Annals of Nutrition and Metabolism

Human Nutrition: Review Article

Ann Nutr Metab 2024;0(0):1–11
DOI: 10.1159/000541226

Received: May 25, 2024
Accepted: August 28, 2024
Published online: November 27, 2024

What Is Normal Growth? Principles, Practicalities and Pitfalls of Growth Assessments in Infants and Children

Tanis R. Fenton[a] **Nicole Gilbert**[a] **Seham Elmrayed**[a, b]
Carol J. Fenton[c] **Dana L. Boctor**[a, d]

[a]Community Health Sciences, O'Brien Institute of Public Health, Alberta Children's Hospital Research Institute, Cumming School of Medicine, University of Calgary, Calgary, AB, Canada; [b]Institute of Global Health and Human Ecology, American University in Cairo, New Cairo, Egypt; [c]School of Population and Public Health, University of British Columbia, Vancouver, BC, Canada; [d]Pediatrics, Cumming School of Medicine, University of Calgary, Calgary, AB, Canada

Key Messages

- Normal child growth is assessed differently in populations versus individuals.
- Normal growth for populations has been defined by the WHO as height <−2 *z*-scores and weight for length/height within ±2 *z*-scores. As 2.3% of healthy children will measure below and above the WHO definition of healthy growth, using the population criteria for normal growth for individuals will therefore misclassify some children.
- Growth patterns of individuals reflect their genetic potential as well as environmental influences. It is challenging to decide for an individual whether their growth pattern is appropriate for their genetic potential or whether it is unduly influenced by environmental factors or disease.

Keywords

Growth disorders · Validation · Failure · Restriction · Retardation · Obesity · Nutrition assessment · Parents · Growth chart

Abstract

Background: Growth assessments are a pillar of public health surveillance, individual health screening, and clinical care. Normal growth is defined differently for individuals versus populations. The World Health Organization (WHO) growth standards were developed to describe the pattern of growth in healthy children without socioeconomic limitations whose mothers planned to breastfeed. The growth standards' cut-off points of ±2 standard deviations (*z*-scores) were defined for population assessments, based on attained size, to describe stunting and wasting at the lower end and overweight at the higher end. In a healthy population, one would expect 2.3% of the population to be above and below these cut-points. Higher child mortality rates associated with higher rates of stunting and wasting noted in observational studies validated these WHO cut-offs. There are knowledge gaps influencing the accuracy and effectiveness of growth assessments in individual children, posing challenges for health care providers. ***Summary:*** The principles of assessing normal growth in children and preterm infants are reviewed, along with pitfalls to be avoided. Growth is determined by genetics and modified by the interplay with nutritional, environmental,

Karger@karger.com
www.karger.com/anm

Correspondence to:
Tanis R. Fenton, tfenton@ucalgary.ca

socioeconomic, and possibly intergenerational factors. This complexity is reflected at both the population and individual level. However, normal growth in an individual has unique-specific factors so requires a comprehensive assessment. Normal growth for an individual child could be defined as the progression of changes in anthropometric measurements to achieve the individual's genetic potential. A misdiagnosis of growth faltering can occur if infants and children are asses with one-time rather than serial measures, and if age is not corrected for prematurity. Health care provider sensitivity and cognizance when communicating about a child's size is important for parental reassurance and avoiding stigma and unnecessary pressures or restrictions around feeding.

Plain Language Summary

Children grow in a variety of patterns and have a variety of heights and weights. A child's height is influenced by the family genetics as well as well as the amount and type of foods they eat, illnesses and by how much they move around. Health care providers must consider all the factors that can affect child growth in order to determine if the pattern over time is normal for the child. As there are many things that affect child growth, it may not always be straightforward to decide whether an individual child has a growth problem. Normal growth is defined differently for individuals versus populations. Some healthy children (2.3%) will measure below and above the WHO definition of healthy growth, but their sizes are appropriate for those children. This paper discusses how to define normal growth and what is considered short stature, a low weight for height, and overweight for a population and how to avoid misclassifying children as underweight, short, or overweight. Labelling a child by these categories can create stigma and lead to unnecessary diet changes. It is important for health care providers to communicate the principles of growth clearly and help prevent unnecessary worry for parents and stigmatization for children.

Introduction

Growth assessments are a pillar of health screening, public health surveillance, and clinical care. The concept of normal growth is different for individuals versus populations. The phrase "normal growth" may make intuitive sense, but concerns can arise when applying the population statistic cut-points to the growth of individuals. Every individual has a growth potential determined by genetics, and a growth pattern which is the result of the interactions between genetic, nutritional, environmental, and intergenerational social and economic factors. This makes identifying normal versus abnormal growth for individuals challenging. The best growth assessments focus on growth patterns rather than on attained size and consider a child's genetic potential and growth history [1]. Communicating with sensitivity and clarity is required when relaying the interpretation of growth charts to parents.

The concept of normal growth is different for individuals versus populations

This chapter focuses on growth of infants and preschool children. The accuracy of any child's growth assessments is dependent first on accurate measurements and then on accurate interpretations. Other sources provide guidance on obtaining accurate measurements [2]. This paper describes the interpretation of the growth of infants and young children, whether they are individuals or population data, whether they were born at term or prematurely. Growth of hospitalized preterm infants [3] and hospitalized infants and children [4] are outside the scope of this chapter and covered elsewhere.

Growth Standards

In the fields of engineering, science, and other areas of medicine, the word "standard" refers to a specific designation that is assigned to a tool or device that has met certain criteria established by an independent organization [5, 6]. For growth assessments, the World Health Organization (WHO) uses the word "standard" when growth data have been based on selected healthy well-nourished individuals [7, 8]. This word "standard" implies that a value judgment has been made that the growth data are a "norm or a desirable target" [8] for how children should grow and that deviations from this represent abnormal growth. In contrast, the term "growth reference" is used when the growth data used to develop the growth chart did not have a specific criterion about healthfulness.

To develop the WHO Growth Standard, the WHO conducted the Multicenter Growth Reference Study [7] to describe population growth in an attempt to describe the "ideal" distribution of size in a population. Communities where economics [9] were not likely to limit child growth were selected from

Table 1. World Health Organization (WHO) recommended *z*-score defined categories as growth indicators for populations versus individuals, for children under 5 years versus children and adolescents 5 years and older [12–14]

	Length or height	Weight for length or BMI			Weight for age
	short stature	wasted	overweight	obesity	underweight
Recommended for populations					
WHO advisory group 2018 [12]	<–2	<–2	>2	–	Do not recommend weight-for-age cut-offs
Recommended for individuals					
WHO interpreting growth indicators 2008 for up to age 5 years [13]	<–2 and <–3*	<–2 and <–3*	>2	>3	Weight status is better assessed from weight-for-length/height or BMI-for-age
WHO defining obesity risk status for 5 years and over 2010 [14]	–	–	>1	>2	Recommend BMI-for-age due to difficulties obtaining measures of body fat and lack of references to interpret them

6 countries and healthy children from nonsmoking mothers were included [7]. The 2006 WHO growth standard charts are often referred to as "breastfed charts" although the charts do not represent exclusively breastfed infants. The inclusion criteria was that prenatally the mothers were required to be planning to breastfeed and planning to introduce solid foods between 4 and 6 months as per the WHO complimentary feeding guidelines at the time. [10]. The actual prevalence of any breastfeeding was 75% at 4 months [10].

The WHO observed that across the six sites the proportions of length and height variability was greater between individuals than between the sites so the data were pooled to construct a single international standard from birth to 5 years of age [11]. The WHO concluded that the variation in growth in the WHO 2006 growth standard as represented by the bell-shaped distribution (shown in Fig. 2; Table 1) likely represents genetic variation alone [11].

For children aged 5 years and older, the WHO also created growth charts for children and adolescents as a growth reference and not a growth standard [15]. After assessing data from 45 counties, the WHO developed growth reference charts based on American data that were collected between 1963 and 1974, prior to the onset of the obesity epidemic. These surveys were chosen based on several strengths, including: data quality, sample size, socioeconomic status of the participating children and data collected before the rise in obesity rates [15]. "Unhealthy weight-for-height" data points were excluded from this dataset. The WHO considered that approximately 15% (85th percentile/+1 *z*-score) of these 5–19 year olds were considered overweight and 2–3% were considered obese (Table 1) on the basis that at 19 years of age, the body mass index (BMI) curves compare closely with the adult BMI curves and the overweight cut-off (>25.0 kg/m^2), and the +2 SD value (29.7 kg/m^2 for both sexes) compares closely with the cut-off for obesity (>30.0 kg/m^2)" [15]. These cut-points for overweight are more inclusive than the cut-points the WHO recommends for children under age 5 years >+2 *z*-score (>98th percentile) [13] (Table 1). When the more inclusive cut-off for overweight the WHO recommended for older children (85th percentile/+1 *z*-score) was used for children under 5 years instead of their recommended cut-off (>+2 *z*-score (98th percentile) the estimated rate of overweight is over-estimated [16]. The abrupt change in the overweight categories from >98th percentile for under age 5 to >85th percentile in over age 5 (Table 1) is not always recognized [16]. It is worth noting the WHO's rationale for the cut-points for overweight (BMI >+2 *z*-score (>98th percentile) and obesity (>+3 *z*-score (>99.9th percentile) in children under 5 years (Table 1):

"WHO opted for a cautious approach … because these children are still growing and thus far there are few data on the functional significance of the cut-offs for the upper end of the BMI-for-age distribution for such an optimally healthy population. The WHO standards sample was prescriptive, and unhealthy weights for length/height were excluded prior to constructing the curves. A further reason to be cautious is to avoid the risk of young children being placed on restrictive diets." [17]. One could argue that these points about the need for a cautious approach also apply to children older than 5 years of age, as programs to support children and families for treatment of overweight for school-aged children are not widely available and evidence is limited regarding the treatment effectiveness [18, 19].

The applicability of the WHO growth standard to children of all countries has been questioned. It has been noted that there is a lack of data from East Asia in the study population and thus the relevance of the growth standards for these populations has been questioned [20]. In addition, the distribution of child heights in some countries differs from the growth standard [21–23]. For example, child height distributions are shifted upwards toward taller statures, in the Netherlands [24] and lower statures as in Indonesia [23]. In countries where higher proportions of children have shorter heights, perhaps due to determinants of health including poverty and intergenerational factors, comparisons to the WHO growth standard could be useful to advocate for better child health support and nutrition programs.

However, on an individual basis, when children are from populations with different height distributions, the growth chart should be interpreted contextually and with serial measures.

The developers of the Intergrowth 21st growth charts described their preterm charts as growth standards [12]. Despite the sample included only a few very (n = 12) preterm births <33 weeks [12] and no females <31 weeks gestational age, growth charts for both sexes beginning at 27 weeks were developed (shown in Fig. 1) [12]. To our knowledge, guideline groups and the WHO have not stated that the Intergrowth charts are growth standards. The American Academy of Pediatrics advised against the use of the Intergrowth 21st project growth charts for infants <36 weeks due to their sample size problem [25].

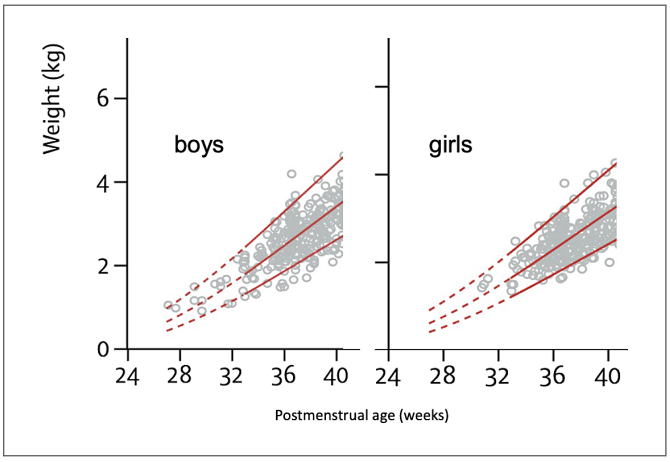

Fig. 1. This figure from the Intergrowth-21 Project postnatal growth standards for preterm infants [23] shows their sample size of only 12 preterm births <33 weeks and no females <31 weeks gestational age. Reproduced under a Creative Commons Attribution License © Villar et al. [12].

Using Growth as a Measure of Population Health

Comparing the distribution of sizes of one population to the standardized distributions of a growth chart at the population level may identify potential areas for intervention. Determinants of health that could affect the growth patterns within a population could include: limited access to healthy foods, poverty, famine, and/or conflict.

The WHO and UNICEF jointly established a Technical Expert Advisory Group on Nutrition Monitoring to update the methodology and definitions using the WHO growth standard (Table 2) [14]. Their goal was to set national and international targets for stunting (short length/height), wasting (low weight-for-length/height) and overweight (high weight-for-length/height) to identify where improvements are needed [14]. In the course of this process, they also defined "normal" growth [14]. This definition of normal growth designed for population assessments does not actually address growth individual assessments since it is based on attained size and not changes in size over time.

After setting these above defined population-based definitions and indicators for stunting, wasting and overweight, the WHO Advisory Group examined nationally representative surveys of children under 5 years from 134 countries with their crude mortality rates [14]. They quantified how many countries had excess stunting, wasting, and overweight and observed a progressive increase in mortality rates with increasing rates of child stunting and wasting rates [14], which effectively validated these definitions for stunting and wasting. Populations with malnutrition rates in the 5–10% range had mortality rates more than 2.4 times that of populations with rates less than 5% [14]. These associations with higher mortality demonstrate the value of the WHO proposed the cut-points of ±2 z-scores for population growth assessments. Increased risks of adverse outcomes increase with the extent of growth deficits without a sudden jump in risk.

Cut-Points

Normal growth for populations has been defined by the WHO as height <–2 z-scores and weight for length/height within ±2 z-scores (Fig. 2; Tables 1, 3). In a healthy population, one can expect 2.3% of the population to be above and below these cut-points [26]. Therefore 2.3% of healthy children will likely measure outside of the WHO definition of healthy growth and using the population criteria for normal growth for individuals will misclassify some children. The WHO population recommended ±2 z-scores cut-points [14] are not particularly sensitive or specific for an individual at identifying whether there is a problem particularly when one anthropometric measurement is used [27]. Before diagnosing growth faltering when there is a downward growth deviation, it is important to quantify the severity and determine whether it has been due to an acute or chronic illness or a shift to grow to at genetic potential (in the first months of life or at puberty) or is signaling a health concern [27].

Using z-scores is a useful statistical way to quantify individual variation from the average value in the population (shown in Fig. 2; Tables 1, 3). Measurements higher than the mean have positive z-scores, while those below the mean have negative z-scores. Figure 2 and Table 3 show how z-scores correspond and differ from percentiles across a distribution. Each z-score corresponds to specific percentiles; z-scores have the advantage that the numerical values for percentiles become meaningless further away from the

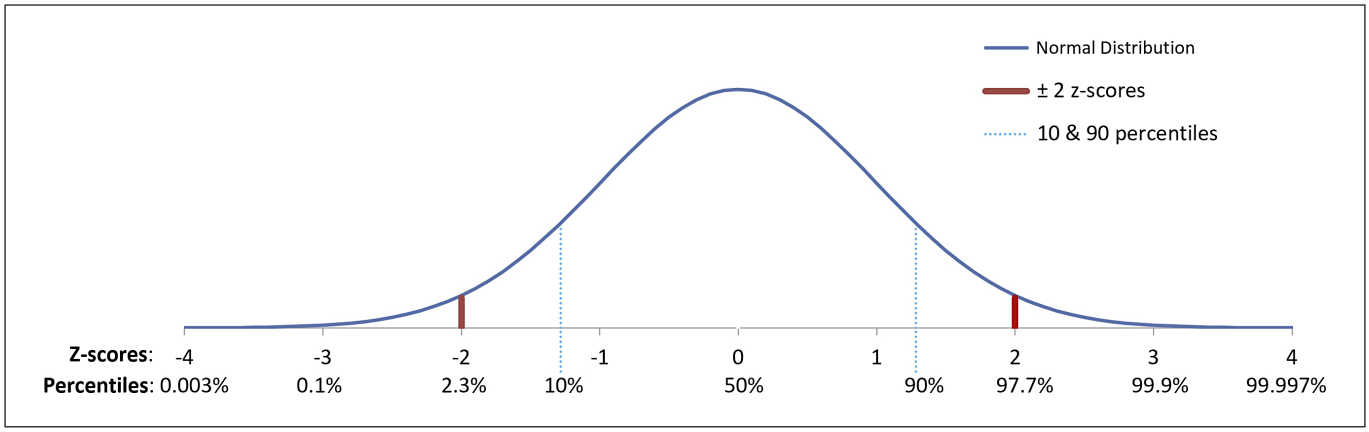

Fig. 2. A bell curve distribution with placement of frequently used *z*-scores and percentiles. Some healthy children (2.3%) will measure below and above the World Health Organization definition of healthy growth (> or < ±2 *z*-scores) [14], but their sizes can be appropriate for those children.

Table 2. The Technical Expert Advisory Group on Nutrition Monitoring recommendations on definitions and risk categories [12]

The WHO-UNICEF Technical Expert Advisory Group on Nutrition Monitoring consensus definition of "normality" for population assessments as length/height-for-age and weight-for-length/height within ±2 *z*-scores of the WHO growth standards medians (2.3rd and 97.7th percentiles) to define stunting (short length/height), wasting (low weight-for-length/height) and overweight (high weight-for-length/height) [12]. In a healthy population, one would expect 2.3% of the population to be above and below these cut-points. This definition of normal growth, designed for population assessments, does not actually address growth assessments but uses attained size

Table 3. Commonly used percentiles with *z*-score equivalents and commonly used *z*-scores with percentile equivalents[1]

Common percentiles with *z*-score equivalents		Key *z*-scores with percentile equivalents	
percentiles	*z*-scores	*z*-scores	percentiles
2	−2.1	−4	0.003
3	−1.9	−3	0.13
10	−1.3	−2	2.3
25	−0.7	−1	15.9
50	0.0	0	50.0
75	0.7	1	84.1
90	1.3	2	97.7
97	1.9	3	99.87
98	2.1	4	99.997

[1]The 10th and 90th percentiles have been used historically to assign size at birth for gestational age, but otherwise these percentiles are not commonly recommended for use in anthropometric assessments.

median while *z*-scores continue to have descriptive value. Percentile values outside of −2 to +2 (i.e., <2nd percentile and >98th percentile) have similar numerical values that are not helpful to describe a child's size, whereas *z*-scores are descriptive across the whole spectrum of sizes (shown in Fig. 2; Tables 2 and 3). When specific *z*-scores are not calculated and a percentile value is applied, for example: <3rd percentile, or <<3rd percentile, the description is limited as this could imply a *z*-score of −2 or −4.0 which are clinically quite different. Specifically, the percentile for 2nd, 3rd, and 4th *z*-scores are the 97.7th, 99.9, and the 99.997 percentiles, respectively, the latter percentile values are not easy to distinguish between. The same problem occurs for low *z*-scores; the −2, −3, and −4 *z*-scores are the 2.3, 0.1, and 0.003 percentiles, respectively.

Defining Normal Growth for Individuals

Every individual has a genetic growth potential and a growth pattern resulting from nutritional intake, metabolism, disease, and determinants of health. Clinical growth assessments are challenged with how to best interpret growth in the face of illness or contributing factors (Table 4). As well, there may be physiologic insults prenatally, or during growth where catch-up growth was not possible.

Catch-up growth and accelerated growth have been calculated mathematically when growth exceeds certain thresholds such as crossing certain percentiles or changes of >0.67 or 1 *z*-score [34]. There are limitations associated with categorizing children simply on the basis of these mathematical calculations and limited evidence that these classifications are defined validly. Genetic growth potential of individuals is not known, body composition data are often lacking and preterm infants often place lower on growth chart curves at hospital discharge before catching up to growth chart curves [35].

Table 4. Tips for interpreting child growth

Principle	Suggestions
The accurate interpretation of a growth chart is reliant on accurate measurements	There are often inaccuracies recorded, especially for supine length [28, 29] or when using parental home measurements
Growth charts are insufficient for a standalone diagnosis of malnutrition so should be regarded as one component of a comprehensive nutritional assessment	It may not be possible to determine "normal growth" with the growth chart alone. When concerned and unsure, it is best to refer for comprehensive medical and feeding assessments [4] prior to advising feeding changes
Single point in time measurements are not adequate to assess growth patterns	Growth should be defined as a progression in increase in size within the context of genetic potential
All anthropometric measures should be done routinely	Assess height and weight status, weight-for-length, or BMI and for infants include head circumference
Concerns about small child sizes	
A certain proportion of the population will place in the lower percentiles. This is not necessarily pathological	Consider genetic potential (ethnicity, mid-parental height, syndromic causes); further screening for determinants of health may be warranted. It is normal for 10% of a healthy population to plot below the 10th percentile
Children growing outside of the growth chart curve boundaries are statistically less common, but not necessarily pathological. The chart curves are statistical markers not growth patterns	Health care providers can have more confidence of a growth problem for an individual child when measurement(s) represent deviations beyond ± 2 *z*-scores [4]. Consider genetic potential (ethnicity, mid-parental height, syndromics); further screening for determinants of health may be warranted
Normal variants of short stature include familial (genetic), constitutional, and idiopathic short stature [29]	Children who are small but growing parallel to the growth chart should be followed to confirm their growth pattern, monitor for possible contributing symptoms and support/reassure parents [30] (see *Talking with Parents about Growth of Young Children*)
For preterm infants, the corrected age should be plotted up until 3 years of age [31]	To avoid this common mistaken identification of "abnormal" growth (unpublished data), consistently use include the corrected gestational age and include this information in the identifying data
Concerns about large child sizes	
The WHO recommends a careful approach to children under age 5 plotting above 85th percentile is required given risks of restrictive diets in children who are still growing [17]. The functional significance of the cut-offs for the upper end of the BMI-for-age distribution are unclear for healthy children	Avoid the use of use of >1 *z*-score for BMI or weight-for-length as an indicator of concern Parental teaching around risk of restrictive diets in growing children with an emphasis on healthy lifestyle rather than weight loss If there are clear concerns with overweight/obesity, consider if supports are available [18, 19, 32, 33] and counsel within the context of family capacity and constraints
BMI does not assess adiposity and thus can be inaccurate especially when the BMI is slightly elevated	Physical exam, waist-hip ratio, and body composition measures, when available, can provide an assess whether an individual has excess adiposity
Identification of overweight and obesity signals for a historical and psychosocial evaluation of determinants of health	Suggestions made should be in the context of considering contribution of poverty, housing, school challenges, social support, feeding/dietary habits, food insecurity, colonialism, access to physical activity, adequate quality sleep, and stress and coping/regulation skills
A household's lack of resources or support to address overweight and obesity should temper the approach, timing and appropriateness of discussing concerns [18]	Learn about the economic reality of the household and the capacity to support lifestyle changes prior to giving recommendations. Consider whether programs are available to support behaviour changes [18, 19, 33]

Therefore, it is challenging to correctly distinguish between catch-up and accelerated growth, especially for individuals and for infants born prematurely. Additionally, a child's growth rate can increase after an illness, which is a growth pattern that needs to be differentiated from excess growth [36]. Misplaced fears should not interfere with correction of "faltering growth" about potentially inducing accelerated growth [36]. Serial growth patterns of the infant or child will help a clinician determine if there are accelerated excess or if gains reflect appropriate catch-up.

Clinicians are often faced with a small or slim child with the need to determine if this is within healthy range for that child or reflecting a disease process. Additionally, there may be scenarios where the clinician must interpret what is clinically acceptable for a given child in a specific clinical context. Rather than simply using the attained size of an individual child as recommended for population assessments, perhaps "the progression of changes in height, weight, and head circumference … to achieve the individual's genetic potential" [37] is a more appropriate definition for individuals. This definition has strengths as it focuses on serial measures and notes the importance of assessing a child's growth progression over time, based on the child's genetic potential.

Anthropometric measurements are considered as only one component of the comprehensive nutritional assessment. As a screening tool, a deviation indicates a need for a detailed assessment of the following:

a. Medical history including prenatal and birth history that may influence nutrient intake, utilization or losses, and growth pattern
b. Functional outcomes
c. Medications/supplements
d. Mid-parenteral height
e. Nutrition focused physical examination [28]
f. Laboratory data and investigations
g. Dietary history
h. History related to the determinants of health.

The diagnosis of malnutrition is outside the scope of this paper. Extensive reviews and position statements on the application of the WHO cut-offs for the diagnosis of malnutrition [38] and the suggested application to etiology-related definitions [4] endorsed by the American Academy of Pediatrics [39] and American nutrition societies [40] are available.

There are 3 reasons why growth assessments of individual children using various definitions for growth faltering in individuals differ from population growth assessments. First, the WHO definition of normal growth for population assessments (Table 1) [14] does not actually refer to "growth" assessments since it uses attained size (length/height and weight for length/height), that is, anthropometric measurements at one point in time, versus serial measures that are needed to describe growth. Second, specific normal and ideal height [37] and BMI [41] for an individual is never known since it is determined by genetics [42] as well as environmental factors [43]. And third, children growing outside of the growth chart curve boundaries are statistically less common, but not necessarily pathological since the cut-points implied by the curves at the extremes of the growth chart curves are statistically defined. For identifying growth problems, these cut-points are highly sensitive (thus helpful at identifying small children) but poorly specific (thus not accurate at excluding small healthy children).

Mid-parental height can be a useful indicator of genetic influences for child height on growth but it is not a specific predictor for an individual child's growth pattern [44]. In clinical practice, it is reasonable to conclude normal growth on the basis that a child is close to or even above mid-parental height, following a fairly regular growth pattern and having an adequate and varied intake of age-appropriate food (Table 4).

Common Pitfalls in Growth Assessments of Preterm Infants

Normal growth for preterm infants is growth that approximates fetal growth rates, that is approximately parallel to growth chart curves after adaptions from the prenatal environment [3] and postnatal weight loss [45, 46]. Most preterm infants without major morbidities can grow to catch up in height and weight for length (to plot greater than –2 *z*-scores) by 2–3 years corrected age [35]. Preterm infants can plot low on growth charts compared to full term infants due to cumulative insults following premature birth and variable nutrition delivery that may result in different growth rates than full term infants. The ability of preterm infants to achieve their genetic growth potential is dependent on their feeding abilities after hospital discharge [47].

The best growth assessments of preterm infants consider the child's prematurity (by correcting for their age [35] and plotting them on the appropriate growth charts [such as the large sample size widely used Fenton [48] and Olsen [49] growth charts]) and then consider the pattern of growth for all three growth parameters (weight, length, and head circumference over time) taking into account prenatal factors that may have influenced their fetal growth and thus their postnatal growth [3, 46]. Preterm infants without major neonatal morbidities can catch up in growth so that the growth of the majority plot within ± 2 *z*-scores by 3 years of age [35].

There are 4 ways preterm infants are often misclassified as having inadequate growth.

1. Overlooking correcting for prematurity when plotting on regular growth charts designed for term-born infants. This problem occurs when the age of the infant is plotted as if they were born at term without age correction, thus plotting their age incorrectly. A recent study found that 73% of very preterm infants would be misdiagnosed as having stunting and 89.8% would be misdiagnosed as having underweight when their age was not corrected [35].
2. The use of single weight measurements at hospital discharge or term equivalent age is not predictive of developmental outcomes [45, 46]. Additional reasons for the lack of diagnostic accuracy for these one point in time growth assessments around hospital discharge include that they are (i) after the postnatal weight loss that places infants lower on growth chart curves even when they grow approximately parallel to growth chart curves, (ii) do not consider size at birth or genetic potential, and (iii) are usually based on weight alone [45].
3. Concerns have been raised about preterm infants' higher body fat percentage at term equivalent age [50]. However, in contrast to these concerns, at 3 months corrected age, preterm infants body fat is not different from infants born at term since term infant also gain body fat postnatally [50].
4. A hypothesis often referred to as the developmental origins of health and disease purports that an infant born with a low birthweight is exposed to a more nurturing environment increases the risk of overweight and developing cardiovascular disease [51]. However, risk of obesity and CVD is still strongly influenced by lifetime environmental factors. Questions about the validity of the developmental origins of health and disease hypothesis have recently been raised based on risks of bias

Table 5. Some tips for discussing child growth with parents

• Focus on non-stigmatizing discussions with families [57]
• Approach conversations about child growth with caution, empathy, and respect
• Understand that parents tend to feel anxious, concerned, and criticized when there are potential growth concerns for their child [58–60]
• Empower and support parents to foster healthy eating and activity habits [57]
• Help parents address barriers such as food insecurity and housing [61]
• Support parents with the day-to-day problems of picky eating, stretching limited food money, creating mealtime schedules [61], limiting child screen time, and increasing child physical activity [62]
• Avoid using medical jargon including: growth failure, failure to thrive, restriction, retardation, stunting, wasted, overweight, and obese
• Report the child's location and growth pattern on a growth chart in a positive way when possible, i.e., "healthy so reassuring" [56] or "not necessarily a problem but reason for further investigation to rule out any problems"
• Determine parental interpretation and understanding. It has been shown that while some parents find growth charts and percentiles can be a good teaching tool [57], others find them difficult to understand [55]
• Reassure parents that children come in different shapes and sizes. Each child has a unique and individual healthy growth pattern, which is expected and often not a concern. There are healthy children who are taller, shorter, heavier, and/or lighter
• Promote responsive feeding (e.g., following infants feeding cues/demands and offering children a variety of foods while allowing them to determine if and how much they decide to eat), regardless of location and growth pattern on the growth chart [63]

and over-adjustments in the fundamental studies [51]. Evidence shows that small for gestational age preterms do not develop the later phenotype (obesity [52] or higher blood pressure [53]) that would reveal any underlying risk compared to appropriate for gestational age preterm infants, so should not have rapid catch up growth [35] limited.

Talking with Parents about Growth of Young Children

Interpreting growth patterns can be challenging. Lay people often consider normal and desirable growth is the achievement of a specific size, often attained size, that is within the cut-points defined by the outermost growth chart curves or by an even narrower criterion: attained size in the upper percentiles [54, 55].

Purposeful and skillful communication that relays information and recommendations in a clear and supportive manner is important to prevent misunderstanding by parents (Table 5). A recent scoping review of parent perceptions of routine growth monitoring noted poor parental understanding of routine growth monitoring [56]. The comprehension of growth charts was affected by socioeconomic status, education, literacy, and minority ethnicity [56]. Common beliefs identified included: heavier babies are healthier and smaller babies raise concern. In addition, when their child was identified as overweight, parents frequently discounted the routine growth monitoring information. One survey identified that there is poor understanding of term "body mass index," the concept of proportionality and 41% of respondents reported that the growth chart was never explained to them [55]. Parents prefer to be reassured that their child is growing well [56].

When health care providers conduct conversations about growth, size, and weight in a responsive, non-blaming way, parents feel supported and empowered (Table 5) [64]. The language used to discuss weight with parents and their children can have negative effects. Health care providers comments on growth and parental concern about their child's weight [65] can lead parents to make potentially harmful changes to feeding, such as discontinuing breastfeeding early [66, 67], pressuring, restricting, or supplementing their child's diet inappropriately [56, 62, 67]. Parents and children can feel stigmatized and judged by the language and terminology that practitioners use to discuss growth [57]. Terms that require sensitivity and translation or avoidance include: growth failure, restriction or retardation, failure to thrive, malnutrition, stunting, wasted, overweight, and obese. It is important to relay that the purpose of assessing growth and relative size is to monitor for patterns that indicate a need for further assessment. Growth charts can be insufficient as a standalone diagnosis of malnutrition and should be regarded as one important component of a nutrition assessment.

It is especially important to avoid stigma around weight and stature. While routine growth monitoring was historically introduced to detect malnutrition and growth faltering, it is increasingly also used for diagnosing childhood overweight and obesity [68]. By definition, a certain proportion of the population will have larger size bodies which can be healthy for them. Weight stigma is a harm in and of itself. It causes lower quality health care, low self-esteem, poor treatment by others, and discouragement to participate in physical activity [69]. Parents have advised that it is better that the child not be present when discussing possible overweight [70]; however, this decision requires careful judgment as it may perpetuate or lessen weight stigma.

Conclusion

Children grow in a variety of patterns and have a variety of heights and weights. Health care providers must consider all the factors (family genetics, nutrition, illnesses, and physical

activity) that can affect child growth in order to determine if the pattern over time is normal for the child. It is challenging to decide whether an individual child has a growth problem. Normal growth is defined differently for individuals versus populations. Some healthy children (2.3%) will measure below and above the WHO definition of healthy growth, but their sizes are appropriate for those children. It can be valuable to understand the definition of normal growth for individuals as well as what is considered short stature, a low weight for height, and overweight for a population and how to avoid misclassifying children as underweight, short, or overweight. Labelling a child by these categories can create stigma and lead to unnecessary diet changes. It is important for health care providers to communicate the principles of growth clearly and to help prevent unnecessary worry for parents and stigmatization for children.

Conflict of Interest Statement

The authors have no conflicts of interest to declare.

Funding Sources

This study was not supported by any sponsor or funder.

Author Contributions

T.R.F. conceptualized and designed the review with assistance from all the other authors (N.G., D.L.B., S.E., C.J.F.), drafted the initial manuscript, and reviewed and revised the manuscript. All the other authors (D.L.B., N.G., S.E., C.J.F.) made substantial contributions to the work and revised it critically for important intellectual content and approved the final of the version to be published.

References

1 Pesch MH, Levitt KJ, Danziger P, Orringer K. Pediatrician's beliefs and practices around rapid infant weight gain: a qualitative study. Glob Pediatr Health. 2021;8:2333794X21992164. https://doi.org/10.1177/2333794X21992164

2 Alberta Health Services. Childhood growth measurements. Available form: https://www.albertahealthservices.ca/assets/info/hp/cgm/if-hp-cgm-clinical-training-measurement.pdf (accessed July 31, 2024).

3 Fenton TR, Dai S, Lalari V, Alshaikh B. Neonatal and preterm infant growth assessment. Clin Perinatol. 2022;49(2):295–311. https://doi.org/10.1016/j.clp.2022.02.001

4 Mehta NM, Corkins MR, Lyman B, Malone A, Goday PS, Carney LN, et al. Defining pediatric malnutrition: a paradigm shift toward etiology-related definitions. JPEN J Parenter Enteral Nutr. 2013;37(4):460–81. https://doi.org/10.1177/0148607113479972

5 ISO. Global standards for trusted goods and services. 2024. Available form: www.iso.org (accessed April 25, 2024).

6 Fenton CJ, Elmrayed S, Fenton TR. 5.1 growth standards. World Rev Nutr Diet. 2022;124:415–24. https://doi.org/10.1159/000516709

7 WHO Multicentre Growth Reference Study Group. Enrolment and baseline characteristics in the WHO multicentre growth reference study. Acta Paediatr Suppl. 2006;450:7–15. https://doi.org/10.1111/j.1651-2227.2006.tb02371.x

8 World Health Organization Expert Committee. Physical status: the use and interpretation of anthropometry. 1995.

9 World Health Organization. Social determinants of health. 2018. Available from: https://www.who.int/social_determinants/sdh_definition/en/(accessed March 27, 2020).

10 WHO Multicentre Growth Reference Study Group. Breastfeeding in the WHO Multicentre Growth Reference Study. Acta Paediatr Suppl.2006;450:16–26.https://doi.org/10.1111/j.1651-2227.2006.tb02372.x

11 De Onis M. Assessment of differences in linear growth among populations in the WHO Multicentre Growth Reference Study. Acta Paediatr. 2006;95(S450):56–65. https://doi.org/10.1111/j.1651-2227.2006.tb02376.x

12 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(11):e681–91. https://doi.org/10.1016/S2214-109X(15)00163-1

13 Interpreting indicators. Training course on child growth assessment. Geneva. World Health Organization. 2008. Available from: https://www.who.int/publications/i/item/9789241595070 (accessed January 9, 2024.

14 De Onis M, Borghi E, Arimond M, Webb P, Croft T, Saha K, et al. Prevalence thresholds for wasting, overweight and stunting in children under 5 years. Public Health Nutr. 2019;22(1):175–9. https://doi.org/10.1017/S1368980018002434

15 De Onis M, Onyango AW, Borghi E, Siyam A, Nishida C, Siekmann J. Development of a WHO growth reference for school-aged children and adolescents. Bull World Health Organ. 2007;85(9):660–7. https://doi.org/10.2471/blt.07.043497

16 Elmrayed S, Gilbert N, Fenton TR. More precise prevalence of overweight and obesity. Pediatr Obes. 2020;15(3):e12599. https://doi.org/10.1111/ijpo.12599

17 De Onis M, Lobstein T. Defining obesity risk status in the general childhood population: which cut-offs should we use? Int J Pediatr Obes. 2010;5(6):458–60. https://doi.org/10.3109/17477161003615583

18 Mead E, Brown T, Rees K, Azevedo LB, Whittaker V, Jones D, et al. Diet, physical activity and behavioural interventions for the treatment of overweight or obese children from the age of 6 to 11 years. Cochrane Database Syst Rev. 2017;6(6). https://doi.org/10.1002/14651858.CD012651

19 Loveman E, Al-Khudairy L, Johnson RE, Robertson W, Colquitt JL, Mead EL, et al. Parent-only interventions for childhood overweight or obesity in children aged 5 to 11 years. Cochrane Database Syst Rev. 2015;2015(12):CD012008. https://doi.org/10.1002/14651858.CD012008

20 Turck D, Michaelsen KF, Shamir R, Braegger C, Campoy C, Colomb V, et al. World Health Organization 2006 child growth standards and 2007 growth reference charts: a discussion paper by the committee on nutrition of the European Society for pediatric gastroenterology, hepatology, and nutrition. J Pediatr Gastroenterol Nutr. 2013;57(2):258–64. https://doi.org/10.1097/MPG.0b013e318298003f

21 Hui LL, Schooling CM, Cowling BJ, Leung SSL, Lam TH, Leung GM. Are Universal standards for optimal infant growth appropriate? Evidence from a Hong Kong Chinese birth cohort. Arch Dis Child. 2008;93(7):561–5. https://doi.org/10.1136/adc.2007.119826

22 Van Buuren S, Van Wouwe JP. WHO child growth standards in action. Arch Dis Child. 2008;93(7):549–51. https://doi.org/10.1136/adc.2007.136010

23 Novina N, Hermanussen M, Scheffler C, Pulungan AB, Ismiarto YD, Andriyana Y, et al. Indonesian National growth reference charts better reflect height and weight of children in West Java, Indonesia, than who child growth standards. J Clin Res Pediatr Endocrinol. 2020;12(4):410–9. https://doi.org/10.4274/jcrpe.galenos.2020.2020.0044

24 Fredriks AM, Van Buuren S, Burgmeijer RJF, Meulmeester JF, Beuker RJ, Brugman E, et al. Continuing positive secular growth change in The Netherlands 1955-1997. Pediatr Res. 2000;47(3):316–23. https://doi.org/10.1203/00006450-200003000-00006

25 Committee on Nutrition American Academy Pediatrics. Assessing nutrition status. In: Pediatric nutrition handbook. 8th ed. 2020.

26 Mindrila D, Balentnyne P. The normal distribution. Available from: https://www.westga.edu/academics/research/vrc/assets/docs/the_normal_distribution_notes.pdf (accessed August 12, 2024).

27 Casey L, Fenton TR. Recognizing and addressing atypical growth. Paediatr Child Health. 2023;28(8):495–501. https://doi.org/10.1093/PCH/PXAD057

28 Green Corkins K. Nutrition-focused physical examination in pediatric patients. Nutr Clin Pract. 2015;30(2):203–9. https://doi.org/10.1177/0884533615572654

29 Nejedly N. Normal and abnormal growth in the pediatric patient. Curr Probl Pediatr Adolesc Health Care. 2020;50(3):100771. https://doi.org/10.1016/j.cppeds.2020.100771

30 Tuohy S, Barnes P, Allen S. Failure to thrive. Paediatr Child Health. 2008;18(10):464–8. https://doi.org/10.1016/j.paed.2008.07.006

31 Hendson L, Church PT, Banihani R. Follow-up care of the extremely preterm infant after discharge from the neonatal intensive care unit. Paediatr Child Health. 2022;27(6):359–71. https://doi.org/10.1093/pch/pxac058

32 Hale I, Jackson E. Evaluating routine pediatric growth measurement as a screening tool for overweight and obese status. Can Fam Physician. 2021;67(3):161–5. https://doi.org/10.46747/cfp.6703161

33 Colquitt JL, Loveman E, O'Malley C, Azevedo LB, Mead E, Al-Khudairy L, et al. Diet, physical activity, and behavioural interventions for the treatment of overweight or obesity in preschool children up to the age of 6 years. Cochrane Database Syst Rev. 2016;3(3). https://doi.org/10.1002/14651858.CD012105

34 Campisi SC, Carbone SE, Zlotkin S. Catch-up growth in full-term small for gestational age infants: a systematic review. Adv Nutr. 2019;10(1):104–11. https://doi.org/10.1093/ADVANCES/NMY091

35 Fenton TR, Samycia 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. Published online May 15. https://doi.org/10.1111/ppe.13081

36 Cooke R, Goulet O, Huysentruyt K, Joosten K, Khadilkar AV, Mao M, et al. Catch-up growth in infants and young children with faltering growth: Expert opinion to guide general clinicians. J Pediatr Gastroenterol Nutr. 2023;77(1):7–15. https://doi.org/10.1097/MPG.0000000000003784

37 Nichols J, Duryea T, Hoppin A. Normal growth patterns in infants and prepubertal children. Up-To-Date. 2020 (accessed 6 April 2024).

38 World Health Organization ref: recommendations for data collection, analysis and reporting on anthropometric indicators in children under 5 years old. 2017. Available from: https://apps.who.int/iris/bitstream/handle/10665/324791/9789241515559-eng.pdf?ua=1

39 Statement of endorsement: defining pediatric malnutrition. Pediatrics. 2013;132(1):e283. https://doi.org/10.1542/peds.2013-1284

40 Becker P, Carney LN, Corkins MR, Monczka J, Smith E, Smith SE, et al. Consensus statement of the Academy of Nutrition and Dietetics/American Society for Parenteral and Enteral Nutrition: indicators recommended for the identification and documentation of pediatric malnutrition (undernutrition). Nutr Clin Pract. 2015;30(1):147–61. https://doi.org/10.1177/0884533614557642

41 Silventoinen K, Jelenkovic A, Sund R, Yokoyama Y, Hur YM, Cozen W, et al. Differences in genetic and environmental variation in adult BMI by sex, age, time period, and region: an individual-based pooled analysis of 40 twin cohorts. Am J Clin Nutr. 2017;106(2):457–66. https://doi.org/10.3945/ajcn.117.153643

42 Yengo L, Vedantam S, Marouli E, Sidorenko J, Bartell E, Sakaue S, et al. A saturated map of common genetic variants associated with human height. Nature. 2022;610(7933):704–12. https://doi.org/10.1038/s41586-022-05275-y

43 McCrory C, O'Leary N, Fraga S, Ribeiro AI, Barros H, Kartiosuo N, et al. Socioeconomic differences in children's growth trajectories from infancy to early adulthood: evidence from four European Countries. J Epidemiol Community Health. 2017;71(10):981–9. https://doi.org/10.1136/jech-2016-208556

44 Garza C, Borghi E, Onyango AW, de Onis M; WHO Multicentre Growth Reference Study Group. Parental height and child growth from birth to 2 years in the WHO Multicentre Growth Reference Study. Matern Child Nutr. 2013;9(Suppl 2):58–68. https://doi.org/10.1111/mcn.12085

45 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(5):704–14. https://doi.org/10.1038/s41372-020-0658-5

46 Fenton TR, Merlino Barr S, Elmrayed S, Alshaikh B. Expected and desirable preterm and small infant growth patterns. Adv Nutr. 2024;15(6):100220. Published online April 24. https://doi.org/10.1016/j.advnut.2024.100220

47 Walton K, Daniel AI, Mahood Q, Vaz S, Law N, Unger SL, et al. Eating behaviors, caregiver feeding interactions, and dietary patterns of children born preterm: a systematic review and meta-analysis. Adv Nutr. 2022;13(3):875–912. https://doi.org/10.1093/advances/nmac017

48 Fenton TR, Kim JH. A systematic review and meta-analysis to revise the Fenton growth chart for preterm infants. BMC Pediatr. 2013;13(1):59. https://doi.org/10.1186/1471-2431-13-59

49 Olsen IE, Groveman SA, Lawson ML, Clark RH, Zemel BS. New intrauterine growth curves based on United States data. Pediatrics. 2010;125(2):e214–24. https://doi.org/10.1542/peds.2009-0913

50 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(2):288. https://doi.org/10.3390/nu12020288

51 Jain S, Samycia 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(9):1244–51. Published online February 9. https://doi.org/10.1038/s41372-024-01889-4

52 Elmrayed S, Pinto J, Tough SC, McDonald SW, Scime NV, Wollny K, et al. Small for gestational age preterm infants and later adiposity and height: a systematic review and meta-analysis. Paediatr Perinat Epidemiol. 2023;37(7):652–68. https://doi.org/10.1111/ppe.13002

53 Fenton TR, Elmrayed S, Scime NV, Tough SC, Pinto J, Sabet F, et al. Small for date preterm infants and risk of higher blood pressure in later life: a systematic review and meta-analysis. Paediatr Perinat Epidemiol. 2023;37(5):458–72. https://doi.org/10.1111/ppe.12955

54 Sullivan SA, Leite KR, Shaffer ML, Birch LL, Paul IM. Urban parents' perceptions of healthy infant growth. Clin Pediatr. 2011;50(8):698–703. https://doi.org/10.1177/0009922811398960

55 Ben-Joseph EP, Dowshen SA, Izenberg N. Do parents understand growth charts? A national, Internet-based survey. Pediatrics. 2009;124(4):1100–9. https://doi.org/10.1542/peds.2008-0797

56 Mansoor Y, Hale I. Parent perceptions of routine growth monitoring: a scoping review. Paediatr Child Health. 2021;26(3):154–8. https://doi.org/10.1093/pch/pxaa041

57 Fangupo L, Daniels L, Taylor R, Glover M, Taungapeau F, Sa'u S, et al. The care of infants with rapid weight gain: should we be doing more? J Paediatr Child Health. 2022;58(12):2143–9. https://doi.org/10.1111/jpc.16247

58 Lakshman R, Landsbaugh JR, Schiff A, Cohn S, Griffin S, Ong KK. Developing a programme for healthy growth and nutrition during infancy: understanding user perspectives. Child Care Health Dev. 2012;38(5):675–82. https://doi.org/10.1111/j.1365-2214.2011.01283.x

59 Gillison F, Beck F, Lewitt J. Exploring the basis for parents' negative reactions to being informed that their child is overweight. Public Health Nutr. 2014;17(5):987–97. https://doi.org/10.1017/S1368980013002425

60 Thomlinson EH. The lived experience of families of children who are failing to thrive. J Adv Nurs. 2002;39(6):537–45. https://doi.org/10.1046/j.1365-2648.2002.02322.x

61 Reifsnider E, Allan J, Percy M. Mothers' explanatory models of lack of child growth. Public Health Nurs. 2000;17(6):434–42. https://doi.org/10.1046/j.1525-1446.2000.00434.x

62 Moore LC, Harris CV, Bradlyn AS. Exploring the relationship between parental concern and the management of childhood obesity. Matern Child Health J. 2012;16(4):902–8. https://doi.org/10.1007/s10995-011-0813-x

63 Ellyn Satter Institute. Feeding to prevent child weight acceleration. 2024. https://www.ellynsatterinstitute.org/feeding-to-prevent-child-weight-acceleration/ (accessed May 18, 2024).

64 Eli K, Neovius C, Nordin K, Brissman M, Ek A. Parents' experiences following conversations about their young child's weight in the primary health care setting: a study within the STOP project. BMC Public Health. 2022;22(1):1540. https://doi.org/10.1186/s12889-022-13803-8

65 Almaatani D, Cory E, Gardner J, Alexanian-Farr M, Hulst JM, Bandsma RHJ, et al. Child and maternal factors associated with feeding practices in children with poor growth. Nutrients. 2023;15(22):4850. https://doi.org/10.3390/nu15224850

66 Redsell SA, Atkinson P, Nathan D, Siriwardena AN, Swift JA, Glazebrook C. Parents' beliefs about appropriate infant size, growth and feeding behaviour: implications for the prevention of childhood obesity. BMC Public Health. 2010;10:711. https://doi.org/10.1186/1471-2458-10-711

67 Sachs M, Dykes F, Carter B. Weight monitoring of breastfed babies in the United Kingdom: Interpreting, explaining and intervening. Matern Child Nutr. 2006;2(1):3–18. https://doi.org/10.1111/j.1740-8709.2006.00019.x

68 Canadian Task Force on Preventive Health Care, Parkin P, Gorber SC, Shaw E. Recommendations for growth monitoring, and prevention and management of overweight and obesity in children and youth in primary care. CMAJ. 2015;187(6):411–21. https://doi.org/10.1503/cmaj.141285

69 Puhl RM, Lessard LM. Weight stigma in youth: prevalence, consequences, and considerations for clinical practice. Curr Obes Rep. 2020;9(4):402–11. https://doi.org/10.1007/s13679-020-00408-8

70 Toftemo I, Glavin K, Lagerløv P. Parents' views and experiences when their preschool child is identified as overweight: a qualitative study in primary care. Fam Pract. 2013;30(6):719–23. https://doi.org/10.1093/fampra/cmt056