Growth charts from birth for infants born at term and preterm: updated guidelines by the Portuguese Neonatal Society.

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Abstract

The Portuguese Neonatal Society updates the growth charts recommended for term and preterm infants. The appropriateness of growth charts depends on the gestational age, the purpose of the measurement, and the stage in the life cycle.

To classify intrauterine growth at birth, the Fenton 2013 growth charts, which are based on anthropometric records at birth, are the most appropriate for both term and preterm infants.

For monitoring postnatal growth in full-term infants, the WHO 2006 Growth Prescriptive Standards are strongly recommended. To specifically monitor weight loss in the first postnatal days, the NEWT® (http://newbornweight.org) nomogram is recommended.

To assess body weight changes in preterm infants while in the hospital, an accurate open-access online calculator (www.growthcalculator.org), based on weight trajectories that take into account the initial physiological weight loss is recommended. Concurrently, the Fenton 2013 growth charts can be employed to monitor length and head circumference growth.

To assess growth in preterm infants following their discharge from the hospital, the Intergrowth-21 prescriptive standards are appropriate in infants born at more than 27 weeks of gestation, up to 64 weeks postmenstrual age. Beyond this age, the WHO 2006 growth prescriptive standards should be employed.

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Key-words: anthropometry, growth charts, preterm infant, recommendation, term infant.

Curvas de crescimento desde o nascimento para crianças nascidas de termo e pré-termo: recomendações atualizadas pela Sociedade Portuguesa de Neonatologia.

Resumo

A Sociedade Portuguesa de Neonatologia atualiza as recomendações para curvas de crescimento de crianças nascidas de termo e pré-termo. A adequação das curvas de crescimento depende da idade gestacional, da finalidade da medição e do período no ciclo de vida.

Para classificar ao nascer o crescimento intrauterino, as curvas de Fenton 2013, baseadas em registos antropométricos no recém-nascido, são as mais adequadas tanto a recém-nascidos de termo como pré-termo.

Para monitorizar o crescimento pós-natal de crianças nascidas de termo, as curvas padrão da OMS 2006 são inequivocamente recomendadas. Para monitorizar especificamente a perda ponderal nos primeiros dias pós-natais, é recomendado o nomograma NEWT® (http://newbornweight.org).

Para avaliar as variações do peso em recém-nascidos pré-termo durante o internamento, é recomendada uma calculadora confiável, *online* e de livre acesso (www.growthcalculator.org), baseada em trajetórias de peso que têm em conta a perda ponderal fisiológica inicial. Durante o internamento, as curvas de crescimento de Fenton 2013 podem ser usadas para monitorizar os crescimentos linear e cefálico.

Para monitorizar, após a alta, o crescimento de crianças nascidas pré-termo, as curvas padrão do Intergrowth-21 são as mais adequadas para crianças nascidas com mais de 27

semanas de gestação, até às 64 semanas de idade pós-menstrual. Após esta idade, devem de linhasser usadas as curvas padrão da OMS 2006.

Palavras-chave: antropometria, curvas de crescimento, recém-nascido de termo, recém-nascido pré-termo, recomendação,

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Introduction

The anthropometric measurements most commonly used to assess growth in infants born at term[1,2] or preterm[3,4] are body weight, length, and head circumference.

The appropriateness of growth charts depends on the infant's gestational age, the intended use of the measurement, and the infant's stage of life[5].

In accordance with the life cycle, it is recommended that appropriate growth charts be selected for the purpose of diagnosing intrauterine growth deviations at birth, monitoring the effectiveness of nutritional intervention while in hospital, particularly in preterm

infants, and monitoring growth and nutritional status after discharge from the hospital[1,6]. Furthermore, it is recommended that specific growth charts be selected for infants born at term or born preterm[2,3].

Prescriptive standards versus descriptive references

Anthropometric measurements can be interpreted in comparison with either prescriptive standards or descriptive references[7].

Prescriptive standards are typically derived from measurements obtained from a cohort of assumed healthy individuals, i.e., without exposures known to adversely affect growth. Consequently, they describe the way healthy individuals are expected to grow[7].

Descriptive references are typically derived from cross-sectional measurements of a convenience sample of individuals and describe how most individuals actually grow. Consequently, they may inadvertently set unhealthy attainment targets[7]. Nevertheless, they are the most widely available, due to their cost-effectiveness and feasibility in construction compared to prescriptive standards[7].

Objective

In 2013 and 2020, the Portuguese Society of Neonatology critically reviewed the published growth charts for infants born preterm and provided guidelines for their use in clinical practice[6,8].

The present document contains updated guidelines for growth charts for infants born at term and preterm.

Table 1 presents a summary of the currently recommended growth charts, along with their respective levels of evidence (LOE) and strengths of recommendation (SOR)[9].

1. Growth charts for classifying intrauterine growth at birth in term and preterm infants

Recommended: Fenton 2013 growth charts[10] (LOE 1, SOR A) (Table 1)

Charts based on anthropometric measurements at birth are appropriate for classifying intrauterine growth and should not be confused with growth charts based on fetal ultrasound measurements, which are appropriate for monitoring fetal growth [6,10].

The cross-sectional sex and gestational age specific Fenton 2013 growth charts[10] include directly measured birth weight, length, and head circumference of preterm infants. The charts are based on a meta-analysis of six large population-based surveys of size at birth, covering gestational ages from 22 to 36 weeks. They were harmonized with the WHO 2006 Growth Standards for infants born at term[1], smoothing the data between the preterm and WHO estimates while maintaining integrity with the data from 22 to 36 weeks and at 50 weeks[10]. The portions of the curves between 37 and 50 weeks were validated by comparing them with the growth of contemporary preterm infants[11]. Consequently, Fenton 2013 growth charts are currently the most appropriate to classify intrauterine growth at birth, both for neonates born at term and preterm.

The most used criterion to classify intrauterine growth relates birth weight with gestational age, classing neonates as large-, appropriate-, or small-for-gestational age[5]. However, there is no consensus on the cut-offs for this classification[12,13]. While some authors define the 10th and 90th percentiles as lower and higher thresholds, respectively, others consider as lower thresholds the 5th percentile, 3rd percentile, or -2 standard deviations to classify as small-for-gestational age, and the 95th percentile, 97th percentile

or +2 standard deviations as higher thresholds to classify as large-for-gestational age[12,13]. The rationale for this derives from the power of a chart in accurately estimating statistically defined thresholds, which is dependent on the sample size for each gestational age group of interest. Only samples comprising a minimum of 120 individuals possess sufficient statistical power to define the 3rd or the 5th percentiles[14,15].

Accordingly, the 3rd and 97th percentiles, as defined by the Fenton 2013 growth charts[10], may be employed as statistical thresholds for the identification of small-for-gestational age and large-for-gestational age infants, respectively.

Strengths[6]:

- The Fenton meta-analysis[10] is the most comprehensive study to date, encompassing a sample size of nearly 4 million neonates with measured weight, 151,527 neonates with measured length, and 173,612 neonates with measured head circumference.
- The curves are stratified throughout percentiles 3 to 97, which allows for a more precise classification.
- The open-access online application *PediTools: Fenton 2013 for iOS* (https://peditools.org/fenton2013/index.php), based on the Fenton 2013 growth charts[10], enables the calculation of z-scores online. This allows for the precise quantification of deviations in weight, length, and head circumference, particularly those that are extreme.

Limitations[6]:

- Although the meta-analysis[10] was based on selected studies from developed countries, the provided charts are not prescriptive standards for birth weight, as they included cross-sectional studies and, in some of them, twin pregnancies, morbidity during pregnancy, poor surveillance, and altered nutrition status of pregnant women were not exclusion criteria.

- In the construction of percentile curves, every study included in the meta-analysis[10] considered gestational age in complete weeks, except for the study by Voigt *et al.*[16], which used gestational age in weeks and days. For the remaining reference curve proposals, anthropometric values for gestational ages between full weeks were mathematically extrapolated.
- To determine the values of each reference percentile (3, 10, 50, 90, and 97) for weight, length, and head circumference, the meta-analysis used the percentiles calculated in each individual study that met the inclusion criteria for each gestational age, instead of the collection of the registered values of each neonate, thus reducing the accuracy, by accumulation of rounding and estimation errors.

2. Growth charts to assess postnatal growth in term infants

2.1. Monitoring weight loss in the first postnatal days

Recommended: NEWT® nomogram (http://newbornweight.org) (LOE 3, SOR C) (Table 1)

Systematic reviews on expected postnatal weight changes in breastfed infants indicate that the average weight loss during the first postnatal days is expected to be between 5% and 8% of the infant's birth weight by two to four postnatal days[17,18]. Furthermore, most neonates regain their birth weight by 10 to 14 postnatal days. A weight loss exceeding 10% of the infant's birth weight warrants attention. This occurs with greater frequency in neonates delivered by cesarean section than by vaginal delivery[19]. In this context, nomograms designed for monitoring early infant weight changes, which take into account the major factors influencing early infant weight loss, are of great value for pediatric healthcare providers and parents[20].

The online open-access Newborn Early Weight Tool - NEWT® (http://newbornweight.org) comprises nomograms that enable the plotting of the infant's weight percentile at any given time during the first postnatal days on an hourly basis. This enables for the identification of infants with excessive weight loss. The NEWT® was constructed from a cohort of 161,471 healthy, singleton newborns born at 36 weeks gestation or more at 14 Northern California Kaiser Permanente hospitals between 2009 and 2013. Data were extracted from hospital records with particular focus on the mode of delivery (vaginal or caesarean section), feeding type (exclusive breastfeeding, exclusive formula feeding, or both), and infant body weights (https://newbornweight.org/about/).

For breastfed newborns, percentiles were estimated from 6 to 72 hours of age for those delivered vaginally (96 hours if cesarean). For exclusively formula fed newborns, these nomograms have lower accuracy and time of surveillance, given the smaller sample size. In these nomograms, weight loss trajectories equal to or greater than the 90th percentile for vaginal deliveries, and equal to or greater than the 75th percentile for caesarean deliveries, are considered excessive. Furthermore, a crossing of percentiles can serve as an early warning for potential breastfeeding difficulties, which should be addressed before hospital discharge [21,22].

2.2. Monitoring short- and long-term growth

Recommended: WHO 2006 growth charts[1] (LOE 2, SOR B) (Table 1)

The WHO Multicentre Growth Reference Study[23] developed sex and age specific growth charts to describe the growth of healthy term infants in six countries from diverse geographical regions, without significant morbidity, living in good sanitation and hygiene, and socioeconomic conditions favorable to growth.

This study combined a longitudinal follow-up of 882 children, generating growth charts from birth to 23 months, with a cross-sectional sample of 6,669 children, from 24 months to five years of age[1]. While exclusive or predominant breastfeeding for at least four months was required for participants in the longitudinal component, a minimum of three months of any breastfeeding was required for participants on the cross-sectional component[23]. Consequently, the growth charts of the longitudinal component are more closely aligned with prescriptive standards than those derived from the cross-sectional component.

Strengths:

- The WHO growth charts are the closest to prescriptive standards ever available for monitoring growth of term infants up to five years of age living anywhere, regardless of ethnicity, socio-economic status, and type of feeding[1].
- The WHO offers online access to age and sex specific values for centiles and z-cores, which are presented in both graphical and tabular formats (https://www.who.int/tools/child-growth-standards/standards/weight-for-age). Furthermore, the open-access WHO AnthroPlus software for calculation of centiles and z-cores can be downloaded (https://who-anthroplus.freedownloadscenter.com/windows/).

Limitations

- The generation of two distinct growth curves from two different samples results in a slight disjunction at two years of age, where the transition from longitudinal to cross-sectional curves occurs[1].
- The inter-country differences in social determinants of health, environmental factors, and genetic composition led some authors to question the suitability of the one-size-fits-all approach of the WHO 2006 growth standards to several settings[24,25].

- This problem does not seem to arise in Portugal, given the country's favorable socioeconomic and health conditions for growth. Therefore, as in several other countries where these standards are widely implemented[26], and in 2013 the Portuguese Directorate General of Health adopted the WHO 2006 growth standards[1] for general use (norm nº 010/2013, May 31st, 2013). The sociodemographic evolution may affect its suitability.

3. Growth charts to assess postnatal growth in preterm infants

The ideal growth charts for assessing postnatal growth in infants born preterm should be prescriptive standards constructed from a large, long-term follow-up cohort of infants recruited at the prenatal period from uneventful pregnancies and including neonates from the threshold of viability to term gestational age at birth, without significant neonatal morbidities, thus allowing their representative use through the infant's early life. Such a tool is currently unavailable[6]. Consequently, while in the neonatal intensive care unit, there is frequently the need to use multiple charts, which may affect the compliance with routine growth monitoring[27].

3.1. Monitoring growth while in hospital

3.1.1. Body weight changes

Recommended: the online calculator: www.growthcalculator.org (LOE 2, SOR B) (Table 1)

Defining postnatal growth charts for preterm infants is a complex task. In these infants, assessment of early postnatal weight changes is affected by suboptimal nutrition that may

be confused with the postnatal weight loss secondary to adaptive contraction of extracellular volume, particularly when weight loss is excessive[27].

The longitudinal Intergrowth-21 prescriptive standards[28] and the cross-sectional Fenton 2013 descriptive references[10] have been the most frequently used to assess postnatal growth in infants born preterm[29]. Both growth charts describe a steady increase in body weight since birth[10,28], which is an erroneous assumption, as the physiological weight loss that occurs during the early postnatal period is not reflected in these charts[30.31].

In this context, a comprehensive longitudinal study in preterm infants revealed that, provided postnatal adaptation is uncomplicated, body weight transits at the 21th postnatal day to a trajectory at 0.8 SD below birth weight, regardless of gestational age at birth[32,33]. Consequently, it is neither anticipated nor desirable that the weight gain of preterm neonates should approximate intrauterine weight gain during the first postnatal month[6] as had previously been suggested[34,35].

An open-access online calculator (www.growthcalculator.org) was constructed from a large longitudinal study[32,33] to accurately monitor the weight changes in preterm neonates while they remain in the hospital. This tool displays graphically the percentile in which the current weight is plotted, as well as the target weight and the deviation from the current weight in grams. As a limitation, this tool does not yet provide a graphic trend or a curve from the infant's weight records.

3.1.2. Linear growth and head growth

Recommended: Intergrowth-21[28] (LOE 2, SOR B) or Fenton 2013 growth charts[10] (LOE 1, SOR B) (Table 1)

As length and head circumference increase in a linear fashion from birth, the cross-sectional Fenton 2013 growth charts[10] can be employed to monitor postnatal linear growth and head growth[36].

3.2. Monitoring growth after discharge

Recommended: Intergrowth-21[28] (LOE 2, SOR B) or Fenton 2013 growth charts[10] (LOE 1, SOR A), and, when reaching term corrected age, the WHO 2006 growth standards[1] (LOE 2, SOR B) (Table 1).

Very preterm and extremely preterm infants are usually discharged after the first postnatal month. By this age, it is expected that most infants had achieved a catch-up in body weight. Both Intergrowth-21[28] and Fenton 2013 growth charts[10] were constructed in such a way that, at those advanced ages, the infant growth overlaps with the WHO 2006 growth standards designed for full-term infants[1]. Therefore, the WHO 2006 growth standards should be employed in preterm infants upon attaining term corrected age or exceeding the age limits of both recommended growth charts for preterm infants. It is noteworthy that to date, no long-term growth follow-up of extremely low and very low birth weight infants has validated such transition from growth charts constructed for preterm infants[10,28] to those constructed for term infants[1].

For infants born at more than 27 weeks of gestation, the longitudinal Intergrowth-21 prescriptive standards are recommended for monitoring growth from 32 postmenstrual weeks to 64 postmenstrual weeks (6 months after term age) [28].

For infants born at less than 27 weeks of gestation, the cross-sectional Fenton 2013 charts can be employed as an alternative to monitor growth up to 50 postmenstrual weeks (2.5 months after term age) [10].

The Intergrowth-21 charts have strengths and one limitation[6]:

Strengths:

- These prescriptive standards are well-designed and should be preferred to monitor growth of infants born preterm after discharge from the hospital.
- An online calculator for body weight, length, and head circumference (http://intergrowth21.ndog.ox.ac.uk/en/ManualEntry/Compute) provides percentiles and z-scores, which permit the precise quantification of growth deviations.

Limitation:

- A strength of the Intergrowth-21 study led to a limitation: because only healthy pregnant women were included, they gave birth to very few preterm births (5%), mostly late preterm births[4,28].
- In fact, of the 201 healthy and stable preterm infants included in the cohort, only 28 infants born at 33 weeks' gestation or earlier contributed data to these standards. Consequently, Intergrowth-21 standards can be considered reliable for monitoring postnatal growth only in infants born at more than 27 weeks of gestation and from 32 weeks' postmenstrual age[28]. It is noteworthy that the American Academy of Pediatrics has expressed reservations about the Intergrowth-21 charts, citing concerns about their construction from a limited sample size, and advising against their use in infants with a gestational age of less than 36 weeks' postmenstrual age[37].

4. Growth charts for use in multicenter and population studies of preterm infants

In the setting of multicenter studies and population databases of infants born preterm, such as the Portuguese Register of Very Low Birth Weight Infants - *Registo Nacional do Recém-Nascido de Muito Baixo Peso*[38], the use of a single representative longitudinal

growth chart would be preferable for the classification of intrauterine growth and the assessment of postnatal growth, covering gestational ages from the threshold of viability. Currently, such a tool is lacking.

As an alternative, during the first postnatal month, the www.growthcalculator.org [32,33] should be employed to monitor postnatal weight gain and the Fenton 2013 charts[10] to monitor length and head growth[6]. In preterm infants, the Fenton 2013 charts[10] may overestimate postnatal weight gain during the first month and misclassify growth within the normal range as growth restriction. After the first postnatal month, the cross-sectional Fenton 2013 charts[10] can be employed to monitor weight, length, and head growth, taking advantage of the fact that they were constructed from the anthropometry at birth of large samples of neonates from the threshold of viability, which is not the case of Intergrowth-21 prescriptive standards[28]. Once the infant has reached term corrected age, the WHO 2006 growth standards for infants born at term[1] should be employed[10,28].

Conclusions

The appropriateness of growth charts depends on the infant's gestational age, the intended use of the measurement, and the infant's stage in the life cycle.

To summarize (Table 1):

- To classify intrauterine growth, the Fenton 2013 growth charts[10] based on anthropometric measurements at birth are the most appropriate for both neonates born at term and preterm.
- To monitor growth in infants born at term, the WHO 2006 growth standards[1] are highly recommended. To specifically monitor weight loss in the first postnatal days, the NEWT® (http://newbornweight.org) nomogram is a good tool.

- To accurately monitor body weight changes in very preterm infants while under intensive care, the open-access online calculator (www.growthcalculator.org) is recommended. Concurrently, the Fenton 2013 growth charts[10] can be employed to monitor the length and head circumference growth.
- Following discharge from the hospital, the Intergrowth-21 prescriptive standards[28] are appropriate for monitoring growth in preterm infants born at more than 27 weeks of gestation, from 32 to 64 weeks postmenstrual age. Subsequently, the WHO 2006 growth standards[1] for term infants should be employed.
- In multicenter studies and population databases of very preterm infants, the www.growthcalculator.org should be used to monitor weight gain during the first postnatal month and concurrently the Fenton 2013 charts[10] should be employed to monitor length and head growth. Following the first postnatal month, the Fenton 2013 charts[10] are recommended to monitor all anthropometric parameters.

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Conflicts of Interest

There are no conflicts of interest to declare.

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Protection of human and animal subjects

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Table 1. Recommended growth charts for infants born at term and preterm, according to the purpose and the period of life cycle.

Infant's maturity	Purpose	Recommendation	LOE*	SOR*
Term and preterm neonates	To classify intrauterine growth	Fenton 2013 growth charts (Fenton 2013_59)	1	A
Infants born at term	To monitor weight loss in the first postnatal days	Online NEWT® nomogram http://newbornweight.org	3	C
	To monitor short- and long-term growth	WHO 2006 growth standards (WHO 2006)	2	B
Infants born preterm	To monitor growth while in hospital:			
	- Weight changes	Online calculator www.growthcalculator.org	2	B
	- Length and head growth	Fenton 2013 growth charts (Fenton 2013_59)	1	A
	To monitor growth after discharge:	- Intergrowth-21 standards (Villar 2015), to monitor growth from 32 to 64 weeks postmentrual age, in infants born >27 weeks gestation.	2	B
		- Fenton 2013 charts (Fenton 2013_59), to monitor growth from up to 50 weeks postmentrual age, in infants born ≤27 weeks gestation†	1	A
		- WHO 2006 growth standards (WHO 2006), after reaching term equivalent age or the more advanced ages covered by Intergrowth-21 (Villar 2015) or Fenton 2013 (Fenton 2013_59) growth charts	2	B

* LOE - level of evidence, SOR – strength of recommendation (adapted from[9])

† In multicenter studies of preterm infants, Fenton 2013 charts are suggested to monitor growth from birth, as they were constructed from large samples of neonates that include gestational ages at the threshold of viability.