ORIGINAL PAPER

JMS Journal of Medical Science

Birthweight for gestational age: standard growth charts for the Polish population of full-term infants

Marek Walkowiak

Department of Reproduction, Poznan University of Medical Sciences, Poland

https://orcid.org/0000-0001-6554-8761

Corresponding author: walkowiak.gpsk@gmail.com

Jan Krzysztof Nowak

Department of Pediatric Gastroenterology and Metabolic Diseases, Institute of Pediatrics, Poznan University of Medical Sciences, Poland

https://orcid.org/0000-0003-0953-2188

Małgorzata Jamka

Department of Pediatric Gastroenterology and Metabolic Diseases, Institute of Pediatrics, Poznan University of Medical Sciences, Poland

https://orcid.org/0000-0002-0257-6180

Paweł Gutaj

Department of Reproduction, Poznan University of Medical Sciences, Poland

https://orcid.org/0000-0003-2885-9792

Ewa Wender-Ożegowska

Department of Reproduction, Poznan University of Medical Sciences, Poland

https://orcid.org/0000-0002-5492-8651

DOI: https://doi.org/10.20883/medical.e730

Keywords: birthweight, standard growth charts, full-term infants

Published: 2022-09-05

How to Cite: Walkowiak M, Nowak JK, Jamka M, Gutaj P, Wender-Ożegowska E. Birthweight for gestational age: standard growth charts for the Polish population of full-term infants. Journal of Medical Science. 2022;91(3):e730. doi:10.20883/medical.e730

ABSTRACT

Introduction. Birthweight is one of the most important factors determining neonatal well-being. From an epidemiological viewpoint, a neonatal reference chart provides a picture of the health status of a population. Global customized growth charts seem to be the most practical in multicultural settings, allowing adjustment for ethnicity. However, regional charts might be a valuable contribution to reliable growth assessment.
Aim. Our study aims to establish a reference tool for growth assessment and visualize the local potential, by creating standard charts based on the data from the tertiary center with the highest number of deliveries per year in Poland.
Material and Methods. We retrospectively analysed 31,353 records from the electronic database of singleton births from a five-year period from a tertiary hospital in Poznań, Poland. We excluded pre-term deliveries and high-risk pregnancies basing on well-known factors influencing fetal growth, bringing the number of records to 21,379. The data were processed separately by gender (girls n = 10,312, 48.2% and boys n = 11,067, 51.8%). Percentiles were calculated for each week of gestational age. Means and standard deviations were determined.
Results. Standard growth charts (including 3rd, 10th, 25th, 50th, 75th, 90th and 97th percentiles) are presented. Descriptive data of population distribution are shown.
Conclusions. In conclusion, obtaining standard growth charts for mature newborns has created the opportunity for a more actual and adequate assessment of the Polish neonatal population. It should allow for the implementation of new standards in future research on perinatal care.

Introduction

Birthweight is one of the most important factors determining neonatal well-being [1]. Either large for gestational age (LGA) or small for gestational (SGA) fetuses are predictors of adverse outcomes. Birthweight is strongly correlated with gestational age and sex of the neonate, maternal and paternal anthropometric parameters, and mother's comorbidities, i.e., diabetes, hypertension, or smoking status. Birthweight is also associated with ethnicity, access to modern healthcare, and proper nutrition, making this attribute strongly dependent on place of birth and susceptible to significant variability [2–4].

From an epidemiological viewpoint, neonatal reference charts provide a picture of the health status of a population. The comparison of charts referring to different and clearly defined populations living in the same country, or different countries, or to the same population in different periods is a way of measuring the extent of inequalities in health between populations. From a clinical viewpoint, a neonatal chart is an essential tool to detect neonates at higher risk of neonatal and postnatal morbidity and growth impairment. At present, further clinical studies are needed to reach a consensus on combining neonatal and prenatal information to discriminate neonates with growth derangements, such as intrauterine growth retardation or overgrowth [5–7].

Global customized growth charts seem to be the most practical in multicultural settings, allowing adjustment for ethnicity [8]. In Europe and in Poland, Fenton Growth Charts and Intergrowth project charts [6] are the most commonly used. However, it has been suggested that such a uniform attitude may result in a significant bias, with a risk of over- or under-estimation of LGA and SGA [9–12]. Therefore, regional charts might be a valuable contribution to reliable growth assessment. Updating neonatal charts has become necessary due to changes in parity, maternal age and weight, but also in socio-economical or environmental conditions, and obstetric or neonatal care.

Kajdy et al. recently analysed 39,032 electronic database records of singleton live births from one hospital in Warsaw between 2010–2016. Subsequently, the authors published reference growth charts for premature and mature newborns (from the 24th to the 41st week of gestation) [6]. The most recent regional growth charts were published in 1995 and 2003, respectively [1, 16]. However, Gadzinowski et al. [16] published reference growth charts, whereas Malewski et al. excluded major defects and developmental anomalies that could influence birthweight (hydrocephalus, anencephalus, hydrops fetalis, etc.). Our study aims to establish a reference tool for growth assessment and visualize the local potential, by creating standard charts based on the data from the tertiary center with the highest number of deliveries per year in Poland.

Material and methods

This retrospective study is based on a five-year analysis period (from February 2017 to February 2022). A total of 31,353 computed records from the electronic database of singleton births at Poznan Obsterics and Gynecological University Hospital were considered. Approximately 99% of patients in the database were Caucasians.

Gestational age was verified and confirmed by the last menstrual period and ultrasound in the first trimester, both as described in the ACOG Committee Opinion [13]. The data were filtered depending on the mother's age (20–40 years) and gestational age at birth (36–42 weeks), bringing the number of analyzed neonates from 31,353 to 28,311. This count was further reduced to 21,379 by excluding pediatric and obstetric conditions with an important impact on development in utero (ICD-10): F17.2, O13, O14.0, O14.1, O24.0, O24.4, Q03.9, Q04.2, Q05.2, Q07.0, Q20.3, Q21.0, Q21.1, Q21.2, Q21.3, Q22.5, Q36.9, Q37.8, Q37.9, Q41.0, Q45.9, Q52.8, Q60.0, Q73.8, Q77.4, Q79.0, Q79.3, Q79.9, Q89.7, Q90.9, Q91.3, Q91.7, Q96.9.

The following records were excluded from the study: fetuses and neonates with abnormal karyotype, major congenital defects, infections, and stillbirth. Minor congenital defects, as defined by the European Surveillance of Congenital Anomalies, were included. High-risk women had the following characteristics: aged < 20 and > 40 years, diabetes mellitus, gestational diabetes mellitus, pregnancy hypertension, pre-pregnancy hypertension, preeclampsia, haemolysis, elevated liver enzymes and low platelets (HELLP) syndrome, or cholestasis of pregnancy.

The data were processed separately depending on the sex of the neonate: females (n = 10,312, 48.2%) and males (n = 11,067, 51.8%). Percentiles were calculated 100 times for each week of gestational age through random sampling of 80% of the population without replacement (bootstrap). Locally estimated scatterplot smoothing (LOESS) was used to plot the data in R (tidyverse). The data are presented graphically and within nomograms for the 3rd, 10th, 25th, 50th, 75th, 90th, and 97th percentiles (from P3 to P97), as well as means and standard deviations. Percentiles for each week were also calculated without smoothing and presented in tables. To compare the currently investigated population with the population previously studied by Gadzinowski et al. [18] and Malewski et al. [1], we compared means and standard deviations. This was done using a 100-fold bootstrap procedure with distribution-preserving random sampling of 1000 values in both groups, and subsequent comparison using the Student's t-test (means) and the F-test (variance). This setup enabled relative comparison of the importance of differences through the minimalization of the impact of sample size on p-values. The analyses were conducted in R 4.1.3 (R Foundation for Statistical Computing, Vienna, Austria).

Results

A total of 21,379 newborns were included in the final analysis. The sex and age distribution are presented in **Table 1**. Boys, on average, were heavier approx. by 5%. Significant differences were observed for all studied gestational age subgroups.

Growth charts of body weight (showing P3, P10, P25, P50, P75, P90, P97) for the term infants are shown in **Figures 1–2**, whereas the means and standard deviations are documented in **Table 2**. Percentiles calculated without smoothing are presented in **Table 3**.

Within the currently studied population older neonates significantly were heavier than in historical data from Gadzinowski et al. [16]; this was true for the majority of age subclasess in the case of Malewski et al. research [1]. Similarly, significantly less variance was observed. In the present study, babies born at 40th and 41st week of pregnancy had 1-2% higher body weight and up to 10% less variance in mass than those in the

Table 1. Number of births by gestational age and sex

Week of gestation*	Study subgroups [N/%]	
	Boys	Girls
37	866 (8.0)	693 (6.9)
38	2197 (20.4)	2020 (20.1)
39	3541 (32.9)	3320 (33.1)
40	2953 (27.5)	2829 (28.2)
41	1156 (10.8)	1148 (11.4)
42	39 (0.4)	30 (0.3)

* week "n" is defined as age from "n" weeks up to "n" weeks +6 days.

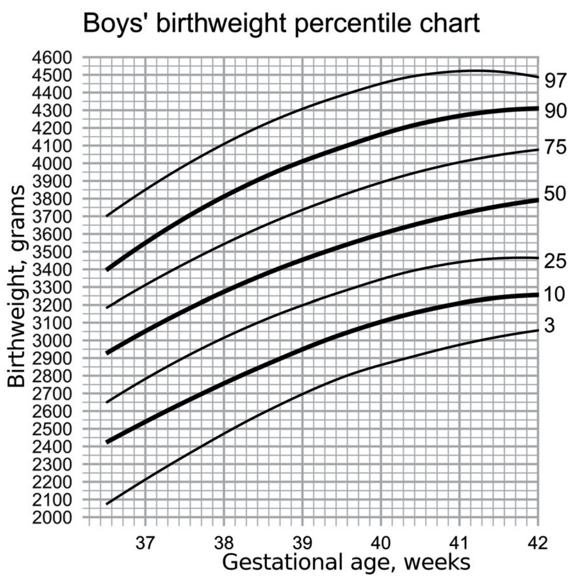

Figure 1. Growth charts of boys' body weight (showing P3, P10, P25, P50, P75, P90, P97) for the term infants

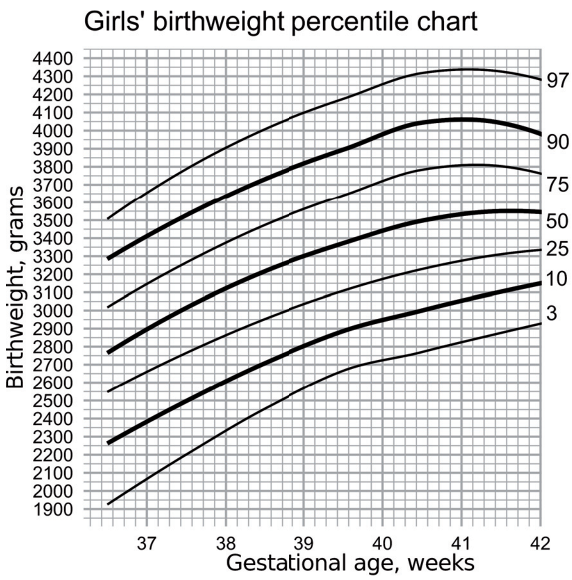

Figure 2. Growth charts of girls' body weight (showing P3, P10, P25, P50, P75, P90, P97) for the term infants

Table 2. Average birthweight of infants by gestational age and sex

Week of gestation*	Birthweight [grams] Mean ± SD		Sex difference p
	Boys	Girls	
37	3157 ± 440	2998 ± 430	1.03×10^{-12}
38	3388 ± 421	3226 ± 398	4.42×10^{-37}
39	3545 ± 428	3383 ± 415	3.20×10^{-56}
40	3677 ± 424	3498 ± 408	8.29×10^{-59}
41	3775 ± 412	3598 ± 400	3.78×10^{-25}
42	3790 ± 434	3522 ± 326	0.00467
All neonates	3543 ± 456	3382 ± 437	3.27×10^{-147}

* week "n" is defined as age from "n" weeks up to "n" weeks +6 days.
SD – standard deviation

Table 3. Birthweight percentiles of infants by gestational age and sex

Gestational age* [weeks]	Birthweight percentiles** (P) – Boys [grams]						
	P3	P10	P25	P50	P75	P90	P97
37	2290	2620	2900	3170	3430	3700	3971
38	2619	2880	3125	3375	3640	3920	4240
39	2795	3020	3260	3520	3820	4080	4380
40	2900	3165	3400	3660	3950	4220	4484
41	3033	3258	3480	3760	4060	4300	4560
42	3063	3236	3440	3820	4100	4320	4397
Gestational age* [weeks]	**Birthweight percentiles** (P) – Girls [grams]**						
	P3	P10	P25	P50	P75	P90	P97
37	2139	2468	2750	3000	3260	3540	3825
38	2483	2720	2960	3230	3475	3720	3980
39	2673	2890	3104	3360	3645	3900	4200
40	2759	2990	3220	3490	3750	4020	4300
41	2877	3100	3320	3580	3865	4104	4360
42	2944	3194	3348	3505	3685	3837	4243

* week "n" is defined as age from "n" weeks up to "n" weeks +6 days. Values are given for the central point of the range (n weeks + 3 days)
** without smoothing

first mentioned study [16]. This trend was found both in male and female neonates. Differences in body weight were more pronounced (4-6%) and spanned from 38th to 41st week of pregnancy when comparison was made between the current data and parameters reported in the second study [1]. Furthermore, the variance in the population investigated by Malewski et al. was greater by up to 17%. The use of previous growth charts would result in improper classification of significant part (even up to one third for the second study) of 10 top and down percent of newborn population.

Discussion

We analysed a large and up-to-date cohort of term newborns from low-risk pregnancies, and created standard growth charts that reflect ideal (normal) growth. Such an attitude seems to be most reasonable for babies born at term. Therefore, in the present study we assessd exclusively children born between 37th and 42nd week of gestation. In contrast, reference growth charts (including both low- and high-risk pregnancies) could be considered more appropriate for preterm neonates and better reflect overall population. Since in the recently studied cohort by Kajdy et al. in another Polish region [6] and investigated in the past in our region by Gadzinowski et al. [16] and Malewski et al. [1] high-risk (all for the latter study significant part of high-risk) pregnancies were included it is difficult to directly compare our results to those data. It is worth underlining that our study was carried out in an ethnically homogenous population, in a region with good access to medical care.

Neonatal growth charts help in identifying values that best discriminate between infants at high and low risk of complications later in life [14]. Historically, studies on fetal growth were primarily associated with low birth weight Birthweight, but the problem of fetal overgrowth increased in the last decades. Detecting LGA fetuses is important to prevent shoulder dystocia, peripartum hemorrhage, or cesarean section, and prevent the risk of maternal diabetes, and metabolic syndrome in childhood [15] SGA is a condition in which the fetus is smaller than expected in the absence of any pathological conditions or toxic factors. SGA fetuses may be compromised, and thus need to be prematurely delivered. Such newborns are at risk of hypoglycemia, hypoxic-ischemic encephalopathy, gastrointestinal bleeding, polycythemia, pulmonary hemorrhage, apnoea, disseminated intravascular coagulation, and prolonged hospitalization [16].

Neonatal growth standards (reflected by growth charts) may differ due to essential differences in parity, maternal age, and prevalence of malnutrition/obesity. The availability and quality of obstetric or neonatal care may also exert a significant impact. All these factors create the basis for potential country/regional differences in growth references (charts). Moreover, growth charts should be updated in conformity with the intensity of the "secular trend of growth" and observed socio-economic changes in the population (e.g., every 10–20 years) [17–18]. The comparison of results obtained in the present study with previous data [1, 16], even considering differences in populations included and methodological issues, suggest the existence of a mentioned secular trend. Consequently, the sensitivity of older norms to pathology would be reduced, resulting in improper classification of up to a third of children in the extreme 20 percent (including both SGA and LGA) of the current newborn population, where high precision is required.

In conclusion, obtaining standard growth charts for mature newborns has created the opportunity for a more actual and adequate assessment of the Polish neonatal population. It should allow for the implementation of new standards in future research on perinatal care.

Acknowledgements

Conflict of interest statement
The authors declare no conflict of interest.

Funding sources
There are no sources of funding to declare.

References

1. Malewski Z. Relacja masy ciała odnoszonej do wieku oraz stanu płodu i noworodka [Correlation of birthweight and the prediction of fetal and neonatal status]. Ginekol Pol. 2003 Feb;74(2):121-7. Polish. PMID: 12715421.
2. Thomas P, Peabody J, Turnier V, Clark RH. A new look at intrauterine growth and the impact of race, altitude, and gender. Pediatrics. 2000 Aug;106(2):E21. doi: 10.1542/peds.106.2.e21. PMID: 10920177. DOI: https://doi.org/10.1542/peds.106.2.e21.
3. Beta J, Khan N, Khalil A, Fiolna M, Ramadan G, Akolekar R. Maternal and neonatal complications of fetal macrosomia: systematic review and meta-analysis. Ultrasound Obstet Gynecol. 2019 Sep;54(3):308-318. doi: 10.1002/uog.20279. Epub 2019 Aug 2. PMID: 30938004. DOI: https://doi.org/10.1002/uog.20279.
4. Lees CC, Romero R, Stampalija T, Dall'Asta A, DeVore GA, Prefumo F, Frusca T, Visser GHA, Hobbins JC, Baschat AA, Bilardo CM, Galan HL, Campbell S, Maulik D, Figueras F, Lee W, Unterscheider J, Valensise H, Da Silva Costa F, Salomon LJ, Poon LC, Ferrazzi E, Mari G, Rizzo G, Kingdom JC, Kiserud T, Hecher K. Clinical Opinion: The diagnosis and management of suspected fetal growth restriction: an evidence-based approach. Am J Obstet Gynecol. 2022 Mar;226(3):366-378. doi: 10.1016/j.ajog.2021.11.1357. Epub 2022 Jan 10. PMID: 35026129; PMCID: PMC9125563. DOI: https://doi.org/10.1016/j.ajog.2021.11.1357.
5. Kajdy A, Modzelewski J, Herman K, Muzyka-Placzynska K, Rabijewski M. Growth charts and prediction of abnormal growth – what is known, what is not known and what is misunderstood. Ginekol Pol. 2019;90(12):717-721. doi: 10.5603/GP.2019.0123. PMID: 31909466. DOI: https://doi.org/10.5603/GP.2019.0123.
6. Kajdy A, Modzelewski J, Filipecka-Tyczka D, Pokropek A, Rabijewski M. Development of birth weight for gestational age charts and comparison with currently used charts: defining growth in the Polish population. J Matern Fetal Neonatal Med. 2021 Sep;34(18):2977-

2984. doi: 10.1080/14767058.2019.1676412. Epub 2019 Oct 16. PMID: 31619090. DOI: https://doi.org/10.1080/14767058.2019.1676412.
7. Hutcheon JA, Liauw J. Should Fetal Growth Charts Be References or Standards? Epidemiology. 2021 Jan;32(1):14-17. doi: 10.1097/EDE.0000000000001275. PMID: 33074926; PMCID: PMC7707154. DOI: https://doi.org/10.1097/EDE.0000000000001275.
8. Gardosi J, Francis A, Turner S, Williams M. Customized growth charts: rationale, validation and clinical benefits. Am J Obstet Gynecol. 2018 Feb;218(2S):S609-S618. doi: 10.1016/j.ajog.2017.12.011. PMID: 29422203. DOI: https://doi.org/10.1016/j.ajog.2017.12.011.
9. Hocquette A, Durox M, Wood R, Klungsøyr K, Szamotulska K, Berrut S, Rihs T, Kyprianou T, Sakkeus L, Lecomte A, Zile I, Alexander S, Klimont J, Barros H, Gatt M, Isakova J, Blondel B, Gissler M, Zeitlin J. International versus national growth charts for identifying small and large-for-gestational age newborns: A population-based study in 15 European countries. Lancet Reg Health Eur. 2021 Jul 15;8:100167. doi: 10.1016/j.lanepe.2021.100167. PMID: 34557855; PMCID: PMC8454535. DOI: https://doi.org/10.1016/j.lanepe.2021.100167.
10. Anand P, Thomas D, Agarwal R, Thukral A, Deorari AK, Paul VK, Sankar MJ. Comparison of regional versus global growth charts for the classification of small-for-gestational age neonates. Arch Dis Child Fetal Neonatal Ed. 2022 May 12:fetalneonatal-2021-322457. doi: 10.1136/archdischild-2021-322457. Epub Journal of Medical Science. 2022;91(3):e. PMID: 35551076. DOI: https://doi.org/10.1136/archdischild-2021-322457.
11. Monier I, Ego A, Benachi A, Hocquette A, Blondel B, Goffinet F, Zeitlin J. Comparison of the performance of estimated fetal weight charts for the detection of small- and large-for-gestational age newborns with adverse outcomes: a French population-based study. BJOG. 2022 May;129(6):938-948. doi: 10.1111/1471-0528.17021. Epub 2021 Nov 30. PMID: 34797926. DOI: https://doi.org/10.1111/1471-0528.17021.
12. Zhang L, Lin JG, Liang S, Sun J, Gao NN, Wu Q, Zhang HY, Liu HJ, Cheng XD, Cao Y, Li Y. Comparison of Postnatal Growth Charts of Singleton Preterm and Term Infants Using World Health Organization Standards at 40-160 Weeks Postmenstrual Age: A Chinese Single-Center Retrospective Cohort Study. Front Pediatr. 2021 Mar 15;9:595882. doi: 10.3389/fped.2021.595882. PMID: 33791257; PMCID: PMC8005644. DOI: https://doi.org/10.3389/fped.2021.595882.
13. Committee opinion no 611: method for estimating due date. Obstet Gynecol. 2014 Oct;124(4):863-866. doi: 10.1097/01.AOG.0000454932.15177.be. PMID: 25244460. DOI: https://doi.org/10.1097/01.AOG.0000454932.15177.be.
14. Sovio U, Smith GCS. The effect of customization and use of a fetal growth standard on the association between birthweight percentile and adverse perinatal outcome. Am J Obstet Gynecol. 2018 Feb;218(2S):S738-S744. doi: 10.1016/j.ajog.2017.11.563. Epub 2017 Dec 2. PMID: 29199029. DOI: https://doi.org/10.1016/j.ajog.2017.11.563.
15. American College of Obstetricians and Gynecologists' Committee on Practice Bulletins—Obstetrics. Practice Bulletin No. 173: Fetal Macrosomia. Obstet Gynecol. 2016 Nov;128(5):e195-e209. doi: 10.1097/AOG.0000000000001767. PMID: 27776071. DOI: https://doi.org/10.1097/AOG.0000000000001767.
16. Liu J, Wang XF, Wang Y, Wang HW, Liu Y. The incidence rate, high-risk factors, and short- and long--term adverse outcomes of fetal growth restriction: a report from Mainland China. Medicine (Baltimore). 2014 Dec;93(27):e210. doi: 10.1097/MD.0000000000000210. PMID: 25501078; PMCID: PMC4602786. DOI: https://doi.org/10.1097/MD.0000000000000210.
17. Karlberg J, Cheung YB, Luo ZC. An update on the update of growth charts. Acta Paediatr. 1999 Aug;88(8):797-802. doi: 10.1080/08035259950168676. PMID: 10503674. DOI: https://doi.org/10.1111/j.1651-2227.1999.tb00050.x.
18. Gadzinowski J, Kaliszewska-Drozdowska MD, Kosińska M, Mazela J, Stoińska B. Urodzeniowa masa ciała a wiek płodowy noworodków regionu Wielkopolski i Ziemi Lubuskiej [Birth weight and gestational age of newborns from Wielkopolski and Lubuski regions]. Ginekol Pol. 2003 Mar;74(3):186-92. Polish. PMID: 12916255.