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A birth weight for gestational age standard based on data in the Swedish Medical Birth Registry, 1985–1989

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Abstract. Birth weight curves according to gestational length are presented based on data from more than 480,000 singleton births, registered in the Medical Birth Registry and with gestational age based on ultrasound examinations in the majority of cases. Curves were constructed from the most common weights in each week (modes) for each sex and standard deviations were estimated under the assumption of a fixed coefficient of variation, the size of which was estimated from 40 weeks infants. This methodology makes it possible to construct graphs for specific subgroups of infants: such graphs for boys and girls for primiparous and multiparous women are given in the paper.

Key words: Birth weight, Gestational duration, Growth, Registry

Introduction

There are many growth curves published in the literature showing the normal birth weight of an infant at a specific gestational age. Such graphs have often been based on a limited number of 'normal' pregnancies which makes estimates for short gestational durations uncertain. It has often been pointed out that population differences probably exist why, in the clinical use, the normal curve should be based on data from the relevant population. For the Swedish population, a normal graph has been in use since long, based on 64% of infants registered as 'normal' among 92,348 infants born in Sweden in 1956–57 [1, 2]. In 1991, Niklasson et al. [3] presented a new standard, based on data on what was regarded as 'normal' infants from the whole population 1977–1981, 79% of 475,588 infants. One major draw-back with the material used by Niklasson et al. is that it consists of pregnancies which to a large extent were not dated by modern techniques. Ultrasound techniques were not generally used in Sweden at that time and when used the results were not entered into the register.

Finally, there is a growth curve based on pregnancy length determined by ultrasound but limited to 4,743 infants and without a division according to sex [4].

The birth weight of an infant depends – except for gestational duration – on a large number of different factors. Some are normal biological factors which affect birth weight, typical examples are infant sex, maternal age and parity, maternal and paternal height, maternal weight and weight gain, genetic (racial) factors. In order to estimate the expected weight of an infant at a certain gestational age, such factors should ideally be taken into consideration. There are efforts in the literature to use such correction factors [e.g., 5–7].

There are also pathological factors which affect birth weight, e.g., maternal diseases like toxicosis and diabetes, placental insufficiency, and infant conditions like congenital malformations or hydrops. To this group can also be added the effect of social factors like nutrition, maternal smoking, alcohol and drug usage, etc.

In clinical practice, the problem is usually to decide whether a specific infant has a birth weight which deviates from the expected one: the usual definition is that it should be two standard deviations below (small for gestational age) or above (large for gestational age) the mean at that gestational week. Often, percentiles are used instead of standard deviations. In order to estimate the expected mean birth weight and its standard deviation (or to determine the percentiles) a material is needed consisting on normal pregnancies and normal infants, unaffected by pathological factors of the nature just exemplified. The problem is to get such data, especially for short gestational durations, which necessitates large numbers. A possible way to obtain large numbers is the use of Medical Birth Registries, but on the other hand the identification of 'normal' pregnancies is less certain in that type of data than in smaller hospital series. In order to overcome this problem, a simple methodology is presented which is applicable to large data sets of the type which can be obtained from population registries, even though data precision is not optimum.

Materials and methods

Material. The study is based on the Swedish Medical Birth Registry [8] which has existed since 1973 and contains data on the vast majority of all infants born in Sweden (about 1% missing each year). It makes it possible to study large numbers of births and therefore to get a reasonable number of infants also of short gestational duration. In the Swedish Registry, birth weight and gestational duration were judged to be of fairly good quality [8].

In the registry, gestational duration is estimated for each infant with a hierarchic method. Information exists on the following data: date of last menstrual period (LMP), the expected date of delivery as estimated in early pregnancy (based on clinical examination and LMP), the expected date of delivery corrected after ultrasound examination (corrected expected date of delivery), and the estimated length of pregnancy stated by the delivery hospital. For the majority of infants (91%), the expected date of delivery and/or the corrected expected date of delivery was available. It is not possible to restrict the analysis to infants with a corrected expected date of delivery because in many hospitals, a corrected date is given only when it deviates a week or more from the uncorrected date. Cases corrected with a week or more may represent a biased sample. The study is therefore based on corrected expected dates or – if not given – on expected dates. If information is missing for both dates, the case is not included.

Assumptions. The principle of the analysis is based on a number of assumptions. Within a population there is a large group of infants which are normal – at term they will represent the vast majority while among preterm infants a substantial proportion will be small-for-date, because such infants have a tendency to be born preterm. As long as a majority of infants born in a certain week are regarded as 'normal', their mean weight can be determined as the mode of the birth weight distribution that week. Such modes will really show the typical weight a specific week which really is the 'normal' degree of growth retardation, not necessarily the weight of a normal baby had it been born that week. The next assumption is that the dispersion of the normal infants is proportional to the mean weight and can then best be estimated from the 40 weeks infants, the vast majority of which are normal.

Methods. For each pregnancy week, the mode (the highest frequency) birth weight value (three moving 10g classes) is determined. The magnitude of the coefficient of variation (the standard deviation in percentage of the mean) is estimated from 40 weeks old infants and that coefficient of variation is applied to all other pregnancy weeks. Using these estimates of modes and dispersions, growth curves are constructed for the population or for subgroups of the population (boys/girls, primiparous/multiparous). A third degree regression is fitted to the set of modes, using least squares technique.

Results

Absurd values. Figure 1 shows the birth weight distribution for each pregnancy week as stated in the registry. It is obvious that at low gestational duration, a substantial number of absurd weights exist. These may be due to wrong data on pregnancy length or birth weight. Impossible such values are automatically excluded in the registry, but if the resulting value is possible, it is retained. At long pregnancy duration – more or less term pregnancies – the secondary peaks to the right have disappeared because such values are impossible and have therefore been excluded. The absurd values do not interfere with the determination of the mode each week and therefore not with the actual analysis but they affect studies on birth weight distributions and were therefore excluded, leaving a reduced number of births on which the study was made. Based on the actual birth weight distribution each week, limits for acceptance based on the main distribution and excluding secondary distributions were set up as shown in Table 1. Table 1 also shows the number of boys and girls in each week after such exclusions for parity 1 and parity 2+. Even though the total number of remaining infants is more than 480,000, in weeks 25–27, less than 200 remain of each sex in each week.

Birth weight distribution a specific week. The distribution of the recorded birth weights a specific

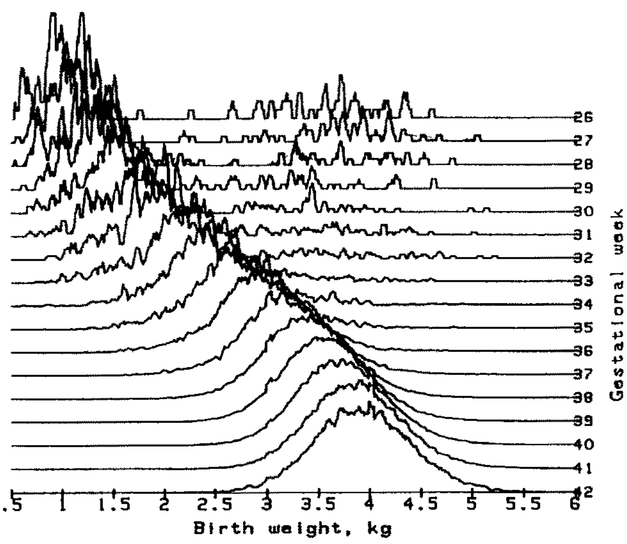

Figure 1. Distribution curves for birth weights at gestational duration 26–42 weeks.

Table 1. Number of infants born at different gestational duration, divided after infant sex and maternal parity. Only singletons. Absurd values excluded – limits for acceptance are stated

Pregnancy week	Boys		Girls		Total	Accepted values
	Parity 1	Parity 2+	Parity 1	Parity 2+		
25	32	45	39	43	159	500–1200
26	69	58	64	82	273	500–1300
27	83	110	78	77	348	600–1400
28	105	96	91	102	394	650–1600
29	132	145	104	110	491	700–1900
30	187	173	149	145	654	700–2300
31	257	245	196	208	906	800–2400
32	363	305	266	278	1212	900–2700
33	568	496	439	439	1942	1100–3200
34	941	796	724	701	3162	1200–3300
35	1647	1538	1239	1230	5654	1400–3400
36	2902	3176	2569	2636	11283	1500–3400
37	5662	7763	5103	6920	25448	1700–3700
38	13450	20616	12827	19586	66479	2200–6000
39	23171	34272	22667	33500	113610	2300–6000
40	27647	39860	27260	38770	133537	2500–6000
41	18649	24278	17564	22566	83057	2500–6000
42	7856	8423	6723	7166	30168	2500–6000
43	1218	986	1034	954	4192	2500–6000
44	267	285	243	318	1113	2500–6000
45	18	27	23	26	94	2500–6000
Total	105224	143693	99402	135867	484176	

gestational week will deviate from a Gaussian distribution. Table 2 shows skewness and kurtosis for boys and girls (irrespective of parity). Below week 38, skewness is negative while at term, skewness is instead positive. As the skewness coefficients are estimated from very large numbers of infants, many will deviate significantly from 0 as shown from the confidence limits.The kurtosis coefficient (equals 3 at a normal distribution) is usually above 3 at short gestational durations and above 3 at term: in the former, the distribution is too broad, in the latter too narrow.

Modes and dispersions. Figure 2 shows for both sexes the growth curves estimated as described above. The graphs are smoothed by three-week moving averages. It can be seen that the mode of the girl weights in each week lies below that of the boys. It can also be seen that the graphs – especially for boys – deflect between weeks 41–42. The dispersion in week 40 was determined for both sexes and was found to be slightly below 12% of the mean birth weight both for boys and girls. A coefficient of variation of 12% was therefore used in estimating the dispersion at other weeks.

Figure 3 divides the growth curves for the boys into parity 1 and parity 2+. Up to week 38, the two graphs follow each other well and then deviate from each other. It can be noted that among infants born in parity 1, no weight decline is seen before week 42, and among infants born in parity 2+, there is no decline but sooner a levelling of the graph. Similar phenomena can be seen for girls in Figure 4.

In spite of the smoothing procedure, the graphs are uneven. They were further smoothed by fitting third

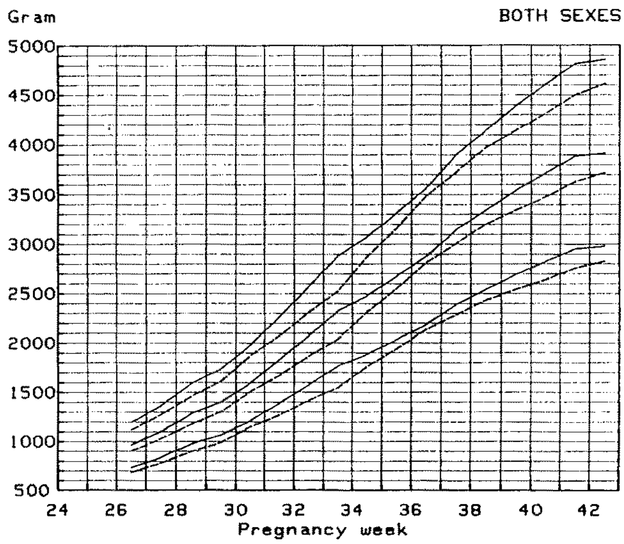

Figure 2. Growth curve based on mode weights in each pregnancy week and double dispersions marked (dispersion = 12% of mode values). Unbroken lines mark boys, dashed lines girls.

Table 2. Coefficients (g) with errors (sg) for skewness and kurtosis in boys and girls (irrespective of maternal parity) at different gestational duration. 95%CL = 95% confidence limits of g. Expected g for skewness at a normal distribution is 0, for kurtosis it is 3

Pregnancy week	Skewness			Kurtosis		
	g	sg	95%CL	g	sg	95%CL
Boys						
25	0.20	0.32	−0.43; 0.83	2.83	0.63	1.60; 4.06
26	−0.41	0.27	−0.94; 0.12	2.62	0.53	1.58; 3.66
27	−0.45	0.21	−0.86; −0.04	2.69	0.42	1.87; 3.51
28	−0.55	0.20	−0.94; −0.16	2.66	0.39	1.90; 3.42
29	−0.29	0.16	−0.60; 0.02	2.55	0.32	1.92; 3.18
30	−0.24	0.14	−0.51; 0.03	3.19	0.28	2.64; 3.74
31	−0.36	0.12	−0.60; −0.12	2.61	0.24	2.14; 3.08
32	−0.39	0.10	−0.59; −0.19	2.76	0.20	2.37; 3.15
33	−0.16	0.08	−0.32; 0.00	3.08	0.16	2.77; 3.40
34	−0.28	0.06	−0.40; −0.16	3.03	0.12	2.79; 3.27
35	−0.49	0.04	−0.57; −0.41	10.92	3.08	2.90; 3.26
36	−0.75	0.03	−0.81; −0.69	3.46	0.07	3.32; 3.60
37	−0.67	0.02	−0.71; −0.63	3.35	0.04	3.27; 3.43
38	0.25	0.01	0.23; 0.27	3.41	0.03	3.35; 3.47
39	0.23	0.01	0.21; 0.25	3.31	0.02	3.27; 3.35
40	0.24	0.01	0.22; 0.26	3.16	0.02	3.12; 3.20
41	0.20	0.01	0.18; 0.22	3.16	0.02	3.12; 3.20
42	0.16	0.02	0.12; 0.20	3.07	0.04	2.99; 3.15
43	0.20	0.05	0.10; 0.30	3.04	0.10	2.84; 3.24
44	0.24	0.10	0.04; 0.44	3.35	0.21	2.94; 3.76
45	0.51	0.36	−0.20; 1.22	4.00	0.71	2.61; 5.39
Girls						
25	0.28	0.31	−0.33; 0.89	2.74	0.61	1.54; 3.94
26	0.18	0.24	−0.29; 0.65	3.08	0.48	2.14; 3.94
27	−0.13	0.23	−0.58; 0.32	2.69	0.46	1.79; 3.59
28	−0.23	0.20	−0.62; 0.16	2.54	0.40	1.76; 3.32
29	−0.19	0.18	−0.54; 0.16	2.29	0.36	1.58; 3.00
30	−0.16	0.16	−0.47; 0.15	2.43	0.31	1.82; 3.04
31	0.03	0.13	−0.22; 0.28	2.82	0.26	2.31; 3.33
32	−0.08	0.11	−0.30; 0.14	2.81	0.22	2.38; 3.24
33	0.16	0.09	−0.02; 0.34	3.03	0.17	2.70; 3.36
34	−0.15	0.07	−0.29; −0.01	2.72	0.13	2.47; 2.97
35	−0.33	0.05	−0.43; −0.23	2.99	0.10	2.79; 3.19
36	−0.60	0.04	−0.68; −0.52	3.16	0.07	3.02; 3.30
37	−0.47	0.02	−0.51; −0.43	3.05	0.05	2.95; 3.15
38	0.37	0.01	0.35; 0.39	3.64	0.03	3.58; 3.70
39	0.29	0.01	0.27; 0.31	3.27	0.02	3.23; 3.31
40	0.33	0.01	0.31; 0.35	3.25	0.02	3.21; 3.29
41	0.24	0.01	0.22; 0.26	3.11	0.02	3.07; 3.15
42	0.21	0.02	0.17; 0.25	3.06	0.04	2.98; 3.14
43	0.24	0.06	0.12; 0.36	2.93	0.11	2.71; 3.15
44	0.12	0.10	−0.07; 0.32	2.61	0.21	2.20; 3.02
45	−0.13	0.35	−0.82; 0.56	2.69	0.69	1.34; 4.04

degree polynomas to the modes, using the least squares technique (Figure 5). The fitted polynomas had the following appearance:

Boys: $y = 11449.78 - 1254.351 \times x + 43.96213 \times x^2 - 0.4359399 \times x^3$

Girls: $y = 27399.31 - 2652.778 \times x + 84.26283 \times x^2 - 0.8216029 \times x^3$

Similar graphs were also prepared for body length and added to the figure.

Discussion

In the literature, nearly all published graphs are based on material which have been weeded for abnormal

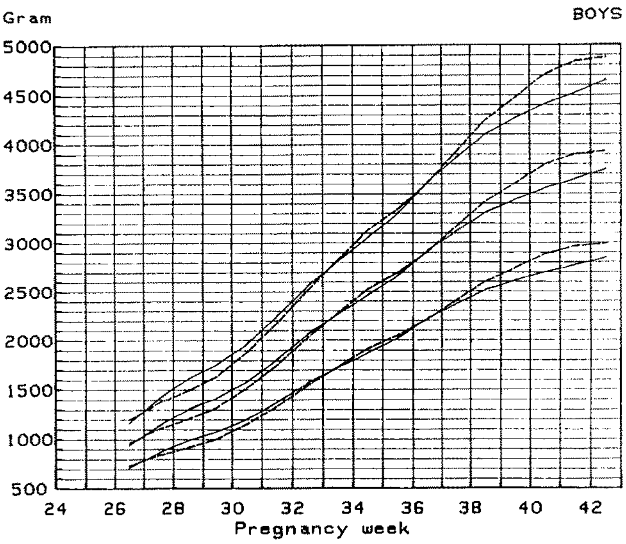

Figure 3. Growth curve for boys based on mode weights in each pregnancy week and double dispersions marked (dispersion = 12% of mode values). Unbroken lines mark parity 1, dashed lines parity 2+.

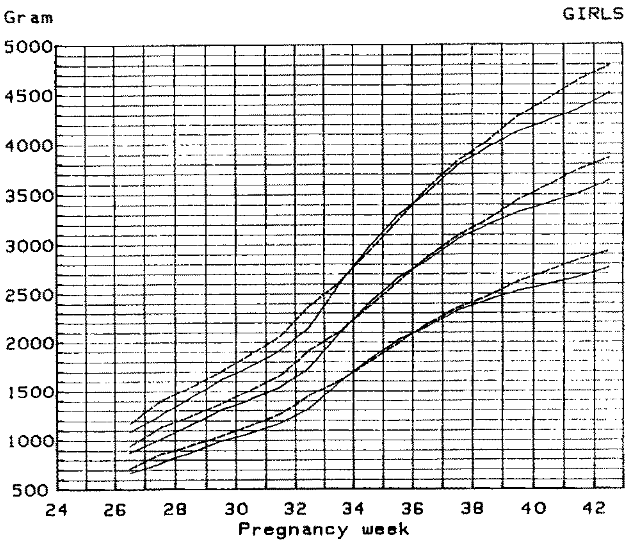

Figure 4. Growth curve for girls based on mode weights in each pregnancy week and double dispersions marked (12% of mode values). Unbroken lines mark parity 1, dashed lines parity 2+.

pregnancies where some *known* cause of growth disturbance existed. It may be maternal or infant diagnoses which represent a *risk* for a growth disturbance. In such materials, some normal infants will be excluded (because these factors do not always cause growth disturbances) and this is of little consequence. A number of growth disturbed infants will, however, be included because no known cause for a growth disturbance was identified. Such a weeding process is probably more effective in small hospital-based materials than in large materials based on medical birth registries. In small materials, however, the number of infants with a short gesta-

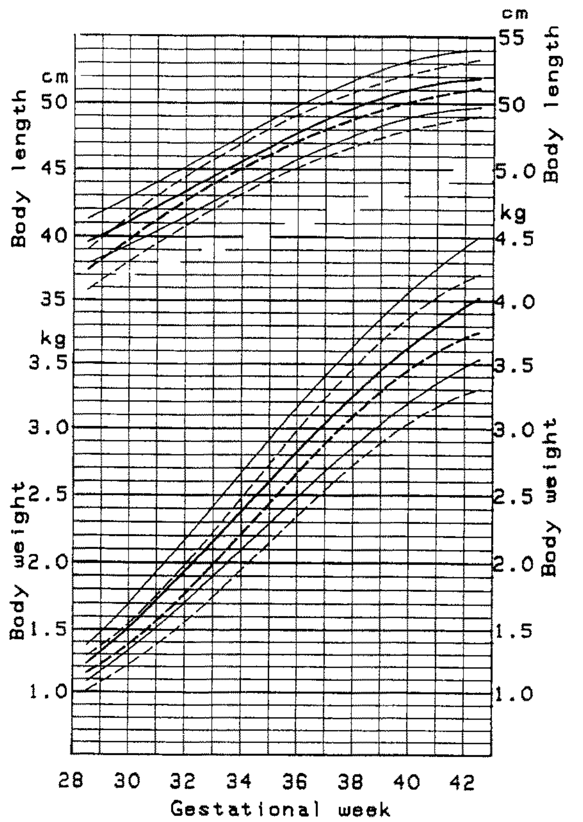

Figure 5. Graphs showing birth weight and birth length at different gestational duration for boys (unbroken graphs) and girls (dashed graphs), all parities. Graphs are based on third degree polynomas fitted to the modes for each pregnancy week. Single dispersions are marked.

tional length will be small and estimates of growth curves at short gestational length will be uncertain.

The next problem is that the birth weight distribution in a certain gestational week is not normally distributed. In this paper it was shown that the distributions differed both with respect to skewness and kurtosis from normal distributions, and that these parameters differed between preterm and term births. It is therefore inappropriate to use the distribution at one specific week (week 40) as the basis for a transformation of the distributions in other weeks [3].

In a medical birth registry some wrongly represented data are found for various reasons. These will represent absurd values and at least the most obvious ones can be weeded from the material while less obvious errors will remain included and can contribute to skewness and kurtosis. With the methodology used in the present paper, such abnormal values will play a minor role as they will not affect the determination of the mode, the most frequent birth weight registered in each week.

Skewness may also have a biological explanation. By and large, skewness was negative in preterm births which means an excess of infants which have a lower than expected birth weight. These probably represent growth retarded infants who have a tendency to preterm birth. A positive skewness at term may also have a biological explanation, e.g., the presence of macrosomic infants due to maternal diabetes. Another study based on a much smaller material basically reported a negative skewness at all pregnancy weeks [9].

In order to overcome these problems, another methodology was chosen. Curves were constructed based on the modes for each week. It is based on the assumption that in a population there is a large group of 'normal' infants – at term they will represent the vast majority. It is not possible to state how large proportion of infants born, for instance, in week 30 are 'normal', but as long as they are in a majority, they will form the mode. Theoretically, all infants born in week 30 may be growth retarded and it is then not possible to estimate the weight of a normal infant born in that week. One way to get round this problem is to try to estimate the infant's weight prenatally from ultrasound measurements of body dimensions [10]. One will then study basically normal infants but the draw-back is that the weight estimate is based on indirect measurements, the exactness of which is open to questions.

The modes determined for each week will form a growth curve which will describe the 'normal' infant's expected weight in different weeks. More exactly, it will show the typical weight for each week, that is, the result of the 'normal' degree of growth retardation that week, not the weight of a normal infant born that week.

It is still more difficult to estimate the dispersion among such 'normal' infants because of the difficulty to identify an unselected group of all normal infants born that week, especially at short gestational length. At week 40, a coefficient of variation of 12% was found. This is rather close to the same parameter found by ultrasound measurements (11%) – the slightly larger dispersion is probably the result of the inclusion of a few small-for-date and a few large-for-date infants, and some wrongly recorded weights. The use of 12% as a coefficient of variation will then give a conservative estimate.

At short gestational duration, it is probable that the dispersion is proportionally less – many factors affecting birth weight act during late pregnancy (e.g., the effect of parity on birth weight). It is therefore probable that the coefficient of variation is less than 12% in preterm births and by keeping the 12% value, the estimate of 'normality' will be conservative.

It should be stressed that the method used does not allow a direct identification of percentiles as the population of normal individuals is never identified.

In this paper, growth curves have been constructed separately for boys and girls and for parity 1 and parity 2+. Using the Medical Birth Registry data, graphs of this nature can easily be prepared also for other subgroups, e.g., infants born in parity 3 or parity 4+, infants born by non-smoking or smoking mothers, infants born by women with a body length within a specified 'normal' interval, etc. It can be expected that the standard deviations in such subgroups will be smaller but on the other hand, the resulting curves may of limited practical importance.

The curves produced can be used for clinical purposes: in order to compare the weight of a specific infant with the expected weight in order to reveal small-for-datedness or large-for-datedness. The curves presented in Figure 5 are most suitable for this. The mathematical functions presented can also be used in epidemiological studies in order to estimate the percentage of small-for-date infants in various groups of infants, for instance.

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