IMR Press

Original Research

Comparison of application of Fenton, Intergrowth-21st and WHO growth charts in a population of Polish newborns

Dominik Jakubowski[1,*], Daria Salloum[1], Marek Maciejewski[1], Magdalena Bednarek-Jędrzejek[2], Anna Kajdy[3], Aneta Cymbaluk-Płoska[4], Ewa Kwiatkowska[5], Andrzej Torbé[2], Sebastian Kwiatkowski[2]

[1] *Pomeranian Medical University, 70-111 Szczecin, Poland*

[2] *Department Obstetrics and Gynecology, Pomeranian Medical University, 70-111 Szczecin, Poland*

[3] *Department of Reproductive Health, Centre of Postgraduate Medical Education, 01-004 Warszawa, Poland*

[4] *Department of Gynecological Surgery and Oncology of Adults and Adolescents, Pomeranian Medical University, 70-111 Szczecin, Poland*

[5] *Department of Nephrology, Transplantology and Internal medicine, Pomeranian Medical University, 70-111 Szczecin, Poland*

*Correspondence: ddominikjakubowski@gmail.com (Dominik Jakubowski)

DOI:10.31083/j.ceog4804150

Submitted: 31 March 2020 Revised: 1 June 2021 Accepted: 8 June 2021 Published: 15 August 2021

Background: Growth charts are the primary tools for evaluating neonatal birth weight and length. They help and qualify the neonates as Appropriate for Gestational Age (AGA), Small for Gestational Age (SGA), or Large for Gestational Age (LGA). The most commonly used neonatal charts include Intergrowth-21st, WHO, and Fenton. The aim of the study was to compare the tools used for assessing neonatal birth weight and the incidence of SGA and LGA using the different charts. *Methods*: Data on 8608 births in the Clinical Department of Obstetrics and Gynecology were compared. We divided the patient population into five gestational age groups. The 10th and 90th percentiles were calculated. The percentage of cases meeting the SGA and LGA criteria was determined. *Results*: Statistically significant differences between growth charts were identified for each of the groups. The 10th percentile for the study population corresponded to 2970 g for females and 3060 g for males born in the 40th week of gestation. The 90th percentile values were 4030 g and 4120 g. Our analysis showed a statistically significant difference in detection of LGA or SGA between three growth charts and our data both in male ($\chi^2(3)$ = 157.192, $p < 0.001$, Kramer's V = 0.444) and female newborns ($\chi^2(3)$ = 162.660, $p < 0.001$, Kramer's V = 0.464). *Discussion*: Our results confirm that differences exist between growth charts. There is a need for harmonizing growth assessment standards. It is recommended that a growth chart should be developed for the Polish population, which would improve the diagnosis of SGA and LGA.

Keywords

Growth charts; Small for gestational age; Large for gestational age; Growth standard

1. Introduction

Growth charts are the primary tool for assessing growth. They help evaluate body weight and length, and head circumference against the entire population, also with regard to the neonatal sex. They help monitor growth and qualify the neonates as Appropriate for Gestational Age (AGA), Small for Gestational Age (SGA), or Large for Gestational Age (LGA).

SGA is birth weight below the 10th percentile. There are three categories of causes: fetal, maternal, and placental. It is much more prevalent in smoking mothers [1]. LGA is defined as a birth weight above the 90th percentile. It is much more prevalent in diabetic mothers. It is a risk factor for perinatal complications such as shoulder dystocia, vaginal and perineal tears, peripartum hemorrhage, and cesarean section [2].

Both obstetricians and neonatologists have developed many different growth charts. Varying methodologies and applications have resulted in many misunderstandings regarding fetal and neonatal growth [3]. The most common charts are designed by the Fenton, the International Fetal and Newborn Growth Consortium (Intergrowth-21st), and WHO. The Fenton preterm growth charts, designed in 2003 and most recently revised in 2013, result from a meta-analysis of growth charts used locally [4]. They are mostly applied in neonatal departments. The Intergrowth-21st project was based on a multicenter and multi-ethnic analysis of the populations of eight countries of North and South Americas, Africa, Europe, and Asia. They hypothesized that body weight and weight gain under optimal health conditions in the prenatal and postnatal periods were independent of one's ethnic background [5]. It is useful in monitoring fetal growth [6], as it shows correlations between estimated fetal weight (EFW) and neonatal birth weight [7]. WHO charts also assumed the optimal health and financial conditions for the child's development [8]. However, they showed differences in the EFW between different parts of the world [9].

Growth charts are not perfect tools. Depending on the methodology applied, different SGA and LGA risk group percentages are identified [10]. This may lead to the introduction of the wrong diagnostic, therapeutic, and preventive procedures.

SGA is much more prevalent in low- and medium-income countries, e.g., in East and South Asia [11]. More frequent dietary deficiencies and a lower caloric value of the diet, and limited access to health care are some causes. Differences in neonatal birth weight have also been identified between ethnic groups. Thus the use of a chart adapted to another population may lead to the overdiagnosis of SGA or LGA [12]. For this reason, projects aiming at developing personalized growth charts are undertaken. This concept was developed by Gardosi *et al.* [13] and consists of creating an individual growth chart adapted to the particular child. When drawing up the chart, such parameters are used as gestational age, fetal sex, maternal height and weight at the first visit, maternal ethnicity, parity, and smoking. The individualized growth charts are characterized by a higher precision in the diagnosis of growth disorders. They help reduce the number of false-positive diagnoses of SGA [14].

The objective of the study was to compare the tools used for assessing neonatal birth weight. The incidence of SGA and LGA—as defined above—was compared between the growth charts studied and our results. Therefore, the aim of the study was to determine whether there are differences in the percentage of SGA or LGA diagnoses depending of growth chart used.

2. Materials and methods

A retrospective assessment of 9235 singleton births delivered between 2015 and 2019 in the Clinical Department of Obstetrics and Gynecology, Pomeranian Medical University in Szczecin, the largest city in northwest Poland, was made. The region's population is ethnically homogeneous. Data on maternal age, week of gestation, gravidity and parity and birth weight were compiled from the medical documentation. The gestational age for all the mothers included in the study was determined either according to the date of their last menstruation or by measuring the CRL, or by combining these methods [15].

The inclusion criteria included singleton pregnancy and gestational age at birth ranging between 24 and 40 weeks. Pregnancies terminated before 24 weeks' gestation and after 40 weeks' gestation (627 records), as well as multiple pregnancies, were excluded. The data were divided into five groups depending on gestational age at birth: A—between 24 and 27, B—between 28 and 31, C—between 32 and 35, D—between 36 and 37, and E—between 38 and 40 weeks.

Subsequently, gestational age and neonatal birth weight were mapped on three growth charts Fenton, the WHO chart, and Intergrowth-21st Project. Gestational age and neonatal sex were included in the analysis. The Shapiro-Wilk test showed that the data obtained did not demonstrate normal distribution. Therefore, the individual growth charts were compared within the groups using the Kruskal-Wallis test.

Next, the LMS method (using the μ median, Box-Cox power λ, and coefficient of variation σ) was used to calculate the 5th, 10th, 90th, and 95th percentiles for the 40th week for males and females, respectively. The percentages of the population meeting the SGA criteria defined as a birth weight below the 10th percentile and LGA defined as birth weight above the 90th percentile were determined. The Chi-square test was used to assess an incidence of SGA and LGA.

Our statistical analysis was performed using the Statistical Package for Social Sciences (SPSS) for Mac, version 27.0.0.0 (IBM Corp. Released 2020, Armonk, NY, USA). For qualitative variables, such data were used as the number of cases and the percentage values. Continuous variables were presented as an arithmetic average along with the standard deviation and the median. The demographic data were compared with the help of the Chi-squared test. The Shapiro-Wilk test was used for the percentile values to establish whether the data demonstrated normal distribution, followed by the Kruskal-Wallis test. All missing values were marked as NA. Statistical significance was determined for p values of <0.05.

The activities undertaken as part of the research were compliant with the Helsinki Declaration on medical research on human subjects. According to Polish law, no consent from an institutional review board was required as the study was a retrospective analysis and had no impact on the patients' routine management.

3. Results

A population of 8608 patients was divided into five groups depending on the gestational age at birth. Group A consisted of 61, group B of 141, group C of 495, group D of 1074, and group E of 7422 patients.

The main data concerning the patients and the births are found in Table 1. Our analysis of the gathered data showed statistically significant differences in gravidity and parity values and pregnancy termination methods between the groups. No differences were observed in respect of the mother's age ($\chi^2(128) = 124.509$, $p = 0.577$) and the neonates' sex ($\chi^2(4) = 6.767$, $p = 0.149$).

In group A, a statistically significant difference between the growth charts was observed ($p = 0.038$). In group B, C, D and E a statistically significant difference between the charts was shown ($p < 0.001$).

The analysis showed that for female children born at 40 weeks' gestation, the 95th percentile for birth weight was 4200 g, the 90th percentile was 4030 g, and the 10th and 5th percentiles were 2970 g and 2840 g, respectively (Table 2). It was shown for male newborns born at 40 weeks' gestation that the 95th percentile for birth weight corresponded to 4230 g, the 90th percentile to 4120 g, and the 5th percentile to 2920 g (Table 2).

Subsequently, using the birth weight percentiles observed in the study population, the percentages of newborns below the 10th percentile (9.77% for female and 9.95% for male newborns) and above the 90th percentile (9.67% for female and 9.14% for male newborns) were determined. For details refer to Tables 3,4,5. Our analysis showed a statisti-

Table 1. Clinical data concerning patients and births.

	Group A	Group B	Group C	Group D	Group E	*p*-value
	n = 61	n = 141	n = 495	n = 1074	n = 7422	
AGE						
Mean SD	29.25 (5.978)	30.489 (6.019)	30.572 (5.979)	30.551 (5.57)	29.981 (5.807)	0.577
Median	30	31	31	31	30	
Min/max	17/42	16/43	16/45	16/45	15/45	
Gravidity						
1	23 (37.7%)	56 (39.71%)	177 (35.76%)	361 (33.61%)	2719 (36.63%)	<0.001
2–4	34 (55.74%)	78 (55.32%)	291 (58.79%)	626 (58.29%)	4461 (60.11%)	
>4	4 (6.56%)	7 (4.97%)	27 (5.45%)	87 (8.1%)	242 (3.26%)	
Parity						
1	27 (44.27%)	69 (48.94%)	188 (37.98%)	437 (40.69%)	3150 (42.44%)	<0.001
2–4	33 (54.1%)	66 (46.81%)	285 (57.58%)	603 (56.15%)	4172 (56.21%)	
>4	1 (1.64%)	6 (4.25%)	22 (4.44%)	34 (31.66%)	100 (1.35%)	
Type of delivery						
Spontaneous delivery	11 (18%)	23 (16.31%)	128 (25.86%)	429 (39.94%)	3792 (51.09%)	<0.001
C. section	50 (82%)	118 (83.69%)	367 (74.14%)	645 (60.06%)	3630 (48.91%)	
Sex						
Female	22 (36.07%)	65 (46.1%)	218 (44.04%)	507 (47.21%)	3586 (48.32%)	0.149
Male	39 (63.93%)	76 (53.9%)	277 (55.96%)	567 (52.79%)	3836 (51.68%)	

Table 2. Percentiles for newborns born in the 40th week of gestation.

	WHO	Fenton	Intergrowth	Our population
95th percentile (female)	4240 g	4430 g	3970 g	4200 g
95th percentile (male)	4360 g	4510 g	4110 g	4230 g
90th percentile (female)	4100 g	4200 g	3810 g	4030 g
90th percentile (male)	4120 g	4300 g	3940 g	4120 g
10th percentile (female)	3090 g	2900 g	2780 g	2970 g
10th percentile (male)	3110 g	3080 g	2980 g	3060 g
5th percentile (female)	2850 g	2740 g	2640 g	2840 g
5th percentile (male)	2900 g	2920 g	2740 g	2920 g

cally significant difference for male newborns in detection of growth abnormalities between three growth charts and our data ($\chi^2(3) = 157.192$, $p < 0.001$, Kramer's V = 0.444). In the case of female newborns our analysis also showed a statistically significant difference comparing three growth charts and our data ($\chi^2(3) = 162.660$, $p < 0.001$, Kramer's V = 0.464).

4. Discussion

Accurate weight assessment using growth charts is key in ensuring proper care during prenatal and postnatal periods. It is essential that the patient is adequately qualified for either the SGA or the LGA group and that appropriate preventive and diagnostic procedures are implemented early. A bodyweight that is too low or too high during an ultrasound may sometimes be the first indication of an ongoing disease or a risk of its development. The literature describes cases of increased risk of preeclampsia [16] in pregnancies complicated by SGA. It should be emphasized that we used a growth charts to assess birth weight.

Studies carried out on other populations have shown differences between growth charts [17, 18]. Such differences lead to different assessments of the patient's condition depending on the methodology used, which results in disagreement between doctors of different specialties. Similar results have been achieved for the Polish population [20]. Our results confirm the data reported in the literature.

In addition to SGA and LGA, discussions focus on fetal growth restriction (FGR). The term applies to fetuses that have not reached their biological growth potential due to growth-restricting factors developing during pregnancy. The etiology of this state is multi-factorial, the most commonly recognized cause being disordered placental blood flow. There is no clear definition for FGR as of yet. The WHO defines it as an estimated fetal weight below the 3rd percentile, while the American College of Obstetrics and Gynecology (ACOG) recognizes the limit to be the 10th percentile. The most commonly used definition is developed by way of international cooperation through a so-called Delphi procedure. Based on the opinions of 56 selected experts deal-

Table 3. Comparison of the number of newborns born in the 40th week of gestation with a birth weight <10th percentile and >90th percentile.

	WHO	Fenton	Intergrowth	Our population
>90th percentile (female)	n = 67 (6.61%)	n = 47 (4.64%)	n = 198 (19.55%)	n = 98 (9.67%)
>90th percentile (male)	n = 90 (9.14%)	n = 31 (3.15%)	n = 202 (20.51%)	n = 90 (9.14%)
<10th percentile (female)	n = 159 (15.69%)	n = 60 (5.92%)	n = 28 (2.76%)	n = 99 (9.77%)
<10th percentile (male)	n = 129 (13.09%)	n = 115 (11.68%)	n = 43 (4.36%)	n = 98 (9.95%)

Table 4. Comparison of the number of female newborns with a birth weight <10th percentile and >90th percentile.

	WHO	Fenton	Intergrowth	Our population
>90th percentile	n = 67 (6.61%)	n = 47 (4.64%)	n = 198 (19.55%)	n = 98 (9.67%)
<10th percentile	n = 159 (15.69%)	n = 60 (5.92%)	n = 28 (2.76%)	n = 99 (9.77%)

Table 5. Comparison of the number of male newborns with a birth weight <10th percentile and >90th percentile.

	WHO	Fenton	Intergrowth	Our population
>90th percentile	90 (9.14%)	31 (3.15%)	202 (20.51%)	90 (9.14%)
<10th percentile	129 (13.09%)	115 (11.68%)	43 (4.36%)	98 (9.95%)

ing with growth disorders, the diagnostic criteria for FGR were developed [19].

An accurate diagnosis of SGA and LGA is essential because of the implications these conditions entail. These patients are predisposed to perinatal pathologies and obesity, insulin resistance, or hypertension in later life [20, 21]. An increased body fat ratio to lean body mass is reported to cause SGA children to develop metabolic syndrome. Also, a higher predisposition to the central distribution of body fat is implicated [22]. In the case of LGA, impaired vascular response to adiponectin and reduced nitrogen oxide production are indicated as the causes of the complications [23].

The literature offers the concept of fetal programming, which presently appears to be the most comprehensive theory combining the different elements of maternal factors. According to this approach, genetic, epigenetic, and environmental factors have a crucial influence on the developing fetus [24]. The effects exerted by these elements are responsible for various disturbances. There are reports on hormonal axes disturbances leading to metabolic syndrome [25]. Maternal obesity is implicated as another factor that may impair the development of the fetus [26]. However, epigenetic changes appear to be an essential element of fetal programming. These are such changes to the DNA as methylation and histone modifications [27]. During fetal life, environmental factors have been shown to lead, through epigenetic changes, to the development of obesity in adult life [28]. This is particularly important in the context of the application of growth charts. If accurately qualified for the LGA group, patients can be provided with adequate prevention of metabolic diseases.

To date, numerous factors predisposing to growth disorders have been identified. In SGA, smoking, hypertension, and previous miscarriages have been implicated as the main maternal factors. In the case of LGA, the main predisposing factors are pre-pregnancy obesity and diabetes mellitus [29]. Ethnicity is also an important consideration [30], which may be particularly relevant when designing appropriate growth charts. The increased risk of metabolic disorders in the children of diabetic mothers suggests that this group of patients should be closely monitored.

The approach proposed by Fetal Medicine Foundation is also an important issue, due to significant number of preterm births. The approach created by Nicolaides *et al.* [31] can help raise awareness of the growth restriction in the preterm birth.

One of our analysis's strengths is that it covered an ethnically homogeneous population, which allowed us to show that there was a need to create a growth chart specifically for this population. Another of its strengths was that it divided the population into gestational age groups, which showed statistically significant differences between the obtained percentiles in each group. Another advantage of our approach was that the patients were hospitalized in one health care center, which facilitated any possible follow-up. That factor can be a strength, but it can also be a limitation. Other limitations of our research are small number of included patients and lack of knowledge about socioeconomic factors. Our results suggest a need for multicenter cooperation to evaluate the Polish population in terms of birth weight and length. The next step would be to develop growth charts for the Polish population, which are uniform for doctors of different specialties. There is a need for harmonizing both growth assessment standards and growth disorder concepts. In the age of computerization, it may be advisable to create a database containing primary data on newborns. Such information could be used to draw up the charts mentioned above. Improved qualification for groups carrying the risk of developing the different metabolic syndrome components would lead to the earlier implementation of lifestyle modifications [32], reducing obesity, insulin resistance, and hypertension. This would entail a reduction in the cost of treatment and a lower rate of hospitalization. Early identification and—primarily non-pharmacological—prevention are the key to controlling the global epidemic of obesity and diabetes mellitus and the subsequent metabolic syndrome [33]. The discrepancy in the number of children diagnosed with SGA depending on the growth chart used, as reported in the literature, is an argument in favor of creating a new growth chart for the Polish population [34]. These results are consistent with the outcomes of our analysis.

5. Conclusions

Our study's results confirm the hypothesis that there are discrepancies in the assessment of birth weight depending on the growth chart used. Besides, it has been proven that the percentage of children qualified for either the SGA or the LGA group varies significantly depending on the methodology used. These outcomes are in line with those reported by other researchers and show a need to introduce population-specific growth charts to increase the sensitivity with which children with abnormal body weight can be identified. It is recommended that a single growth chart should be developed for the Polish population that could be used by doctors of all specialties. It is also necessary to harmonize the concepts related to growth disorders.

Abbreviations

AGA, Appropriate for Gestational Age; SGA, Small for Gestational Age; LGA, Large for Gestational Age; CRL, Crown rump length.

Author contributions

DJ, DS and MM collected and assembled the data. DJ analyzed and interpreted the data. SK, AT, AK designed the research concept. DJ, MBJ, AK, ACP, EK, SK and AT wrote the article. MBJ, AK, ACP, EK and SK revised the article critically. All authors read and approved the final manuscript.

Ethics approval and consent to participate

The activities undertaken as part of the research were compliant with the Helsinki Declaration on medical research on human subjects. According to Polish law, no consent from an institutional review board was required as the study was a retrospective analysis and had no impact on the patients' routine management.

Acknowledgment

We thank two/three anonymous reviewers for excellent criticism of the article.

Funding

This research received no external funding.

Conflict of interest

The authors declare no conflict of interest.

References

[1] McCowan LME, Roberts CT, Dekker GA, Taylor RS, Chan EHY, Kenny LC, *et al.* Risk factors for small-for-gestational-age infants by customised birthweight centiles: data from an international prospective cohort study. BJOG: an International Journal of Obstetrics and Gynaecology. 2010; 117: 1599–1607.

[2] Margareta M, Henrik H, Börje B, Håkan L, Lars L. High birthweight and shoulder dystocia: the strongest risk factors for obstetrical brachial plexus palsy in a Swedish population-based study. Acta Obstetricia et Gynecologica Scandinavica. 2005; 84: 654–659.

[3] 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. Ginekologia Polska. 2019; 90: 717–721.

[4] Villar J, Cheikh Ismail L, Victora CG, Ohuma EO, Bertino E, Altman DG, *et al.* International standards for newborn weight, length, and head circumference by gestational age and sex: the Newborn Cross-Sectional Study of the INTERGROWTH-21st Project. Lancet. 2014; 384: 857–868.

[5] Stirnemann J, Villar J, Salomon LJ, Ohuma E, Ruyan P, Altman DG, *et al.* International estimated fetal weight standards of the INTERGROWTH-21st Project. Ultrasound in Obstetrics & Gynecology. 2017; 49: 478–486.

[6] Cheng YKY, Lu J, Leung TY, Chan YM, Sahota DS. Prospective assessment of INTERGROWTH-21st and World Health Organization estimated fetal weight reference curves. Ultrasound in Obstetrics & Gynecology. 2018; 51: 792–798.

[7] Dietitians of Canada; Canadian Paediatric Society; College of Family Physicians of Canada; Community Health Nurses of Canada, Secker D. Promoting optimal monitoring of child growth in Canada: using the new who growth charts. Canadian Journal of Dietetic Practice and Research. 2010; 71: e1–e3.

[8] Kiserud T, Piaggio G, Carroli G, Widmer M, Carvalho J, Neerup Jensen L, *et al.* The World Health Organization Fetal Growth Charts: a Multinational Longitudinal Study of Ultrasound Biometric Measurements and Estimated Fetal Weight. PLoS Medicine. 2017; 14: e1002220.

[9] Fenton TR, Kim JH. A systematic review and meta-analysis to revise the Fenton growth chart for preterm infants. BMC Pediatrics. 2013; 13: 59.

[10] Tuzun F, Yucesoy E, Baysal B, Kumral A, Duman N, Ozkan H. Comparison of INTERGROWTH-21 and Fenton growth standards to assess size at birth and extrauterine growth in very preterm infants. Journal of Maternal-Fetal & Neonatal Medicine. 2018; 31: 2252–2257.

[11] Lee ACC, Katz J, Blencowe H, Cousens S, Kozuki N, Vogel JP, *et al.* National and regional estimates of term and preterm babies born small for gestational age in 138 low-income and middle-income countries in 2010. The Lancet Global Health. 2013; 1: e26–e36.

[12] Hauzer M, Rubin, L, Grotto I, Calderon-Margalit R. Are the World Health Organization growth standards universal? The Israeli children validity study. Journal of Public Health. 2020; 1: 1–11.

[13] Gardosi J, Mongelli M, Wilcox M, Chang A. An adjustable fetal weight standard. Ultrasound in Obstetrics and Gynecology. 1995; 6: 168–174.

[14] Gardosi J, Francis A, Turner S, Williams M. Customized growth charts: rationale, validation and clinical benefits. American Journal of Obstetrics and Gynecology. 2018; 218: S609–S618.

[15] Committee opinion no 611: method for estimating due date. Obstetrics & Gynecology. 2014; 124: 863–866.

[16] Zhang J, Han L, Li W, Chen Q, Lei J, Long M, *et al.* Early prediction of preeclampsia and small-for-gestational-age via multimarker model in Chinese pregnancies: a prospective screening study. BMC Pregnancy Childbirth. 2019; 19: 304.

[17] Fernandez-Rodriguez B, de Alba C, Villalain C, Pallás CR, Galindo A, Herraiz I. Obstetric and pediatric growth charts for the detection of fetal growth restriction and neonatal adverse outcomes in preterm newborns before 34 weeks of gestation. The Journal of Maternal-Fetal & Neonatal Medicine. 2021; 34: 1112–1119.

[18] Nwabuobi C, Odibo L, Camisasca-Lopina H, Leavitt K, Tuuli M, Odibo AO. Comparing INTERGROWTH-21st Century and Hadlock growth standards to predict small for gestational age and short-term neonatal outcomes. The Journal of Maternal-Fetal & Neonatal Medicine. 2020; 33: 1906–1912.
[19] Gordijn SJ, Beune IM, Thilaganathan B, Papageorghiou A, Baschat AA, Baker PN, *et al.* Consensus definition of fetal growth restriction: a Delphi procedure. Ultrasound in Obstetrics & Gynecology. 2016; 48: 333–339.
[20] 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. Journal of Maternal-Fetal & Neonatal Medicine. 2019; 1–8.
[21] Reinehr T, Kleber M, Toschke AM. Small for gestational age status is associated with metabolic syndrome in overweight children. European Journal of Endocrinology. 2009; 160: 579–584.
[22] Wang X, Liang L, Junfen FU, Lizhong DU. Metabolic syndrome in obese children born large for gestational age. Indian Journal of Pediatrics. 2007; 74: 561–565.
[23] Fiala M, Baumert M,Walecka Z, Pacula M. Early onset of metabolic syndrome. Endocrinology, Obesity and Metabolic Disorder. 2010; 6: 42–46.
[24] Muñoz-Muñoz E, Krause BJ, Uauy R, Casanello P. LGA-new born from patients with pregestational obesity present reduced adiponectin-mediated vascular relaxation and endothelial dysfunction in fetoplacental arteries. Journal of Cellular Physiology. 2018; 233: 6723–6733.
[25] Marciniak A, Patro-Małysza J, Kimber-Trojnar Ż, Marciniak B, Oleszczuk J, Leszczyńska-Gorzelak B. Fetal programming of the metabolic syndrome. Taiwanese Journal of Obstetrics & Gynecology. 2017; 56: 133–138.
[26] Kulik-Rechberger B, Bury AM, Rakuś-Kwiatosz A, Beń-Skowronek I. Cortisol, leptin and free leptin index (FLI) in newborns in the first days of life and their importance for body weight programming. Italian Journal of Pediatrics. 2019; 45: 141.
[27] Elshenawy S, Simmons R. Maternal obesity and prenatal programming. Molecular and Cellular Endocrinology. 2016; 435: 2–6.
[28] Desai M, Jellyman JK, Ross MG. Epigenomics, gestational programming and risk of metabolic syndrome. International Journal of Obesity. 2015; 39: 633–641.
[29] Ross MG, Desai M. Developmental programming of offspring obesity, adipogenesis, and appetite. Clinical Obstetrics and Gynecology. 2014; 56: 529–536.
[30] Chiavaroli V, Castorani V, Guidone P, Derraik JGB, Liberati M, Chiarelli F, *et al.* Incidence of infants born small- and large-for-gestational-age in an Italian cohort over a 20-year period and associated risk factors. Italian Journal of Pediatrics. 2016; 42: 42.
[31] Nicolaides KH, Wright D, Syngelaki A, Wright A, Akolekar R. Fetal Medicine Foundation fetal and neonatal population weight charts. Ultrasound in Obstetrics & Gynecology. 2018; 52: 44–51.
[32] Brand JS, West J, Tuffnell D, Bird PK, Wright J, Tilling K, *et al.* Gestational diabetes and ultrasound-assessed fetal growth in South Asian and White European women: findings from a prospective pregnancy cohort. BMC Medicine. 2018; 16: 203.
[33] Kapral N, Miller SE, Scharf RJ, Gurka MJ, DeBoer MD. Associations between birthweight and overweight and obesity in school-age children. Pediatric Obesity. 2018; 13: 333–341.
[34] Lee EY, Yoon K. Epidemic obesity in children and adolescents: risk factors and prevention. Frontiers of Medicine. 2018; 12: 658–666.