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A need for an update of Polish birth weight reference norms

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ABSTRACT: The indicators of perinatal outcome are birth weight and gestational age. The standard method of assessing the outcome is comparing the newborn's birth weight with the reference system, presented in the form of percentile charts. Acceleration or delay in prenatal development, which are associated with environmental changes, stress the need to validate the developmental norms. The goal of this study is to evaluate the need to construct new and accurate reference standards. The study includes data of newborns from singleton pregnancies: 4919 born in 2000 and 3683 born in 2015. Study variables included gestational age, sex, and birth weight. Percentile values estimated for two groups of infants born in years separated by a 15-year period, born in 2000 and in 2015, were compared. Birth weight percentiles, from the 28th to the 42nd week of gestation, were calculated using the Lambda Mu Sigma method. Estimated values revealed the birth weight standards in different weeks of gestational age for both years: 2000 and 2015. Comparison among medians estimated for infants born in these years showed the existence of significant differences among boys in the 28th, 36th, and 39th weeks and among girls in the 34th and 41st weeks of gestational age. As the period between the two measurements involves several years, environmental changes during this time period might have significantly affected the course of pregnancy and thus the birth weight. Hence, there is a need to validate the developmental norms. The reference standards should be renewed, and must be done on a periodical basis.

KEY WORDS: developmental norms, percentile charts, gestational age, birth weight

Introduction

Newborn health is an essential indicator of population well-being. Poor newborn status is associated with long-lasting consequences (De Bie et al. 2010; Giapros et al. 2012; Szwed and Kosińska 2012; Ouyang et al. 2013; Chauhan et al. 2017). Therefore, monitoring of newborn perinatal outcome plays a key role in predicting the mortality and morbidity among infants, children, adolescents, and adults. The indicators commonly used to determine the perinatal outcome are birth weight and gestational age. These parameters allow assessing the level of development and maturity, and subsequently indicate the physiological and pathological status of the infant.

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There exists a mutual relationship between birth weight and gestational age, due to which it is possible to distinguish between the group of newborns with birth weight appropriate to their gestational age and group of newborns showing hypotrophy or hypertrophy. The standard method of assessing the birth weight value and indicating its deviations from the standard value is comparing the examined newborn's birth weight with the reference system. This reference system is presented in the form of percentile charts that describe and illustrate the distribution of birth weights at each gestational age. The assessment of birth weight according to the percentile charts allows comfortably and reliably distinguishes the groups of infants with birth weight inappropriate for gestational age and presumes disturbances during fetal development.

Widespread standards of birth weight for a given sex and age are published by World Health Organization (WHO) (Villar et al. 2014). The WHO recommends that the growth of human beings should be monitored according to the guidelines prescribed by international standards (Villar et al. 2018). These percentile charts are based on multicenter studies, but the source data have not been collected from all the centers of the world and hence do not represent the entire population. Due to the occurrence of inter-population differences, perinatal outcomes are usually assessed using numerous local charts that are constructed based on the data obtained from particular geographical, economic, and social regions (Badade et al. 2013; Davidson et al. 2008; Gadzinowski et al. 2003; Zhao et al. 2019).

The percentile charts are rarely updated. Many environmental changes, including climatic, social, economic, medical, and demographic, can occur over the period of several years, which might cause an impact on perinatal outcome. Poland has seen many changes in the medical, social, and economic fields in the past years (Kosińska et al. 2019). These changes can significantly affect the course of pregnancy, which in turn influences the perinatal state of the newborn (including birth weight). These alterations resulted in greater viability of fetus at earlier gestational age (Norris et al. 2018). Acceleration or delay in prenatal development, which results in variations in birth weight, is associated with the need to validate the developmental norms. Based on this observation, there is a need to reconsider if reference guidelines should be amended and if so should this be done on a periodical basis.

The main goal of this study is to evaluate the need to construct new and appropriate reference standards to assess the neonatal outcome.

Materials and methods

The percentile values calculated for two groups of infants born in years separated by a 15-year period, that is, infants born in 2000 and 2015, were compared. The data for both the study periods were collected from the Gynaecological and Obstetric Teaching Hospital of the Poznań University of Medical Sciences, and thus the study sample represents births from the same region of Poland (Great Poland). The study includes data of newborns from singleton pregnancies: 4919 (2549 boys and 2370 girls) born in 2000 and 3683 (2012 boys and 1671 girls) born in 2015. The variables considered for comparison included gestational age, sex, and birth weight.

Gestational age was calculated on the basis of the first day of mother's last menstrual period, verified in the first trimester of pregnancy using an ultrasound scanner and confirmed after birth according to the Ballard score. The body weight of newborns was measured immediately after birth, accurate to 10 g.

To ensure power and appropriate sample size in each week of gestational age, the studies were limited to the range from the 28th to the 42nd week. The obtained data were divided taking into account the subsequent weeks of gestational age, separately for boys and girls.

To compute percentiles and z-scores for reference standards, we used formulae based on the Lambda Mu Sigma (LMS) method (Cole and Green 1992). Computed percentiles were limited to the values corresponding to the 3rd, 10th, 25th, 50th, 75th, 90th, and 97th centiles for each age and sex group. Finally, the statistical analysis involved means, standard deviations, and selected (3, 10, 25, 50, 75, 90, 97) centile values conditioned on age and sex.

For the comparison of mean birth weight values in the particular weeks of gestational age, estimated for investigated years (2000 and 2015), we applied one-sample Student's t-test. Median values of birth weight by gestational age (50th percentile) between groups from subsequent years of research were compared.

The Bioethical Commission of University of Medical Sciences in Poznan provided approval for the conductance of this study and waived off the need for obtaining consent from the patients for publishing the results (Bioethical Commission approval numbers: 2431/00 and 538/14).

Statistical analyses were performed using R v.3.5.2 (R Development Core Team 2018).

Results

The obtained results allow approximation of the birth weight standards in different weeks of gestational age for both the considered years (2000 and 2015). Means and standard deviations for birth

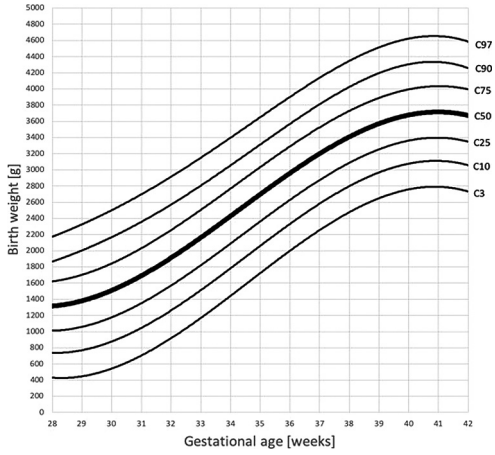

Fig. 1. Percentile charts for boys' birth weight in 2000

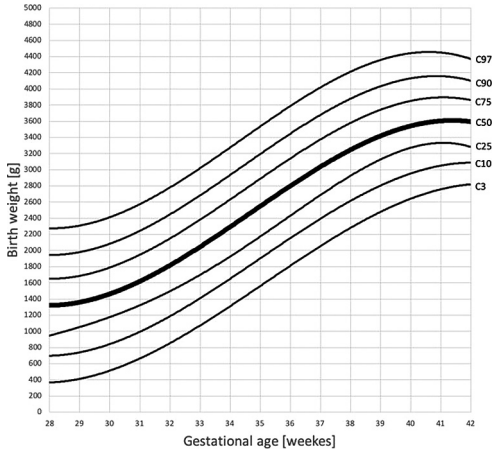

Fig. 2. Percentile charts for girls' birth weight in 2000

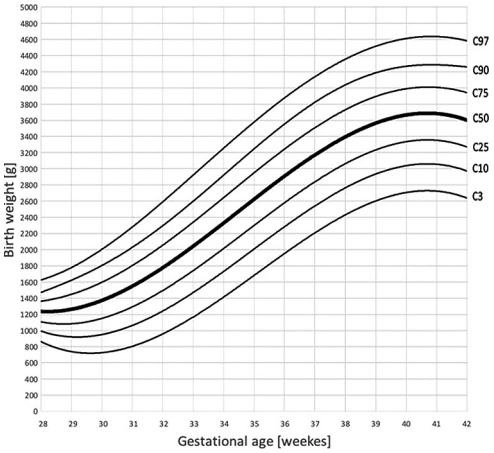

Fig. 3. Percentile charts for boys' birth weight in 2015

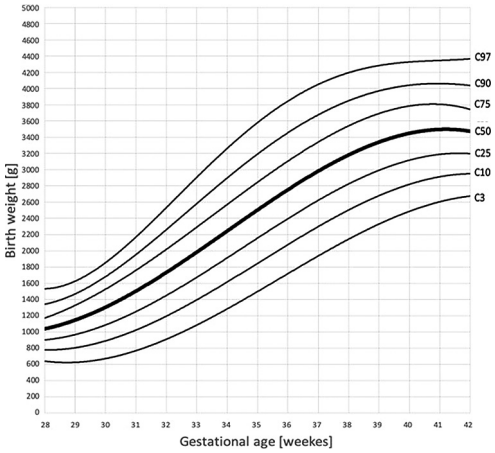

Fig. 4. Percentile charts for girls' birth weight in 2015

Table 1. Birth weight percentiles for boys born in 2000

GA [weeks]	N	$\bar{x}$	SD	Min.	Max.	Percentiles						
						3	10	25	50	75	90	97
28	14	1225.0	424.4	720	2270	393	681	939	1225	1511	1769	2057
29	19	1450.5	530.6	920	3440	411	770	1092	1451	1809	2131	2491
30	22	1654.5	525.9	480	3440	624	980	1300	1655	2010	2329	2685
31	25	1657.6	361.1	620	2190	950	1195	1414	1658	1901	2121	2365
32	27	1883.0	642.4	920	3840	624	1059	1449	1883	2317	2707	3142
33	27	2070.4	410.1	1060	2820	1267	1545	1794	2070	2347	2596	2874
34	40	2322.0	534.6	1000	4220	1274	1637	1961	2322	2683	3007	3370
35	41	2793.9	502.2	1700	3780	1810	2150	2455	2794	3133	3438	3778
36	124	3039.9	525.3	1400	4540	2010	2367	2685	3040	3394	3713	4069
37	314	3189.4	464.9	1640	5220	2278	2593	2876	3189	3503	3785	4101
38	485	3391.9	471.0	1270	5400	2469	2788	3074	3392	3710	3996	4315
39	562	3554.6	461.8	1550	5160	2649	2962	3243	3555	3866	4147	4460
40	508	3669.0	460.3	1860	5200	2767	3079	3358	3669	3980	4259	4571
41	249	3762.2	484.3	2200	5280	2813	3141	3435	3762	4089	4383	4711
42	92	3644.5	478.9	2640	4880	2706	3031	3321	3644	3968	4258	4583

Table 2. Birth weight percentiles for girls born in 2000

GA [weeks]	N	$\bar{x}$	SD	Min.	Max.	Percentiles						
						3	10	25	50	75	90	97
28	11	1321.8	617.4	770	3000	112	530	905	1322	1739	2113	2532
29	17	1332.9	390.6	950	2250	567	832	1069	1333	1597	1834	2099
30	14	1547.9	417.7	790	2480	729	1012	1266	1548	1830	2083	2366
31	20	1655.0	368.4	1100	2530	933	1183	1406	1655	1904	2127	2377
32	23	1659.6	474.4	860	3060	730	1051	1339	1660	1980	2268	2589
33	19	1984.2	585.7	1000	3200	836	1233	1589	1984	2380	2735	3132
34	31	2378.1	590.9	1420	3560	1220	1621	1979	2378	2777	3136	3536
35	40	2592.8	562.1	1300	3600	1491	1872	2213	2593	2972	3313	3694
36	101	2845.0	574.4	1220	4500	1719	2109	2457	2845	3233	3581	3971
37	290	3044.2	471.0	780	5040	2121	2440	2726	3044	3362	3648	3967
38	442	3221.6	403.0	2140	4700	2432	2705	2950	3222	3494	3738	4011
39	523	3389.4	454.5	1240	5100	2499	2807	3083	3389	3696	3972	4280
40	499	3504.5	409.0	2160	4860	2703	2980	3228	3505	3781	4029	4306
41	258	3614.0	416.2	2550	4890	2798	3080	3333	3614	3895	4147	4430
42	82	3615.0	462.4	2460	4920	2709	3022	3303	3615	3927	4208	4521

Table 3. Birth weight percentiles for boys born in 2015

GA [weeks]	N	$\bar{x}$	SD	Min.	Max.	Percentiles						
						3	10	25	50	75	90	97
28	13	1278.6	177.8	812	1225	930	1051	1159	1279	1399	1507	1627
29	10	1138.0	280.0	725	1540	589	779	949	1138	1327	1497	1687
30	25	1429.0	377.6	695	2080	689	945	1174	1429	1684	1913	2169
31	31	1596.8	321.4	880	2340	967	1185	1380	1597	1814	2009	2227
32	36	1788.1	434.7	825	2590	936	1231	1495	1788	2082	2345	2640
33	55	2049.4	429.6	745	3320	1207	1499	1759	2049	2339	2600	2891
34	49	2200.5	416.9	1310	3030	1383	1666	1919	2201	2482	2735	3018
35	95	2704.5	495.0	1550	1620	1734	2070	2370	2704	3039	3339	3675
36	86	2877.2	553.5	1620	4360	1792	2168	2504	2877	3251	3587	3962
37	186	3214.0	508.7	1750	4700	2217	2562	2871	3214	3557	3866	4211
38	432	3386.8	495.6	1880	4990	2415	2751	3052	3387	3721	4022	4358
39	513	3509.4	469.7	1475	5400	2589	2907	3192	3509	3826	4112	4430
40	340	3694.3	446.6	2060	4780	2819	3122	3393	3694	3996	4267	4570
41	134	3704.2	490.3	2660	4880	2743	3076	3373	3704	4035	4333	4665
42	7	3581.4	512.8	2520	4120	2576	2924	3235	3581	3928	4239	4587

Table 4. Birth weight percentiles for girls born in 2015

GA [weeks]	N	$\bar{x}$	SD	Min.	Max.	Percentiles						
						3	10	25	50	75	90	97
28	15	977.3	281.0	390	1300	427	617	788	977	1167	1338	1528
29	8	1190.6	232.7	750	1455	735	892	1034	1191	1348	1489	1647
30	10	1289.5	243.4	875	1540	812	977	1125	1290	1454	1602	1767
31	21	1572.6	332.6	1040	2385	921	1146	1348	1573	1797	1999	2224
32	22	1806.8	431.1	1010	2160	962	1254	1516	1807	2098	2360	2652
33	32	1984.2	465.4	980	2810	1072	1388	1670	1984	2298	2581	2896
34	45	2197.6	472.7	1040	2930	1271	1592	1879	2198	2517	2803	3124
35	58	2337.2	568.5	1210	3620	1223	1608	1954	2337	2721	3066	3451
36	66	2676.0	648.9	1360	4600	1404	1844	2238	2676	3114	3508	3948
37	145	3059.9	572.6	1750	4460	1938	2326	2673	3060	3446	3794	4182
38	339	3246.1	454.2	1850	4800	2356	2664	2939	3246	3553	3828	4136
39	424	3409.9	462.5	1830	5070	2503	2817	3098	3410	3722	4003	4316
40	340	3472.6	432.5	2150	4560	2625	2918	3181	3473	3765	4027	4320
41	140	3428.2	418.2	2150	4610	2609	2892	3146	3428	3711	3964	4248
42	6	3466.7	486.9	2740	4080	2512	2842	3138	3467	3795	4091	4421

Table 5. Comparison among medians estimated for boys (median test)

GA [weeks]	C50		Median test	*p*-value
	2000	2015		
28	1225	1279	5.143	0.030
29	1451	1138	2.042	0.153
30	1655	1429	0.521	0.471
31	1658	1597	3.541	0.060
32	1883	1788	0.896	0.344
33	2070	2049	0.055	0.814
34	2322	2201	0.140	0.708
35	2794	2704	0.017	0.896
36	3040	2877	5.041	0.025
37	3189	3214	0.064	0.800
38	3392	3387	0.218	0.641
39	3555	3509	4.515	0.034
40	3669	3694	0.573	0.449
41	3762	3704	1.558	0.212
42	3644	3581	0.176	0.675

Table 6. Comparison among medians estimated for girls (median test)

GA [weeks]	C50		Median test	*p*-value
	2000	2015		
28	1322	977	0.540	0.462
29	1333	1191	0.019	0.7891
30	1548	1290	1.731	0.188
31	1655	1573	0.223	0.636
32	1660	1807	0.551	0.458
33	1984	1984	0.033	0.856
34	2378	2198	0.490	0.484
35	2593	2337	4.224	0.040
36	2845	2676	1.164	0.281
37	3044	3060	1.035	0.309
38	3222	3246	1.027	0.311
39	3389	3410	0.029	0.865
40	3505	3473	0.406	0.524
41	3614	3428	8.511	0.004
42	3615	3467	0.715	0.398

weight by gestational age and birth weight percentiles at 3rd, 10th, 25th, 50th, 75th, 90th, and 97th weeks are listed for girls and boys in Tables 1–4.

Smoothed reference curves, corresponding to the results summarized in Tables 1–4, are shown in Figures 1–4. Graphs allow for visual comparison between reference values estimated for the investigated years.

Tables 5 and 6 present results of comparison among medians estimated for infants born in the studied years: 2000 and 2015. The obtained results showed the existence of significant differences among boys in the 28th, 36th, and 39th weeks and among girls in the 34th and 41st weeks of gestational age.

Discussion

In the course of clinical trials, pediatricians and neonatologists take advantage of perinatal outcome information to assess the newborns' maturity and predict the risk of morbidity and mortality (Evans et al. 2007; Kirby and Wingate 2010; Peck et al. 2010). Primary determinants of maturity are gestational age and birth weight. These features, and especially their relationship, allow to assess whether an infant has attained satisfactory intrauterine growth and to divide infants into categories of impaired developmental risk. Approximation of the relationship between newborns' birth weight and gestational age at birth enables to distinguish between natural variation and subpathological or pathological deviations, and distinction is done on the basis of the values estimated for anthropometric variables. Therefore, clinicians are specifically interested in birth weight. Birth weight norms allow for the assessment of newborn's development in comparison to his peer group. They indicate distribution of birth weight with reference to gestational age. A practical and reliable tool for their assessment is by using reference standards that express the frequency of birth weight distribution, which is presented as percentile values or graphical charts. In many countries, past years have seen changes in the environment, which have subsequently influenced the development of an offspring (Sowada et al. 2018). These changes can significantly affect the course of pregnancy, which in turn determines the perinatal outcome (including birth weight) (Kosińska 2011). Acceleration or delay in prenatal development, and thus variations in the birth weight range, is associated with the need to update the developmental norms. Given the medical, social, and economic changes that occurred over the last years, which resulted in greater viability of the fetus at earlier gestational age, it should be considered if the existing birth weight norms represent contemporary births.

The percentile grids that are given in most Polish health books have been developed by the Institute of Mother and Child in Warsaw in 1999. In 2013, as part of larger-scale research projects, the Children's Health Center published new percentile grids for children up to the age of 7 years (Różdżyńska-Świątkowska et al. 2015).The percentile grids showing birth weight norms (birth weight relative to fetal age) were presented in articles published in the years 1992 (Kaliszewska-Drozdowska 1992), 2003 (Gadzinowski et al. 2003), and 2018 (developed for twins) (Kosińska et al. 2018). Meanwhile, the results obtained in the course of the presented analysis showed the presence of differences in the reference standards of birth weight,

estimated for 2000 and 2015. Significant differences were evident in the estimated median values, which are visible in several gestational age categories. Differences were significant in the 28th, 36th, and 39th weeks of gestational age within the group of boys and in the 34th and 41st weeks of gestational age within the group of girls. The reason for the occurrence of diversity may be attributed to the fact that the 15-year period between studies was marked by significant progress in the economic and medical fields, and increasing consciousness regarding diet and lifestyle among the population (Kosińska 2011; Kosińska et al. 2019).

The occurrence of pronounced differences from the 28th week of pregnancy may be explained by intrauterine developmental pathway: in early pregnancy, uterine conditions promote pregnancy duration and maintain size, whereas in later pregnancy, they promote gain in birth weight (Kosińska et al. 2018). The differences are clearly visible while comparing with the norms estimated in 1992 (Kaliszewska-Drozdowska 1992). Values of the 10th–50th and the 75th percentile obtained in this study seem to be significantly lower than the values estimated for both 2000 and 2015. The study of Kaliszewska-Drozdowska (1992) comprises the group of newborns that were born in the late 80s, that is, before the political changes that took place in Poland and neighbouring countries. The political changes that took place in 1990s brought in economic changes (free market economy, change in working conditions, increase in unemployment) and social changes the emergence of new social classes, changes in access to social services or medical services (Bobak et al. 2000; Koupilova et al. 2000; Salavecz et al. 2010).

Prenatal development is influenced by a complex set of conditions, such as medical, climatic, ecological, and socioeconomic changes (Feldman et al. 2000; Hanke et al. 2001; Beeckman et al. 2009; Strand et al. 2011; Arroyo et al. 2016). Therefore, it is crucial that the norms (and consequently percentile charts) used must be representative of the population to which they are applied. However, they are rarely updated. Over the years, there has been a rapid change in the environmental conditions, which have significantly affected the course of pregnancy and thus the perinatal outcome. This finding emphasizes the need for the validation and improvement of developmental norms, such that the reference standard can be universally applied to the entire population.

Conclusions

Medical, social, economic, and demographic changes are associated with inadequacy in the use of existing percentile charts. Unless they are updated, they may not represent the current distribution of birth weights. This observation further emphasizes the need to renew and improve the reference standard such that it represents the contemporary population.

Ethical Issues

The project was implemented with the permissions of the Bioethics Committee (Statement of the Institutional Review Board at Poznań University of Medical Sciences, no. 2431/00 and 538/14).

Authors' contributions

MK contributed to establishing the database, analysis and interpretation of data,

drafting and critical revision of manuscript, study conception and design; TH contributed to establishing the database, acquisition of data, analysis of data, drafting and critical revision of manuscript.

Conflict of interest

The authors declare that they have no competing interest.

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