Original Article

Maltese national birth weight for gestational age centile values

Valerie Zammit, Patrick Zammit, Charles Savona-Ventura, Anton Buhagiar, Victor Grech

Abstract

The relevance of using literature derived birth weight for gestational age centile charts for the Maltese population is debatable. The study set out to develop national weight for gestational age centile charts and compare these to other populations.

Method: Anonymised birth weight for gestational age data with relevant maternal and neonatal observations over the period 1995-2009 were obtained from national statistics. The formats were standardised and imported into an SQL database that enabled filtration for single live births and grouping by sex. The data was scrutinized manually for obvious keying errors. The best estimate of gestational age from the last menstrual period (LMP) and expected date of delivery (EDD) was selected using established guidelines. A Box-Cox gamma transform was used to fit the model and generate separate centile charts. The data was compared to previous birth weight data reported in Maltese newborns in previous decades and to data from other countries.

Results: A total of 58,899 neonates were included in the study and birth weight for gestational age centile charts were generated between 23 and 42 weeks of gestation using Revolution R with VGAM. There has been a statistically significant gradual fall in mean birth weight in Maltese newborns over the last four decades. There are also statistically significant differences between the Maltese data and those from other countries.

Conclusion: The observed differences make the use of national birth weight for gestational age centile charts desirable both for routine clinical assessment and epidemiological studies.

Keywords

Birth weight; gestational age; infant newborn; growth charts; population

Valerie Zammit* MRCP(Paeds), DCH
Department of Paediatrics, Mater Dei Hospital, Malta
Email: zammit.valerie@gmail.com

Patrick Zammit FEBU, MSc(Urol)
Urology Unit, Department of Surgery, Mater Dei Hospital, Malta

Charles Savona-Ventura DScMed, FRCOG
Department of Obstetrics and Gynaecology, University of Malta Medical School, Malta

Anton Buhagiar MSc, PhD
Department of Mathematics, University of Malta, Malta

Victor Grech PhD, FRCPCH
Department of Paediatrics, Mater Dei Hospital, Malta

** corresponding author*

Introduction

The appropriate classification of neonates according to birth weight in relation to gestational age is of clinical importance in predicting perinatal outcomes and in the identification of infants at risk needing closer monitoring.[1] Simply categorising infants as low birth weight or very low birth weight is not adequate as gestational duration also has a significant impact on perinatal outcome.[2,3,4] Centile charts and correct assignment to gestational age are also relevant in epidemiological studies.[5]

In 2008 the Maltese Islands were reported to have a population amounting to 395,472 individuals. The number of live annual births ranged from 4613 in 1995 to 3721 in2008.[6] The genetic makeup of the population has been described as being typically Mediterranean, primarily Levantine with Greco-Roman, Arabic, Italian, Spanish, French and Anglo-Saxon influences reflecting the varied history of the islands with various successive colonisations.[7]

The aim of this study was to develop birth weight for gestational age centile charts specific to the Maltese population. The charts obtained were compared to other population studies to evaluate differences and trends.

Method

Anonymised birth weight for gestational age data with relevant maternal and neonatal observations were obtained from computerised records kept by the National Department of Health Information and Research of Malta – The National Obstetrics Information System (NOIS). The data is contained in two data sets: one for 1995-1998 which includes all deliveries occurring in the national hospital accounting for 86.9% of all deliveries, and one for the period 1999-2009 which includes all the births occurring in the Maltese Islands. A further data set for births occurring in the national hospital during 1981 was studied to enable secular comparisons. The database had been initiated in conjunction with the International Fertility Research Programme (IFRP). The latter dataset included a total of 4619 maternities accounting for 87.3% of all deliveries occurring in the Maltese Islands during that year. The IFRP data is summarised in Table 1. A literature review was also carried out to identify relevant national and international studies.

The 1995-2009 NOIS database was standardised and subjected to structured query language (SQL) filtration to identify singleton live births and group these by gender. Unrecoverable errors such as absent birth weight or unspecified gender were excluded from the data set. SQL was used to query the observations for range and consistency, and highlight potential capturing errors for manual scrutiny and recovery.

The gestational age at delivery was calculated for each infant using two methods. The data set included both the date of the first day of the last menstrual period (LMP) and the expected date of delivery (EDD) together with the date of birth (DOB). Two gestational ages were calculated for each birth: the first – the LMP-derived gestational age – was obtained by subtracting the LMP from the DOB; the second – EDD-derived gestational age – was obtained by subtracting 280 from the EDD then subtracting this from the DOB.

The birth weight data was divided into 100g bins and for each bin a mean and standard deviation of the weight for the two separate gestational ages was calculated. A z-score for each observation was calculated as a ratio of the difference between the calculated gestational age and the mean gestation for the relevant 100g bin to the standard deviation of the gestation for the relevant 100 g bin. The gestational estimate with the lowest squared z-score for each individual was selected.

Bivariate quantile regression was performed by maximum likelihood fitting of a Box-Cox (lms) power transform model.

Table 1: *International fertility research programme (Malta data) 1981*

Gestation range (weeks)	***Mean birth weight (g)***	***Standard deviation (g)***	***n***
24-27	1075	412	6
28-31	1703	861	19
32-35	2001	731	42
36-37	3006	528	191
38-39	3301	469	1698
40-41	3455	463	2514
42	3514	450	76
43+	3654	1364	12
Overall	**3356**	**525**	**4558**

Table 2: *Boy birth weight in grams at specified centiles – Malta 1995-2009*

	0.4%	***2%***	***9%***	***25%***	***50%***	***75%***	***91%***	***98%***	***99.6%***
23	216	267	334	401	472	545	619	700	768
24	271	339	429	518	614	712	812	921	1013
25	322	408	521	635	757	883	1011	1150	1268
26	369	473	612	753	903	1060	1218	1391	1538
27	413	537	704	874	1056	1246	1439	1649	1826
28	457	603	800	1001	1218	1445	1674	1924	2136
29	507	674	902	1137	1390	1655	1923	2215	2463
30	567	757	1016	1284	1572	1874	2180	2513	2796
31	647	859	1148	1444	1764	2098	2436	2805	3118
32	757	990	1302	1621	1964	2321	2683	3078	3412
33	905	1153	1482	1815	2171	2540	2914	3321	3666
34	1090	1349	1686	2023	2381	2751	3125	3532	3877
35	1309	1572	1908	2240	2590	2951	3315	3711	4046
36	1552	1812	2138	2458	2793	3137	3484	3860	4179
37	1808	2058	2369	2671	2986	3307	3631	3982	4280
38	2053	2291	2584	2866	3159	3458	3758	4083	4358
39	2250	2478	2759	3029	3308	3592	3877	4186	4447
40	2378	2606	2886	3154	3431	3713	3995	4301	4560
41	2451	2684	2969	3243	3525	3812	4100	4411	4675
42	2502	2741	3033	3314	3603	3898	4193	4513	4784

LMS here stands for lambda, mu and sigma coefficients rather than least mean squares. The gamma transform takes log(sigma) to change the distribution to normality.[8,9] The fitted Box-Cox gamma model was used to generate centile charts. The R package Vector Generalized Linear and Additive Models(VGAM) library was used.[10]

Convergence of the mathematical model above was achieved by sequentially excluding outliers identified off a scatter plot. Outlier elimination amounted to 16 boys (0.05%) and 7 girls (0.03%).

Results

During the period 1st January 1995 to 31st December 2009, the Maltese National Obstetric Information System register recorded a total of 61,063 births of whom 60,742 were live births (99.5%).The number of live, singleton, gender-identified births born at a gestational age of 23 to 42 weeks was 58,899 (97% of live births). Of these 30159 were boys and 27922 were girls.

Birth weights for male infants exceeded those of female infants at all gestations. At 40 weeks of gestation (± 0.5), there was a statistically significant difference (p<0.001) of 125g (95% CI 113 to 136g) between the sexes. Percentile tables and charts for the 0.4th, 2nd,9th, 25th, 50th, 75th, 91st, 98th and 99.6th centiles for male and female infants were generated from the fitted models between 23 and 42 weeks gestation (Table 2, Table 3, Figure 1, Figure 2). Charts designed for clinical use may be downloaded from the online appendix to article at http://www.mmj-web.org

There appears to be a decreasing trend in the mean birth weights of infants born over the past sixty years. A statistically significant difference can be observed between the 2009 mean birth weight (3211±516g) and the mean birth weight in the Maltese population in 1995 (3235±536g p=0.034), 1981 (3356±525g, p<0.001) and 1965 (3338±469 p<0.001) suggesting that a gradual

***Table 3:** Girl birth weight in grams at specified centiles – Malta 1995-2009*

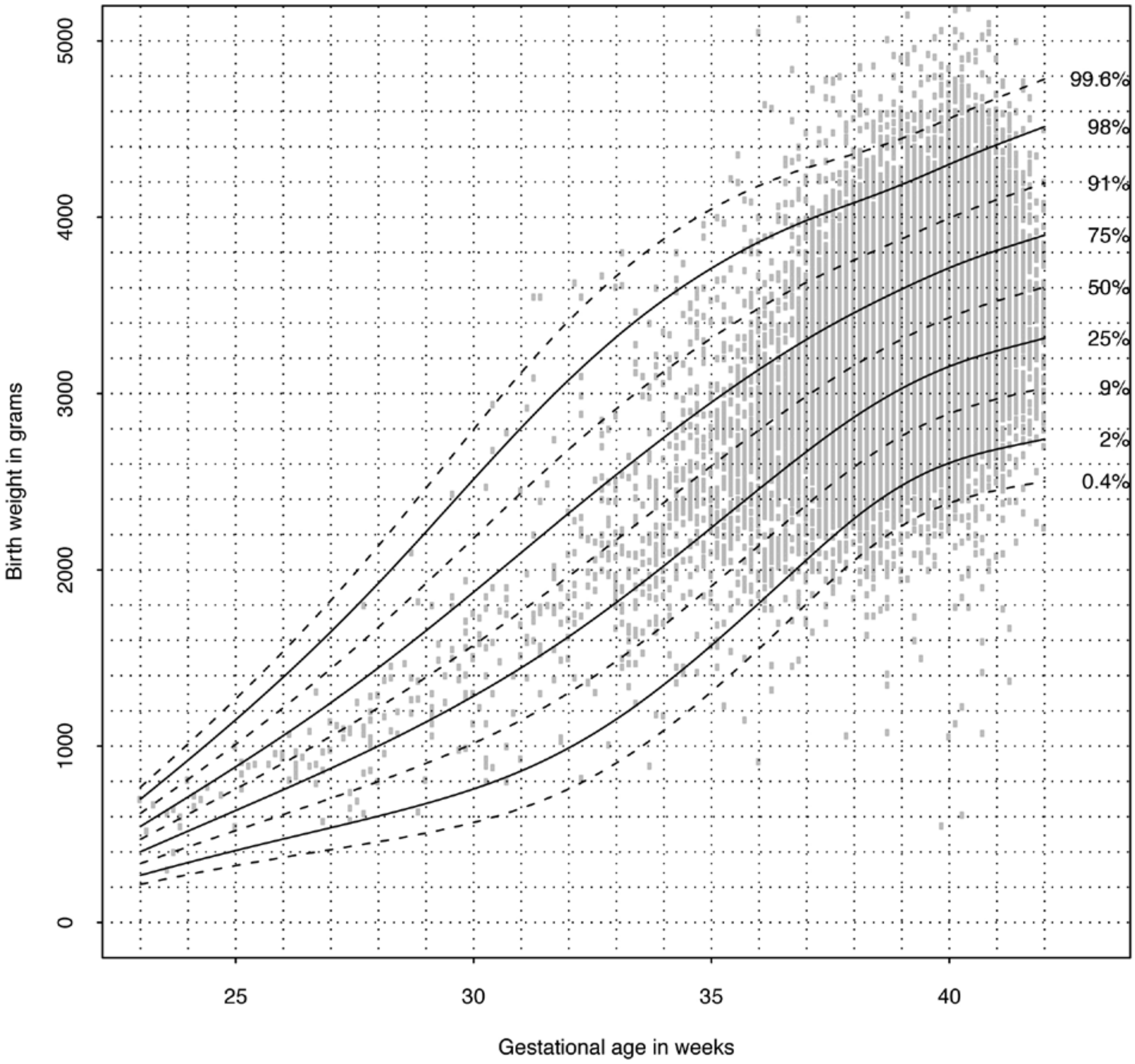
	0.4%	2%	9%	25%	50%	75%	91%	98%	99.6%
23	197	241	298	358	424	494	568	652	726
24	252	312	391	473	564	663	766	883	986
25	302	377	479	586	704	832	968	1121	1257
26	346	438	564	697	844	1005	1175	1368	1538
27	388	498	649	809	988	1183	1390	1626	1835
28	433	561	738	927	1139	1370	1617	1898	2146
29	484	631	835	1053	1299	1568	1854	2181	2470
30	548	714	946	1193	1471	1775	2099	2468	2795
31	632	818	1074	1348	1654	1989	2345	2751	3109
32	743	947	1226	1520	1849	2206	2585	3016	3396
33	887	1106	1402	1710	2052	2422	2812	3255	3645
34	1067	1296	1601	1915	2260	2630	3019	3459	3846
35	1281	1515	1820	2131	2468	2828	3203	3625	3995
36	1521	1753	2051	2349	2671	3011	3363	3758	4102
37	1771	1995	2279	2561	2862	3177	3502	3865	4180
38	2011	2224	2492	2755	3033	3324	3621	3952	4238
39	2208	2412	2668	2917	3180	3454	3733	4041	4308
40	2337	2541	2794	3041	3301	3570	3845	4148	4410
41	2415	2621	2879	3129	3392	3665	3943	4250	4514
42	2473	2684	2946	3201	3469	3747	4030	4343	4613

***Table 4:** Comparison of mean birth weight suggesting a deceasing trend in birth weight*

	Year	n series	% of total births	SD	Mean BW (g)	p*
Agius[17]	1951-59	4103	5%	na	3380	
Cremona[18]	1965	2517	44%	469	3338	<0.001
IFRP	1981	4558	87%	525	3356	<0.001
NOIS	1995	4451	87%	536	3254	0.034
NOIS	2009	4146	100%	516	3252	

*with comparison to 2009 data

Figure 1: *Boys birth weight for gestational age, Malta 1995–2009*



fall in mean BW has occurred in the last forty years (Table 4).

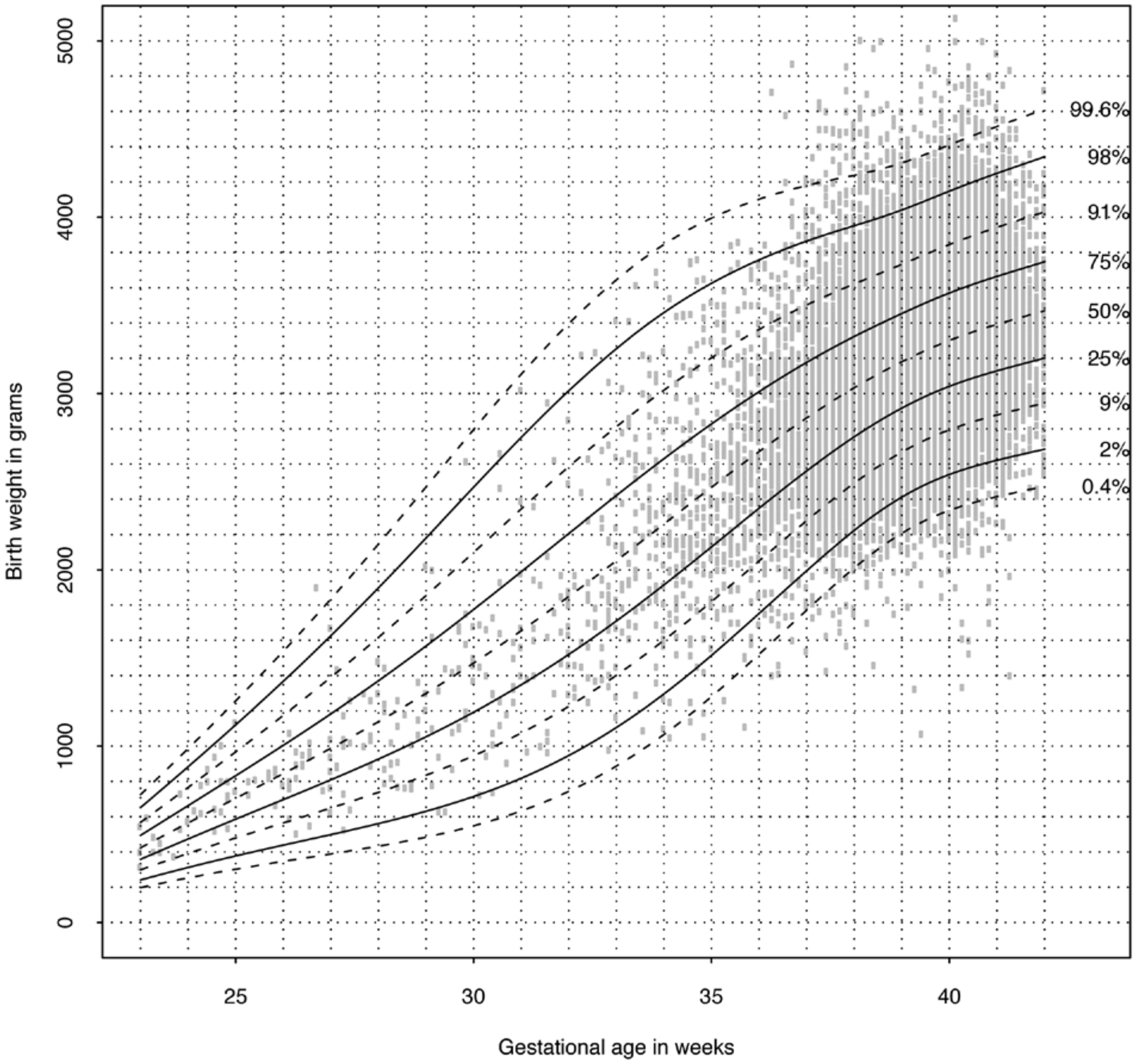
Statistically significant differences can be observed between the Maltese mean birth weight data at 40 weeks gestation and values reported for different populations reported in the literature.[11-16] The closest values were observed for infants born in the United Kingdom and Italy (Table 5).

Discussion

The current practice in Malta is to relate the newborn birth weight for gestational age to centile charts published in 1987 by Yudkin *et al.*[11] These charts were derived from the birth weight by gestation data of infants born at John Radcliff Hospital, Oxford in the United Kingdom between 1978 and 1984. The relevance of these centile charts to the local infant population is debatable. Dedicated and updated national centile charts are preferred tools for the clinical assessments of newborns and epidemiological studies.

The series of studies carried out on Maltese newborns over the last forty years has suggested that there has been a statistically significant gradual decrease in newborn mean birth weights from a mean value of 3338g in 1965 to 3234g in 2009.[17,18] This observation contrasts with the findings of various other authors who, comparing the same population at different decades, have highlighted the increasing trend in birth weight.[12,13] Statistical comparison between these historical data samples and the present population dataset must be cautious since the historical data was not assessed using the same standards and methods as the current study. They also utilised a proportion of the total births rather than a total national population. The factors contributing to the observed decreasing trend in mean birth weights can only be postulated: decreasing parity, increasing maternal age, and better management of gestational diabetes may be relevant. It is clear that further work

Figure 2: *Girls birth weight for gestational age, Malta 1995–2009*



is necessary to investigate this apparent difference.

The accuracy of gestational age is of crucial importance in generating this form of epidemiological study. Different methods have been used to limit errors in this parameter. Most authors look at the distribution of birth weight within gestational age strata and assume a normal distribution within the specific group.[19,20,21] In the present study, the more probable of two gestational estimates derived from LMP and EDD was selected; the latter being more likely to have been corrected by other obstetric observations.[22] Birth weight for gestational age data distribution can be explained as a mixture of populations.[22,23,24] For example, a subpopulation where the mother had a breakthrough bleed would have 4 weeks less apparent gestation. This subpopulation would have the same density distribution as the main population but left-shifted by four weeks. Contamination of the sparser data in the premature tail results in widening and upward shift of the quantile plot. The nature of the present dataset precluded the use of the more usual methods for bivariate outlier detection as they would have caused significant loss of the already sparse premature data. A more selective visual method of identifying outliers directly off a scatter plot was utilised. This resulted in maximum utilisation of our data.

The mean birth weight at 40 weeks of gestation in the present series has been shown to have statistically significant differences with similar birth weight means from population studies from Hong Kong, the United Kingdom, Australia, Canada, Norway and Italy.[11-16] The closest datasets appeared to be those of the United Kingdom and Italy, though these still exhibited statistically significant differences. These observations emphasise the need to use nationally-derived as opposed to international centile charts in clinical practice and epidemiological studies.[25,26]

Table 5: *Comparison of mean birth weight at 40 weeks gestation in different populations*

Males	***Years of data collection***	***p value***	***Difference from Maltese data (g)***	***95%LCI (g)***	***95%UCI (g)***
Hong Kong[12]	1998-2001	<0.001	-81	-55	-107
UK[11]	1978-1984	0.004	-26	-8	-44
Australia[15]	1991-1994	<0.001	114	125	103
Canada[13]	1994-1996	<0.001	142	153	131
Norway[14]	1987-1998	<0.001	229	241	217
Italy*[16]	1991-2002	<0.001	30	36	24
Females	***Years of data collection***	***p value***	***Difference from Maltese data (g)***	***95%LCI (g)***	***95%UCI (g)***
Hong Kong	1998-2001	<0.001	-92	-67	-117
UK	1978-1984	<0.001	-40	-23	-57
Australia	1991-1994	<0.001	93	103	83
Canada	1994-1996	<0.001	116	127	105
Norway	1987-1998	<0.001	205	216	194
Italy*	1991-2002	<0.001	10	16	3.9

**Global means used*

References

1. Gutbrod T, Wolke D, Soehne B, Ohrt B, Riegel K. Effects of gestation and birth weight on the growth and development of very low birthweight small for gestational age infants: a matched group comparison. Arch Dis Child Fetal Neonatal Ed. 2000 May; 82(3):F208-14.
2. Allen MC. Developmental outcome and followup of the small for gestational age infant. Semin Perinatol. 1984 Apr; 8(2):123-56.
3. Wilcox AJ, Russell IT. Birthweight and perinatal mortality: II. On weight-specific mortality. Int J Epidemiol. 1983 Sep; 12(3):319-25.
4. Wilcox AJ, Skjaerven R. Birth weight and perinatal mortality: the effect of gestational age. Am J Public Health. 1992 Mar; 82(3):378-82.
5. Arnold CC, Kramer MS, Hobbs CA, McLean FH, Usher RH. Very low birth weight: a problematic cohort for epidemiologic studies of very small or immature neonates. Am J Epidemiol. 1991 Sep 15; 134(6):604-13.
6. National Statistics Office Malta. Children 2010. 2010 Mar 9, ISBN 9789990973945.
7. Gerada-Azzopardi E, Zuber C. Malta an island republic. Boulogne: Deroisse; 1980.
8. Box GEP, Cox DR. An analysis of transformations. Journal of the Royal Statistics Society 1964; B-26:211-52.
9. Cole TJ, Green PJ. Smoothing reference centile curves: the LMS method and penalized likelihood. Stat Med. 1992 Jul; 11(10):1305-19.
10. Yee TW, Wild CJ. Vector Generalized Additive Models. Journal of the Royal Statistics Society 1996; B-58(3):481-93.
11. Yudkin PL, Aboualfa M, Eyre JA, Redman CW, Wilkinson AR. New birthweight and head circumference centiles for gestational ages 24 to 42 weeks. Early Hum Dev 1987 Jan; 15(1):45-52.
12. Fok TF, So HK, Wong E, Ng PC, Chang A, Lau J, *et al.* Updated gestational age specific birth weight, crown-heel length, and head circumference of Chinese newborns. Arch Dis Child Fetal Neonatal Ed. 2003 May; 88(3):F229-36.
13. Kramer MS, Platt RW, Wen SW, Joseph KS, Allen A, Abrahamowicz M, *et al.* A new and improved population-based Canadian reference for birth weight for gestational age. Pediatrics. 2001 Aug; 108(2):E35.
14. Skjaerven R, Gjessing HK, Bakketeig LS. Birthweight by gestational age in Norway. Acta Obstet Gynecol Scand. 2000 Jun; 79(6):440-9.
15. Blair E. Australian national birthweight percentiles by gestational age. Med J Aust. 1999 Jul; 171(1):53-4.
16. Festini F, Procopio E, Taccetti G, Repetto T, Cioni ML, Campana S, *et al.* Birth weight for gestational age centiles for Italian neonates. J Matern Fetal Neonatal Med. 2004 Jun; 15(6):411-7.
17. Agius EA, Cachia EA, Lenicker HM. Average Birth Weight in Malta. St Luke's Hosp Gazzette 1966; 1(2):77-9.
18. Cremona A, Camilleri AP. The Variability of Birth Weight. St Luke's Hosp Gazzette 1969; 4(2):125-31.
19. Lubchenco LO, Hansman C, Dressler M, Boyd E. Intrauterine Growth As Estimated From Liveborn Birth-Weight Data At 24 To 42 Weeks Of Gestation. Pediatrics. 1963 Nov; 32:793-800.
20. Milner RD, Richards B. An analysis of birth weight by gestational age of infants born in England and Wales, 1967 to 1971. J Obstet Gynaecol Br Commonw. 1974 Dec; 81(12):956-67.
21. Oja H, Koiranen M, Rantakallio P. Fitting mixture models to birth weight data: a case study. Biometrics. 1991 Sep;47(3):883-97.
22. Gjessing HK, Skjaerven R, Wilcox AJ. Errors in gestational age: evidence of bleeding early in pregnancy. Am J Public Health. 1999 Feb; 89(2):213-8.
23. Alexander GR, Himes JH, Kaufman RB, Mor J, Kogan M. A United States national reference for fetal growth. Obstet Gynecol. 1996 Feb; 87(2):163-8.
24. Tentoni S, Astolfi P, De PA, Zonta LA. Birthweight by gestational age in preterm babies according to a Gaussian mixture model. BJOG. 2004 Jan; 111(1):31-7.
25. Dunn PM. A perinatal growth chart for international reference. Acta Paediatr Scand Suppl. 1985; 319:180-7.
26. Wharton BA. Sorrento studies of birthweight. Case for international reference data. Acta Paediatr Scand Suppl. 1985; 319:170-9.