

REVIEW PAPER

Postnatal growth patterns and growth faltering in preterm infants

Justyna Anna Rogulska^{1,2}, Tanis Fenton³, Katarzyna Ewa Wróblewska-Seniuk¹

¹II Department of Neonatology, Poznan University of Medical Sciences, Poznan, Poland

²Doctoral School, Poznan University of Medical Sciences, Poznan, Poland

³Community Health Sciences, O'Brien Institute for Public Health, Alberta Children's Hospital Research Institute, Cumming School of Medicine, University of Calgary, Calgary, Alberta, Canada

ABSTRACT

Preterm infants are at high risk of future adverse neurodevelopment and suboptimal postnatal growth. Maintaining optimal growth, imitating that of the foetus, is challenging in the population of premature newborns, especially those with very low birth weight (< 1500 g). Due to a lack of consensus on the definition of postnatal growth faltering, determining its true incidence remains difficult. Longitudinal and careful anthropometric assessment continues to play a crucial role in evaluating well-being in the neonatal intensive care unit. Genetics, socioeconomic factors, and morbidities influence growth. The risk factors of postnatal growth faltering in preterm infants include the following: neonatal morbidities, e.g., bronchopulmonary dysplasia, necrotising enterocolitis, and inadequate nutritional support. Some studies suggest that growth faltering is associated with neurodevelopment and long-term metabolic outcomes, but the origins of these conditions are multifactorial.

KEY WORDS:

very low birth weight, preterm infants, body weights and measures, body weight trajectory.

INTRODUCTION

Physical growth in infants and children is a natural process that occurs in tandem with neurodevelopment. Normal growth involves steady changes in an infant's height, weight, and head circumference (HC). Growth progression reflects the child's well-being and nutritional status. Although many factors influence growth, genetics play a leading role, so each child's growth should be understood in the context of their own genetic potential [1]. Foetal health plays a key role in growth and development. Maternal, placental, or foetal disturbances may result in intrauterine growth restriction (IUGR), also referred to as foetal growth restriction (FGR), where prenatal impaired growth is observed because of insufficient transfer of oxygen and/or nutrients to the foetus [2]. The "foetal programming" theory proposed that developmental

adaptations before birth influence a range of metabolic and structural changes. Specifically, Barker hypothesised that low birth weight might influence insulin resistance, cholesterol metabolism, blood clotting, and blood pressure in later life [3]. According to this hypothesis, maternal and foetal malnutrition are also associated with a higher risk of ischaemic heart disease in adulthood. Nowadays, the "first 1000 days" (from conception through the first 2 years of life) are considered decisive for organ development and neurodevelopment [4]. However, some researchers point out limitations of this hypothesis. They argue that health outcomes in adulthood are shaped not only by pregnancy and infancy, but also by later health-related decisions. Moreover, the research on Barker's hypothesis tends to have a high risk of bias due to confounding effects, since the origins of both cardiovascular and metabolic diseases are multifactorial [3].

ADDRESS FOR CORRESPONDENCE:

Justyna Anna Rogulska, II Department of Neonatology, Poznan University of Medical Sciences, Poznan, Poland, e-mail: justyna.latacz162@gmail.com

Still, it is worth mentioning that promoting healthy nutrition and lifestyle during pregnancy and early childhood is beneficial for children's health. Environmental and social factors can influence growth in both positive and negative ways. The socioeconomic conditions of a child's community can affect overall height [5]. Linear growth is limited by socioeconomic [6] and environmental factors that reflect social inequalities [5]. Very low birth weight (VLBW), below 1500 g, may result from IUGR or prematurity, or both. Growth assessment in preterm and VLBW newborns is important because these populations are at risk of growth faltering. Prematurity and hypotrophy may predispose infants to neonatal morbidities that increase stress, prolonged hospitalisation in the neonatal intensive care unit (NICU), and in some cases interfere with adequate feeding. Neonatal morbidities, as well as the quality and quantity of nutrition the infants receive during their stay in the NICU, play an important role in shaping growth patterns. Insufficient nutritional support may impact further adverse growth and development. Prenatal hypotrophy, prematurity, neonatal morbidities, and nutrition separately and simultaneously can lead to postnatal growth faltering (PGF) [7].

ANTHROPOMETRY IS AN ELEMENTARY ASSESSMENT THAT IS AN INDICATOR OF HEALTH AND WELL-BEING

Anthropometric measurements are non-invasive, inexpensive, and universally applicable techniques, used in paediatric care [8]. Evaluation of growth dynamics enables the detection of chronic disorders and remains an important screening tool for identifying children at risk of morbidities and undernutrition. In neonatology, longitudinal monitoring measurements of weight, length, and HC longitudinally are recommended [7]. Because singular anthropometric measurements cannot be used as growth indicators, it may be helpful to focus instead on the evaluation of preterm infant weight gain velocity expressed as g/kg/day [9]. Preterm neonates with a gestational age (GA) < 35 weeks are expected to gain approximately 15–20 g/kg/day, which should be assessed over five to seven days [10, 11]. Even though targets for weight gain are often used in daily practice, calculating centiles and z-scores for measurements, and evaluating them based on growth charts is helpful for tracking infants' growth and is recommended by the World Health Organisation (WHO) [8]. Head circumference is an essential measurement for monitoring brain growth. Studies show that HC can serve as a proxy for the overall total brain volume, which can be assessed during magnetic resonance imaging (MRI). Consecutive HC measurements are essential because insufficient HC growth might be a predictor of adverse neurodevelopment [12]. Neubauer reported that preterm infants with an HC z-score < 2 at eight months of corrected age, on average, had poorer cognitive outcomes and worse academic achievement

at eight years of age compared to children with HC within the normal range [13]. Up to 36 weeks postmenstrual age (PMA), the expected rate of HC growth is approximately 0.8–1 cm/week [10]. Not only insufficient head growth, but also rapid and excessive increase of HC can indicate morbidities, e.g. posthaemorrhagic hydrocephalus that may negatively affect a child's further development. To replicate foetal growth, infants' linear growth to term equivalent age needs to increase approximately 0.9–1.5 cm per week [10]. Linear growth assessment has advantages over weight measurements because it is not affected by the child's fluid status, whereas weight gain can also reflect increased fat gain [7]. Accurate measurements depend on proper techniques, trained personnel, and well-calibrated equipment. Weight should be measured with calibrated scales, while head and other circumferences should be taken using non-stretchable tape. Length measurements remain challenging in the NICU. Although infantometers (length boards) are recommended for linear growth, many centres still rely on non-stretchable tapes, which can differ by up to 2 cm on average [14]. Anthropometry includes proportionality indices, such as the weight-to-length ratio (W/L), body mass index (BMI), or ponderal index (PI). Body mass index is calculated as the division of weight (kg) by height (m) squared, while PI is a result of dividing weight (kg) by height (m) cubed. The Ponderal index helps to determine the body's leanness, and in comparison to BMI, it puts greater emphasis on height. While W/L is mainly used for infants up to two years of age, BMI is still recommended for children older than two years [15]. However, in preterm infants under 2 years old, corrected age proportionality indices have been found not useful [16, 17]. Nagel *et al.* [16] showed that both BMI and W/L poorly associate with total body adiposity in preterm infants, whereas in term infants, these proportionality measures can reflect adiposity at 43–63 weeks PMA. Ramel *et al.* [17] observed that linear growth is suppressed to a greater degree than weight and that weight gain catch-up occurred earlier, while length remained suppressed at 24 months, which makes proportionality measurements less useful for preterm infants.

GROWTH IN THE NEONATAL INTENSIVE CARE UNIT SHOULD BE EVALUATED USING SPECIFIC PRETERM GROWTH CHARTS

Growth charts are crucial for assessing measurements in preterm neonates. Although there are recommended growth curves for preterm newborns, some practitioners use local charts as references. We can divide growth charts into two types: intrauterine and postnatal. Intrauterine growth charts that reflect foetal size at birth are used to categorise birth size and to evaluate whether early postnatal growth is similar to foetal growth [18]. Postnatal growth charts were developed to compare postnatal growth of preterm infants with that of healthy

preterm infants rather than with that of the foetus [19]. The standard, intrauterine charts are prescriptive, based on multicentre meta-analyses that incorporate birth weight, HC, and length at specific GA. The most widely used for the evaluation of preterm infants are Fenton growth charts, revised in 2025 [10]. These charts allow comparison of postnatal growth with foetal growth from 22 weeks of gestation to 36 weeks PMA, with a transition section that seamlessly connects to the WHO charts at 50 weeks PMA [20]. Another well-known project is INTERGROWTH-21, which was developed prospectively. Only low-risk pregnant women were recruited to assess foetal and infant growth. This enabled the creation of foetal growth standards based on prenatal ultrasound measurements [21] and postnatal growth charts for preterm infants [22]. The children were then followed to create growth charts for newborns without congenital malformations and with prescribed nutritional support [19, 20, 22]. Unfortunately, INTERGROWTH-21 charts were based on a relatively small dataset, which included only 12 neonates born < 32 weeks [22]. Any growth measurement can be converted into a *z*-score, which expresses how many standard deviations it lies from the reference population mean. *Z*-scores indicate how far an individual measurement is from the average. An important advantage of *z*-scores is that they allow more precise assessment of infants at the extremes of a growth chart (e.g. below the 3rd and above the 97th percentile). While percentiles are easier to visualise in clinical practice, *z*-scores are more suitable for statistical analyses and enable comparison of different measurements because the standard deviation provides a common, standardised unit. For preterm infants after NICU discharge, age correction for prematurity is necessary when plotting growth to avoid misclassification of suboptimal growth and neurodevelopment [23]. There is no universal consensus on how long corrected age should be used. Some suggest correcting weight, length, and HC until the age of two years for children born before 32 weeks of gestation and at least until 12 months for children born between 32 and 36 weeks of gestation [24]. Elmraged *et al.* [23] observed that age correction, even up to 36 months in extremely and very preterm children, lessens misdiagnoses such as stunted and underweight.

BODY COMPOSITION MAY BECOME A USEFUL TOOL FOR GROWTH EVALUATION IN THE PRETERM POPULATION

Recently, an additional approach to growth assessment has emerged through the examination of neonatal body composition to assess fat mass (FM), fat-free mass (FFM) or lean mass (LM), and percentage body fat. Studies show that infants' FFM correlated positively with brain size at term equivalent age [25]. It has been observed that protein intake and energy supply in the nutritional

management of preterm infants are associated with greater LM at term-corrected age [25]. Several studies have shown that preterm infants tend to have higher FM and lower LM at term-corrected age compared to term-born counterparts [14, 24, 26]. These results raised concerns about potential long-term metabolic consequences in the preterm population. However, further research showed that premature infants tend to have similar FM and FFM by 3 months corrected age [26]. It seems that gaining FM is a short-term adaptation to the ex-utero environment in the first months of life [26]. Among methods used to assess neonatal body composition, air-displacement plethysmography (ADP) is one of the most common. There are even growth charts that have been developed specifically for ADP-based assessment [26]. Unfortunately, ADP remains expensive, time-consuming, and can only be used for infants who are not on respiratory support [27]. Alternatives include bioelectrical impedance analysis, dual-energy X-ray absorptiometry, or MRI. Bioelectrical impedance analysis can be performed at the bedside and is easier to use, although it is less accurate than ADP. Dual-energy X-ray absorptiometry provides detailed data but exposes the newborn to small doses of radiation. Magnetic resonance imaging is a safe, radiation-free method and shows potential for high precision, but preterm newborns on respiratory support cannot easily undergo MRI assessment. Although body composition assessment might be helpful for evaluating nutritional support in the NICU, these methods are not yet a standard procedure.

LONGITUDINAL ASSESSMENT PLAYS A KEY ROLE IN THE EVALUATION OF GROWTH

According to the American Academy of Pediatrics, the nutritional management of low-birth-weight infants should aim to approximate the growth patterns observed *in utero*, thereby supporting optimal physiological and neurodevelopmental outcomes [28]. The European Society for Paediatric Gastroenterology Hepatology and Nutrition (ESPGHAN) recommends that, in the population of preterm newborns, growth faltering is described as those whose "growth slows and does not grow parallel to a centile during the period of established growth" [19]. In the population of VLBW neonates, we often observe that weight gain falters compared to growth charts. Neither European nor American guidelines indicate that preterm infants at term-equivalent age or discharge should regain their birth percentile [29]. Postnatal growth faltering is generally defined as insufficient postnatal growth after preterm birth. However, this definition is not specific enough to be applied in daily clinical practice. While reviewing the literature, we encounter many definitions that refer to infants' postnatal growth. The terms used in nomenclature to describe postnatal growth disturbances are extrauter-

TABLE 1. Prevalence of growth disorders according to Goldberg recommendations [31]

Primary indicators (1 indicator is required)	Mild malnutrition	Moderate malnutrition	Severe malnutrition
Decline in weight-for-age z-score	Decline of 0.8–1.2 SD	Decline of > 1.2–2 SD	Decline of > 2 SD
Weight-gain velocity	< 75% of expected rate of weight gain needed to maintain growth rate	< 50% of expected rate of weight gain needed to maintain growth rate	< 25% of expected rate of weight gain needed to maintain growth rate
Nutrient intake	3–5 consecutive days with protein/energy intake < 75% of estimated needs	5–7 consecutive days with protein/energy intake < 75% of estimated needs	> 7 consecutive days of protein/energy intake < 75% of estimated needs

ine growth restriction (EUGR) and PGF, which fall into one of the two main approaches: static and dynamic. The static definition, often referred to as EUGR, is a cross-sectional metric that evaluates growth at a specific single time point and classifies infants as growth-restricted if their weight falls below a specific centile (10th or 3rd). The dynamic approach, commonly referred to as PGF, is a longitudinal assessment that assesses changes in weight centile or z-score between birth or the postnatal weight nadir and a determined time point [30]. The static definitions do not account for birth size, which means that constitutionally small for gestational age infants (birth-weight below the 10th centile) can grow well, following their expected centile canal, but can still be diagnosed with EUGR based on that single cut-point. For instance, Izquierdo *et al.* [9] showed that, when applying the definition of EUGR < 10th centile, only 3.7% of IUGR patients were assessed as non-EUGR. It seems that a longitudinal approach assessing growth at predetermined times since birth should be used because it uses continuous knowledge of infants' growth patterns and can help identify those who need additional nutritional support during their stay in the NICU and in follow-up. One proposed dynamic classification is from Goldberg *et al.* [31], who divided malnutrition into three stages: mild, moderate, and severe, based on the weight z-score declines ranging 0.8–2.0 (Table 1). The suggested guidelines need further research because they are based on expert opinion. Their recommendations also apply to other measurements, including HC and length, which may be considered either individually or in combination.

Several aspects should be considered when evaluating growth. First, most definitions do not consider the physiological postnatal weight loss after birth, which is due to extracellular water loss and ranges 5–15% of birthweight, depending on GA and size for GA [19]. This phenomenon will influence the centile or z-score values used to assess growth, with evidence showing that physiological weight loss corresponds to the average decrease of approximately 0.8 z-score among the healthiest of preterm infants to 3 weeks postnatal age, which limits the use of this aspect of the Goldberg recommendations, since one-half of these healthy infants lost > 0.8 z-scores [32]. Therefore, assessing growth from the postnatal weight

nadir, rather than from birth, may improve accuracy. However, this approach introduces additional challenges, such as how to define each infant's nadir precisely and how to determine when weight loss is excessive. Another important factor is the timing of the assessment. Most definitions refer to anthropometric status at 36–40 weeks of PMA, 28 days of postnatal age, or at hospital discharge. However, the relevance of these reference points varies depending on the GA at birth. If the child's GA at birth was close 36–40 weeks, the physiologic weight loss could be misclassified as growth faltering [30]. Moreover, studies show that the growth patterns of preterm infants often approximately follow the foetal growth pattern, with lower weight achieved at term-equivalent age compared to term infants. In the phase just before term, when the foetal growth velocity tends to slow, preterm infants continue near-linear growth [33]. Differences seen at term-equivalent age can reflect expected preterm infant growth patterns rather than growth failure. Establishing a standardised definition of PGF is important for both clinical practice and further research. Misclassification of undernutrition may lead to additional nutrition interventions that may have adverse effects, such as overfeeding the infant, increased risk of childhood obesity, and further long-term metabolic consequences. Clinically, a unified definition may help determine a superior identification of growth faltering for neonates who need special nutritional support, and to develop more reliable nutritional recommendations for the preterm population. It should be emphasised that an individual approach in growth assessments is crucial and there might not be, in fact, a specific definition of growth faltering that differentiates between superior vs. suboptimal growth.

THE PREVALENCE OF IMPAIRED GROWTH IS DIFFICULT TO ASSESS DUE TO THE VARIOUS DEFINITIONS USED

Using a longitudinal approach, Peila *et al.* [30] reported that the incidence of PGF, defined as a loss of weight z-score > 1, ranged from 55% in babies born > 30 weeks of gestation up to 92% in those born < 30 weeks. Izquierdo *et al.* [9] found that 67.4% of patients met the PGF criteria, defined as a weight z-score loss of 1.34, at 36 weeks PMA.

Roggero *et al.* [34] reported that the loss of > 2 weight z -score occurred in 13% of VLBW infants at discharge, while Lima *et al.* [35] showed an incidence as high as 26%. In our retrospective study, the incidence of loss of weight z -score > 2 was 11% among preterm infants (< 32 weeks GA) [36]. These results demonstrate that the incidence of PGF varies substantially depending on the applied definition and the characteristics of the study population.

NEONATAL MORBIDITIES AND NUTRITION ARE CONTRIBUTING FACTORS TO POSTNATAL GROWTH FALTERING

Postnatal growth faltering is a multifactorial complication in VLBW preterm infants, determined by social determinants of health, inadequate nutritional support, and neonatal morbidities [9, 37, 38]. Much research indicates that PGF is associated with longer hospital stay and prolonged respiratory support, which corresponds to the fact that most critically ill patients are at risk of inadequate growth. Neonatal morbidities frequently associated with PGF include bronchopulmonary dysplasia (BPD) [9, 37, 39], late-onset sepsis [9, 35], patent ductus arteriosus [9], necrotising enterocolitis (NEC) [35, 38], severe brain injuries, and severe retinopathy of prematurity (ROP) [9]. The suboptimal growth pattern, especially in infants with severe BPD, may result from increased energy demands, chronic hypoxia, and/or poor oral feeding. Neonates with BPD require higher energy intake compared to healthy preterm infants, while fluid intake and nutrient density are often restricted, limiting nutrition intakes [40]. Another mechanism linking PGF to BPD is the low level of IGF-1, a mediator of foetal and postnatal growth. Löfqvist *et al.* [41] observed low IGF-1 levels in the first weeks of life in infants who later developed BPD, possibly due to suboptimal nutrition and work of breathing. Interestingly, low levels of IGF-I impair VEGF signalling and are strongly associated with severe ROP. Some researchers have used weight gain as an estimate of low IGF-1 levels to examine the association with ROP risk. Ingolfsson *et al.* [42] reported that greater weight gain was associated with a lower risk of $\geq$ stage 2 ROP. Sepsis is another comorbidity that may affect postnatal growth. Flannery *et al.* [43] found that preterm VLBW infants with sepsis presented a higher degree of growth faltering by 3 weeks after the infection, which persisted until NICU discharge. Several studies show the association between NEC and PGF [44], whereas others suggest that growth impairment is rather a consequence of only surgically treated NEC [45]. Surgical NEC can lead to intestinal failure and malabsorption, because a smaller absorptive intestinal surface decreases the absorption of macronutrients, water, and electrolytes. Medical NEC is associated with a slow advancement of enteral nutrition and feedings, which can predispose to further oral feeding challenges. Moreover, infants with NEC requiring surgical management were

found to have smaller increases in HC, which may, in turn, lead to suboptimal neurodevelopment [46].

At the same time, neonatal morbidities may negatively affect feeding tolerance and nutrient absorption, predisposing preterm infants to further growth impairment. In periods of clinical deterioration, infants' high energy expenditure combined with limited nutrition intake can result in suboptimal growth, as their nutrition requirements are not met. Nutritional protocols for very preterm infants recommend early introduction of parenteral nutrition along with early trophic feeding and rapid advancement of enteral feeds [47]. In clinically stable preterm infants, the recommended advancement rates can be as high as 18–40 ml/kg/day. Faster achievement of full enteral nutrition at 30–40 ml/kg/day is often well tolerated and does not increase the risk of NEC [47]. Providing both enteral and parenteral nutrition early promotes rapid weight regain and faster achievement of full enteral feeds. Early implementation of parenteral and enteral nutrition in the first 24 hours of life remains associated with higher discharge weight z -score [48]. In our retrospective study, infants with PGF received longer parenteral nutrition, later achieving 100 ml/kg enteral feeds, an energy supply of 120 kcal/kg, and milk fortification [36]. Similarly, Starc *et al.* [49] found that infants with PGF (defined as weight loss > 1 z -score) required more time to reach 100 ml/kg/day of enteral feeding, and Kim *et al.* [50] observed that parenteral nutrition was discontinued later in neonates with PGF. Not only the quantity, but also the quality of early nutritional support contributes to growth. Higher protein advancement (≥ 3 g/kg by 5 days of life) has been associated with improved weight gain and head growth [51] and reduced declines in weight z -scores [9]. Ehrenkranz *et al.* [52] found that decisions regarding nutritional support and the provision of nutrition were associated with the perceived severity of the child's illness, so that the impact of critical illness on adverse outcomes was mediated by the total daily energy intake during the first week of life. Higher enteral intake in critically ill patients was associated with less neurodevelopment impairment [52]. Human milk provides not only important nutrients but also some immunological support for preterm newborns. Its use is associated with a lower risk of neonatal morbidities, including NEC or late-onset sepsis [53]. Preterm infants fed with human milk gain more FFM, which is associated with better recovery of body composition [54]. It should be noted that human milk is more likely to be supplied by mothers with better determinants of health and social support, so the causal links may not be from the milk itself [55]. Despite its many benefits, human milk does not meet the high nutritional needs of preterm newborns; therefore, breastmilk fortification is recommended. ESPGHAN recommends starting human milk fortifier when enteral intake reaches 40–100 ml/kg/d, to help meet nutrition needs.

POSTNATAL GROWTH FALTERING CAN COEXIST WITH ADVERSE LONG-TERM CONSEQUENCES

Neurodevelopment. Greater postnatal weight gain is associated with better neurodevelopmental outcomes. Bel-fort *et al.* [56] demonstrated that greater gains in weight, BMI, and HC were associated with higher Bayley Scales of Infant Development – Second Edition scores, and that both greater gains in weight and linear growth from term up to 4 months were associated with higher psychomotor development index scores. Both lower growth during NICU hospitalisation and during infancy have been associated with a higher risk of suboptimal brain development. O'Shea *et al.* [39] found that among neonates with very low weight gain (defined as a change in weight *z*-score < -1.67), some presented with an association with lower scores on cognitive and language assessments. Studies also show that insufficient growth, especially in HC, is associated with poor neurocognitive skills [13]. Interestingly, it seems that neonatal morbidities have a greater impact on neurodevelopment than postnatal growth by itself. Bando *et al.* [57] found that lower weight and HC gains were associated with suboptimal motor and cognitive outcomes; however, changes in growth parameters alone were insufficient to distinguish the at-risk population because morbidities played an important role.

Metabolic consequences Much research supports the idea that prematurity and undesirable growth may have long-term metabolic consequences, consistent with the assumptions of the developmental origins of health and disease (DOHaD). Infants born as extremely preterm are considered to be at risk of abdominal adiposity, obesity, insulin resistance, type 2 diabetes, dyslipidaemia, higher blood pressure, and coronary artery disease [37, 58], especially if they have rapid catch-up growth. In contrast to this concern, preterm infants without major complications tend to catch up in HC, weight, and length measurements within the first 24–36 months after term-equivalent age [1]. The mechanisms possibly leading to potential metabolic and cardiovascular consequences are complex and multifactorial. In contrast with the DOHaD hypothesis, the current body composition of 19-year-old individuals born very preterm, rather than early growth, are more strongly associated with cardiovascular risk [59]. Similarly, in their evaluation of diabetes mellitus risk, Finken *et al.* [60] found only a weak association between early postnatal weight gain and insulin level in adulthood, while adult FM was clearly associated with hyperinsulinaemia. The question remains if interventions reducing infant weight gain would improve adult body composition and reduce the chance of developing type 2 diabetes or cardiovascular risk, or whether limiting growth would be more detrimental to both the child's feeding relation-

ship and neurodevelopment than helpful for possible adult-onset diseases.

CONCLUSIONS

Continuous and longitudinal anthropometric assessments using growth charts remain a fundamental part of infant growth assessment. The relationship between neonatal morbidities and inadequate nutrition during NICU stays can be bidirectional because both these factors may predispose to and exacerbate PGF. Although a unified definition is of great value for research and development of nutritional support for the most vulnerable preterm population, determining a definitive specific value to distinguish proper and suboptimal growth will be a great challenge. Postnatal growth faltering is associated with impaired neurodevelopment. There is a need for further research on the relationship between PGF and its long-lasting consequences, as well as evaluation of body composition in the assessment of quality of growth in preterm newborns.

DISCLOSURES

1. Institutional review board statement: None.
2. Assistance with the article: None.
3. Financial support and sponsorship: None.
4. Conflicts of interest: None.

REFERENCES

1. Fenton TR, Samyia L, Elmrayed S, Nasser R, Alshaikh B. Growth patterns by birth size of preterm children born at 24–29 gestational weeks for the first 3 years. *Paediatr Perinat Epidemiol* 2024; 38: 560-569.
2. Beune IM, Damhuis SE, Ganzevoort W, Hutchinson JC, Khong TY, Mooney EE, et al. Consensus definition of fetal growth restriction in intrauterine fetal death: a Delphi procedure. *Arch Pathol Lab Med* 2021; 145: 428-436.
3. Jain S, Samyia L, Elmrayed S, Fenton TR. Does the evidence support in utero influences on later health and disease? A systematic review of highly cited Barker studies on developmental origins. *J Perinatol* 2024; 44: 1244-1251.
4. Faa G, Fanos V, Manchia M, van Eyken P, Suri JS, Saba L. The fascinating theory of fetal programming of adult diseases: a review of the fundamentals of the Barker hypothesis. *J Public Health Res* 2024; 13: 22799036241226817.
5. Veiga GRS, da Silva GAP, Padilha BM, de Carvalho Lima M. Determining factors of child linear growth from the viewpoint of Bronfenbrenner's bioecological theory. *J Pediatr (Rio J)* 2023; 99: 205-218.
6. World Health Organization. Social determinants of health [Internet]. Geneva: WHO. Available from: <https://www.who.int/teams/social-determinants-of-health> (accepted: 18.02.2026).
7. Fenton TR, Merlino Barr S, Elmrayed S, Alshaikh B. Expected and desirable preterm and small infant growth patterns. *Adv Nutr* 2024; 15: 100220.
8. World Health Organization. Physical status: the use and interpretation of anthropometry. Report of a WHO Expert Committee. *World Health Organ Tech Rep Ser* 1995; 854: 1-452.

9. Izquierdo Renau M, Aldecoa-Bilbao V, Balcells Esponera C, del Rey Hurtado de Mendoza B, Sanz MI, Iglesias-Platas I. Applying methods for postnatal growth assessment in the clinical setting: evaluation in a longitudinal cohort of very preterm infants. *Nutrients* 2019; 11: 2772.
10. Fenton TR, Elmrady S, Alshaikh BN. Fenton third-generation growth charts of preterm infants without abnormal fetal growth: a systematic review and meta-analysis. *Paediatr Perinat Epidemiol* 2025; 39: 543-555.
11. Fenton TR, Senterre T, Griffin IJ. Time interval for preterm infant weight gain velocity calculation precision. *Arch Dis Child Fetal Neonatal Ed* 2019; 104: F218-F219.
12. Mayrink MLS, Villela LD, Méio MDBB, Soares FVM, de Abranches AD, Nehab SRG, et al. The trajectory of head circumference and neurodevelopment in very preterm newborns during the first two years of life: a cohort study. *J Pediatr (Rio J)* 2024; 100: 483-490.
13. Neubauer V, Fuchs T, Griesmaier E, Kager K, Pupp-Peglow U, Kiechl-Kohlendorfer U. Poor postdischarge head growth is related to a 10% lower intelligence quotient in very preterm infants at the chronological age of five years. *Acta Paediatr* 2016; 105: 501-507.
14. Corkins MR, Lewis P, Cruse W, Gupta S, Fitzgerald J. Accuracy of infant admission lengths. *Pediatrics* 2002; 109: 1108-1111.
15. Muth ND, Bolling C, Hannon T, Sharifi M. Section on Obesity; Committee on Nutrition. The role of the pediatrician in the promotion of healthy, active living. *Pediatrics* 2024; 153: e2023065480.
16. Nagel E, Desjardins C, Earthman C, Ramel S, Demerath E. Weight-for-length measures may not accurately reflect adiposity in preterm infants born appropriate for gestational age. *Pediatr Obes* 2021; 16: e12744.
17. Ramel SE, Demerath EW, Gray HL, Younge N, Boys C, Georgieff MK. The relationship of poor linear growth velocity with neonatal illness and two-year neurodevelopment in preterm infants. *Neonatology* 2012; 102: 19-24.
18. Embleton ND, Moltu SJ, Lapillonne A, van den Akker CHP, Carnielli V, Fusch C, et al. Enteral nutrition in preterm infants (2022): a position paper from the ESPGHAN Committee on Nutrition. *J Pediatr Gastroenterol Nutr* 2023; 76: 248-268.
19. Cordova EG, Belfort MB. Updates on assessment and monitoring of the postnatal growth of preterm infants. *NeoReviews* 2020; 21: e98-e108.
20. Silveira RC, Procianny RS. Preterm newborn's postnatal growth patterns: how to evaluate them. *J Pediatr (Rio J)* 2019; 95: 42-48.
21. Papageorgiou AT, Ohuma EO, Altman DG, Todros T, Ismail LC, Lambert A, et al. International standards for fetal growth based on serial ultrasound measurements: the Fetal Growth Longitudinal Study of the INTERGROWTH-21st Project. *Lancet* 2014; 384: 869-879.
22. Villar J, Giuliani F, Bhutta ZA, Bertino E, Ohuma EO, Ismail LC, et al. Postnatal growth standards for preterm infants: the Preterm Postnatal Follow-up Study of the INTERGROWTH-21(st) Project. *Lancet Glob Health* 2015; 3: e681-e691.
23. Elmrady S, Dai S, Lodha A, Kumar M, Fenton TR. Preterm growth assessment: the latest findings on age correction. *J Perinatol* 2025; 45: 607-615.
24. Wright CM, Williams AF, Elliman D, Bedford H, Birks E, Butler G, et al. Using the new UK-WHO growth charts. *BMJ* 2010; 340: c1140.
25. Bell KA, Matthews LG, Cherkerzian S, Palmer C, Drouin K, Pepin HL, et al. Associations of growth and body composition with brain size in preterm infants. *J Pediatr* 2019; 214: 20-26.e2.
26. Hamatschek C, Yousuf EI, Möllers LS, So HY, Morrison KM, Fusch C, et al. Fat and fat-free mass of preterm and term infants from birth to six months: a review of current evidence. *Nutrients* 2020; 12: 288.
27. Norris T, Ramel SE, Catalano P, Caoimh CN, Roggero P, Murray D, et al. New charts for the assessment of body composition at birth and across the first 6 months of life. *Am J Clin Nutr* 2019; 109: 1353-1360.
28. American Academy of Pediatrics Committee on Nutrition. Nutritional needs of low-birth-weight infants. *Pediatrics* 1985; 75: 976-986.
29. Fenton TR, Cormack B, Goldberg D, Nasser R, Alshaikh B, Eliasziw M, et al. "Extrauterine growth restriction" and "postnatal growth failure" are misnomers for preterm infants. *J Perinatol* 2020; 40: 704-714.
30. Peila C, Spada E, Giuliani F, Maiocco G, Raia M, Cresi F, et al. Extrauterine growth restriction: definitions and predictability of outcomes in a cohort of very low birth weight infants. *Nutrients* 2020; 12: 1224.
31. Goldberg DL, Becker PJ, Brigham K, Carlson S, Fleck L, Gollins L, et al. Identifying malnutrition in preterm and neonatal populations: recommended indicators. *J Acad Nutr Diet* 2018; 118: 1571-1582.
32. Rochow N, Raja P, Liu K, Fenton T, Landau-Crangle E, Göttler S, et al. Physiological adjustment to postnatal growth trajectories in healthy preterm infants. *Pediatr Res* 2016; 79: 870-879.
33. Fenton TR, Nasser R, Eliasziw M, Kim JH, Bilan D, Sauve R. Validating the weight gain of preterm infants between the reference growth curve of the fetus and the term infant. *BMC Pediatr* 2013; 13: 92.
34. Roggero P, Gianni ML, Orsi A, Amato O, Piemontese P, Liotto N, et al. Implementation of nutritional strategies decreases postnatal growth restriction in preterm infants. *PloS One* 2012; 7: e51166.
35. Lima PA, Carvalho M, Costa AC, Moreira MEL. Variables associated with extrauterine growth restriction in very low birth weight infants. *J Pediatr (Rio J)* 2014; 90: 22-27.
36. Rogulska J, Fenton TR, Szczapa T, Wróblewska-Seniuk K. Association of Neonatal Morbidities and Postnatal Growth Faltering in Preterm Neonates. *Healthcare (Basel)* 2025; 13: 235.
37. Rover MM, Viera CS, Silveira RC, Guimarães ATB, Grassioli S. Risk factors associated with growth failure in the follow-up of very low birth weight newborns. *J Pediatr (Rio J)* 2016; 92: 307-313.
38. González-García L, Mantecón-Fernández L, Suárez-Rodríguez M, Arias-Llorente R, Lareu-Vidal S, Ibáñez-Fernández A, et al. Postnatal growth faltering and height improvement at two years in children with very low birth weight. *Children (Basel)* 2022; 9: 1800.
39. O'Shea TM, Jensen ET, Yi JX, Lester B, Aschner JL, Stroustrup A, et al. Association of growth during infancy with neurodevelopment and obesity in children born very preterm. *J Pediatr* 2024; 271: 114050.
40. Trindade GS, Benincasa BC, Procianny GS, Silveira RC, Procianny RS. Nutrition strategies for the preterm infant with bronchopulmonary dysplasia. *Nutrients* 2025; 17: 3472.
41. Löfqvist C, Hellgren G, Niklasson A, Engström E, Ley D, Hansen-Pupp I. Low postnatal serum IGF-I levels are associated with bronchopulmonary dysplasia. *Acta Paediatr* 2012; 101: 1211-1216.
42. Ingolfsson EC, Haapala JL, Buckley LA, Demerath EW, Guiang SE, Ramel SE. Late growth and body composition changes and retinopathy of prematurity. *Nutrients* 2019; 12: 78.
43. Flannery DD, Jensen EA, Tomlinson LA, Yu Y, Ying GS, Binenbaum G. Poor postnatal weight growth after sepsis in very preterm infants. *Arch Dis Child Fetal Neonatal Ed* 2021; 106: 298-304.
44. Clark RH, Thomas P, Peabody J. Extrauterine growth restriction remains a serious problem in premature neonates. *Pediatrics* 2003; 111: 986-990.
45. Chong C, van Druten J, Briars G, Eaton S, Clarke P, Tsang T, et al. Neonates living with enterostomy following necrotizing enterocolitis are at high risk of severe underweight. *Eur J Pediatr* 2019; 178: 1875-1881.
46. Shin SH, Kim EK, Kim SH, Kim HY, Kim HS. Head growth and neurodevelopment of preterm infants with surgical necrotizing enterocolitis. *Children (Basel)* 2021; 8: 833.

47. Hay WW Jr. Nutritional support strategies for the preterm infant in the neonatal intensive care unit. *Pediatr Gastroenterol Hepatol Nutr* 2018; 21: 234-247.
48. Shen RL, Ritz C, Li Y, Sangild PT, Jiang PP. Early parenteral nutrition is associated with improved growth in very low birth weight infants: a retrospective study. *Arch Dis Child Fetal Neonatal Ed* 2024; 109: 495-499.
49. Starc M, Giangreco M, Centomo G, Travan L, Bua J. Extrauterine growth restriction according to different growth charts: a retrospective 10-year study. *PloS One* 2023; 18: e0283367.
50. Kim YJ, Shin SH, Cho H, Shin SH, Kim SH, Song IG, et al. Extrauterine growth restriction in extremely preterm infants based on Intergrowth-21st and Fenton growth charts. *Eur J Pediatr* 2021; 180: 817-824.
51. Poindexter BB, Langer JC, Dusick AM, Ehrenkranz RA. Early provision of parenteral amino acids in extremely low birth weight infants: relation to growth and neurodevelopmental outcome. *J Pediatr* 2006; 148: 300-305.
52. Ehrenkranz RA, Das A, Wrage LA, Poindexter BB, Higgins RD, Stoll BJ, et al. Early nutrition mediates the influence of severity of illness on extremely low birth weight infants. *Pediatr Res* 2011; 69: 522-529.
53. Miller J, Tonkin E, Damarell RA, McPhee AJ, Suganuma M, Suganuma H, et al. Human milk feeding and morbidity in very low birth weight infants: a systematic review and meta-analysis. *Nutrients* 2018; 10: 707.
54. Cerasani J, Ceroni F, De Cosmi V, Mazzocchi A, Morniroli D, Roggero P, et al. Human milk feeding and preterm infants' growth and body composition. *Nutrients* 2020; 12: 1155.
55. Boghossian NS, Geraci M, Edwards EM, Horbar JD. Racial and ethnic differences in outcomes of neonates born at less than 30 weeks' gestation, 2018–2022. *JAMA Netw Open* 2024; 7: e2451707.
56. Belfort MB, Rifas-Shiman SL, Sullivan T, Collins CT, McPhee AJ, Ryan P, et al. Infant growth before and after term and neurodevelopment in preterm infants. *Pediatrics* 2011; 128: e899-e906.
57. Bando N, Fenton TR, Yang J, Ly L, Luu TM, Unger S, et al. Association of postnatal growth changes and neurodevelopmental outcomes in preterm neonates < 29 weeks' gestation. *J Pediatr* 2023; 256: 63-69.e2.
58. Cole TJ, Statnikov Y, Santhakumaran S, Pan H, Modi N. Birth weight and longitudinal growth in infants born below 32 weeks' gestation. *Arch Dis Child Fetal Neonatal Ed* 2014; 99: F34-F40.
59. Finken MJ, Inderson A, Van Montfoort N, Keijzer-Veen MG, van Weert AWM, Çarfil N, et al. Lipid profile and carotid intima-media thickness in very preterm subjects. *Pediatr Res* 2006; 59: 604-609.
60. Finken MJ, Keijzer-Veen MG, Dekker FW, Jefferies C, Knight DB, Robinson EM, et al. Preterm birth and later insulin resistance. *Diabetologia* 2006; 49: 478-485.