictated by medical reasons had odds of CS before labour that were 9 and 14 times higher respectively, compared with women who expressed a preference for vaginal birth. Following adjustment for case-mix variables, women who expressed either a preference for CS or reported that their preference was dictated by medical reasons had odds of CS before labour that was five to six times higher than women who expressed a preference for vaginal birth. However, this association varies according to whether or not a woman has had a previous CS. The relative effect of previous CS for women who expressed either a preference for CS or reported that their preference was dictated by medical reasons is an increase in odds of CS before labour that is about ten times higher when compared with women with similar birth preferences who did not have previous CS. This reflects the difference in the role of women's birth preferences for women according to whether or not they have had a previous CS. For women with previous CS who attempt a vaginal birth after CS, there is at least a 1 in 200 risk of uterine rupture. Moreover the risk of perinatal death associated with vaginal birth after CS is approximately twelve times higher when compared to a planned CS. These factors could explain the strong association seen between preference for CS and subsequent CS in the index pregnancy for women who have had a previous CS.

For women who expressed a preference for vaginal birth, the relative effect of a previous CS was an increase in odds of CS before labour that was about six times higher. Among women who went into labour, those who expressed a preference for CS in the antenatal period had odds of CS that were about twice as high as women who expressed a preference for vaginal birth, after allowing for the effects of case-mix variables. This raises two issues. Firstly, the relationship between previous CS and birth preference is not clear. It is possible that women with a previous CS express a preference for CS in the index pregnancy and therefore are more likely to have CS, such that preference for CS is on the causal pathway between previous CS and CS in the index pregnancy. However, the relationship between birth preference and CS in the previous pregnancy is not known. It is possible that preference for CS led to CS in both the previous and index pregnancy. In this way, birth preference would be a confounder in the relationship between previous CS and CS in this index pregnancy. It is unclear how much of the effect of previous CS on mode of delivery can be attributed to birth preferences in the previous pregnancy. It is also not known how birth preferences might have changed between pregnancies. Secondly, it is unclear whether women who reported that their preferences were dictated by medical reasons perceived a previous CS or the reasons for the previous CS to be a clinical indication for repeat CS. In the NSCSA antenatal survey of women's views of childbirth, the majority of women reported that they would like more information on risks, benefits and reasons for CS[1]. In the survey of obstetricians' views on childbirth, about 5% of consultant obstetricians surveyed in England and Wales reported that they would offer elective CS to women who had a previous CS either for breech presentation or fetal distress while about 28% reported they would offer an elective CS for women with one previous CS for failure to progress in labour[1].

The inclusion of birth preferences in both phase 1 (single imputation of birth preferences) and phase 2 resulted in an increase in the standard errors of the log odds ratios of CS that compare women with different case-mix characteristics with women in the reference group. This was not unexpected and is explained by the fact that in the absence of confounding, covariate adjustment in logistic regression can result in larger and less precise estimates of effect[198]. This is not the case in linear regression where adjustment for covariates generally does not alter the estimate of effect but increases precision. The standard errors of the log odds ratios of CS that compare women with different case-mix characteristics to women in the reference group were much larger in phase 1 data using 20 imputations of birth preferences compared with data with a single imputation. This reflects the between-imputation variability in estimates resulting from imprecise estimation of the effect of birth preferences.

8.4.2 Advantages and disadvantages of using multiple imputations

It was thought that using multiple imputations to impute birth preferences for women in phase 1 would enable more precise estimates of the association between the various case-mix characteristics and CS as mode of delivery, when compared with analysis of the completely observed data in phase 2. There was a loss in the precision of the estimates of odds of CS associated with the various case-mix variables in the analysis of 20 datasets with imputed birth preferences compared with analysis of phase 1 data excluding birth preferences. This is mainly due to the loss in precision with covariate adjustment in logistic regression in the absence of confounding. However, between phase 1 (with imputed birth preferences) and phase 2, there was a gain in precision of the estimates of odds ratios of CS comparing women with different case-mix characteristics with those in the reference group. This gain in precision is not as large as might have been anticipated because the confounding effect of the imputed preference variable is not precisely estimated.

Firstly, the adjusted odds ratios of CS comparing women with different birth preferences to women who expressed a preference for vaginal birth had similar direction of association but differed in magnitude (this effect was more apparent in the model for CS before labour than in the model for CS during labour). This could be due to chance as there is overlap between the confidence intervals for the estimates obtained. Another explanation is that the phase 2 dataset with completely observed data is small (1888 women), and therefore the effect of the confounding case-mix variables cannot be as accurately estimated as in the phase 1 dataset that includes 140,969 women. Therefore the estimates of odds ratios for CS according to birth preferences are probably less biased in the analysis of phase 1 data because the allowance for confounders is based on a larger number of women. There is no material gain or bss in the precision of these estimates, suggesting that there was some benefit in using multiple imputations for birth references in the phase 1 data.

Secondly, the estimates of odds ratios for CS comparing women with different case-mix characteristics (except previous CS) with those in the reference group are less biased in the model that includes birth preferences as this allows for any confounding effects of this variable. However, the trade off for this is a loss in precision of these estimates.

In summary, although the estimates of the odds ratios for the case-mix variables are less biased and less precise when compared with the analysis of phase 1 data that does not allow for the effect of birth preferences, there is a gain in precision when compared with the analysis of completely observed data in phase 2. For birth preferences, the odds ratios obtained in phase 1 data with imputations is less biased with no loss or gain in precision when compared with completely observed data in phase 2 because the confounding effects of the case-mix variables are better controlled for in the larger dataset.

9 CS rates standardised for case-mix and birth preference

In this chapter, standardised CS rates (SCR) that are adjusted for case-mix variables (age, ethnicity, previous deliveries, gestational age, mode of onset of labour, and birth weight) and women's birth preference are calculated for each maternity unit. The aim is to quantify the amount of variation in CS rates between maternity units that can be explained by both case-mix differences and birth preferences.

For each maternity unit, overall standardised CS rates are calculated and compared with the respective observed CS rates using methods similar to those reported in chapter 5. Outlying maternity units are identified. Meta-analytical techniques are then used to examine the change in the between maternity units component of variance, before and after standardisation, in order to quantify the amount of variation between maternity units that can be explained by (i) case-mix adjustment and (ii) birth preferences.

9.1 Methods

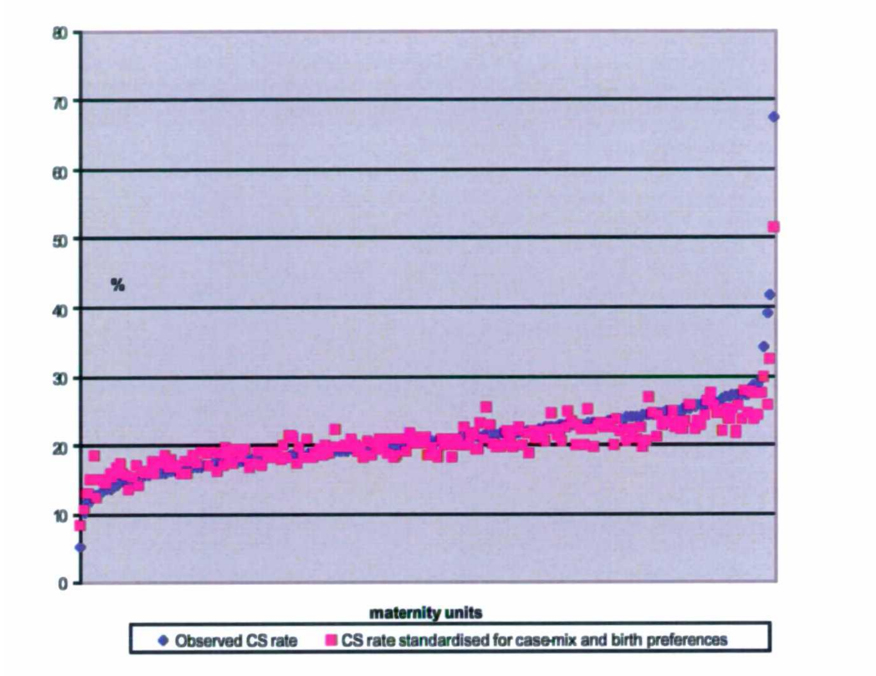
Following multiple imputations of the birth preference variable within phase 1 data (as described in the previous chapter – section 8.2.1), there were 20 pairs of datasets, each pair consisting of a CS before labour and CS during labour dataset, with imputed birth preferences. The logistic regression models for CS before and during labour (as described in section 8.2.1) were fitted to the respective datasets within each pair separately. The expected number of CS for each maternity unit was calculated as the sum of the expected probabilities of CS predicted by the logistic regression models for CS before and during labour, as described in chapter 5. As there were 20 pairs of datasets, each maternity unit had 20 estimates of their expected number of CS. The average expected number of CS was calculated across the 20 estimates for each maternity unit. The observed number of CS that took place within a maternity unit was then compared with the expected number of CS for that unit (as described in chapter 5) to calculate the standardised CS rate (SCRs standardised for case-mix and birth preference). Assuming that the expected values were error-free and that the observed proportions followed a binomial distribution, standard errors for these SCRs were calculated using the normal approximation to the binomial distribution (as in chapter 5).

A random effects meta-analysis of CS rates was carried out to investigate the heterogeneity between maternity units before and after this standardisation process. The Q test statistic and I^2 statistic were used to assess heterogeneity in CS rates between maternity units[163].

9.2 Results

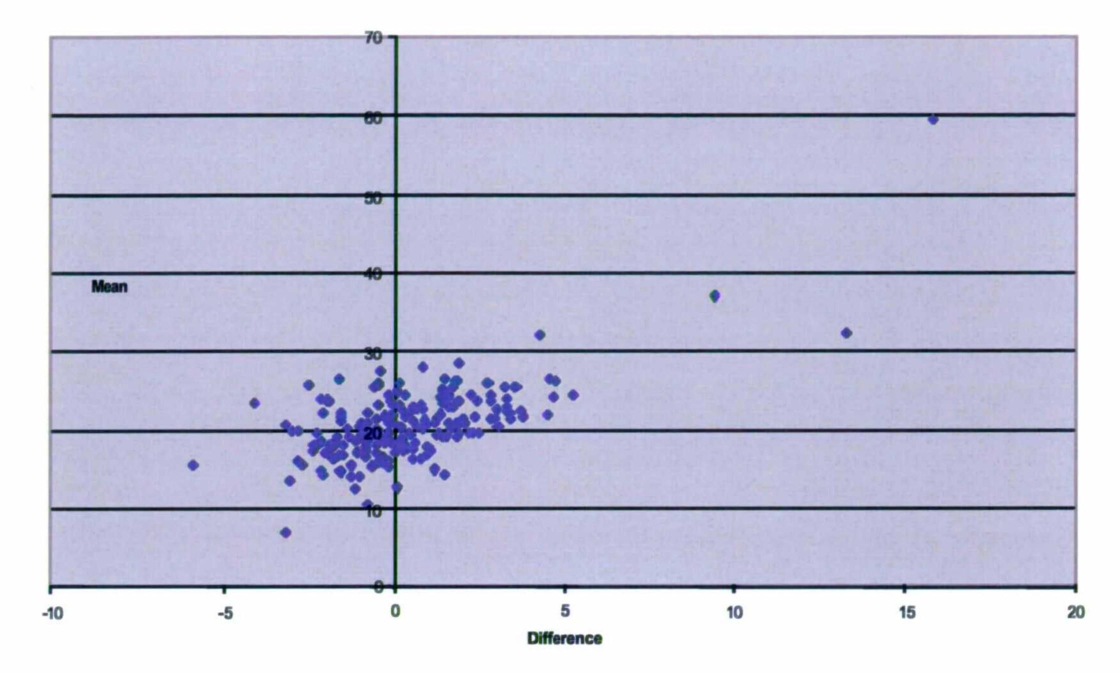
The median observed CS rate for the maternity units was 20.5% (IQR: 17.9%, 23.3%). Figure 9.2.1 shows the observed and standardised CS rates for all women, for the 216 maternity units, ordered by their observed CS rates. Figure 9.2.2 shows the relationship between the difference and mean for observed and standardised CS rates (standardised for case-mix differences and birth preferences). Figure 9.2.3 shows the standardised CS rate (SCR) with 95% CI for maternity units.

Figure 9.2.1: CS rates: Observed and standardised for case-mix and birth preferences for 216 maternity units



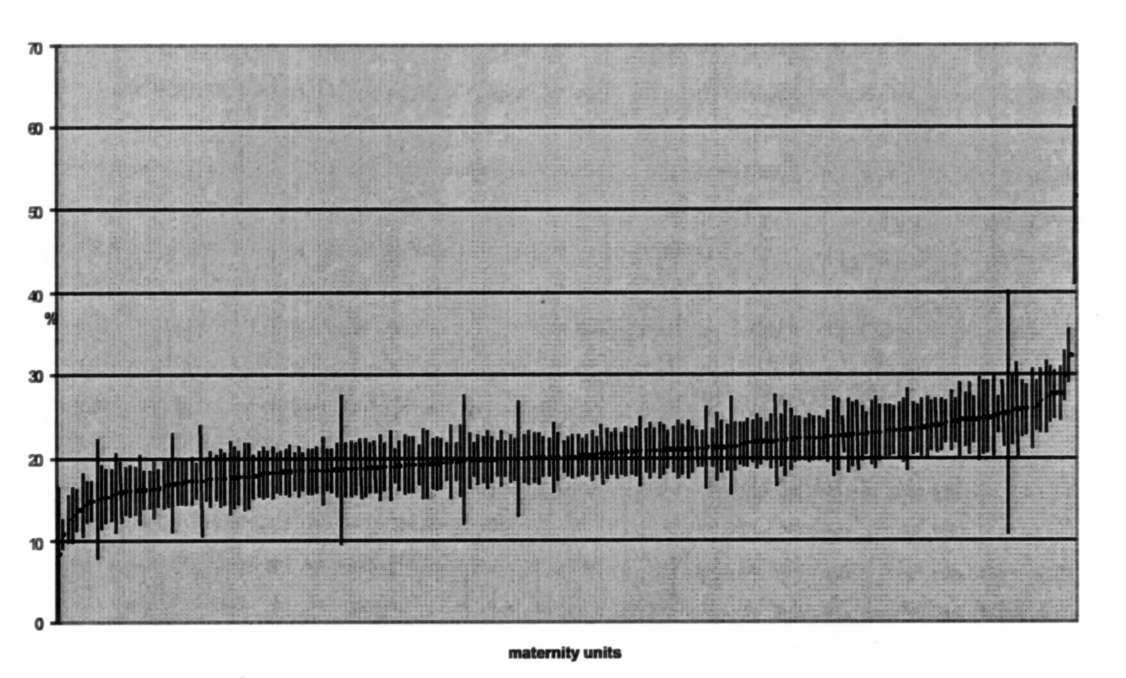
Twenty-eight maternity units had observed CS rates that were lower than the lower limit of their 95% reference range for the calculated expected overall CS rate (taking into account case-mix and birth preferences). The majority of these (n=22) were also highlighted in chapter 5 to have observed CS rates that were lower than the lower limit of their 95% reference range for the calculated expected overall CS rate (taking into account case-mix only). A further 28 maternity units had observed CS rates that were higher than the upper limit of their 95% reference range for the calculated expected overall CS rate (taking into account case-mix and birth preferences). The majority of these (n=26) were also highlighted in chapter 5 to have observed CS rates that were higher than the upper limit of their 95% reference range for the calculated expected overall CS rate (taking into account case-mix only).

Figure 9.2.2: CS rates for maternity units: Difference and mean crude and standardised for case-mix and birth preferences



The mean difference between observed and standardised CS rates was 0.42% (SD 2.32%). The median difference was 0.13% (IQR: –0.80%, 1.47%). As shown in Figure 9.2.2 above, there are three outlying maternity units. These are the same private maternity units that were highlighted in chapter 5, with observed CS rates of 39%, 41% and 67% and standardised rates of 26%, 32% and 52% (taking into account case-mix and birth preferences). The standardised rates for these maternity units reported in chapter 5 (taking into account case-mix only) were 29%, 34% and 43%, respectively. The standard deviation of the difference between observed and adjusted CS before labour rates was reduced from was 2.32% to 1.77% when these outlying maternity units were excluded.

Figure 9.2.3: CS rates standardised for case-mix and birth preferences (with 95% CI) for individual maternity units



9.2.1 Proportion of variance explained by case-mix and birth preferences

A random effects meta-analysis was carried out to look at the change in the between maternity units component of variance, before and after standardisation of overall CS rates for (i) case-mix only, and (ii) case-mix and birth preferences. There was statistically significant heterogeneity ($p<0.0001$) in observed CS rates between maternity units. For observed CS rates, the moment-based estimate of variance between maternity units was 14.17. For CS rates standardised for case-mix only it was 9.56, equating to a 35% reduction in true between-maternity-unit variance in CS rates following adjustment for case-mix only. For CS rates standardised for case-mix and birth preferences, the moment-based estimate of variance between maternity units was 7.77, equating to a 45% reduction in true between-maternity-unit variance in CS rates following adjustment for case-mix and birth preferences. These results remained similar when the outlying maternity units were excluded.

9.3 Discussion

In this chapter the aim was to quantify the amount of variation in CS rates between maternity units that can be explained by both case-mix differences and birth preferences. The method used was adapted from that described in chapter 5 to take into account the 20 imputations of the birth preference variable within the phase 1 dataset.

The main difference between the logistic regression models for CS before and during labour that were used in this analysis and those used in chapter 5 was the inclusion of the birth preference variable in this analysis. However, there were also some differences in the case-mix variables that were used. For example, in the logistic regression models for CS before and during labour in this analysis, ethnicity and gestation were simplified to binary variables (White, non-White; term, preterm) and presentation was not included as an explanatory variable. This was done because, as shown in section 8.3.1, there were very small numbers of women with observed data on birth who were non-White, or who gave birth before 37 weeks, or who had pregnancies with non-cephalic presentation. The logistic regression models used in this analysis included a two-way interaction term between birth preferences and previous CS, and two-way interaction term between previous CS and previous vaginal deliveries. This last interaction term between the case-mix variables was chosen as t was thought to be the most important in terms of its effect on the odds of CS before and during labour for individual women. In contrast, the analysis in chapter 5 included 13 and 10 two-way interactions between case-mix variables within the logistic regression models for CS before and during labour, respectively. The final difference is that the analysis presented in this chapter only included women with completely observed data for all case-mix variables while the analysis presented in chapter 5 included women with missing data on case-mix variables. However, as reported in the previous chapter, the pattern of missing data on case-mix variables can be assumed to be 'missing completely at random' and exclusion of these women is unlikely to have had a big impact on the results obtained.

In chapter 5, it was reported that case-mix adjustment resulted in a 34% reduction in the true between-maternity-unit variance in CS rates. The results of analysis in this chapter show that using the simpler logistic regression models to calculate expected CS rates for maternity units, there was a 35% reduction in the true between maternity unit variance in CS rates. Therefore, although the more complex logistic regression models used in chapter 5 provided a better fit to the data, they did not have much additional impact on the amount of variation that is explained in CS rates that is accounted for by case-mix differences. Adjustment for case-mix and birth preferences resulted in a 45% reduction in the true between-maternity-unit variance in CS rates. Interestingly, the private hospital with the highest observed CS rate (66%) had standardised (for case-mix only) CS rate of 43% and a standardised (for case-mix and birth preferences) CS rate of 52%, which is much closer to the observed CS rate.

A full discussion of other studies that have reported methods for adjusting CS rates for comparisons between maternity units has been given in chapter 5. However, none of these studies have examined the impact of women's birth preferences on the amount of variation in CS rates that is observed between maternity units.

10 Summary of work presented in this thesis, further work and overall conclusions

A summary of the work undertaken in this thesis is outlined in section 10.1. This is followed by a summary of suggestions for further work in section 10.2. The overall conclusions are presented in section 10.3.

10.1 Summary of work presented in this thesis

10.1.1 Chapter 1

This chapter provided the motivation for the work presented in the subsequent chapters. CS rates have increased over the last three decades. In England and Wales the overall CS rate is 21%, but this varies between maternity units from 6% to 66%. Differences in demographic and clinical factors (case-mix) of women giving birth at these maternity units should be taken into account in order to make valid comparisons between maternity units. Using the large NSCSA databases, the focus of the work undertaken in this thesis was (i) to adjust CS rates for individual maternity units taking into account differences in population characteristics, and (ii) to quantify the amount of variation in CS rates between maternity units that can be explained by differences in population characteristics.

10.1.2 Chapter 2

This chapter reviewed the literature on the methods available for comparing CS rates. This was followed by a review of the factors associated with CS rates to determine which factors should be included in an explanatory statistical model that describes the relationship between case-mix and CS for individual women.

Methods for comparing CS rates

The methods available for comparing CS rates include (i) selection of standard groups that lead to exclusion of other groups of women, (ii) stratification and (iii) standardisation (direct and indirect). Indirect standardisation refers to the application of observed rates in a reference population (women giving birth in England and Wales) to a study population (maternity units). This was the method chosen for use in this thesis as it allows comparisons of the CS rates with adjustment for case-mix, without excluding specific groups of women. Furthermore, it does not require the selection of a particular maternity unit profile for use as the standard reference population. The expected number of CS for individual maternity units is calculated and compared with the observed number of CS to produce a standardised CS rate.

Factors associated with CS rates

CS rates have been shown to vary according to demographic factors (such as age, ethnicity, education and sociocultural factors), clinical factors such as (previous deliveries, gestational age, birth weight, type of onset of labour, presentation and body mass index) and women's birth preferences.

10.1.3 Chapter 3

For each of the demographic and clinical characteristics (case-mix variables) an overall description of the data on women who gave birth in England and Wales is provided together with CS rates according to these characteristics.

10.1.4 Chapter 4

In this chapter, the main aim was to develop a statistical model to obtain expected probabilities of CS (before and during labour) for individual women, for calculation of expected numbers of CS within maternity units in the following chapter. The purpose of these logistic regression models was to explain the relationship between the various case-mix variables and odds of CS (before and during labour) for individual women. A two-stage modelling process using logistic regression was adopted, to allow for differences in the relationship between the case-mix variables and (i) CS before labour, and (ii) CS during labour. As the CS before labour rate varies between maternity units, and preliminary analysis showed that the relationship between case-mix variables and CS was different for CS before and during labour, it was considered important to model the two outcomes (CS before labour and CS during labour) separately.

In England and Wales, women who are older were more likely to have CS (before and in labour). Women from ethnic minority groups have lower odds of CS before labour, and increased odds of CS in labour. Women with previous CS had higher odds of both CS before and during labour although the magnitude of this association was reduced for women who also had previous vaginal births.

It was acknowledged that clinically, the effect of some case-mix variables on CS as mode of delivery may vary according to other case-mix variables. However, as the NSCSA database includes a large number of women (n=147,087), there is potentially enough statistical power to include many statistically significant high level interactions between the case-mix variables that (i) are of limited interest clinically, and (ii) increase the complexity for interpretation. Therefore, it was decided that initially a set of interactions that were considered clinically relevant would be included. The goodness of fit of the logistic regression models for (a) CS before labour, and (b) CS during labour was assessed by examining the predicted probabilities for both CS before labour and CS among women in labour for individual women in order to determine at what stage to stop investigating complex interactions. The final logistic regression models included 13 and 8 two-way interactions between case-mix variables for CS before and during labour, respectively.

The goodness of fit of these models was judged to be adequate although for CS before labour, there were some small discrepancies between the observed number of CS and the sum of predicted probabilities, particularly in the first three deciles of the distribution of predicted probability of CS before labour.

10.1.5 Chapter 5

Chapter 5 illustrates the method for calculating standardised CS rates for individual maternity units (that take into account differences in case-mix variables for women giving birth) using indirect standardisation. The results from the explanatory logistic regression models described in chapter 4 were used to compute expected probabilities of CS for individual women, such that the total expected number of CS for a particular maternity unit can be calculated. The observed number of CS was then compared with the expected number of CS and multiplied with the average CS rate for England and Wales to compute a standardised CS rate. The results showed that in England and

Wales, 31% of maternity units had observed overall CS rates that were outside the 95% reference range of their calculated expected CS rates. Furthermore, three maternity units were highlighted to have standardised overall CS rates that were substantially higher than the national average. All three were private maternity units and it is unlikely that these were outliers due to random variation but probably reflect differences in practice within these units. Consistent with findings from other studies, the unreliability of using ranks as a means of assessing performance of maternity units was also demonstrated.

Using techniques analogous to meta-analysis, it was found that 34% of the true between-maternity-unit variance was accounted for by differences in demographic and clinical characteristics (case-mix variables). This is consistent with findings from others studies reported in the literature.

10.1.6 Chapter 6

The aim of this chapter is to examine the contribution of women's birth preferences to variation in CS rates. Within the NSCSA, data on women's birth preferences were only collected during the second phase of the study, using a survey of women's views during the antenatal period. The response rate to this survey was 37%. Analysis of the data on the women who responded to the survey may produce spurious results as there may be differences between responders and non-responders, and it cannot be assumed that 'non-response' was a random occurrence. Furthermore, limiting the analysis to responders also means discarding an unacceptably large portion of data and a subsequent loss of power. Therefore, the challenge here was to utilise the information from the large phase 1 database in estimating the association between women's antenatal birth preferences and mode of delivery.

The advantage of using phase 1 data is that it provides more precise estimates due to the larger number of women involved. However, there is no information on birth preferences for these women who gave birth during the phase 1 study period. Phase 2 data were therefore compared with phase 1 data to investigate whether or not there was a 'time period effect'. As there was no significant time 'period effect' between the two phases of the study, it was possible to use the information from the survey of women's views on childbirth carried out during phase 2 to 'predict' these 'missing data' on birth preferences for the women in phase 1 using techniques for analysing missing data.

10.1.7 Chapter 7

In chapter 7, a review of the literature on methods for handling missing data is presented, together with an explanation of the types of missing data and mechanism of missingness.

In the NSCSA data, the missing birth preferences data can be thought of as item non-response with a univariate pattern. The mechanism for missingness in the NSCSA was assumed to be missing at random (MAR), making the assumption that the relationship between missing data on birth preferences and outcome is similar to that of observed data on birth preferences and outcome.

Of the methods reviewed (case deletion, single imputation and multiple imputations), analysis of the NSCSA data using multiple imputations to deal with the 'missing data' on birth preferences seemed to be a reasonable option.

The main advantage of using multiple imputations is that the 'uncertainty' associated with the 'missing data' is accounted for in the final analysis. The predictive model based method was used for generating the imputations. The application of this method to the NSCSA data was illustrated using a simplified dataset containing only three variables.

The overall aim was to fit a model that relates CS in the index pregnancy to previous CS and birth preference. Models were fitted using three different approaches (discriminant function analysis, sequential logistic regression and a log linear model), to the compbtely observed data to estimate the relationship between women's preference (dependent variable); and two explanatory variables (previous CS and CS before labour). These estimations were then applied to incompletely observed data to predict 'women's preference' for each individual woman for whom data on preference were not available. This was done m times, to create m imputed datasets. Each dataset was then analysed separately using logistic regression (with CS before labour as the outcome variable and previous CS and preference as explanatory variables). The estimates and standard errors from the m datasets were then combined by computing the mean of the m estimates and a variance estimate that included both a within-imputation and a between-imputation component.

Model for imputation using discriminant function analysis

In this section it was shown that although it is reported that a normal distribution can be used to approximate a discrete distribution such that the use of discriminant function analysis for the imputation of categorical variables is justified, this is not the case when one or more categories of response are rare. The results of this analysis show that the relative frequencies obtained by approximating the discrete distribution of the NSCSA data with a bivariate normal distribution are not in good agreement with the observed relative frequencies.

Imputation using loglinear and logistic regression models

The aim of this section was to decide on the type of model that would be appropriate for imputation of the birth preference variable. As this is a categorical variable with five non-ordered categories, a loglinear model would have been the model of choice. However, in the NSCSA data there are seven explanatory variables (all categorical with two to six categories per variable) for inclusion in the imputation model for birth preference. While it is possible to fit complex loglinear models with two- and three-way interactions between explanatory variables, it is more difficult to use this approach in predicting counts for combined categories with more complex models. This latter part of the process is easier to deal with using logistic regression when there are many explanatory variables. However, as birth preference is an ordinal variable it was necessary to use four dummy variables as outcome variables in four logistic regression models fitted sequentially. It was possible that the results obtained using the sequential logistic regression models could vary according to the sequence that was used. Therefore, this was compared with the results from the loglinear model. Both the sequential logistic regression models and a loglinear model yielded similar results. However, generating the imputations using the logistic regression approach is computationally easier to deal with and this method was preferred for imputing the birth preference variable in the NSCSA data.

10.1.8 Chapter 8

This chapter describes the relationship between women's birth preference and CS as mode of delivery, having adjusted for case-mix variables. This analysis is carried out using phase 1 data with imputed data on birth preferences. The advantage of using phase 1 compared with phase 2 data is that they include all maternity units in England and Wales, so that the results are applicable to women giving birth in England and Wales. In addition, the phase 1 dataset is large (compared with phase 2 data) and enables more accurate assessment of the confounding effects of case-mix variables in the relationship between birth preferences and CS as mode of delivery.

The findings from this analysis show that women who express a preference for CS in the antenatal period are more likely to have CS either before or during labour. In the univariate analysis, women who expressed either a preference for CS or reported that their preference was dictated by medical reasons had odds of CS before labour that were 9 and 14 times higher, respectively, compared with women who expressed a preference for vaginal birth. Following adjustment for case-mix variables, women who expressed either a preference for CS or reported that their preference was dictated by medical reasons had odds ratios of CS before labour that were five to six times higher than women who expressed a preference for vaginal birth. However, this association varies according to whether or not a woman has had a previous CS. The relative effect of previous CS was an increase in the odds of CS before and during labour.

The nature of the relationship between previous CS and birth preference is not clear. It is possible that women with a previous CS express a preference for CS in the index pregnancy and therefore are more likely to have CS, such that preference for CS is on the causal pathway between previous CS and CS in the index pregnancy. However, the relationship between birth preference and CS in the previous pregnancy is not known. It is possible that preference for CS led to CS in both the previous and index pregnancy, confounding the relationship between previous CS and CS in this index pregnancy. It is unclear how much of the effect of previous CS on mode of delivery can be attributed to birth preferences in the previous pregnancy. It is also not known how birth preferences might have changed between pregnancies. It is also unclear whether women who reported that their preferences were dictated by medical reasons perceived a previous CS or the reasons for the previous CS to be a clinical indication for repeat CS.

Advantages and disadvantages of using multiple imputations

The estimates of the odds ratios for the case-mix variables were less biased and less precise in the analysis of phase 1 data with imputed birth preferences when compared with the analysis of phase 1 data that did not allow for the effect of birth preferences. However, there was a gain in precision when compared with the analysis of completely observed data in phase 2.

For birth preferences, the odds ratios obtained in phase 1 data with imputations is less biased with no loss or gain in precision when compared with completely observed data in phase 2 because the confounding effects of the case-mix variables are better controlled for in the larger dataset.

However, adjustment for birth preferences led to a loss in precision of the estimated relationship between case-mix variables and CS, in both phase 1 and phase 2 data because of inaccurate assessment of the confounding effects of birth preferences. This is because the confounding effects of birth preferences are based on analysis of the smaller phase 2 dataset, and these relationships are simply carried over to the phase 1 dataset with the use of multiple imputations for the birth preference variable.

10.1.9 Chapter 9

In this chapter the aim was to quantify the amount of variation in CS rates between maternity units that can be explained by both case-mix differences and birth preferences.

In chapter 5, it was reported that case-mix adjustment resulted in a 34% reduction in the true between maternity unit variance in CS rates. The results of analysis in this chapter show that using the slightly simpler logistic regression models to calculate expected CS rates for maternity units, there was a 35% reduction in the true between maternity unit variance in CS rates. This latter analysis only included women with completely observed data on all case-mix variables and therefore the population varied from that included in the chapter 5 analysis. Although the more complex logistic regression models used in chapter 5 provided a better fit to the data, they did not have a material impact on the amount of variation that is explained in CS rates that is accounted for by case-mix differences. Adjustment for case-mix and birth preferences resulted in a 45% reduction in the true between-maternity-unit variance in CS rates.

10.2 Further work

In this analysis of the NSCSA data, 45% of the true between maternity units variance in CS rates was accounted for by adjusting for case-mix differences and women's birth preferences. Some of the variation in CS rates between maternity units that is not accounted for by case-mix differences or women's birth preferences will be due to chance. Other factors that possibly contribute to this variation include organisational characteristics of maternity units (such as size, type of maternity units and staffing levels). In addition, the attitudes of obstetricians, midwives and other health care professionals and variation in their practice within maternity units may also impact on the CS rate.

Further work should address more formal evaluations of these potential sources of variation. It is important to understand the factors that contribute to variation between maternity units, such that these can be addressed in order to ensure the quality of obstetric care provided.

10.3 Statistical conclusions

Multiple imputations were used in this analysis to handle the 'missing data' on women's birth preferences. The use of multiple imputations for this NSCSA data was interesting and challenging as it was necessary to impute the vast majority of observations for a single variable. In carrying out this analysis, firstly an attempt was made to use the available software. This highlighted some of the pitfalls with the methods for imputation made available within the software.

In particular, the inappropriateness of using discriminant function analysis (as available in SOLAS) for imputation of categorical variables when one or more response category is rare. However, the use of logistic regression and loglinear models for imputation of categorical variables was a reasonable approach and this was explored and used for this work. The challenge was the high proportion of women for whom imputation of birth preferences was required. Much of the literature on the application of multiple imputations for handling missing data in practice focused on situations where the proportion of missing data was low (about 10–20%). Hence, it was necessary in this work to investigate empirically the number of imputations that would be required in order to obtain reliable estimates.

Comparison of analysis of the smaller phase 2 dataset (with completely observed data on case-mix and birth preferences) with the much larger phase 1 dataset (with completely observed data on case-mix and imputed data on birth preferences) showed a gain in precision of the estimates for case-mix variables. For birth preferences, the estimates obtained in phase 1 data with imputations are less biased with no loss or gain in precision when compared with completely observed data in phase 2 because the confounding effects of the case-mix variables are better controlled for in the larger dataset. However, adjustment for birth preferences led to a loss in precision of the estimated relationship between case-mix variables and CS, in both phase 1 and phase 2 data due to inaccurate assessment of the confounding effects of birth preferences in the smaller completely observed dataset.

Therefore, the use of multiple imputations was on the whole useful in the analysis of these data, as it enabled the results to be generalisable to all women giving birth in England and Wales.

10.4 Overall conclusions

CS rates have increased over the last three decades internationally but there is variation between countries. Within England and Wales, there is variation between maternity units. It is important to understand the factors that contribute to this observed variation between maternity units in order to be able to assess the quality of care received by women giving birth.

In this analysis of the NSCSA data, 34% of the true between maternity units variance in CS rates was accounted for by adjusting for case-mix differences. Women's birth preferences also influence the type of birth that they have and can therefore impact on the CS rate. However, the majority of women express a preference for a vaginal birth. Only 5% of pregnant women express a preference for a CS and the majority of these women have had a previous CS. In the work presented in this thesis, it was shown that adjusting for case-mix differences and women's birth preferences accounted for 45% of the true between maternity units variance in CS rates.

Some of the variation in CS rates between maternity units that are not accounted for by case-mix differences or women's birth preferences will be due to chance. Other factors that possibly contribute to this variation include organisational characteristics of maternity units (such as size, type of maternity units and staffing levels). In addition, the attitudes of obstetricians, midwives and other health care professionals within maternity units may also impact on the CS rate. The main reasons for CS have not changed over the last three decades, these are (i) presumed fetal compromise, (ii) failure to progress in labour, (iii) previous CS, and (iv) breech presentation. Results from the NSCSA showed that there is variation in clinical practice in the decision-making for CS in these situations, reflecting clinical uncertainty about the magnitude and direction of risk–benefit of CS in some of these clinical situations. It is important to address these areas of clinical uncertainty in order to try to standardise the care that is received by women giving birth in England and Wales. It is thought that the recent publication of the national evidence-based guideline on Caesarean section may help to reduce some of this observed variation in clinical practice. However, as the longer term impact of CS on women's health is not clear, the public health implications of the rising CS rate are unclear. Therefore, it is important to understand the factors that contribute to variation between maternity units, so that these can be addressed in order to ensure the quality of obstetric care provided.

Currently in England and Wales, there is no routine maternity dataset to enable such comparisons of CS rates between maternity units to be carried out on an ongoing basis. Such datasets exist in Scotland and analysis of these data has helped inform the discussions about maternal and infant morbidity related to mode of delivery. The Office for National Statistics obtains hospital episode statistics but the coverage of this is limited to 72% of all maternity units in England and Wales. It is anticipated that the National Service Framework for Children will include recommendations for a routine maternity dataset for England and Wales.

A variety of methods are currently being used for case-mix adjustment, utilising various sources of data and accounting for different risk factors. This highlights the need for a standard risk-adjustment methodology that utilises data that are collected routinely in a uniform manner across different maternity units, using consistent definitions of data items that are collected.

The success of the NSCSA showed that it is possible to collect good-quality data prospectively from all maternity units. The methodology of the NSCSA and its data-collection tools can help inform this process. The work undertaken in this thesis includes methodology for comparing CS rates between maternity units. This method is based on indirect standardisation with the sophistication of a two-stage prediction model. Although the statistical models that were used were complex and included two-way interactions between variables, it was also shown that simpler models can be used to produce similar results. Therefore, this work can be adapted for use on a routine maternity dataset to enable further comparisons and exploration of variation in CS rates between maternity units on an ongoing basis.

Within the framework of clinical governance, standardised CS rates are useful as they enable maternity units to compare their practice with average national practice to monitor and potentially improve their practice over time. It can also be useful in evaluation of the effectiveness of interventions that have been used to reduce CS rates or improve the quality of care provided to women giving birth.

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12 Appendix

Table 1: Coefficients obtained from logistic regression models for predicting birth preferences derived from observed data (for use in analysis of association between CS before labour, casemix variables and birth preferences)

	Predicting preference for vaginal birth ß (S.E.) n=1888	Predicting preference for CS ß (S.E.) n= 443	Predicting 'no preference' ß (S.E.) n=327	Predicting preference dictated by medical reasons ß (S.E.) n=212
Maternal age (years)				
12–19	0.22 (0.32)	0.23 (0.83)	-1.04 (0.67)	-2.94 (1.28)
20–24	-0.10 (0.21)	0.95 (0.42)	-0.09 (0.47)	-0.70 (0.67)
30–34	-.083 (0.15)	-0.30 (0.32)	-0.04 (0.31)	0.60 (0.50)
35–39	-0.08 (0.17)	-0.52 (0.37)	-0.49 (0.37)	0.32 (0.54)
40–50	-0.26 (0.29)	0.03 (0.55)	-0.28 (0.67)	0.18 (0.83)
Non-White	-0.27 (0.27)	-0.13 (0.55)	-0.44 (0.59)	-1.93 (1.37)
At least 1 previous vaginal delivery	0.39 (0.13)	0.75 (0.30)	-0.75 (0.28)	0.54 (0.43)
At least 1 previous CS	-0.58 (0.28)	0.32 (0.61)	-1.06 (0.54)	1.03 (0.83)
Interaction term between previous vaginal deliveries and previous CS	-0.16 (0.42)	-1.15 (0.64)	*	0.22 (1.21)
Less than 37 weeks gestation	-0.62 (0.30)	0.76 (0.52)	1.64 (0.67)	0.91 (1.29)
Birth weight (g)				
≤ 2500	0.03 (0.33)	-2.34 (1.11)	-1.77 (0.75)	-0.80 (0.92)
> 4000	0.07 (0.18)	-1.04 (0.46)	-0.35 (0.36)	-0.39 (0.47)
CS before labour	-1.21 (0.21)	1.02 (0.36)	-1.51 (0.49)	0.97 (0.67)
Interaction term between CS before labour and previous CS	-0.75 (0.40)	0.44 (0.71)	-0.02 (0.94)	-1.15 (1.13)
constant	1.63 (0.29)	-1.65 (0.58)	0.85 (0.60)	2.55 (1.41)

* all 3 women who had previous CS and previous vaginal deliveries expressed no preference

Table 2: Coefficients obtained from logistic regression models for predicting birth preferences derived from observed data (for use in analysis of association between CS during labour, casemix variables and birth preferences)

	Predicting preference for vaginal birth ß (S.E.) n=1684	Predicting preference for CS ß (S.E.) n= 320	Predicting 'no preference' ß (S.E.) n=262	Predicting preference dictated by medical reasons ß (S.E.) n=129
Maternal age (years)				
12–19	0.08 (0.33)	0.35 (0.86)	-1.05 (0.68)	**
20–24	-0.09 (0.22)	0.88 (0.51)	-0.51 (0.49)	-0.56 (0.76)
30–34	-0.06 (0.16)	-0.25 (0.43)	-0.001 (0.34)	0.57 (0.59)
35–39	-0.08 (0.19)	-0.37 (0.47)	-0.63 (0.40)	0.10 (0.65)
40–50	-0.38 (0.31)	0.63 (0.69)	-0.16 (0.71)	0.16 (1.04)
Non-White	-0.28 (0.30)	-0.08 (0.70)	-0.24 (0.63)	***
At least 1 previous vaginal delivery	0.36 (0.14)	0.76 (0.36)	-0.72 (0.31)	0.85 (0.52)
At least 1 previous CS	0.002 (0.41)	-0.29 (1.22)	-1.57 (0.93)	1.11 (1.20)
Interaction term between previous vaginal deliveries and previous CS	0.57 (0.69)	-0.20 (1.44)	*	
Induction of labour	-0.18 (0.14)	0.68 (0.34)	-0.13 (0.30)	0.90 (0.54)
Less than 37 weeks gestation	-0.88 (0.34)	1.06 (0.64)	1.77 (0.77)	1.89 (1.80)
Birth weight (g)				
≤ 2500	-0.05 (0.36)	-1.80 (1.13)	-1.74 (0.79)	-1.49 (1.15)
> 4000	0.09 (0.19)	-1.79 (0.76)	-0.19 (0.39)	-0.40 (0.63)
CS	-0.52 (0.18)	0.47 (0.43)	-.057 (0.39)	0.89 (0.72)
Interaction term between CS and previous CS	-1.40 (0.57)	0.33 (1.37)	0.86 (1.16)	-0.21 (1.72)
constant	1.79 (0.32)	-2.08 (0.74)	0.67 (0.64)	0.08 (0.53)

*All 3women in this category had vaginal delivery

**All 7 women in this category had vaginal delivery

***All 5 women in this category had CS