Ultrasound Obstet Gynecol 2008; **32**: 884–889
Published online 5 August 2008 in Wiley InterScience (www.interscience.wiley.com). **DOI:** 10.1002/uog.5372

Customized birth weight: coefficients and validation of models in a UK population

D. S. SAHOTA*, K. O. KAGAN†, T. K. LAU*, T. Y. LEUNG* and K. H. NICOLAIDES†

**Department of Obstetrics and Gynaecology, The Chinese University of Hong Kong, Prince of Wales Hospital, Hong Kong, China and †Harris Birthright Research Centre for Fetal Medicine, King's College Hospital, London, UK*

KEYWORDS: birth weight; customization; small for gestation; validation

ABSTRACT

Objectives *To produce a customized birth weight model in a UK population.*

Methods *This was a population-based, multiethnic, retrospective cohort study of 42 583 women with uncomplicated singleton pregnancies resulting in a live birth at 37–42 weeks of gestation between 1997 and 2005. Multivariate analysis was undertaken and a double cross-over approach was employed to validate the models estimating customized birth weight.*

Results *Coefficients confirmed the findings of previous studies, indicating that birth weight was strongly influenced by maternal ethnicity, age, parity, body mass index, smoking, fetal gender and gestational age at delivery.*

Conclusions *We have derived models to determine customized or predicted birth weight in a UK population that are both robust and reproducible. Copyright © 2008 ISUOG. Published by John Wiley & Sons, Ltd.*

INTRODUCTION

Birth weight is one of the key measurements of pregnancy, reflecting the intrauterine environment to which the fetus was exposed. There are extensive data on the association between birth weight and perinatal mortality as well as susceptibility to cardiovascular disease and diabetes in adulthood.

Population-based standard birth weight tables and charts permit the birth weight of any individual neonate to be measured in terms of its deviation from a gestation-specific norm. However, such charts do not reflect whether the weight of a newborn is appropriate for that individual because birth weight is influenced by maternal factors, such as age, height, weight, ethnic origin, past reproductive history and smoking, as well as fetal factors, including gender and maturity at delivery.

Statistical models have been developed that incorporate maternal and fetal factors to calculate a 'customized' or 'individualized' optimal weight 'at term' for a given pregnancy[1,2]. Formulae describing the optimal birth weight at term have now been produced for homogeneous or mixed ethnic populations in several countries[3–14]. The optimal birth weight at term has been combined with a standard proportional growth curve to describe how a fetus would be expected to reach that endpoint at any gestational age in an uncomplicated pregnancy[1,2]. However, it remains unclear whether the expected birth weight adjusted to earlier gestation using the 'proportional' equations is equivalent to the predicted birth weight in which gestational age is included as a specific independent variable along with physiological characteristics of the pregnancy.

There is evidence that babies defined as small-for-gestational age (SGA) using customized standards are more likely to be compromised than those defined by a population-based standard[9,11,15]. Consequently, the Royal College of Obstetricians and Gynaecologists in the UK recommended the use of customized interpretation of birth weight in the investigation and management of SGA fetuses[16].

This study aimed to validate the customized birth weight model, and to produce an updated set of reference coefficients for estimating a customized birth weight in a UK population for use in maternity care and future research. Furthermore, the expected birth weight estimated using the proportionality growth formula approach was compared with that derived from a model in which gestational age at delivery is included as an independent factor.

Correspondence to: Dr D. S. Sahota, Department of Obstetrics and Gynaecology, The Chinese University of Hong Kong, Prince of Wales Hospital, Shatin, Hong Kong, China (e-mail: daljit@cuhk.edu.hk)

Accepted: 23 January 2008

 ORIGINAL PAPER

METHODS

Patients

Data were extracted from the clinical audit databases of women with singleton pregnancies attending for routine antenatal ultrasound assessment at or before 20 weeks of gestation in the Fetal Medicine Centre or King's College Hospital, London, UK, between 1997 and 2005. We selected those women who delivered a live infant with no obvious abnormalities at term (37–42 weeks) and excluded those of mixed ethnicity and those whose pregnancies were complicated by pre-eclampsia, diabetes mellitus or antepartum hemorrhage.

Gestational age at delivery was calculated from the measurement of fetal crown–rump length or head circumference at the time of the first ultrasound examination[17,18].

Customized birth weight models

The variables extracted from the databases were: maternal age at estimated date of delivery (years), height (centimeters) and weight (kilograms) recorded at first antenatal assessment, parity (number of previous live births at 24 weeks of gestation or more), cigarette smoking (non-smoker, stopped smoking before pregnancy, smoker of ≤ 5 cigarettes/day, smoker of 6–10 cigarettes/day and smoker of ≥ 11 cigarettes/day), ethnicity (European, Afro-Caribbean, Asian (Indian Subcontinent) and Oriental (East Asian)), baby's sex, birth weight (grams) and gestational age at delivery (days). Factors such as social class, educational attainment and marital status were not collected routinely and so were excluded from the modeling process.

Multiple regression analysis was performed in order to model the effect of individual parameters on birth weight. The categorical variables ethnicity, parity, smoking status and baby's gender were converted to a number of binary variables using dummy coding[19]. The continuous variables maternal height and weight, and their polynomials were represented as departures from the study mean value. Gestational age at delivery and its polynomials were represented as the difference in days from 280.

Three customized birth weight models were developed. Model 1 included only maternal and fetal parameters, namely age, ethnicity, parity, height, weight and fetal gender. In addition the coefficients obtained were derived only from those cases within the dataset delivering between 39 and 41 weeks. Model 2 included the fetal maturity at delivery in addition to the fetal and maternal parameters included in Model 1. Model 3 included the additional pathological factor of smoking status in addition to the fetal and maternal parameters included in Model 2. The coefficients obtained in Models 2 and 3 were derived from all cases within the dataset.

A double cross-validation scheme was employed to validate the statistical models obtained. The dataset was randomly assigned into one of two sample groups, A or B. Individual models were developed for each group and their reproducibility was assessed by their ability to predict the birth weight in the other group. Cross-validation correlation and shrinkage statistics were calculated to assess the reproducibility[20]. The final models were established using all of the available data if the absolute shrinkage was below the accepted level of 0.1[20].

Comparison of Model 2 and proportionality growth formula

The final Model 2 was used to calculate the predicted birth weights (W_g) for gestational ages between 259 and 287 days. These were converted into a percentage of the predicted weight at 280 days (W_{280}): % weight $= 100 \times W_g/W_{280}$. The modified proportionality growth formula (% weight $= 298.8 - 31.85 \times$ gestational age $+ 1.094 \times$ gestational age$^2 - 0.01055 \times$ gestational age^3) proposed by Gardosi *et al.* was used to estimate the predicted birth weight for the same gestational period[1,2].

Statistical analysis

All data used in the analysis were taken from a pseudoanonymized dataset from which all patient identifiers had been removed. All analysis was performed on this non-attributable dataset.

SPSS for Windows version 14.0 (SPSS Inc., Chicago, Illinois, USA) was used for statistical analysis of all data. The demographic characteristics of those allocated to Groups A and B for initial modeling and cross-validation were compared using Student's *t*-test for continuous variables and Chi-square test for categorical measures. Paired *t*-test was used to compare the differences in the proportion of predicted weight using the proportionality growth formula and that estimated using Model 2. $P \leq 0.05$ was considered statistically significant.

RESULTS

In total 42 583 pregnancies fulfilled the selection criteria, including 73.6% European, 21.4% Afro-Caribbean (mainly from the West Indies), 3.7% Asian (Indians, Pakistani and Bangladeshi) and 1.3% Oriental (Chinese, Japanese, Korean). The maternal and pregnancy outcome characteristics are summarized in Table 1. There were no statistically significant differences with regard to the factors under study between those randomized to Groups A or B. The proportions of mothers who delivered at 37, 38, 39, 40, 41 and 42 completed weeks of gestation were 6.9%, 17.7%, 25.6%, 28.2%, 19.9% and 1.6% respectively.

The results of the double cross-validation modeling scheme are summarized in Table 2. The multiple correlation coefficients (R) ranged from 0.35 to 0.52 for models derived from cases in the Group A dataset and from 0.36 to 0.53 for models derived from cases in the Group B dataset. The inclusion of the gestational and smoking status factors in Models 2 and 3 resulted in an enhanced model, reflected by the increase in the multiple correlation coefficients. No shrinkage was observed when

Table 1 Summary of maternal and pregnancy outcome characteristics in each of the two sample Groups A and B

Characteristic	*Group A* (n = 21 292)	*Group B* (n = 21 291)	P
Age at EDD (years)	33.4 ± 5.7	33.4 ± 5.7	0.61
Height (cm)	164.8 ± 6.8	164.7 ± 6.8	0.50
Weight (kg)	66.8 ± 13.2	66.8 ± 13.2	0.98
Parity			0.22
0	8507 (40.0)	8587 (40.3)	
1	6332 (29.7)	6356 (29.9)	
2	4495 (21.1)	4449 (20.9)	
3	1315 (6.2)	1216 (5.7)	
≥ 4	643 (3.0)	683 (3.2)	
Ethnicity			0.16
European	15 645 (73.5)	15 691 (73.7)	
Afro-Caribbean (African/West Indian)	4560 (21.4)	4551 (21.4)	
Asian (Indian, Pakistani, Bangladeshi)	824 (3.9)	753 (3.5)	
Oriental (Chinese, Japanese)	263 (1.2)	296 (1.4)	
Smoking history			0.25
Non-smoker	18 046 (84.8)	17 969 (84.4)	
Stopped smoking before pregnancy	1533 (7.2)	1624 (7.6)	
≤ 5 cigarettes/day	953 (4.5)	924 (4.3)	
6–10 cigarettes/day	478 (2.2)	514 (2.4)	
≥ 11 cigarettes/day	282 (1.3)	260 (1.2)	
Sex of baby			0.42
Male	10 947 (51.4)	10 973 (51.5)	
Female	10 345 (48.6)	10 318 (48.5)	
Birth weight (g)	3440 ± 489	3440 ± 481	0.95
Gestational age at delivery (days)	278.9 ± 8.5	278.9 ± 8.5	0.94

Values are mean ± SD or *n* (%). EDD, estimated date of delivery.

Table 2 Comparison of performance of the models derived from each of the datasets on the alternative dataset

			Cross-prediction performance			
	Model correlation coefficient (R)		*Model derived from Dataset B on Dataset A*		*Model derived from Dataset A on Dataset B*	
Model number	*Group A dataset*	*Group B dataset*	*Shrinkage*	*Birth weight difference**	*Shrinkage*	*Birth weight difference**
1	0.350	0.364	0.033	1.03 ± 458	0.024	0.30 ± 450
2	0.505	0.517	0.021	0.36 ± 422	0.019	−0.83 ± 412
3	0.517	0.529	0.002	0.40 ± 419	0.002	−0.83 ± 409

Shrinkage was assessed as the difference in correlation coefficients. *Mean ± SD difference between the actual birth weight and that predicted by the relevant model.

the models derived from Group A dataset were applied to the Group B dataset. Similarly, there was no shrinkage when models derived from Group B dataset were applied to the Group A dataset. The mean and SD of the difference between the predicted and actual birth weights decreased as the additional independent factors of gestational age and smoking were included in Models 2 and 3.

The coefficients obtained for the final models using the complete set of data are presented in Table 3. The multiple correlation coefficients for Models 1, 2 and 3 were 0.356, 0.506 and 0.523, respectively. The mean ± SD difference between the predicted (customized birth weight) and actual birth weight for Models 1, 2 and 3 were −0.6 ± 454 g, −0.4 ± 417 g and 0 ± 414 g, respectively.

Comparison of the predicted birth weight using Model 2 and the proportionality growth formula for the gestational range 259–287 days is shown in Figure 1. There was a significant difference between the estimated birth weight proportion using the proportionality growth formula and that estimated using a regression model including gestational age at delivery in addition to the fetal and maternal parameters (mean ± SD paired difference 0.44 ± 0.88; $t = 2.54$, $P < 0.001$).

DISCUSSION

The findings of this study confirm the strong association between birth weight and both maternal and fetal factors[1–14]. In our models gestational age, maternal height, weight, parity, ethnicity and the baby's gender all had significant influence on the birth weight. In addition, the results from the cross-validation procedure

Table 3 Final model coefficients for customized birth weight for Models 1–3

	Model 1			*Model 2*			*Model 3*		
	Coefficient (g)	*SE*	P	*Coefficient (g)*	*SE*	P	*Coefficient (g)*	*SE*	P
Constant	3529.729	4.901	< 0.001	3546.177	4.982	< 0.001	3558.162	5.005	< 0.001
Parity									
1	98.614	5.431	< 0.001	121.578	5.014	< 0.001	123.464	4.984	< 0.001
2	76.018	6.035	< 0.001	100.567	5.564	< 0.001	112.892	5.538	< 0.001
3	101.375	9.931	< 0.001	134.777	9.148	< 0.001	157.022	9.121	< 0.001
≥ 4	116.954	13.338	< 0.001	143.752	12.279	< 0.001	179.819	12.275	< 0.001
Ethnicity									
Afro-Caribbean	−185.639	6.046	< 0.001	−151.642	5.579	< 0.001	−169.844	5.582	< 0.001
Asian	−168.482	12.005	< 0.001	−125.581	11.060	< 0.001	−148.017	11.005	< 0.001
Oriental	−21.009	19.601	0.284	6.119	18.043	0.735	−8.431	17.904	0.638
Maternal height (Ht − 164.77) cm*									
Linear	8.813	0.358	< 0.001	7.846	0.330	< 0.001	7.575	0.327	< 0.001
Maternal weight (Wt − 66.79) kg*									
Linear	8.127	0.233	< 0.001	7.822	0.215	< 0.001	7.967	0.213	< 0.001
Quadratic	−0.156	0.013	< 0.001	−0.125	0.012	< 0.001	−0.118	0.012	< 0.001
Cubic	0.001	0.000	< 0.001	0.001	0.000	< 0.001	0.001	0.000	< 0.001
Maternal age (Age − 33.41) years*									
Linear	1.518	0.455	< 0.001	3.430	0.419	< 0.001	1.512	0.424	0.001
Quadratic	−0.259	0.052	< 0.001	−0.171	0.048	0.001	−0.061	0.048	0.204
Sex									
Female	−136.45	4.396	< 0.001	−142.667	4.047	< 0.001	−142.735	4.013	< 0.001
Gestation (GA − 280) days*									
Linear				18.284	0.460	< 0.001	18.199	0.457	< 0.001
Quadratic				−0.287	0.034	< 0.001	−0.279	0.034	< 0.001
Cubic				0.008	0.003	0.004	0.008	0.003	0.003
Smoking									
Stopped smoking							−32.785	7.832	< 0.001
≤ 5 cigarettes/day							−143.996	10.256	< 0.001
6–10 cigarettes/day							−235.722	13.521	< 0.001
> 10 cigarettes/day							−302.033	18.168	< 0.001

*Parameter centered on population mean. GA, gestational age; Ht, height; SE, standard error; Wt, weight.

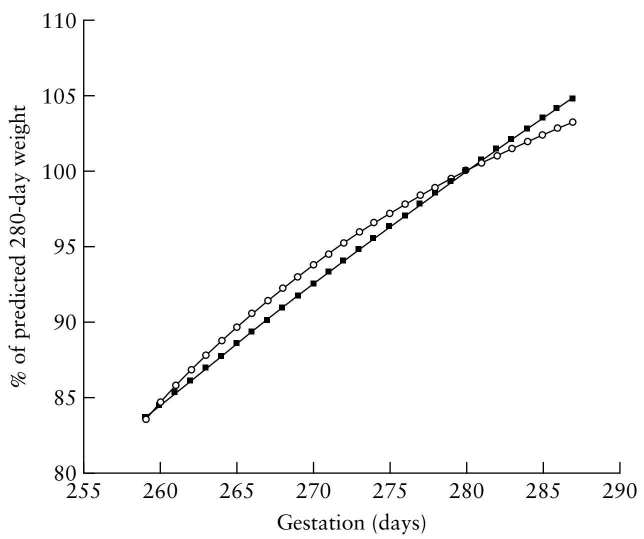

Figure 1 Comparison of 280-day weight estimated using the proportionality growth formula (■) and that obtained using Model 2 (○). Comparison was done for a nulliparous Caucasian whose age at estimated date of delivery, body mass index and height were assumed to be equivalent to those of the study population means.

showed that the shrinkage was well below the accepted level of 0.1 and that the mean difference between the predicted and actual birth weight decreased as additional factors were included. These results suggest that the relationship between the predicting factors and birth weight is reliable and that the models are reproducible. In common with other studies we observed that the coefficients for smoking, self-reported at the first antenatal visit, demonstrated a dose-dependent reduction in birth weight[1,21].

The common characteristics of the available regression models used in published studies are summarized in Table 4[2,4,10,22,23]. There are several similarities between the population in this study and those used elsewhere. Our population mean height and weight were similar to those of the previous studies (range of mean values, 163–167 cm and 63–69 kg, for height and weight, respectively). In our study the predicted birth weight of a male infant born at 280 days to a non-smoking 33-year-old European woman in her first pregnancy, and of average height (164.77 cm) and weight (66.79 kg) for our study population, would be 3530 g. The predicted birth weights using the models summarized in Table 4 for the same individual were 3541 g (Nottingham), 3623.2 g (Sweden), 3569 g (New Zealand) and 3651 g (Brisbane). The predicted birth weight using our model is therefore within 3% of the maximum estimated birth weight of the other reported models. In this respect,

Table 4 Summary of weight correction factors for common aspects of the developed multiple regression models

	Nottingham (UK) model[2]	*Swedish model*[22]	*New Zealand model*[10,23]	*Brisbane (Australia) model*[4]
Constant	3455.6	3544.5	3530	3576
Parity				
1	101.9	147.1	101.6	55
2	133.7	197.3	101.8	86
3	140.2	215.9	123.3	80
≥ 4	162.7	232.6	174.5	
Sex				
Male	48.9	64.4	57.7	66
Female	−48.9	−64.4	−57.7	−66
Height adjustment	$6.7\Delta h$ where $\Delta h = \text{Ht} - 163$	$\Delta h\ (8.316 - 0.004\Delta h^2)$ where $\Delta h = \text{Ht} - 167$	$9.55\Delta h$ where $\Delta h = \text{Ht} - 165$	$13.2\Delta h$ where $\Delta h = \text{Ht} - 165$
Weight adjustment	$9.1733\Delta w - 0.151\Delta w^2 - 0.001\Delta w^3$ where $\Delta w = \text{Wt} - 64$	$8.872\Delta w - 0.0548\Delta w^2 + 0.00006\Delta w^3$ where $\Delta w = \text{Wt} - 63$	$7.134\Delta w - 0.1028\Delta w^2 + 0.0007\Delta w^3$ where $\Delta w = \text{Wt} - 69$	$20.8\Delta \text{BMI} - 1.31\Delta \text{BMI}^2 + 0.0276\Delta \text{BMI}^3$ where $\Delta \text{BMI} = \text{BMI} - 24$
Ethnic adjustment				
Indian	−149.4	−150.5	−149.5	−28
Pakistani	−187.3	−212.4		−28
Bangladeshi	−79.3	−218.5		−28
Chinese	−0.3		100.9	−28

The constant represents mean term expected fetal weight for a non-smoking nulliparous woman who is of average height and booking weight within the population under study. BMI, body mass index; Ht, height; Wt, weight.

our data provide supportive evidence in favor of the suggestion that customized fetal growth charts could move towards becoming an international standard[24]. In this way, limitations within individual studies owing to small numbers of subjects of the same ethnicity could be overcome, allowing a more accurate estimation.

The multiple regression correlation coefficients for our models ranged from 0.35 to 0.53. Consequently, the maternal and fetal factors we have examined could explain from 12% to 27% of the overall variance in birth weight of our term deliveries. It is possible that the inclusion of additional factors, such as social status and first vs. subsequent generation could provide further improvement of the models[25]. However, data from two recent studies indicate that inclusion of intergeneration differences may not add significantly to the predictive ability of the overall models. Among women of South Asian or Afro-Caribbean origin living in the UK there were no significant differences in mean birth weight of infants of mothers who were themselves born in the UK and mothers of the same ethnic origin who were born overseas[26,27]. Furthermore, there was no observable trend over time to increased average birth weight in either first- or second-generation babies, and it is therefore likely that any generational effect on birth weight has already been accounted for by adjustments in maternal size[27].

No additional lifestyle-related or sociodemographic determinants of birth weight other than maternal ethnicity, anthropometry and smoking habits were included in our models. Significant additional determinants of birth weight reported in the literature include maternal age, education level, marital status, alcohol consumption and paternal height[28–31]. However, the effects of these additional determinants on birth weight may only be marginal compared with the impact of maternal ethnicity and anthropometry[32].

The estimated birth weight using the proportionality growth formula approach was significantly different from the one derived from a model in which gestational age at delivery was included as an independent factor. Furthermore, the direction of the difference changed after 280 days. However, the difference between the two approaches, as a percentage of the predicted weight at 280 days, was always less than 3% (Figure 1) and it is therefore unlikely to be clinically significant. We have derived models to determine customized or predicted birth weight in a UK population that are both robust and reproducible, and could be used in further investigations.

REFERENCES

1. Gardosi J, Mongelli M, Wilcox M, Chang A. An adjustable fetal weight standard. *Ultrasound Obstet Gynecol* 1995; **6**: 168–174.
2. Gardosi J, Mongelli M, Wilcox M, Chang A, Sahota D, Francis A, McCowan L, Stewart AW. Gestation related optimal weight (GROW) program. Software version 7.2, 2004; Perinatal Institute. http://www.gestation.net [Accessed 4 September 2006].
3. Keeping JD, Chang A, Morrison J. Birth weight: analysis of variance and the linear additive model. *Br J Obstet Gynaecol* 1979; **86**: 342–347.
4. Pain S, Chang AMZ, Flenady V, Chan FY. Customised birth weight: coefficients for an Australian population and valdation of the model. *Aust N Z J Obstet Gynaecol* 2006; **46**: 388–394.
5. Rogers MS, Wong FW, Chang AM. Determinants of birth-weight in the new territories of Hong Kong. *Aust N Z J Obstet Gynaecol* 1987; **27**: 314–319.
6. Pang MW, Leung TN, Sahota DS, Lau TK, Chang AMZ. Development of a customised birth weight standard for ethnic Chinese subjects. *Aust N Z J Obstet Gynaecol* 2002; **40**: 161–164.

7. Mathai M, Jacob S, Karthikeyan NG. Birth weight standards for south Indian babies. *Indian Pediatr* 1996; **33**: 203–209.
8. Shahi V, Tandon J. A study of maternal determinants and foetal weight. *Indian J Matern Child Health* 1999; **10**: 13–15.
9. de Jong CL, Gardosi J, Dekker GA, Colenbrander GJ, van Geijn HP. Application of a customised birth weight standard in the assessment of perinatal outcome in a high risk population. *Br J Obstet Gynaecol* 1998; **105**: 531–535.
10. McCowan L, Stewart AW, Francis A, Gardosi J. A customised birth weight centile calculator developed for a New Zealand population. *Aust N Z J Obstet Gynaecol* 2004; **44**: 428–431.
11. Clausson B, Gardosi J, Francis A, Cnattingius S. Perinatal outcome in SGA births defined by customised versus population-based birth weight standards. *BJOG* 2001; **108**: 830–834.
12. Gardosi J, Chang A, Kalyan B, Sahota D, Symonds EM. Customised antenatal growth charts. *Lancet* 1992; **339**: 283–287.
13. Wilcox M, Gardosi J, Mongelli M, Ray C, Johnson I. Birth weight from pregnancies dated by ultrasonography in a multicultural British population. *BMJ* 1993; **307**: 588–591.
14. Spencer J, Chang TC, Robson SC, Gallivan S. Fetal size and growth in Bangladeshi pregnancies. *Ultrasound Obstet Gynecol* 1995; **5**: 313–317.
15. Sanderson DA, Wilcom MA, Johnson IR. The individualised birth weight ratio: a new method of identifying intrauterine growth retardation. *Br J Obstet Gynaecol* 1994; **101**: 310–314.
16. Royal College of Obstetricians and Gynaecologists (RCOG). Guideline number 31: the investigation and management of small-for-gestational-age fetus. RCOG Press: London, 2002.
17. Robinson HP, Fleming JE. A critical evaluation of sonor crown–rump length measurements. *Br J Obstet Gynaecol* 1975; **82**: 702–710.
18. Snidjers RJ, Nicolaides KH. Fetal biometry at 14–40 weeks' gestation. *Ultrasound Obstet Gynecol* 1994; **4**: 34–48.
19. Pedhazur E. *Multiple Regression in Behavioural Research: Explanation and Prediction* (3rd edn). Harcourt Brace College Publishers: Fort Worth, TX, 1997.
20. Kleinbaum D, Kupper L, Muller K. *Applied Regression Analysis and Other Multivariate Methods* (2nd edn). PWS-Kent Publishing: Boston, MA, 1988.
21. Rush D, Cassano P. Relationship of cigarette smoking and social class to birth weight and perinatal mortality among all births in Britain. *J Epidemiol Community Health* 1983; **37**: 249–255.
22. GROW Swedish Version. Software version 5.15.8, 2006; Perinatal Institute. http://www.gestation.net [Accessed 4 September 2006].
23. GROW New Zealand Version. Software version 7.21, 2006; Perinatal Institute. http://www.gestation.net [Accessed 4 September 2006].
24. Gardosi J. Fetal growth: towards an international standard. *Ultrasound Obstet Gynecol* 2005; **26**: 112–114.
25. Dhawan S. Birth weights of infants of first generation Asian women in Britain compared with second generation Asian women. *BMJ* 1995; **311**: 876.
26. Margetts BM, Mohd Yusof S, Al Dallal Z, Jackson AA. Persistence of lower birth weight in second generation South Asian babies born in the United Kingdom. *J Epidemiol Community Health* 2002; **56**: 684–687.
27. Harding S, Rosato MG, Cruickshank JK. Lack of change in birthweights of infants by generational status among Indian, Pakistani, Bangladeshi, Black Caribbean, and Black African mothers in a British cohort study. *Int J Epidemiol* 2004; **33**: 1279–1285.
28. Raatikainnen K, Heiskanen N, Heinonen S. Marriage still protects pregnancy. *BJOG* 2005; **112**: 1411–1416.
29. Fraser AM, Brockert JE, Ward RH. Association of young maternal age with adverse reproductive outcomes. *N Engl J Med* 1995; **332**: 1113–1117.
30. Millar WJ, Chen J. Maternal education and risk factors for small-for-gestational-age births. *Health Rep* 1998; **10**: 43–51.
31. Abel EH, Hannigan JH. A J-shaped relationship between drinking during pregnancy and birthweight: a reanalysis of prospective epidemiological data. *Alcohol Alcohol* 1995; **30**: 345–555.
32. Troe EJ, Raat H, Jaddoe VW, Hofman A, Looman CW, Moll HA, Steegers EA, Verhulst FC, Witteman JC, Mackenbach JP. Explaining differences in birthweight between ethnic populations. The Generation R Study. *BJOG* 2007; **114**: 1557–1565.

