Original Research

A Revised Birth Weight Reference for the United States

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OBJECTIVE: To generate birth weight curves based on the obstetric estimate of gestational age as specified in the revised 2003 U.S. birth certificate.

METHODS: Using National Center for Health Statistics data from 2011, we constructed birth weight curves for neonates between 24 and 42 weeks of gestation. Curves were developed using the obstetric estimate of gestational age that is included in the revised 2003 U.S. birth certificate, which, when available, incorporates ultrasound dating information. Live-born singleton neonates between 500 and 6,000 g without malformations were included. These curves were compared with curves we generated using 1991 data on which the current national reference of Alexander and colleagues is based, a reference that used only last menstrual period to establish gestational age.

RESULTS: The 1991 curves were based on 3,684,778 U.S. live births and the 2011 on 3,252,011 births. Birth weight percentile values were greater from 28 to 36 weeks of gestation in the 1991 data set. That is, the birth weights for preterm neonates were overestimated when 1991 reference curves were used compared with the proposed 2011 reference. For example, in 1991, a birth weight of 2,000 g was at the 50th percentile between 31 and 32 weeks of gestation, whereas in 2011, a birth weight of 2,000 g now corresponds to the 50th percentile between 33 and 34 weeks of gestation.

CONCLUSIONS: Our revised reference curve for the United States provides an updated national reference for birth weight.

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LEVEL OF EVIDENCE: II

Birth weight percentile is an important clinical measurement used in the prediction of newborn morbidity and mortality. Extremes of birth weight are associated with specific neonatal risks, and many reference curves have been constructed to classify newborns based on their birth weight. Lubchenco[1] published the first widely used birth weight curve in 1963, which was based on a group of live-born white neonates delivered in a single Denver hospital. This was a ground-breaking publication that created a tool by which both small-for-gestational-age as well as large-for-gestational-age neonates could be more precisely identified. However, this study has limited application given the well-described phenomena of decreased third-trimester weight gain at higher altitudes.[2] Multiple subsequent birth weight curves have been constructed from various populations, many stratified by parity, race, and neonate sex.[3–6] These reference curves have been limited by their localized populations and inexact criteria for gestational age. In 1996 Alexander et al[7] published a national fetal growth curve based on birth weights of all single live-born neonates reported in 1991 by the National Center for Health Statistics. Gestational age for this curve was calculated using the last menstrual period reported on the birth certificate.

The majority of contemporary obstetric practitioners use ultrasonography to evaluate for fetal abnormalities and confirm or refute gestational age. It has been estimated that more than 90% of women in the United States undergo ultrasound examination in pregnancy.[8] The objective of this study was to

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reanalyze birth weight curves based on the obstetric estimate of gestation age as specified in the revised 2003 U.S. Certificate of Live Birth, which, when available, incorporates ultrasound dating information.

MATERIALS AND METHODS

Publically available data sets from the National Center for Health Statistics for live births from 1991 to 2011 were used to construct birth weight curves for neonates between 24 and 42 weeks of gestation. This study was institutional review board-exempt. Liveborn singleton neonates without known malformations and with recorded birth weights between 500 and 6,000 g were included. In construction of the curve for 1991, gestational age was based on last menstrual period only as was done by Alexander et al. In the 2003 revision of the birth certificate, a new component entitled "obstetric estimate" was added. The instruction manual for health care providers completing the birth certificate describes this as "the obstetric estimate of the infant's gestation in completed weeks based on the birth attendant's final estimate of gestation which should be determined by all perinatal factors and assessments such as ultrasound, but not the neonatal exam."[9] Additional instructions prohibit completing this field based solely on the neonate's date of birth and the mother's date of last menstrual period. Thirty-six states had adopted the 2003 revision by 2011, which accounted for 86% of reported live births in 2011.[10] In the construction of the reference curves now reported for 2011, the obstetric estimate was used with 3,252,011 births meeting inclusion criteria.

For both 1991 and 2011, data were stratified by gestational age and curves for the 10th, 50th, and 90th percentiles were prepared using quantile regression with gestational age entered as a cubic smoothing spline with knot selection as data-specific. Quantile regression is a method used to estimate the curve under which a targeted percentage (quantile) of the data is expected to be present.[11] As a regression function, the neighboring gestational age percentiles affect the estimation of a particular gestational age. Using a cubic smoothing spline allows a nonparametric smooth figure relating the outcome (birth weight percentile) to the independent variable (gestational age). We estimated the birth weight reference curves for both the 1991 and 2011 data using the same method to ensure that any differences between the curves were data-related

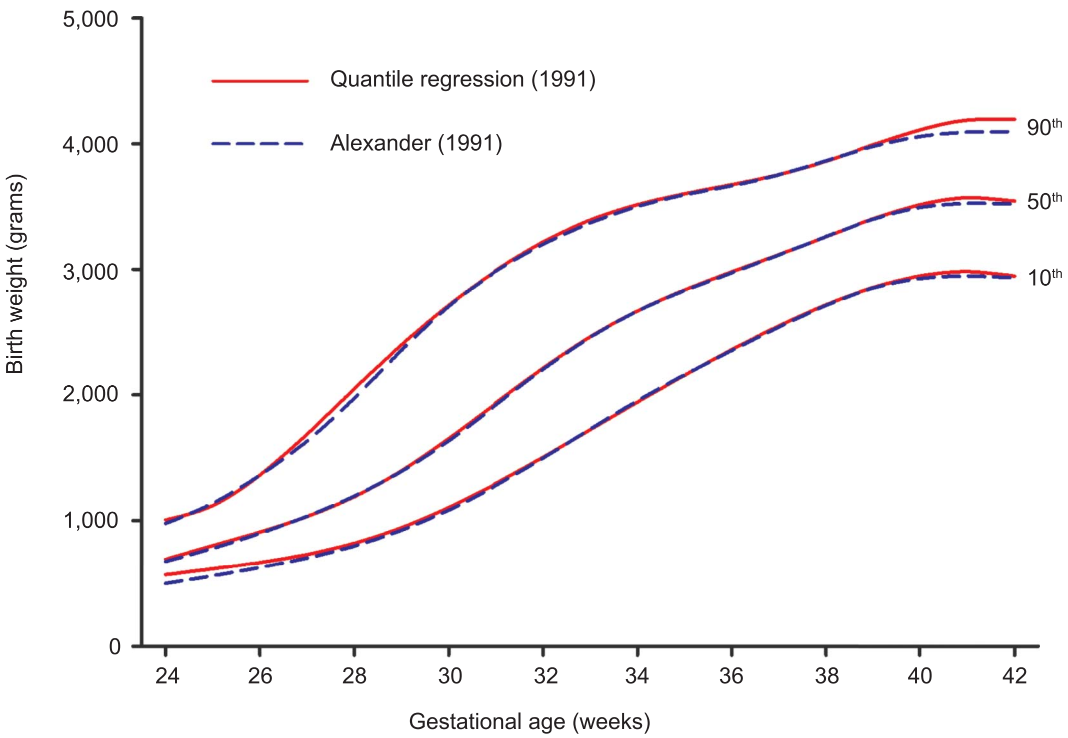

Fig. 1. Birth weight curves for 1991 using quantile regression with cubic smoothing spline (the method used to generate the 2011 curves for our analysis) compared with the original Alexander 1991 curves as published.
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rather than influenced by the statistical method. The curves published by Alexander et al were also compared with our 1991 estimate and were virtually identical, assuring again that differences are not the result of the method of estimation (Fig. 1).

RESULTS

Maternal demographics for 1991 compared with 2011 are shown in Table 1. The distribution has changed over the past 20 years with an increasing proportion of total live births to Hispanic women. The average maternal age has increased over time with fewer teenage pregnancies and more births to women of advanced maternal age.

Shown in Figure 2 are birth weight curves for 1991 compared with those for 2011. The percentile curves diverge between 28 and 36 weeks of gestation with significantly greater birth weight values in the 1991 data set. For example, in 1991, a birth weight of 2,000 g was at the 50th percentile between 31 and 32 weeks of gestation, whereas in 2011, a birth weight of 2,000 g now corresponds to the 50th percentile between 33 and 34 weeks of gestation. Shown in Table 2 is a birth weight percentile distribution chart for neonates in 2011. When comparing male and female neonates at all weeks of gestation and percentiles, female neonates were consistently smaller except at the 95th percentile. This is demonstrated in Table 3, a birth weight percentile chart for male and female neonates. Of note, shown in Figure 3 are birth weight curves for 1991 and 2011 both with gestational age estimate based on last menstrual period only. In an effort to clinically apply our 2011 birth weight curves, we analyzed the proportions of small-for-gestational-age, appropriate-for-gestational-age, and large-for-gestational-age neonates in 2011 that would be identified with the 1991 reference. Small for gestational age, appropriate for gestational age, and large for gestational age were defined, respectively, as birth weights less the 10th, 10th to 90th, and greater than the 90th percentile based on the 2011 reference. A table of these values during various weeks of the third trimester was constructed (Table 4). Use of the 1991 reference curves in the current population overestimates small for gestational age in the preterm population and underestimates its prevalence at term.

DISCUSSION

The 2011 revised birth weight reference now proposed for the United States differs substantially from that in current use, which was based on 1991 births dated by last menstrual period. Birth weight percentiles were greater from 28 to 36 weeks of gestation in the 1991 data set compared with 2011 with the magnitude of the difference greatest at 32 weeks of gestation. Specifically, the difference was 886 g for large-for-gestational-age neonates, 378 g for appropriate-for-gestational-age neonates, and 122 g for those classified as small for

Table 1. Maternal Demographics for Births in 1991 Compared With 2011

Demographic	1991 (n=3,684,778)	2011 (n=3,252,011)
Age (y)		
15 or younger	35,866 (1)	13,247 (0.4)
16–34	3,299,859 (90)	2,772,556 (85.3)
35 or older	349,053 (9)	466,208 (14.3)
Maternal race or ethnicity		
Non-Hispanic white	2,329,194 (63)	1,746,289 (54)
Non-Hispanic black	588,290 (16)	464,349 (14)
Hispanic	562,194 (15)	797,684 (25)
Asian or Pacific Islander*	220,438 (6)	220,438 (7)
Other	23,251 (1)	23,251 (1)
No previous live births†	1,512,853 (41)	1,311,858 (41)
At least 1 prior live birth†	2,158,714 (59)	1,916,027 (59)
Maternal weight gain (lb)		
Less than 11	119,076 (3)	263,749 (8)
11–20	448,289 (12)	496,424 (15)
21–30	995,505 (27)	878,299 (27)
31–40	752,537 (20)	789,895 (24)
41 or more	426,732 (12)	652,293 (20)
Unknown or not stated	942,639 (26)	171,351 (5)

Data are n (%).
* Excluded "unknown or not stated" for the denominator for the percentage.
† Taken as "non-Hispanic other races."

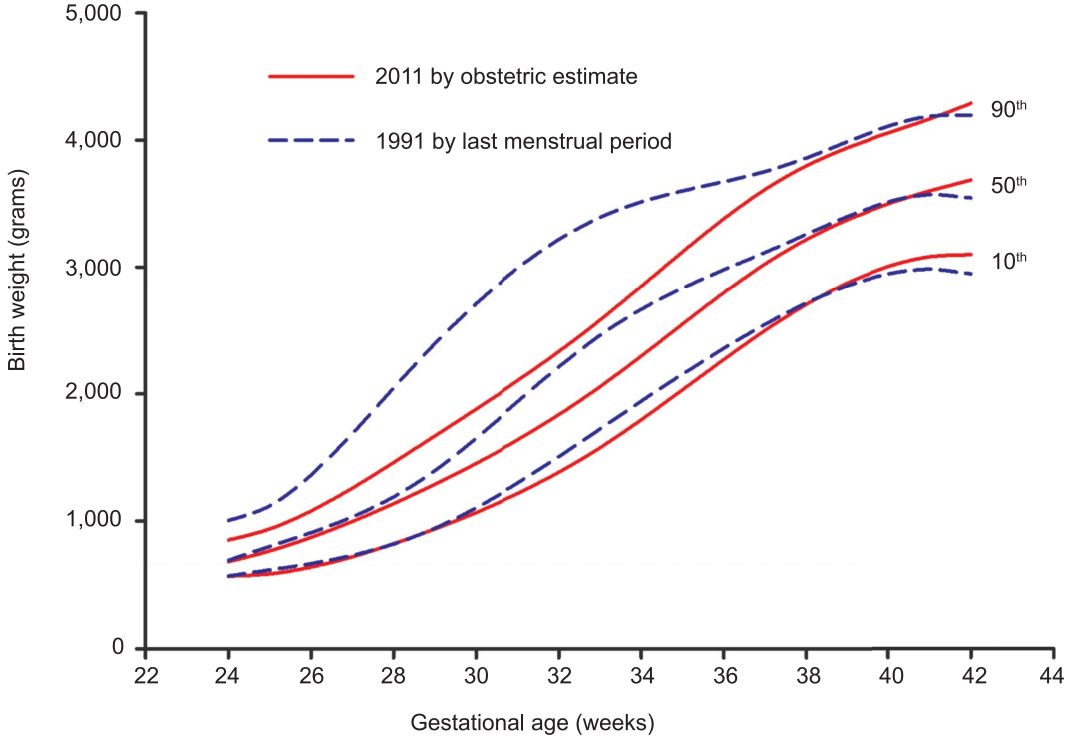

Fig. 2. Birth weight curves for 1991 neonates dated by last menstrual period compared with 2011 neonates dated by obstetrics estimate.

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gestational age. We are of the view that this difference is attributable to use of the recently (2003) revised U.S. birth certificate, which specifies assignment of gestational age based on obstetric criteria to include ultrasound dating when available rather than the last reported menses alone. Put another way, gestational age was estimated using only the last menses in the 1991 data set, whereas in 2011, the last menstrual period was augmented by ultrasound examination. Importantly, the reference curves we derived for our analysis of the 1991 data are virtually superimposable onto those reported for the same year by Alexander and colleagues, supporting that it was not our method of analysis that accounted for the differences, but rather the underlying data.

Table 2. 2011 Gestational Age Birth Weight Percentiles

Week of Gestation	5th	10th	50th	90th	95th
24	539	567	680	850	988
25	540	584	765	938	997
26	580	637	872	1,080	1,180
27	650	719	997	1,260	1,467
28	740	822	1,138	1,462	1,787
29	841	939	1,290	1,672	2,070
30	952	1,068	1,455	1,883	2,294
31	1,080	1,214	1,635	2,101	2,483
32	1,232	1,380	1,833	2,331	2,664
33	1,414	1,573	2,053	2,579	2,861
34	1,632	1,793	2,296	2,846	3,093
35	1,871	2,030	2,549	3,119	3,345
36	2,117	2,270	2,797	3,380	3,594
37	2,353	2,500	3,025	3,612	3,818
38	2,564	2,706	3,219	3,799	3,995
39	2,737	2,877	3,374	3,941	4,125
40	2,863	3,005	3,499	4,057	4,232
41	2,934	3,082	3,600	4,167	4,340
42	2,941	3,099	3,686	4,290	4,474

When the last menses is certain and the menses regularly occur approximately every 28 days, it has been shown that reliance on the last menses alone is an acceptable method of pregnancy dating. However, there are many factors that may contribute to inaccurate determination of gestational age. For example, women may have difficulty with recall of the exact day of the onset of their last menses, have a longer than average intermenstrual interval, or have irregular menses as a result of anovulatory bleeding. Today, the obstetric estimate for assignment of gestational age as described in the 2003 birth certificate is the most common and clinically accepted method for dating pregnancy.[12]

Table 3. 2011 Birth Weight Percentiles for Male and Female Neonates

	Female					Male				
Week of Gestation	5th	10th	50th	90th	95th	5th	10th	50th	90th	95th
24	530	545	652	820	992	553	580	706	855	973
25	532	567	740	912	964	550	595	790	964	1,021
26	571	622	845	1,047	1,144	592	652	900	1,110	1,203
27	639	702	967	1,217	1,446	666	741	1,031	1,284	1,466
28	725	800	1,102	1,410	1,786	762	851	1,177	1,479	1,758
29	822	911	1,250	1,616	2,082	867	972	1,332	1,686	2,028
30	928	1,033	1,411	1,831	2,306	980	1,102	1,496	1,901	2,258
31	1,052	1,173	1,588	2,055	2,486	1,109	1,247	1,674	2,128	2,466
32	1,199	1,335	1,784	2,291	2,651	1,262	1,414	1,871	2,367	2,670
33	1,377	1,526	2,001	2,540	2,832	1,446	1,608	2,091	2,622	2,888
34	1,590	1,747	2,240	2,801	3,049	1,666	1,834	2,335	2,892	3,132
35	1,826	1,987	2,489	3,063	3,288	1,910	2,078	2,592	3,165	3,390
36	2,070	2,230	2,734	3,311	3,526	2,160	2,325	2,846	3,426	3,643
37	2,306	2,461	2,961	3,533	3,741	2,401	2,560	3,082	3,661	3,870
38	2,518	2,664	3,155	3,714	3,910	2,615	2,766	3,283	3,856	4,054
39	2,693	2,829	3,311	3,856	4,035	2,791	2,935	3,445	4,010	4,194
40	2,821	2,950	3,431	3,973	4,140	2,920	3,062	3,572	4,135	4,309
41	2,891	3,020	3,517	4,082	4,252	2,994	3,143	3,669	4,242	4,417
42	2,893	3,033	3,572	4,198	4,397	3,005	3,175	3,740	4,345	4,536

Many authors have previously described the possibility of excessive birth weights in preterm neonates reflecting systematically underestimated gestational ages.[13] This is presumably caused by larger neonates at later gestational ages that are misclassified as an earlier gestational age. Therefore, given that term

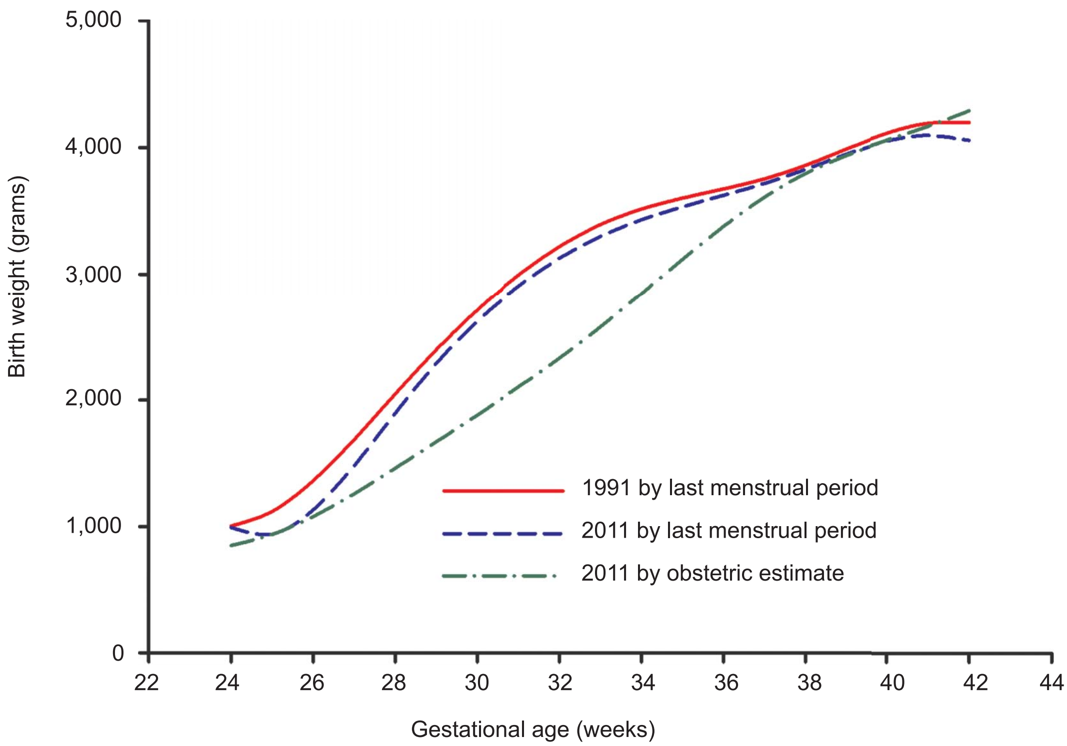

Fig. 3. Birth weight curves (90th percentile) for both 1991 and 2011 neonates dated by last menstrual period alone in comparison to those for 2011 dated by obstetric estimate, which, when available, included ultrasound data.
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Table 4. Percentage of 2011 Neonates Who Would Be Identified as Small for Gestational Age, Appropriate for Gestational Age, or Large for Gestational Age Using the 1991 Reference

Gestational Age (wk)	SGA (Less Than 10th Percentile)	Appropriate for Gestational Age (10–90th Percentile)	LGA (More Than 90th Percentile)
Early preterm (33 or less)	8,760 (14)	50,695 (83)	1,578 (3)
Late preterm (34–36)	28,579 (15)	154,291 (82)	5,933 (3)
Early term (37–38)	91,125 (11)	686,477 (82)	60,084 (7)
Term (39–41)	179,608 (8)	1,788,728 (83)	182,989 (9)
Postterm (42 or more)	675 (5)	10,707 (81)	1,782 (14)
Total (24–42)	308,747 (9)	2,690,898 (83)	252,366 (8)

SGA, small for gestational age; LGA, large for gestational age.
Data are n (%).

live births greatly outnumber the number of neonates born prematurely, this has a greater effect at lower gestational ages in which a few misclassified term neonates can significantly skew birth weight curves.[14] Alexander et al noticed this effect in what they described as a bimodal distribution for each gestational age group. They attempted to control for this effect by setting a specific birth weight "cut point" for each gestational age based on the second larger mode of the bimodal distribution. This was likely insufficient because the effect of inaccurate dating would be continuous and skew the entire distribution. On analysis of the 2011 data by obstetric estimate, a much less pronounced bimodal distribution at 27–32 weeks of gestation was found, which was significantly improved from that seen with the 1991 data and did not necessitate any exclusion of neonates, as was done by Alexander et al.

Although demographics of pregnant women in the United States have changed over the past 20 years, the difference in our new reference curve can be most attributed to the use of new obstetric dating. This is demonstrated by Figure 3, in which the 90th percentile curve for 2011 with dating by last menstrual period alone is superimposed on those for 1991 without much visible difference.

Our study has limitations. Although the birth certificate is usually completed by a professional medical provider, the process is subject to collection errors. For example, the history provided that includes the last menstrual period or other dating criteria can be recorded based solely on maternal recall when medical records are unavailable at the time of delivery. Although not necessarily a limitation, it is important to note that the cohort of women used for our analysis includes women with known maternal disease and fetal complications other than anomalies. Therefore, our curves must be viewed as a reference and not a standard with standard meaning a limited cohort of only healthy and uncomplicated pregnancies. That is, the 2011 cohort includes neonates with abnormal growth.

There has been a long-standing controversy over the merits of routine ultrasonography during pregnancy. This was truer in the early days of ultrasound use in obstetrics compared with more recent years when assessment of fetal anatomy has become of paramount interest for prenatal diagnosis. Perhaps an unexpected advantage of routine ultrasonography can be proposed based on the results now reported, which suggest that routine use of ultrasonography coupled with menstrual history has facilitated more accurate reference birth weight curves.

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