New and Improved Israeli Reference of Birth Weight, Birth Length, and Head Circumference by Gestational Age: A Hospital-Based Study

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Abstract

Background: Many centers in Israel still use pre-1970 reference data for neonatal weight, length and head circumference. A recently published population-based reference overestimated the weight of premature infants.

Objective: To develop a national reference for birth weight, birth length and head circumference by gestational age for singleton infants in Israel.

Methods: Data were collected on all singleton live births documented in the neonatal registry of Rabin Medical Center from 1991 to 2005 (n=82,066). Gestational age estimation was based on the last menstrual period until 1977 and early fetal ultrasound thereafter. Neonates with an implausible birth weight for gestational age (identified by the rule of median ± 5 standard deviations or expert clinical opinion) were excluded. Reference tables for fetal growth by gestational age were created for males and females separately.

Results: The growth references developed differed markedly from the Usher curves currently used in our department. Compared to the recently published population-based birth weight reference, our data were free of the problem of differential misclassification of birth weight for gestational age for the premature infants and very similar for the other gestational age groups. This finding reinforced the validity of our measurements of birth weight, as well as of birth length and head circumference.

Conclusions: Use of our new (birth length and head circumference) and improved (birth weight) gender-specific hospital-based reference for fetal growth may help to define normal and abnormal growth in the neonatal population of Israel and thereby improve neonatal care and public health comparisons.

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Reference data for birth weight, birth length and head circumference were first published in the 1970s [1,2] and revised regularly thereafter [3-10]. The anthropometric reference curves formulated by Usher and McLean [2] in 1969 are still in use in our department. However, they are based on a small sample (300 neonates), lack gender differentiation, and do not provide percentiles but rather means and two standard deviations. Furthermore, the premature group (gestational week 24–30 weeks) numbered only 45 infants.

The first birth weight curves for neonates in Israel were formulated and published in 1993 by Leiberman et al. [11], but they were not incorporated into clinical practice because the data were based on infants of more than 30 weeks gestation and a large non-representative proportion of Bedouin infants relative to the Israeli population. The more recent attempt by Dolberg et al. [9] to establish a population-based birth weight reference for Israeli neonates which was published in the *Israel Medical Association Journal* in 2005 was also limited because birth weight was the sole variable measured; other potential limitations were underscored in a follow-up letter to the editor [12].

There are two main difficulties in establishing reference growth curves for newborns from large data sets. The first is the calculation of gestational age, which together with intrauterine growth determines the birth weight. Anthropometric studies that calculate gestational age by the last menstrual period may yield systematic differences from those that use obstetric methods, such as early fetal ultrasound (the gold standard) or neonatal examination [10,13-16]. LMP-based gestational age determinations are limited by irregularities in the menstrual cycle, individual variations in cycle length, bleeding early in pregnancy, and recall bias. Thus, although menstrual dating is generally accurate for term neonates (± 7 days of the ultrasound estimate), the error worsens with progressive prematurity and, especially, post-maturity [13]. Furthermore, the magnitude and direction of the error vary, with underestimation of the proportion of neonates born before term and gross overestimation of neonates born after term [8,13]. Since nearly one-fourth of infants classified as premature by the LMP are in fact term infants, LMP-based estimates are likely to substantially overestimate birth weight in preterm neonates. To overcome this type of misclassification, researchers have applied, with limited success, different statistical methods [17]. This phenomenon was very apparent on comparison of the population-based Canadian growth reference [8] with data published by Alexander and collaborators [6] in the United States and by Dolberg et al. [9] in Israel.

The second challenge in establishing a reference percentile is the identification and exclusion of live births with implausible values of birth weight for gestational age. Some of the methods proposed for this purpose are the rule of median ± 4 or 5 standard deviations, Tukey's statistical method, and "expert clinical opinion" [6,9,18,19].

LMP = last menstrual period

Although more recent population-based references for birth weight have tried to eliminate these problems in whole or in part [6-9], none provided anthropometric references for birth length or head circumference.

The objective of the present study was to construct a gender-specific growth reference for birth weight, birth length and head circumference by gestational age on the basis of the computerized perinatal registry of Rabin Medical Center (Beilinson Hospital), a major university-affiliated tertiary facility in central Israel. The use of early fetal ultrasound to determine gestational age (by crown-rump length measurements), introduced in 1997, added to the validity of the study.

Materials and Methods

The Beilinson computerized medical birth registry database was searched for data on birth weight, birth crown-heel length and head circumference for all liveborn singleton neonates delivered at 24-43 weeks gestation from 1991 through 2005.

Birth weight is routinely measured in our department by trained nurses within one hour of delivery using electronic scales accurate to 5 g and calibrated before each measurement. Crown-heel length is measured at the same time to the nearest millimeter with an infantometer, with the head placed against the head plate and the knees fully extended. Head circumference is measured, by a physician, around the glabella and the occipital protuberance at the largest occipito-frontal circumference at birth, and again at discharge in cases of caput succedaneum or cephalhematoma.

From 1991 to 1997, the determination of gestational age in our department was based mainly on the LMP and was recorded in complete weeks. Thereafter, early fetal ultrasound (crown-rump length measurement) was used to correct the gestational age computation when the discrepancy between the recorded LMP and the fetal ultrasound was greater than 1 week.

The rule of median ± 5 standard deviations was used to exclude neonates with implausible anthropometric measurements for gestational age. In a few cases, expert clinical opinion was used as well. Tables were created for males and females separately, for the 1st, 3rd, 5th, 10th, 25th, 50th (median), 75th, 90th, 95th, 97th, and 99th percentiles at 24–43 completed weeks.

Results

A total of 85,320 singleton neonates were born in our center during the study period. Birth weight data from the computerized registry were available for 42,085 male and 39,953 female neonates.

Table 1 summarizes the birth weight, birth length and head circumference characteristics (number, minimum, maximum) of the sample (combined gender) for each week of gestational age. Tables 2-4 summarize the growth percentiles for weight [Table 2], length [Table 3] and head circumference [Table 4] for female and male neonates, separately. As the number of infants born at 43 weeks gestation was very small (8 males, 14 females), this gestational age group was excluded from the analysis. The entire set of growth reference tables (percentile 1st to 99th) is available on request.

Discussion

Findings of the present study

The growth references formulated from the data of the Beilinson registry differ grossly from currently available curves [6-9] in that they include not only birth weight, but also birth length and head circumference for both preterm and term singleton neonates born at 24–42 weeks gestation. For birth length and head circumference, our department is still using the Usher reference created almost 40 years ago on the basis of a very small sample of combined male and female neonates [2].

Validity of the present study

Our results can be considered valid in terms of the two main challenges in formulating reference growth curves for newborns: gestational age assessment [13-16] and implausible birth weight for gestation [6,9,18,19]. The increased reliance on early fetal ultrasound-based estimates of gestational age in our center decreased the rate of misclassification and attenuated the overestimated weight in premature infants. This might also be one of the reasons for the very small number of infants born at 43 weeks (who were therefore excluded from the reference tables). The latter may also be attributable to the increased number of cesarean sections performed for post-term deliveries. Our rate of exclusion due to implausible weight for gestational age was very low, similar to the numbers reported by Kramer et al. [13] in the Canadian reference curves, and it held true for birth length and head circumference. Of special interest is the comparison of our hospital-based findings with the Israeli population-based study of Dolberg and co-authors [9] and the Canadian growth reference [8]. The growth percentiles of Dolberg et al. [9] are similar to ours, apart from the excessive weight (200–1000 g, 90th–99th percentile) in the 30–35 week gestational age group. This difference probably reflects a misclassification in their study of term infants as preterm. Otherwise, our birth weight data are close to the national data. This also supports the validity of our findings for birth length and head circumference. Interestingly, the Israeli neonates were consistently smaller than their Canadian counterparts at 24–42 weeks. The reason for this disparity remains unclear; potential contributory factors include genetics and race, maternal size, maternal nutrition during pregnancy, smoking, and other environmental determinants.

The main limitation of our hospital-based study, other than its general (non-population-based) and cross-sectional design, is the computation of gestational age in the first period of the study mainly by the LMP, which places our gestational age assessment at risk of misclassification bias. This bias was accounted for by the use of ultrasound-based crown-rump measurements in the later part of the study, when the delivery rate in our hospital doubled.

Another limitation of the study is the small size of the preterm infant group born at 24–30 weeks gestation, especially in terms of birth length and head circumference data. Nevertheless, the number is huge compared to the study of Usher and McLean [2]. The group of infants of 43 weeks gestational age was so small it had to be excluded from the analysis.

Table 1. Birth weight, birth length and head circumference by gestational age: Inclusion criteria for infants included in the growth references

	Birth weight				Birth length				Birth head circumference			
GA	No.	No. excluded (%)*	Minimum	Maximum	No.	No. excluded (%)*	Minimum	Maximum	No.	No. excluded (%)*	Minimum	Maximum
24	66	4 (6)	410	980	–	–	–	–	17	0	19.5	24
25	75	3 (4)	400	1150	–	–	–	–	28	0	21.0	24.5
26	109	3 (2.7)	440	1480	8	0	31.8	38.0	43	0	21.0	26.5
27	123	4 (3.1)	457	1500	19	3 (14)	32.0	41.0	54	0	20.5	28.0
28	134	3 (2.2)	550	1570	20	1 (5)	32.5	41.0	61	0	21.5	28.5
29	128	5 (3.8)	650	1940	29	2 (6)	33.0	42.7	65	2 (3)	23.0	30.0
30	138	0	730	2170	28	1 (3.4)	35.0	44.0	98	1 (1)	24.0	30.7
31	187	2 (1.1)	837	2390	41	1 (2.4)	36.0	47.0	122	1 (0.8)	25.0	34.0
32	276	1 (0.36)	891	3100	55	3 (5.2)	36.0	47.0	171	0	24.9	32.7
33	322	1 (0.3)	820	3500	111	2 (1.8)	38.0	50.0	215	3 (1.4)	25.5	35.0
34	695	0	720	3920	378	0	39.0	53.0	436	2 (0.5)	27.0	36.0
35	1007	6 (0.6)	1380	4250	643	2 (0.3)	39.0	54.0	670	2 (0.3)	28.0	35.6
36	2146	3 (0.14)	1146	4860	1577	5 (0.3)	40.0	53.0	1584	3 (0.2)	28.0	38.0
37	4848	9 (0.19)	1440	5000	3890	12 (0.3)	40.0	56.0	3889	12 (0.3)	27.0	38.5
38	12416	20 (0.16)	1245	5150	10048	19 (0.2)	40.0	59.5	10053	23 (0.2)	28.5	39.5
39	18382	20 (0.1)	1160	5330	14997	29 (0.2)	39.0	59.5	14992	20 (0.13)	29.0	39.0
40	25168	34 (0.13)	1570	5370	20120	28 (0.14)	40.0	59.5	20193	26 (0.13)	30.0	39.5
41	11950	3 (0.02)	1908	5370	9543	14 (0.15)	41.0	59.5	9542	8 (0.08)	30.0	39.5
42	2349	2 (0.08)	1970	5020	1876	3 (0.16)	43.0	58.0	1868	2 (0.1)	31.4	39.5
43	22	0	2500	4500	12	0	45	54	12	0	32	37

* Based on the rule of median ± 5 SD and/or expert clinical opinion

GA = gestational age

Table 2. Birth weight (g) for gestational age for singleton female and male neonates born in Israel between 1991 and 2005

	Female (percentile)							Male (percentile)						
GA/wk	3	5	10	50	90	95	97	3	5	10	50	90	95	97
24	420	427	460	634	815	852	859	415	426	483	650	820	889	957
25	402	484	534	730	892	938	955	470	528	602	785	924	980	1103
26	452	489	600	830	1050	1115	1126	568	596	678	900	1088	1160	1190
27	498	544	615	892	1200	1318	1490	519	596	709	985	1252	1290	1340
28	541	586	704	1044	1294	1408	1430	619	648	769	1088	1389	1430	1539
29	683	713	789	1150	1434	1457	1688	701	778	968	1325	1579	1668	1671
30	780	840	945	1350	1675	1750	1850	793	898	1023	1470	1700	1917	2038
31	900	1000	1100	1500	1790	1970	2140	970	997	1077	1590	1930	2065	2100
32	986	1045	1134	1630	2110	2396	2538	1020	1160	1269	1800	2300	2432	2600
33	1050	1180	1322	1852	2374	2525	2598	1264	1363	1467	2000	2499	2700	2755
34	1336	1386	1548	2135	2595	2790	2907	1414	1490	1669	2225	2650	2900	3070
35	1583	1700	1847	2360	2880	3003	3210	1653	1730	1900	2450	2958	3100	3246
36	1880	1949	2077	2580	3130	3373	3650	1952	2030	2180	2710	3300	3555	3715
37	2055	2160	2322	2807	3420	3620	3759	2155	2270	2423	2950	3500	3730	3870
38	2330	2430	2567	3030	3590	3770	3890	2420	2520	2666	3148	3722	3910	4030
39	2490	2570	2700	3150	3680	3841	3958	2575	2670	2808	3300	3830	4000	4113
40	2605	2690	2830	3280	3808	3960	4070	2712	2800	2935	3414	3940	4100	4208
41	2710	2799	2915	3375	3880	4040	4140	2815	2900	3040	3530	4071	4230	4346
42	2715	2810	2955	3450	3970	4130	4256	2793	2895	3020	3553	4120	4274	4400

Table 3. Birth length (cm) for gestational age for singleton female and male neonates born in Israel between 1991 and 2005

	Female (percentile)							Male (percentile)						
GA/wk	3	5	10	50	90	95	97	3	5	10	50	90	95	97
24	–	–	–	–	–	–	–	–	–	–	–	–	–	–
25	–	–	–	–	–	–	–	–	–	–	–	–	–	–
26	–	–	–	–	–	–	–	31.8	31.8	32.0	36.5	37.5	37.5	37.5
27	34.0	34.0	34.0	37.5	39.5	39.5	39.5	32.0	32.0	32.5	36.8	40.4	41.0	41.0
28	32.5	32.5	32.5	36.3	40.0	40.0	40.0	33.0	33.0	33.0	36.2	41.0	41.0	41.0
29	33.0	33.0	33.4	38.8	41.0	41.5	41.5	35.0	35.9	36.0	39.5	42.5	42.7	42.7
30	36.0	36.0	36.4	38.5	42.7	43.0	43.0	35.0	35.0	36.7	41.0	44.1	44.2	44.2
31	36.7	36.8	37.5	40.5	44.0	45.0	45.5	36.0	36.6	38.5	42.5	46.6	47.0	47.0
32	37.0	37.5	38.2	41.2	44.5	45.9	46.2	36.0	36.5	38.7	43.2	45.9	46.4	47.0
33	39.5	39.5	40.0	42.8	45.5	47.2	47.5	39.0	39.4	40.7	44.3	47.2	48.0	48.8
34	40.0	40.9	42.0	45.0	47.5	48.7	49.9	41.2	42.0	42.9	45.9	48.0	48.6	48.8
35	41.0	41.9	43.5	46.0	48.7	49.0	50.0	42.6	43.0	44.0	46.5	49.0	49.5	50.0
36	43.0	43.5	44.0	46.9	49.0	50.0	50.5	43.5	44.0	45.0	47.5	50.0	51.0	51.0
37	43.9	44.8	45.5	47.9	50.0	50.8	51.0	45.0	45.5	46.0	49.0	51.0	52.0	52.0
38	45.4	45.9	46.5	48.8	50.9	51.8	52.0	46.0	46.5	47.0	49.5	51.9	52.0	53.0
39	46.0	46.5	47.0	49.0	51.2	51.9	52.0	47.0	47.0	48.0	50.0	52.0	53.0	53.0
40	46.5	46.9	47.8	49.9	51.9	52.5	52.8	47.0	47.9	48.0	50.5	52.9	53.0	54.0
41	46.9	47.5	47.9	50.0	52.0	52.9	53.0	48.0	48.0	49.0	51.0	53.0	53.8	54.0
42	47.0	47.5	48.0	50.5	52.5	53.0	53.8	47.6	48.0	49.0	51.0	53.0	53.8	54.0

Table 4. Birth head circumference (cm) for gestational age for singleton female and male neonates born in Israel between 1991 and 2005

	Female (percentile)							Male (percentile)						
GA/wk	3	5	10	50	90	95	97	3	5	10	50	90	95	97
24	19.5	19.5	19.5	20.8	22.1	22.5	22.5	20.0	20.0	20.4	22.2	23.7	24.0	24.0
25	21.0	21.0	21.3	22.5	23.7	23.9	24.0	22.0	22.0	22.0	22.9	24.2	24.4	24.5
26	21.4	21.4	21.5	23.4	24.7	25.1	25.3	21.0	21.5	22.5	23.5	25.2	25.6	26.5
27	21.7	22.0	22.9	24.5	26.0	27.0	27.2	20.5	21.4	23.2	25.1	26.8	27.3	28.0
28	22.7	22.9	23.0	25.0	27.0	27.5	28.0	21.5	22.0	23.1	25.8	26.9	27.3	28.0
29	23.0	23.1	23.5	26.0	27.5	27.2	28.5	23.8	24.3	25.2	27.6	29.3	29.6	29.9
30	24.3	24.9	25.5	27.2	29.0	29.5	29.7	25.0	25.4	26.5	28.0	29.5	30.0	30.3
31	25.4	26.0	26.4	28.0	29.8	30.2	30.9	25.9	26.5	27.3	29.0	30.5	31.5	31.7
32	25.3	26.0	26.5	28.7	31.5	31.9	32.2	25.8	26.8	27.4	29.9	31.6	31.9	32.0
33	26.0	26.2	27.3	29.9	31.9	32.4	32.8	27.6	27.6	28.5	30.8	32.6	33.1	33.5
34	27.9	28.2	29.0	31.0	32.5	33.2	33.9	29.0	29.1	29.8	31.5	33.7	34.2	34.8
35	29.0	29.7	30.0	32.0	33.5	34.0	34.3	29.7	30.0	30.5	32.3	34.0	34.5	35.0
36	30.0	30.5	31.0	32.5	34.2	35.0	35.4	30.6	31.0	31.5	33.0	35.0	35.3	35.5
37	30.9	31.2	31.5	33.0	34.7	35.1	35.5	31.3	31.5	32.0	34.0	35.5	36.0	36.0
38	31.4	31.8	32.0	33.5	35.0	35.5	35.9	32.0	32.2	32.6	34.0	35.8	36.2	36.5
39	31.9	32.0	32.5	33.9	35.3	35.8	36.0	32.5	32.5	33.0	34.5	36.0	36.5	36.5
40	32.0	32.4	32.9	34.0	35.5	35.9	36.0	32.7	33.0	33.4	34.9	36.0	36.5	37.0
41	32.5	32.6	33.0	34.4	35.9	36.0	36.4	33.0	33.0	33.5	35.0	36.5	36.9	37.0
42	32.6	32.9	33.0	34.5	36.0	36.4	36.6	32.8	33.0	33.5	35.0	36.5	36.9	37.0

Application of our results to patient care

The anthropometric references formulated in the present study are more appropriate than the Usher curves for use in the Israeli population. They are for the most part similar to the findings of Dolberg et al. [9] for birth weight, while correcting for the overestimation at 30–35 weeks, and they add invaluable data on the other growth parameters of birth length and head circumference. Our inclusion of birth length and head circumference can be regarded as an early response to the editorial of Shinwell [20] regarding the study of Dolberg et al. [9], in which he addresses the need to collect and analyze data on birth length and head circumference and ponderal index as well. Our next study will include growth references by gestational age to body mass index and weight to length ratios, two variables commonly used today

in the growth charts of infants and children to monitor growth and obesity. To our knowledge, not all centers in Israel measure length at birth. We believe our newly developed growth references for length might urge neonatologists to include length measurement as a mandatory part of the routine newborn examination, as strongly suggested by Laron [21].

However, the generalizability of our growth references beyond Israel is questionable. For example, they are probably not applicable to Canadian or Scandinavian neonates who are heavier at birth at each gestational age, although secular trends in fetal growth in both countries have shown a similar increase in mean birth weight over the last quarter of a century [22-24]. The consistently smaller size of our near-term and term neonates than those in the USA and Canada over more than 40 years should alert public health providers to search for possible unwarranted intrauterine factors that need to be managed.

At the same time, our data may have greater applicability in less developed countries for the classification of neonates who are small, appropriate, or large for gestational age, and as a tool for epidemiological comparisons between geographic locations and cultures. They may also facilitate subgroup comparisons and epidemiological investigations aimed at improving our understanding of intrauterine growth. Yunis et al. [25] recently reported growth standards for birth weight, birth length and head circumference based on singleton liveborn infants delivered at 28–42 weeks gestation in a well-defined urban population in greater Beirut, Lebanon. The study was limited, however, by the very small size of the sample at 28–31 weeks gestation (male n=50, female n=32) and overestimation of the anthropometric measurements (misclassification). Nevertheless, for infants of 38–42 weeks gestation, the measurements were quite similar to ours, probably due to the common ethnicity of the populations and to their similar geographic location and socioeconomic profile.

Summary

We present a hospital-based growth reference for preterm and term singleton neonates in Israel based on a population born between 1991 and 2005. Besides birth weight, our data include crown-heel length and head circumference, two parameters that have scarcely been reported in the recent worldwide growth-reference literature. Our birth weight data are compatible with the national data, adding to the validity of all three dimensions. The new growth references may facilitate neonatal care, subgroup comparisons, and epidemiological investigations.

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