Poor Weight Gain

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Abstract

Purpose of Review  Poor weight gain is a common presenting problem in pediatrics. We review literature supporting the notion that extensive workup is generally not needed, particularly in younger children and discuss a management approach depending on a patient’s age.

Recent Findings  Understanding normal growth, particularly in infancy, is important. Breast-fed and formula-fed infants as well as older children have different etiologies for poor growth. Diagnostic workup and hospitalization are rarely indicated or useful. An attempt to increase energy intake is often the appropriate first step in management.

Summary  Poor weight gain can affect children of all ages. Understanding expected growth, common etiologies by age, and how to assess nutritional status can help with appropriate diagnostic workup and management.

Introduction

Poor weight gain is a common problem in childhood and frequently leads to outpatient clinic visits and inpatient hospitalizations for workup and management. In the USA, failure to thrive occurs in up to 10% of children in the primary care setting and in up to 5% of pediatric hospitalizations [1••, 2]. Recent literature demonstrates long-lasting adverse effects of early growth problems [3], making poor growth a potentially significant problem with long-term sequelae. Infants with poor growth have a higher prevalence of
feeding problems, and failure to thrive in infancy has been associated with worse intellectual outcomes later in life [3]. Weight and height differences may persist beyond infancy, as well [4•]. Malnutrition can potentially lead to immune dysfunction, developmental delay, and poor wound healing [5••]. From an economic standpoint, diagnostic investigations and hospitalizations for poor weight gain may be unhelpful and simultaneously lead to increased health care costs [6]. Finally, poor growth requiring medical attention may be a source of ongoing stress for children and parents [7, 8].

Definitions

Various terminologies are used interchangeably when discussing poor weight gain including poor weight gain itself, weight loss, decreased growth velocity from expected, failure to thrive, malnutrition, undernutrition, and faltering weight/growth. Of note, these are clinical findings rather than diagnoses [1••, 9].

Historically, the term “failure to thrive” (FTT) has been used to describe a state where energy intake is insufficient to maintain growth. However, this term can be potentially pejorative, critical, or alarming for parents and caretakers [1••]. Qualitatively, FTT is described as a condition where a child has suboptimal weight velocity in which improvement would better the child’s outcome [1••]. There are several quantitative definitions for FTT [10]. However, a consensus definition is lacking.

The American Society for Parenteral and Enteral Nutrition (ASPEN) defines malnutrition (undernutrition) as “an imbalance between nutrition requirement and intake which results in cumulative deficits of energy, protein, or micronutrients that may negatively affect growth, development, and other outcomes” [11••]. The World Health Organization (WHO) classifies malnutrition as moderate or severe based on various parameters including presence of symmetrical edema, mid-upper arm circumference, weight-for-age z-score, and height-for-age z-score [12].

While the ASPEN malnutrition criteria have attempted to quantify poor weight gain based upon WHO weight gain velocity, due to the dynamism of growth in the first 2 years of life, these criteria either do not identify all children with poor weight gain or also include children with normal growth. Hence, weight gain should be assessed using subjective measures using some of the nuances of expected growth. Also, weight loss that is inexplicable and/or persistent is always likely to be abnormal in children [13].

Expected Growth

Understanding expected growth is critical to recognizing normal patterns versus abnormal variations (Table 1). Children born small for gestational age (SGA) show “catch-up” growth, while children who are born large for gestational age (LGA) show “catch-down” growth to reach their appropriate growth curve [14]. Mei et al. analyzed longitudinal growth data in 10,844 children and found shifts in growth rates to be most common from birth to 6 months, and somewhat less common between 6 and 24 months of age [15•]. Roughly 25% of normal
infants experience shifts to a lower growth percentile in the first 2 years of life then continue on that percentile [16]. In general, children born at or above the 75th percentile for weight are much more likely to cross percentiles downwards. In addition, children born LGA typically gain weight more slowly than expected such that their weight is between a z-score of 0 and 1 (50–85th percentile at age 2 months). While children born LGA are more likely to be overweight later in life, children who catch down are less likely to be overweight [14, 17]. On the contrary, 85% of children born SGA will catch up with regard to weight. When children are born after 30–32 weeks gestation and are SGA, it is debatable as to whether they should be made to catch up by increasing energy intake. Premature infants born SGA derive significant neurodevelopmental benefits from catching up but like in all SGA infants, catch-up growth is associated with a higher risk of metabolic syndrome later in life [18–20].

There are also other normal variants of growth that may accompany poor weight gain in older children, including genetic short stature and constitutional delay. Patients with genetic short stature have parents with relatively short height. These patients track along low growth percentiles but do not cross percentiles. Patients with constitutional delay often have a family history of similar growth patterns. These patients have an initial drop in percentile points, then follow their own curve. These cases highlight the importance of obtaining and trending serial measurements over time.

| Normal variants of growth | Characteristic growth pattern |
|---------------------------|------------------------------|
| Premature infant          | • Low weight and length percentiles if uncorrected, but normal percentiles if corrected for gestation  
                          | • May show “catch-up” growth |
| Small for gestational age with “catch-up” growth | • Typically show “catch-up” growth in weight and length in the first 24 months of life, although approximately 10% have persistent poor growth |
| Large for gestational age with “catch-down” growth | • Typically show “catch-down” growth in weight and length, often during the first 2 months of life |
| Familial short stature     | • Final adult height will be below the third percentile of the mean for patient’s age, gender, and population  
                          | • Consistent with parental height (parental height often below the 10th percentile)  
                          | • Normal growth velocity and bone age |
| Constitutional growth delay | • Children are born appropriate for gestational age but will fall in height percentiles  
                          | • After this period, growth velocity will be normal. Bone age is delayed  
                          | • Children have delayed onset of puberty  
                          | • Adult height is normal |
Etiology: Breastfed Infant

Human milk is universally recommended as the optimal source of nutrition for infants due to numerous health benefits. Human milk contains variable amounts of carbohydrate, protein, and fat and changes in composition as an infant grows [21]. Both the WHO and the American Academy of Pediatrics (AAP) recommend exclusive breastfeeding for the first 6 months of life and continued periods of breastfeeding until ages 1–2 while complementary foods are introduced and advanced [22].

Knowing the differences in growth patterns between breastfed and formula-fed infants helps one understand what is normal, expected growth depending on nutritional intake. Of note, poor weight gain is more common in infancy as compared to later stages in life due to high growth rates and nutritional needs during this time. Breastfeeding is associated with lower rates of weight and length gain after 2 months of age and may be due to human milk macronutrient composition or lower total energy intake [23]. After initial increases in weight and length in the first 2 to 3 months of life, these infants have a slower velocity up to 12 months when compared to formula-fed infants [24]. Bell et al. assessed 276 infants from birth to age 7 months, obtaining anthropometric data and dual-energy X-ray absorptiometry to assess body composition at 1, 4, and 7 months. They found that formula-fed infants had lower birth-weight z-scores than breastfed infants but gained more in weight and body mass index (BMI) through 7 months of age [25].

Problems with Supply

Secretory activation and copious milk production occur within 48 to 72 h after birth and are related to a rapid decline in maternal progesterone levels [26••]. Delayed secretory activation beyond 72 h has been associated with suboptimal lactation outcomes such as lower milk production and reduced duration of breastfeeding. Delayed secretory activation has been associated with long labor, cesarean section, stressful deliveries, poorly controlled diabetes, and obesity [27]. Early intervention to assist with maternal lactation needs is critical, as failure to remove colostrum has been associated poor prognosis of successful lactation [27]. After birth, frequent and effective milk removal is critical to establishment and maintenance of milk production. A minimum of 5 expressions per 24-h period is needed to maintain milk production, though more frequent expressions may be warranted in those who have not yet established their supply [28]. Perceived insufficient milk supply is a common problem and a frequent reason women seek lactation counseling [28]. Milk production is established in the first 1 to 2 weeks. Milk production has been shown to be similar over the first 6 months of lactation in exclusively breastfeeding women [28], suggesting breastfed infants take in
similar volumes of milk during this period while formula-fed infants have increasing milk and energy intake.

Problems with Infant Feeding

Healthy infants should feed effectively and without distress within 20 to 30 min [29]. Variation from this, in addition to poor weight gain, may suggest a feeding problem. Feeding disorders have been classified in various ways, including structural abnormalities, neurological conditions, behavioral, cardiorespiratory problems, metabolic dysfunction, and mixed [30]. Anatomic abnormalities which can affect feeding include ankyloglossia and cleft/lip palate [31]. Infants may also have difficulty creating an effective vacuum due to ineffective latch or various medical conditions including low tone, prematurity, and Down syndrome.

Etiology: Formula-Fed Infant

Infant formulas attempt to mimic the nutritional composition of human milk and are generally based on cow’s milk protein. There are limited indications for use of soy protein formulas, including patients with disorders of carbohydrate metabolism such as galactosemia or hereditary primary lactase deficiency or when a strict vegetarian diet is preferred [32]. Compared to breastfed infants, formula-fed infants appear to have more rapid gains in weight-for-length and higher absolute weights in the first year of life [33]. However, poor weight gain may occur in the formula-fed patient population for some of the reasons listed below.

Proper Mixing

Infant formulas are available “ready to feed” or in powder form, requiring mixing with water prior to use. When infants have poor growth, it is important to ensure caregivers are properly mixing powered infant formula. Formula that is mixed incorrectly can lead to formula dilution. This can lead to either hypocaloric or hyper-concentrated formula and electrolyte imbalances. Traditionally, formula is mixed to a 1 scoop to 2 oz of water ratio to yield a 20 kcal/oz formula, with the powder being added to water that has already been measured out. However, exceptions to this rule exist, and pediatricians should be cognizant of the exceptions or read individual labels.
Infant Feeding Problems

Infant feeding problems among formula-fed infants are similar to those of breastfed infants, as mentioned above.

Beyond Newborn up to age 2 years

Current guidelines recommend using the 2006 WHO growth charts to assess growth and nutrition for children up to 2 years of age. These growth charts included data from 6 countries, Brazil, Ghana, India, Norway, Oman, and the USA. Specialized growth charts should be used for infants born prematurely. The Fenton growth charts and the intergrowth charts for premature infants both segue into the WHO growth charts and are preferred.

When approaching a patient with poor growth, it can be helpful to think about a framework of inadequate energy intake, inadequate nutrient absorption, and increased energy expenditure. Detailed history taking and a thorough physical exam can help determine etiology and guide further workup and management.

Insufficient Energy Intake

In most cases (greater than 90%), poor weight gain is due to inadequate energy intake. Decreased energy intake can lead to insufficient energy available for adequate growth. This could be due to insufficient energy intake whose causes range from food insecurity to improper formula mixing. Children may also have difficulty with inadequate food intake due to developmental delay, poor oral neuromotor coordination, gastroesophageal reflux, eating disorder, or craniofacial abnormalities such as cleft lip or palate.

Increased Energy Losses (Malabsorption)

Another category of poor weight gain is inadequate nutrient absorption. Clinically, this may present with poor weight gain and diarrhea, with or without emesis. These etiologies may include gastrointestinal (GI) conditions such as pancreatic insufficiency, celiac disease, inflammatory bowel disease, milk protein allergy, and eosinophilic esophagitis. Two important etiologies where the losses may be covert include pancreatic insufficiency and celiac disease; these may present with constipation and without emesis.

Increased Energy Expenditure

Diseases associated with poor weight gain may include those leading to increased energy expenditure and metabolism. These include congenital heart disease, pulmonary disease (cystic fibrosis), renal disease (renal tubular
acidosis, Bartter’s syndrome, renal failure), inflammatory diseases (asthma, inflammatory bowel disease), immunodeficiency, and thyroid disease (hyperthyroidism). When a child fails to gain weight due to cardiopulmonary disease, the child usually has significant symptomatology (i.e., it is not the child with a murmur that does not gain weight but the child who has cardiorespiratory difficulties during feeding and struggles to finish feeds).

**Older Child**

For children and adolescents aged 2 to 20 years, the Center for Disease Control (CDC) 2000 growth charts are recommended. These growth charts are intended for children in the USA, as they were based on national survey data and incorporated an estimation for size-for-age. Condition-specific growth charts can be used for children with specific diagnoses such as Down syndrome. While specialty growth charts provide useful growth references, most do not include BMI charts and in those cases, the CDC BMI charts should be used. In general, specialized growth charts are not encouraged due to concerns about their limitations such as small sample sizes, lack of heterogeneity, and unresolved questions of whether altered growth is due to genetic potential or external conditions.

**Eating Disorders**

Eating disorders such as anorexia nervosa and bulimia are particularly common in adolescent females. They are being increasingly recognized in younger children and in boys. Anorexia nervosa is characterized by an intense fear of weight gain, a disturbed body image, or both which leads to dietary restriction or weight loss behaviors such as excessive physical activity or purging [31]. Bulimia nervosa is characterized by recurrent episodes of binge eating with compensatory measures such as self-induced vomiting, fasting, inappropriate use of medication, and extreme physical activity to prevent weight gain. It may occur in patients with normal weight or elevated BMI [31].

**Avoidant/Restrictive Food Intake Disorder**

The DSM-V classification of avoidant/restrictive food intake disorder (ARFID) characterizes this condition by avoidant or restrictive eating behavior that may be linked to various underlying features such as low interest in food or eating, avoidance linked to sensory issues, and fear-related avoidance.

**Stimulant Medication**

When considering poor weight gain in the older child, it is important to consider medications that could lead to decreased appetite. Attention-deficit hyperactivity disorder is common in pediatrics and treated with stimulant
medications such as methylphenidate and dexamphetamine. Poulton and Cowell retrospectively reviewed growth data from the first 6 months on stimulant medication in 51 children [32]. Weight loss was noted in 76% of children, and weight standard deviation scores showed a decline that was significant after 6 and 18 months. Faraone et al. assessed the effects of stimulant medication on height and weight in a quantitative analysis of longitudinal studies [33]. They found that treatment with stimulant medication led to statistically significant delays in height and weight, although there was evidence of attenuation over time. They also found that growth deficits did not seem to differ between methylphenidate and amphetamine, growth deficits seemed to be dose dependent, and treatment cessation led to normalization of growth.

Assessment of Nutrition Status

Assessment of the child with poor weight gain should take into account age, gender, birth weight, parental size, medical history, nutrient intake, socioeconomic background, and medications. The current preferred method for determining poor growth is via anthropometric z-scores [5••]. Serial measurements of weight and height should be accurately obtained and charted on an appropriate growth chart. It should be noted that ongoing severe malnutrition first affects weight, followed by length, and then head circumference.

Physical exam tools such as measurement of mid-upper arm circumference from children greater than 2 months and triceps skinfold measurement in children 3 months and older can also be helpful as a screening and diagnostic tool for poor weight gain and malnutrition. These measurements can be particularly useful in children with disease states that can elevate weight measurement through fluid retention, such as ascites or organomegaly.

Various subjective assessment exist which can help identify pediatric patients at risk for poor growth and malnutrition. The Subjective Global Nutritional Assessment (SGNA) is validated in for hospitalized pediatric patients [34•]. The Semi-Objective Failure to Thrive (SOFTT) diagnosis tool was shown to correlate with anthropometric measurements in children with poor weight gain [35].

When to get Labs

Although frequently obtained, laboratory, radiologic, and endoscopic workup rarely yield diagnostic clarity in the diagnosis of children with poor growth [36•]. Sills et al. retrospectively reviewed charts of 185 patients hospitalized for evaluation of FTT and found 18% had proven organic etiologies. However, only 1.4% of laboratory studies performed were diagnostically helpful [37]. A more recent study assessed patients presenting with FTT in a tertiary pediatric gastroenterology clinic and confirmed that laboratory testing is not helpful in young children (most children in this study were under 2 years of age) [38].
No standard set of laboratory tests is recommended in the workup of poor growth but instead should be obtained in a focused manner depending on history obtained. In general, younger children should get labs only if they do not respond to standard nutritional intervention. It is reasonable for older children (likely older than ages 2 or 3) to get screening labs at the first or second visit to the general pediatrician or subspecialist (Table 2).

Management

Early identification and management addressing poor weight gain are vital. Treatment of poor weight gain due to an underlying disease state should address the underlying etiology. In cases of poor weight gain without an identified underlying etiology, management should focus on behavioral intervention and increasing energy intake. In both cases, nutritional assessment and co-management with a dietitian can be very helpful. Multidisciplinary care with social workers and occupational therapists should be considered if needed based on the patient’s history. With most patients, an appropriate weight velocity can be attained with outpatient management including nutritional counseling and support.

Table 2 Targeted workup in children with poor weight gain

| Serum testing                          | Notes                                                   |
|----------------------------------------|---------------------------------------------------------|
| Complete blood count                   |                                                         |
| Erythrocyte sedimentation rate         |                                                         |
| C reactive protein                     |                                                         |
| Complete metabolic panel               |                                                         |
| Celiac screening (Anti-TTG IgA, total IgA) | Celiac screening is only done in children consuming gluten |
| Stool testing                          |                                                         |
| Fecal elastase                         | Consider if child has a voracious appetite or if child is not gaining weight despite greater-than-adequate energy intake. Note that fecal elastase can be falsely low in diarrhea |
| Reducing substances                    | Screening test for carbohydrate malabsorption and to be done only in the presence of diarrhea |
| Urine testing                          |                                                         |
| Urinalysis                             | To screen for underlying renal disease                 |
| Sweat chloride testing                  | Newborn screening for cystic fibrosis is now the norm in all 50 US states. However, rare children with CF will slip through this testing. Selected children with poor weight gain may need sweat chloride testing |
Newborn

In the newborn child, increasing energy intake may consist of increasing the volume or frequency of breastmilk or formula feeds. Breastfed infants may require formula supplementation if maternal breast milk supply is inadequate. In some formula-fed infants, particularly in infants who were born prematurely and require catch up growth, gradual formula fortification up to 24 kcal/oz or even 27 kcal/oz may be required.

Beyond newborn up to age 2 years

Some interventions that can be taken to increase daily energy intake are decreasing or eliminating juice intake and adding or increasing infant formula fortification. High-energy beverages such as high-energy milk drinks or powders that can be added to whole milk can be used beyond the first year of life. Regular, scheduled mealtime and snacks can also be helpful, including (1) offering a meal or snack every 3 h, (2) limiting meals to 20 min, and (3) allowing only water outside of mealtime. High-energy foods can be added such as avocados, butter, cream, cheese, and oil. Children may need up to 150% of their recommended daily energy intake based on their expected weight for catch up growth [39].

Older Child

In older children, similar methods of increasing energy intake as younger children can be utilized. However, it may be easiest to institute high-energy beverages in these children as it is not easy to manipulate the diets of children attending school. The use of high-energy beverages also makes it easier to measure compliance to the regimen. When using these beverages, it is important that they either be given towards the end of a meal (4–8 oz), or they can be used as a snack (typically 4 oz). Children should not drink them in small amounts during the day as that can curb appetite for food. Also, they can be given as a bedtime beverage (usually 8 oz) as this routine is not likely to interfere with other meals.

If these interventions do not help, cyproheptadine can be added as an appetite stimulant. Cyproheptadine is a histamine H1 antagonist which promotes gastric accommodation. The main side effect is drowsiness, and so parents should be counseled accordingly and may be advised to administer it at nighttime. Cyproheptadine is FDA approved for children 2 years and greater. Sant’Anna et al. retrospectively assessed 82 pediatric patients (age 7–80 months) who received cyproheptadine in combination with
multidisciplinary programmatic intervention for poor weight gain. They noted a significant improvement in weight z-score after starting cyproheptadine [40].

In the older child, the clinician should utilize a multidisciplinary approach with social worker or psychology colleagues in the case that there is a challenging social situation or underlying psychological concern.

Long-term Outcomes of Poor Growth

Several studies have investigated the long-term physical and cognitive outcomes of FTT. Most studies demonstrate long-lasting decreased height, weight, and BMI years after FTT in infancy, but results are conflicting regarding cognitive outcomes later in life [3, 4•, 41, 42]. A systematic review by Rudolf and Logan found minimal IQ difference (3 IQ points) with a greater difference in weight and height [4•]. Black et al. assessed the impact of a randomized, controlled trial of home visiting in infants with FTT. At age 8 years, they found children with previous FTT had worse short stature, poorer arithmetic performance, and poor work habits, although these findings were attenuated by the home visits [43]. Corbett and Drewett performed a meta-analysis assessing long-term cognitive outcomes of FTT in infancy and showed adverse intellectual outcomes later in life and noted the effect size was smaller when children were older. It is important to note that these studies are relatively dated, and updated studies would be beneficial [3]. Finally, given that overall IQ is not affected by cocaine exposure during pregnancy [44, 45] and that breastfeeding causes a change in only 2–3 IQ points [44], it is unclear whether IQ is the optimal method to study outcomes of early life interventions.

Conclusion

Poor weight gain is common in pediatric patients. This is usually due to insufficient energy intake and improves with behavioral and nutritional intervention. Thorough history taking and an understanding of common etiologies by age is helpful. Subjective elements should be involved in the assessment of nutritional status. Children presenting with poor weight gain often do not need a diagnostic workup and management should start with a trial of increased energy intake.
Declarations

Conflict of Interest
Tanyaporn K. Kaenkumchorn and Praveen S. Goday each declare no potential conflicts of interest.

Human and Animal Rights and Informed Consent
This article does not contain any studies with human or animal subjects performed by any of the authors.

References and Recommended Reading

Papers of particular interest, published recently, have been highlighted as:
• Of importance
•• Of major importance

1. •• Olsen EM. Failure to thrive: still a problem of definition. Clin Pediatr (Phila). 2006;45:1–6. This paper acknowledged the lack of consensus definition for failure to thrive via a cross-sectional review of articles on failure to thrive to better define this entity.
2. Mitchell WG, Gorrell RW, Greenberg RA. Failure-to-thrive: a study in a primary care setting. Epidemiology and follow-up. Pediatrics. 1980;65:971–7.
3. Corbett SS, Drewett RF. To what extent is failure to thrive in infancy associated with poorer cognitive development? A review and meta-analysis. J Child Psychol Psychiatry. 2004;45:641–54.
4. • Rudolf MC, Logan S. What is the long term outcome for children who fail to thrive? A systematic review. Arch Dis Child. 2005;90:925–31. This was a systematic review including 13 cohort studies to determine long-term outcomes in children with failure to thrive.
5. •• Mehta NM, Corkins MR, Lyman B, Malone A, Goday PS, Carney LN, Monczka J, Plogsted SW, Schwenk WF. American Society for Parenteral and Enteral Nutrition Board of Directors. Defining pediatric malnutrition: a paradigm shift toward etiology-related definitions. JPEN J Parenter Enteral Nutr. 2013;37:460–81. A pediatric malnutrition definitions workgroup reviewed existing literature related to various domains of malnutrition to arrive at an overall new definition and classification scheme.
6. Guenter P, Abdelhadi R, Anthony P, Blackmer A, Malone A, Mirtallo JM, Phillips W, Resnick HE. Malnutrition diagnoses and associated outcomes in hospitalized patients: United States, 2018. Nutr Clin Pract. 2021;36:957–69.
7. Lobo ML, Barnard KE, Coombs JB. Failure to thrive: a parent-infant interaction perspective. J Pediatr Nurs. 1992;7:251–61.
8. Singer LT, Song L, Hill BP, Jaffe AC. Stress and depression in mothers of failure-to-thrive children. J Pediatr Psychol. 1990;15:711–20.
9. Rybak A. Organic and nonorganic feeding disorders. Ann Nutr Metab. 2015;66(Suppl 5):16–22.
10. Olsen EM, Petersen J, Skovgaard AM, Weile B, Jørgensen T, Wright CM. Failure to thrive: the prevalence and concurrence of anthropometric criteria in a general infant population. Arch Dis Child. 2007;92:109–14.
11. •• Becker P, Carney LN, Corkins MR, Monczka J, Smith E, Smith SE, Spear BA, White IV, Academy of Nutrition and Dietetics, American Society for Parenteral and Enteral Nutrition. 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;30:147–61. The Academy of Nutrition and Dietetics and the American Society for Parenteral and Enteral Nutrition described a standardized set of diagnostic indicators to be used to identify pediatric malnutrition.
12. WHO. Malnutrition. Who.int/news-room/fact-sheets/detail/malnutrition. 2021. Accessed March 3 2022.
13. Bouma S. Diagnosing pediatric malnutrition. Nutr Clin Pract. 2017;32(52):67.
14. Taal HR, Vd Heijden AJ, Steegers EA, Hofman A, Jaddoe VW. Small and large size for gestational age at birth, infant growth, and childhood overweight. Obesity (Silver Spring). 2013;21:1261–8.
15. • Mei Z, Grummer-Strawn LM, Thompson D, Dietz WH. Shifts in percentiles of growth during early childhood: analysis of longitudinal data from the California Child Health and Development Study. Pediatrics. 2004;113:e617-27. This study assessed greater than 10,000 children up to 60 months of age to determine growth-velocity changes in early childhood.
16. Krugman SD, Dubowitz H. Failure to thrive. Am Fam Physician. 2003;68:879–84.
17. Dunn RK, Uhing M, Goday PS. Catch-down growth in infants born large for gestational age. Nutr Clin Pract. 2021;36:1215–9.
18. Victora CG, Barros FC, Horta BL, Martorell R. Short-term benefits of catch-up growth for small-for-gestational-age infants. Int J Epidemiol. 2001;30:1325–30.
19. Kerkhof GF, Wiikenssen RW, Breukhoven PE, Hokken-Koelega AC. Health profile of young adults born preterm: negative effects of rapid weight gain in early life. J Clin Endocrinol Metab. 2012;97:4498–7.
20. Nobili V, Alisi A, Panera N, Agostoni C. Low birth weight and catch-up-growth associated with metabolic syndrome: a ten year systematic review. Pediatr Endocrinol Rev. 2008;6:241–7.
21. Martin CR, Ling PR, Blackburn GL. Review of infant feeding: key features of breast milk and infant formula. Nutrients. 2016;8:279.
22. Section on Breastfeeding. Breastfeeding and the use of human milk. Pediatrics. 2012;129:e827–41.
23. Prentice P, Ong KK, Schoemaker MH, van Tol EA, Verhoort J, Hughes IA, Acrerini CI, Dunger DB. Breast milk nutrient content and infancy growth. Acta Paediatr. 2016;105:641–7.
24. Lind MV, Larnkjær A, Melgaard C, Michaelsen KE. Breastfeeding, breast milk composition, and growth outcomes. Nestle Nutr Inst Workshop Ser. 2018;89:63–77.
25. Bell KA, Wagner CL, Feldman HA, Shypailo RJ, Belfort MB. Associations of infant feeding with trajectories of body composition and growth. Am J Clin Nutr. 2017;106:491–8.
26. Geddes DT, Gridneva Z, Peroula SL, Mitoulas LR, Kent JC, Stinson LF, Lai CT, Sakalidis V, Tigger AL, Hartmann PE. 25 years of research in human lactation: from discovery to translation. Nutrients. 2021;13:3071.
27. Neville MC, Morton J. Physiology and endocrine changes underlying human lactogenesis II. J Nutr. 2001;131:3005S–3008.
28. Burklow KA, Phelps AN, Schultz JR, McConnell K, Rudolph C. Classifying complex pediatric feeding disorders. J Pediatr Gastroenterol Nutr. 1998;27:143–7.
29. Bhatia J, Greer F. American Academy of Pediatrics Committee on Nutrition. Use of soy protein-based formulas in infant feeding. Pediatrics. 2008;121:1062–8.
30. Appleton J, Russell CC, Laws R, Fowler C, Campbell K, Denney-Wilson E. Infant formula feeding practices associated with rapid weight gain: a systematic review. Matern Child Nutr. 2018;14:e12602.
31. Treasure J, Duarte TA, Schmidt U. Eating disorders. Lancet. 2020;395:899–911.
32. Poulton A, Cowell CT. Slowing of growth in height and weight on stimulants: a characteristic pattern. J Paediatr Child Health. 2003;39:180–5.
33. Faraone SV, Biederman J, Morley CP, Spencer T J. Effect of stimulants on height and weight: a review of the literature. J Am Acad Child Adolesc Psychiatry. 2008;47:994–1009.
34. Secker DJ, Jeejeebhoy KN. Subjective Global Nutritional Assessment for children. Am J Clin Nutr. 2007;85:1083–9.
35. Larson-Nath C, Mavis A, Duesing L, Van Hoorn M, Walia C, Karls C, Goday PS. Defining pediatric failure to thrive in the developed world: validation of a semi-objective diagnosis tool. Clin Pediatr (Phila). 2019;58:446–52.
36. Larson-Nath C, St Clair N, Goday P. Hospitalization for failure to thrive: a prospective descriptive report. Clin Pediatr (Phila). 2018;57:212–9.

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