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Growth Faltering: The New and the Old

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Abstract

Growth faltering has an evolving history in terms of definition, methods of assessment, management, and long-term outcomes. This phenomenon was first known as "cease to thrive" in 1897, and has since been described as failure to thrive, growth faltering or weight faltering. Pediatric under-nutrition or malnutrition can be further described as non-organic, organic or both. This literature review discusses the latest work in the field of growth faltering, its evolving definition, categorization, assessment, diagnosis, treatment, outcomes and future directions. This review may prove useful to pediatric health care providers who need to identify and manage malnutrition. A literature search was conducted using PubMed, Medline, Scopus, Web of Science, and Academic Search Complete. Keywords included infant, pediatric, failure to thrive, growth faltering, and malnutrition.

Introduction

Growth faltering was first known as "cease to thrive" in 1897, but has also been described as failure to thrive, growth faltering or weight faltering. Other terminology for malnutrition in children includes marasmus, protein-energy malnutrition, and kwashiorkor (predominately in developing countries). The American Society for Parenteral and Enteral Nutrition (A.S.P.E.N.) describes pediatric malnutrition as "an imbalance between nutrient requirement and intake, resulting in cumulative deficits of energy, protein, or micronutrients that may negatively affect growth, development and other relevant outcomes" [1]. For this literature review, we chose Growth Faltering to describe pediatric malnutrition.

Growth faltering continues to be an important issue, but it must also be considered alongside the current childhood obesity epidemic. In 2014, 42 million children under the age of five worldwide, were overweight or obese; but 156 million were affected by stunting (low height for age), while 50 million were affected by wasting (low weight for height). In some cases, malnutrition and growth faltering can be less visible. The WHO describes this as "the double burden of malnutrition where children are undernourished, but are overweight or obese according to growth curves" [2]. The research compiled by the WHO demonstrates that under-nutrition early in life (even in utero) may predispose children to obesity and non-communicable disease such as diabetes and heart disease later in life. Furthermore, rapid weight gain in infants may also predispose to long-term weight excess in adulthood [2]. In this context, it is important to consider the various circumstances in which pediatric malnutrition can occur and how nutrition therapy can affect health later in life.

The prevalence rate of growth faltering varies in the literature where some studies report 5% to 10% of infants in primary care settings and 3% to 5% of infants in hospital settings are considered growth faltering [3]. In the Danish birth cohort report, depending on the criteria used, 1.3% to 22% of infants exhibited growth faltering [4-6]. True prevalence rates of growth faltering are widely varied (6% to 51%) because there is no single definition or measure of pediatric malnutrition [7].

The objectives of this literature review are to discuss the latest work in the field of growth faltering, discuss its evolving definition, categorization, assessment, diagnosis, treatment, and outcomes; as well as to introduce recent transformations in this area of research and to hypothesize future directions. This review may prove useful to pediatric health care providers who may need to identify and manage malnutrition. The literature, including PubMed, Medline, Scopus, Web of Science, and Academic Search Complete, was searched using the following terms: infant, pediatric, failure to thrive, FTT, growth faltering, and malnutrition.

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Table 1: Etiology of Growth Faltering [3,8,10,11,13,16,23,25,27].

Malabsorption/Excessive Losses	- Cystic Fibrosis - Celiac Disease - Inflammatory Bowel Disease - Protein insensitivity - Pancreatic insufficiency - Eosinophilic esophagitis - Gastroenteritis/Food Allergy - Cow's milk enterocolitis - Congenital Diarrhea - Anemia, Iron Deficiency - Biliary Atresia - Pancreatic Cholestatic Conditions - Vomiting (gastroesophageal reflux, structural anomalies, CNS lesion) - Diarrhea (chronic toddler diarrhea, Infectious, malabsorption) - Hepatic (chronic hepatitis, glycogen storage disease)
Increased Requirement (Hypermetabolism)	- Insulin resistance - Congenital infections: Tuberculosis, HIV, TORCH - Syndromes: Russell-Silver, Turner, Down - Chronic Disease (Cardiac, Renal, Pulmonary, Endocrine, Liver etc.) - Thyroid Disease - Immunodeficiency - Malignancy - Laryngomalacia
Structural Abnormalities	Naso-oropharynx - Choanal atresia - Cleft lip or palate - Pierre Robin sequence - Macroglossia - Ankyloglossia Larynx & Trachea - Laryngeal cleft - Laryngeal cyst - Subglottic stenosis - Laryngo-tracheomalacia Esophagus - Tracheoesophageal fistula - Congenital esophageal atresia or stenosis - Esophageal stricture - Vascular ring
Psychosocial Considerations	- Poverty (family employment, nutritional assistance, homelessness, shelter, transportation) - Health Insurance - Family Dysfunction - Parent/Child Interaction - Marital Stress - Mental Illness - Postpartum depression - Substance Abuse - Family history of child abuse - Child maltreatment - Abuse - Intentional/non-intentional neglect - Assessment of feeding - Feeding technique - Parental dietary attitudes - Infant comorbidity - Parent-infant temperament while feeding
Neurological Conditions	- Cerebral Palsy - Arnold-Chiari malformation - Myelomeningocele - Familial dysautonomia - Muscular dystrophies and myopathies - Moebius Syndrome - Congenital myotonic dystrophy - Myasthenia gravis - Oculopharyngeal dystrophy
Decreased Intake	- Food Insecurity - Caregiver lack of knowledge regarding infant/child's nutritional needs - Poor Dietary Transitions (Breast to Bottle/Cup, Liquids to Solids etc.) - Improper Formula Dilution - Excessive Juice Intake - Breastfeeding difficulties - Avoidance of high calorie foods - Neglect - Dysphagia - Aspiration - Developmental Delay

Decreased Intake	- Behavioral feeding problems - Pain and conditioned food aversion (fear of feeding) - Mood Disorder (child or adolescent) - Eating Disorder (child or adolescent) - Food Fixation (Selective/Extreme dietary limitations) - Caregiver Feeding Style (Responsive, Controlling, Indulgent, Neglectful)

Etiology and Clinical Manifestations of Growth Faltering

Growth faltering describes a negative weight gain pattern and can be explained by three mechanisms: inadequate nutrient intake to support growth; sufficient intake, but malabsorption of nutrients; or sufficient intake and normal absorption, but increased metabolic demand from underlying chronic disease or genetic metabolic disorders [8,9]. Growth faltering can be classified as organic or non-organic in origin or both simultaneously. Organic feeding disorders arise from an underlying medical condition, whereas non-organic feeding disorders arise from maladaptive feeding behaviors or psychosocial factors [8,10]. These classifications will guide the treatment plan, and although these are considered separate or dichotomous categories it is common to see overlap as growth faltering is a multifactorial condition [8,11,12].

Table 1 summarizes medical conditions which put infants and children at higher risk for growth faltering. The most at risk include: preterm infants; infants and children with medical conditions affecting the coordination of feeding, breathing and swallowing, and/or the ability to absorb or utilize nutrients; and infants living in social and/or environmental deficits, such as poverty, substance abuse or neglect [10]. Growth failure is a clinically important issue considering the rapid growth characterized in newborns and infants. This time is thought to be a sensitive period for development, and without adequate nutrition, infants may not reach their full growth potential. Pediatric malnutrition comes with other consequences including immune dysfunction; poor wound healing, developmental delay, increased hospital costs, and in extreme cases, can result in death [1].

Assessment

Considering the complicated, multifactorial conditions that result in growth faltering, a multidisciplinary team including a pediatrician, dietitian, speech and language therapist, occupational therapist, or play therapist [13] may be warranted. Gahagan [16], in her review of growth faltering, describes the assessment or evaluation portion of the healthcare process as the ultimate test that demands the ability to simultaneously evaluate biomedical and psychosocial information obtained from the physical examination, medical and social history. The clinical evaluation for growth faltering should include accurate anthropometric measurements, a physical examination, and a comprehensive history (Table 2).

Anthropometric Measurements

A consensus in the literature regarding growth faltering is that it is not a disease, but a physical sign of under nutrition or inadequate dietary intake to support optimal growth and development [8,9,15-17]. Growth faltering depends on the child's anthropometric measurements over time compared to normal growth of children their same age and sex. Accurate measurements are fundamental for growth monitoring; therefore, it is imperative that healthcare providers are well trained, follow a standardized measurement technique, and use calibrated and accurate equipment [17,18]. One-time measurements reflect a child's size while plotting measurements over time reflect a child's growth pattern and are more informative when assessing for abnormal growth. The American Academy of Pediatrics recommends length/height and weight be measured at every regular visit to the primary care provider [17,18]. Growth assessment, including length/height, weight, and weight for length or Body Mass Index (BMI), is suggested within one to two weeks after birth, one, two, four, six, nine, 12, 18 and 24 months, then once per year for children over two years and for adolescents [19]. Head circumference should also be included until 24 months of age.

These measurements plotted on appropriate growth charts (such as the WHO growth curves for Canada) will determine growth velocity and weight pattern [32]. Specialized growth charts can be used for children born prematurely or with specific diagnoses such as Turner Syndrome or Trisomy 21 [3]. Growth can also be evaluated by calculating the child's z-score, which is the deviation of the patient's height from the mean height for children of same gender and age [17]. Infant/children's height, weight and BMI for age are scored from -3 to +3, therefore the higher the z-score the larger the infant/child. Percentiles and z-scores can be used interchangeably as there is a direct relationship between them. It is important to consider all measurements and to use percentiles and z-scores together when assessing for growth patterns [18]. The cutoffs listed in Table 2 are meant to guide health care providers towards further assessment, referral or intervention, not diagnostic criteria [18].

Definition

There is no consensus on the definition (Table 3) of childhood growth faltering, although the term is associated with infants and children with weight below the 3rd percentile for sex and age. Under circumstances where the infant being measured is born premature, then their age must be corrected when using growth charts [18]. The criteria most frequently used for evaluating growth faltering include: weight falling through two major centile lines on standard weight charts, weight falling below the 3rd centile, or weight for height less than 2 standard deviations below the mean for age and sex. Under circumstances where accurate height measurements are difficult to obtain other techniques such as measuring arm span, or the ratio of upper body to lower extremity length [8] may be warranted to adequately address growth concerns [3].

Care must be taken in interpreting growth changes in the first 3 years of life. It is common for infants' growth to change one or two major centile curves in their first 1-3 years of life. Afterwards children typically follow the same percentile for weight, length/height, and BMI until puberty. Growth crossing percentiles in the early years typically is explained by infants following their own genetic potential to be taller or shorter, and heavier or lighter than average [18]. Wright and Garcia [15] acknowledge that if growth faltering is diagnosed based on weight falling below a centile line, there is potential for over-selection of infants. For this reason, it is important to consider the height and weight of the infants' parents, and their family history of weight/height gain to rule out genetic influences [18].

Physical Examination

Anthropometric measurements help diagnose growth faltering

Table 2: Assessing for Growth Faltering [3,8,9,10,11,13,24].

Feeding History
- Environment (Regular routine at home and daycare)
- Family eating patterns (culture/religious food restrictions, immigrant familiarity with local foods)
- Preparation of food (formula mixing technique, frequency of feedings, use of baby foods and table foods)
- Resources (Use of Women, Infants and Children programs, social workers, home health visits, access to food supplies
Personal Medical History
- Pregnancy and birth history
- Medical Conditions
- Prematurity
- Surgeries
- Medications
Family Medical History
- Gastrointestinal Disorders
- Parental childhood nutrition
- Parental height, parental age at puberty
- Psychiatric illness, substance abuse
Social History
- Living conditions
- Parent-child interactions
- Primary caregivers
- Stressors
Systems Review
- Structural
- Gastrointestinal
- Cardiorespiratory
- Neural
- Metabolic
Anthropometrics
- Length/Height for age
- BMI/Weight for age
- Length/Height for Weight
Physical Examination
- Infant/Child's developmental skills
- Infant/Child's interactions with parents/examiners
- Signs of Muscle mass loss/wasting:
- Hollow cheeks and temples
- Square shoulders and knees
- Visible rib cage and scapula)
- Edema/ Fluid retention
- Infant/Childs demeanor

but are not always accurate. Other indicators of malnutrition should be investigated to confirm growth faltering, as it tends to be multi-factorial [9]. A tool commonly used in adult populations that assesses for malnutrition is the Subjective Global Assessment (SGA) [24]. This assessment requires accurate measurement of anthropometrics (height, weight and weight/height, weight gain/loss), assessing for adequacy of nutrient intake, symptoms affecting oral intake including pain, anorexia, early satiety, gastrointestinal (GI) symptoms, functional status, metabolic stress, as well as a physical exam investigating for muscle wasting, fat loss, and edema. This assessment calls for the examination of specific landmarks for fat loss such as hollow depressions around the eye sockets, cheekbones, temples, ribs, and scapula; a prominent iliac crest, clavicle, squared shoulders and knees; and low, thin, flat quadriceps and calf muscle [24]. This physical examination requires techniques such as palpating for fat and muscle tissue to identify the severity of wasting. Palpation is also used to assess for edema, or excess fluid, described by the depth of pitting (millimeters) as well as the duration of pitting (seconds). Fluid retention can mask malnutrition in many ways. At first glance, it may seem like the child is a normal weight on the scale, and the excess fluid fills the hollow depressions of examination sites such as the eye sockets, cheekbones and iliac crest. Although the SGA is not routinely used in pediatric populations [24], the concepts remain relevant and routine examination of these patients and their weight is important to identify major changes.

Comprehensive Medical History

Evaluation of growth faltering should begin with the child's medical history including prenatal history, current or past medical conditions, developmental history, and feeding history including 72-hr dietary intake record, gastrointestinal symptoms, sleep patterns, medications, and allergies. Considering the family's typical growth velocities is helpful, as their inherited genetic potential may explain seemingly abnormal growth. Lastly, investigating for possible genetic inheritance of chronic diseases, including endocrine or genetic conditions that influence metabolism or nutrient absorption, may also justify the growth faltering. Common red flags of underlying chronic disease are failure to gain weight despite adequate caloric intake, dysphagia (difficulty swallowing), vomiting, diarrhea, dehydration, or developmental delays; and dysmorphic features, heart murmurs and/or edema on exam [11]. If the examination indicates an organic feeding disorder, treatment must focus on the underlying condition that is causing the growth faltering.

Healthcare providers should be wary of signs of abuse or neglect indicating a non-organic feeding disorder [9]. The parent and child relationship/family dynamic should be evaluated, as well as screening for socioeconomic status since poverty is the greatest single risk factor for growth faltering worldwide [9,12]. Common signs include parental depression, marital stress or strife, divorce, and single parenting without social supports or resources. Parental medical history should also screen for history of eating disorders, mental illness and psychological abnormalities, history of abuse as a child, and substance abuse [9,11,12]. Observation of parent-child interaction for warning signs of neglect is critical, as children who are

Table 3: Definitions [1,2,4,14].

Pediatric Malnutrition (under nutrition): an imbalance between nutrient requirement and intake, resulting in cumulative deficits of energy, protein or micronutrients that may negatively affect growth, development and other relevant outcomes (A.S.P.E.N.). Malnutrition can be 1. Illness related, or 2. Caused by environmental/behavioral factors associated with decreased nutrient intake/delivery (or both). • **Acute pediatric malnutrition:** less than 3months duration, typically illness related (Z score <-1, mild malnutrition). • **Chronic pediatric malnutrition:** 3months or longer, typically behavioral or socioeconomic reasons (Z score between -2 and -3, moderate malnutrition. Anything below -3 is considered severe malnutrition).
Growth Faltering: Infants and children who fail to grow and develop at a normal rate compared to other infants and children of similar age and sex.
Organic Growth Faltering: Denotes growth faltering resulting from a medical disease or underlying condition.
Non-Organic Growth Faltering: Denotes growth faltering resulting from social or environmental factors.
Failure to Thrive: An inadequate rate of weight gain, when weight is less than the 3rd percentile for age and sex, or the crossing of two major percentiles on standard weight curves below a previously established rate of growth.
Wasting: very low weight-for-height (less than -3 standard deviations (SD) (z-scores) of the median WHO growth standards, by visible wasting in mid-upper arm circumference <115 mm, or by the presence of nutritional edema.
Stunting: Having a height-for-age (or length-for-age) that is less than -2 SD (z score) of the median of the NCHS/WHO International reference.
Underweight: Having a low weight-for-age (Below 3rd percentile using appropriate growth curves).
Cachexia: an extreme state of underweight characterized by loss of appetite or desire to eat and resultant loss of adipose and skeletal muscle mass and is mediated by pro-inflammatory cytokines.

Table 4: Components of Feeding Observations [8,13,16].

Can be performed in the office, but is enhanced as part of a home visit.
Child's Transition Periods: - Breast to bottle/cup, liquids to solids, transition to independent/self-feeding
Child's Feeding Skills: - Suck/swallow coordination - Chewing/swallowing coordination - Coughing while swallowing - Time required to chew, swallow and finish a meal
Child's Feeding Behavior: - Picky Eater/Very Selective/Limited food repertoire (<10-15 foods) - Limited Appetite - Energetic Child (More interested in playing/talking) - Oral interest or aversion (tastes, textures, smells, temperatures, appearance of foods) - Fear of Feeding - Neophobia (Rejection of new/unfamiliar foods) - Food Jagging (sudden refusal of previously eaten food)
Feeding Environment - Disruptive and stressful mealtimes - Nocturnal eating in infants and toddlers - Introducing distractions to increase intake (toys, screen time, books etc.)
Parent-child interactions before, during and after feeding
Caregiver's Feeding Style: - Responsive (Guide eating rather than control it) - Controlling (Ignore hunger signals and force feed) - Indulgent (Feed child whatever and whenever the child demands) - Neglectful (Abandon responsibility to feed child)
Observation of: 1. Intentional withholding of food from child 2. Strong beliefs in health and/or nutrition regimens that jeopardize the child's well-being 3. Resistance to recommendations despite multidisciplinary team approach These three criteria warrant concern for abuse or neglect.

growth faltering are four times more likely to be abused or neglected [11,12].

Organic Growth Faltering

Organic growth faltering may be exacerbated by inadequate intake to meet needs, medical conditions characterized by increased metabolism or gastrointestinal malabsorption. When investigating adequacy of intake, it is important to evaluate the infant or child's ability to latch, suck, chew, or swallow and overall feeding efficiency, according to their age and appropriate milestones. The most critical indications of feeding difficulties include dysphagia, aspiration, choking or coughing while eating [22]. Further investigation by an Occupational Therapist (OT) or Speech-Language Pathologist (SLP) regarding swallowing difficulties is required to identify which phase of swallowing is disorganized [22]. Less urgent, yet warranting investigation by a pediatric gastroenterologist includes diarrhea and vomiting [22].

Growth failure is a common complication in many children with chronic diseases caused by increased energy demands, and inadequate intake resulting in protein-energy wasting cachexia [23]. Cachexia is characterized by anorexia, increased basal metabolic rate, wasting of lean tissue and underutilization of fat tissue for energy [23]. There

Table 5: Behavioral/Feeding Interventions [13,23].
Some general guidelines to feeding all children are summarized here:

Behavioral Interventions	Nutritional Interventions	Environmental Interventions
Eliminate grazing by eating only at set meal and snack times. Plan appropriate frequency of meals and snacks. • Infants should feed every three hours minimum. • Children should have three meals and two snacks spread through-out the day. Limit meal times to 20-30 minutes. Meals should take place in developmentally appropriate locations. • Highchair for young children. • Around the table for older children. Allow only water between meals to encourage hunger by meal time. Avoid distractions during meal times such as television, cell phones, technology, or toys.	Assure proper and adequate preparation of formula. Fortify formula if needed in increments starting at 22, to 24, and then 27 kcal/oz. Add fats or oils to foods to increase energy density. Serve age appropriate foods • Formula for infants • Soft foods for 6month olds and older Provide increased caloric beverages with snacks or meals. Give small portions to start and increase gradually. Eat solids first, fluids last. Encourage self-feeding as much as possible. If child plays without eating, or throws a temper tantrum, then food is removed. Wiping the child's mouth and cleaning up occurs only after the meal is completed. Introduce new foods systematically (up to 8-15 times). Prepare foods in different ways, with different textures.	Ensure a neutral atmosphere (no force feeding or arguing). No game playing during meal time. Food should not be used as a reward or present. Use of a sheet under the chair to catch excess mess on the floor.

are factors that contribute to cachexia and they include steroid drugs (interference with growth hormone and insulin-like growth factor-1) that are prescribed for treatment of the chronic disease, the pro-inflammatory nature of chronic disease (increased IL-6, IL-1β, TNF-α, IFN-γ cytokines), increased fever, infection, catch-up growth, anemia, acidosis, and insulin resistance [23]. Patients with cystic fibrosis, chronic kidney disease, chronic liver disease, congenital heart disease, human immunodeficiency virus, inflammatory bowel disease, short bowel syndrome are specific populations that are at high risk of growth faltering for the above stated reasons.

Cystic fibrosis (CF)

Cystic fibrosis is a genetic disease that affects the lungs, pancreas, gastrointestinal tract and liver. Poor growth is commonly seen in this population, as well as lung disease and pancreatic insufficiency. The North American Cystic Fibrosis Foundation along with the European Cystic Fibrosis Society and the Australian Cystic Fibrosis Federation agree that nutrition is a key component to improved CF outcomes and that the major goal of nutrition therapy is to promote normal growth from infancy. Maintaining normal growth for CF patients is very difficult as this disease is characterized by increased resting energy expenditure, nutrient malabsorption, decreased nutrient intake, pulmonary infections, and abnormal glucose tolerance. To avoid growth-faltering, young patients are recommended to consume 120% to 150% daily recommended intake (DRI) for total energy and 150% to 200% above the DRI for protein for their age. A high-calorie, high-fat diet, with 35% to 40% of total calories from fat, is recommended to satisfy these increased metabolic demands. Nocturnal enteral feedings are recommended in addition to oral intake, as it can be difficult to meet these increased needs with solid food alone. Growth is closely monitored to ensure optimal nutrition, for early detection of any problems, and to adjust nutrition therapy. Infants with cystic fibrosis should be measured (weight, length, and head circumference) and compared to growth charts every month until they reach 6 months old, and then every 3 months thereafter to ensure nutrition therapy is supporting normal growth in this sensitive development period.

Chronic kidney disease (CKD)

Chronic kidney disease is described along five stages based on the presence of kidney damage and the degree of functional impairment. Growth failure is a major concern for children with CKD stages 2 through five as demonstrated in the 2005 annual report of the North American Pediatric Transplant Cooperative Study (NAPRTCS) where more than one-third of the 5927 children with CKD had significant growth failure [24].

To avoid end-stage kidney failure (stage 5), dialysis and therapeutic diets are used to decrease stress on the kidneys. However, this place's young patients at risk for malnutrition as many foods are prohibited. It is also common for CKD patients to experience frequent nausea, vomiting, anorexia (loss of desire to eat), altered taste sensations, and emotional distress [24], impacting intake and nutrition status. Additionally, CKD patients experience many other metabolic abnormalities that contribute to failure to thrive, such as increased state of acidosis, abnormalities in the Growth Hormone (GH), Insulin-like Growth Factor (IGF)-I axis, and renal osteodystrophy [24], all of which negatively impact growth. The characteristic state of acidosis impairs growth by suppressing albumin synthesis resulting in muscle protein degradation [24]. Metabolic acidosis is also responsible for reducing GH and IGF secretion, which are both integral to normal growth in infants and children. Specific dietary restrictions can correct this acidosis; therefore, normal weight gain depends on adherence to these prescribed diets.

Infancy and childhood are periods of rapid growth in all organ systems, but one system that is especially involved in rapid growth, particularly height, is the skeleton. High-turnover bone disease due to secondary hyperparathyroidism, low-turnover osteomalacia and a dynamic bone are common comorbidities of CKD and affect skeletal growth [24]. Considering that children attain one-third of their final adult height during their first 2 years of life [24], this growth impairment is a significant concern for adult stature and bone health. Without adequate nutrition, these patients risk reduced bone mineral density and resultant increased risk of fractures and bone deformities [24] throughout their lifetime.

Chronic liver disease (CLD)

CLD refers to diseases of the liver, which last over a period of 6 months. It consists of a wide range of liver pathologies, which include inflammation (chronic hepatitis), liver cirrhosis, and hepatocellular carcinoma. The liver is responsible for making bile and other digestive enzymes that help facilitate digestion of food products and subsequent absorption of nutrients. These functions are diminished in patients with CLD and they experience high rates of nutrient malabsorption

resulting in weight loss and nutrient deficiencies. Additional factors include decreased intake because of anorexia, nausea, vomiting, hospitalization-related depression, unpalatable diet, and mechanical difficulties caused by tense ascites [25].

CLD is also characterized by increased metabolic rate, which places patients at even higher risk of growth faltering. To compensate, CLD patients are prescribed 130% to 150% of the DRI for protein and energy, MCT (medium chain triglycerides) as a fat choice to ease absorption, as well as vitamin and mineral supplements to avoid micronutrient deficiencies [23]. Routine nutritional assessment is integral to identifying and preventing malnutrition and growth delays in this population. These assessments must closely follow weight changes as CLD is characterized by edema and ascites, or fluid retention, which can mask weight loss and delay malnutrition diagnosis. For children, tracking height on growth charts is a reliable way to assess for malnutrition [25]. Triceps skinfold and arm muscle measurements along with grip-strength tests provide a sensitive indicator of muscle mass and nutrition status [25].

Congenital heart disease (CHD)

Congenital heart disease is a malformation of the heart, aorta, or other large blood vessels that is the most frequent form of major birth defect in newborns. CHD is characterized by an increased inflammatory-state, increased basal metabolic rate, inadequate intake and comorbidities affecting the GI tract resulting in malabsorption. These circumstances increase the risk of wasting, stunting and being underweight. A review of the literature conducted by Leitch [26] found that several authors report caloric intake in this clinical population are adequate for chronological age or body weight, yet they still experience growth delay. This would indicate significant nutrient malabsorption or insufficient intake to support an increased basal metabolic rate. The literature shows that this malnutrition and resultant growth delay increases surgical risks, leads to continued growth failure after surgical repair, and contributes to delayed motor and cognitive development [26]. CHD patients, who have not undergone corrective surgery, should consume 100% to 140% the DRI for overall energy intake and 100% the DRI for protein intake. After corrective surgery, age-appropriate energy and protein intake are enough to support sustained growth [23].

Cancer

Cancer is a disease caused by an uncontrolled division of abnormal cells resulting in malignant growth or tumor in a part of the body. Pediatric oncology patients are at increased risk of malnutrition leading to what is called cancer cachexia. This is characterized by anorexia and loss of adipose and skeletal muscle mass [23]. The magnitude of malnutrition and weight loss depends on the type of cancer, stage of disease, intensity of chemotherapy and radiation treatments, and inflammatory state. The incidence of malnutrition in pediatric oncology patients is 6% to 50%, and the severity tends to increase in the later stages of malignancies [23]. Chemotherapy and radiation treatments decrease pituitary function in patients with brain tumors, which affects Growth Hormone (GH) production and further contributes to stunting in young oncology patients [23]. The inflammatory state, increased metabolic rate, loss of appetite, GH dysfunctions and comorbidities associated with treatment all contribute to the protein-energy wasting and eventual growth faltering in this population. Parenteral and enteral nutrition support is recommended to meet energy and protein needs (100% to 130% of the DRI) [23].

Human immunodeficiency virus (HIV)

HIV is a virus that causes Acquired Immune Deficiency Syndrome (AIDS), a chronic, potentially life threatening condition. HIV damages the immune system and decreases defense against disease [27]. HIV can be passed from mother to baby during pregnancy, birth or breastfeeding [27]. Wasting, underweight and stunting are commonly seen in HIV-infected children [23,28]. The drastic loss in weight in this population is a result of the combination of anorexia, oral and upper GI symptoms, nutrient losses in diarrhea, malabsorption, altered metabolism due to uncontrolled HIV infection, opportunistic infections, malignancies, hormonal deficiencies and resistance, and cytokine dysregulation [28]. The primary goal of nutrition therapy is to avoid significant weight loss as it increases mortality rates and negatively influences disease interventions [23]. To meet increased metabolic demand and nutrient malabsorption, 100% to 150% of DRI for energy and 150% to 200% of DRI for protein are recommended to ensure growth.

Inflammatory bowel disease (IBD)

The two main types of inflammatory bowel disease are Crohn's disease and ulcerative colitis where the clinical presentation depends on the location and extent of inflammation. The most commonly encountered gastrointestinal symptoms are abdominal pain and diarrhea, but also include blood in the stool, weight loss, nausea, vomiting, loss of appetite and fever [29]. It is common for pediatric patients to present with at least one extra intestinal manifestation as presenting signs as well. These occur system wide and include mouth ulcers, skin rashes, episcleritis (eye inflammation), arthritis, hepatitis, pancreatitis, kidney stone formation, osteoporosis, blood clots, anemia, pubertal and growth delay [29]. Malnutrition is multifactorial in IBD patients including decreased overall intake for fear of worsening GI symptoms, including pain from esophagitis and/or gastritis. IBD causes increased release of pro-inflammatory cytokines, which may have direct influence on growth in young patients. Nutrients are lost from malabsorption in the intestine and colon resulting in steatorrhea and nutrient losses in the stool. IBD during critical periods of growth, as in childhood and adolescence, is problematic, as it is extremely difficult to compensate for the increased metabolic demands and the consequences of poor nutrition are long lasting [29]. Many children with IBD may never reach their genetic potential based on parental height, as bone mineralization is negatively influenced and peak bone mass is lower than normal. Nutrition therapy is, therefore, a critical part of the care plan, often using intravenous or enteral methods of delivery [29]. These methods are typically given supplementary to oral feedings, and they have been shown to improve height and weight velocities.

Short bowel syndrome (SBS)

Surgical resection of the small intestine is a common procedure for treatment of various disorders including IBD, malignancy, mesenteric ischemia, traumatic injury, or vascular accidents. When less than 200 cm of viable bowel is left or resultant loss of 50% or more of the small intestine qualifies as short bowel syndrome. This is a substantial loss, and as the small intestine is responsible for absorption of many macronutrients, micronutrients, vitamins, and minerals, the patient is at risk for malnutrition and a wide variety of deficiencies. Growth failure is common in patients with SBS due to the lack of surface area to absorb adequate nutrients to maintain normal weight and to support growth [23]. The primary goal of nutrition therapy is to support dietary requirements that encourage growth and development, but it

is also important to support gut adaptation and function to achieve intestinal autonomy [23]. It is common for pediatric patients to go on intravenous nutrition to avoid malnutrition and subsequent growth faltering, with supplemental Enteral Nutrition (EN) feeds to support gut function [23]. Therefore, it may be necessary to start EN feeds with semi-elemental formulas (macronutrients are already broken down into polysaccharides, protein, and triglycerides) with lower osmolality (small concentration of nutrients) to ensure absorption without damaging the gut [23].

Treatment of organic growth faltering

The correct approach to treating organic growth faltering will vary depending on the underlying condition. Consulting with a subspecialist may be warranted for specific management recommendations [11]. Increased nutrient needs can be difficult to meet through oral intake alone, in which case enteral or parenteral feeding may be prescribed. Enteral feeds, such as nasogastric feeds, can be bolus or continuous throughout the day or overnight depending on the patients' tolerance, lifestyle, activity, and sleep. Parenteral nutrition may be used for those who are unable to digest or absorb oral or enterally delivered nutrients for a significant period of time, and/or have non-functional, inaccessible or damaged a gastrointestinal tract. Nutritional goals are always to support optimal growth and development.

Non-Organic Growth Faltering

Non-organic growth faltering describes infants and children with inadequate intake in the absence of organic disease [13]. Four areas of functioning require assessment when considering non-organic feeding disorders: parental feeding style, the child's feeding behaviors and temperament at mealtimes and psychosocial factors [30]. These factors can be assessed with family interviews, formal observations of feeding and play, developmental assessments, and home visits.

Feeding technique

The parents' knowledge of feeding techniques and proper food selection should be assessed first, to correct any malpractices causing the inadequate intake [11]. Common malpractices occur in breastfeeding surrounding proper technique, latch-on and swallowing [11]. This observation requires a health professional who is specifically trained in lactation counseling and assessment [11]. Observing and measuring infant intake of breast-milk or formula can provide information regarding adequate intake in young infants. Parents may also lack knowledge on proper formula mixing, appropriate juice and milk intake, or age appropriate food introduction [11]. It is also common for older infants and toddlers to have difficulties transitioning to solid foods, which can result in inadequate intake. A 3-day food record filled out by the parents would assist in assessing whether intake is adequate.

Parental feeding style

The caregivers' actions, temperament and feeding style at mealtime can alter an infant or child's eating behavior [31,32]. For this reason, caregivers are an essential part of managing and treating feeding disorders. Kerzner et al. [22] identifies four feeding styles: responsive, controlling, indulgent and neglectful that can influence infant or child eating behaviors.

1. Responsive feeders determine where, when and what the child is fed; the child determines how much. Responsive feeders guide the child's eating instead of controlling it, model appropriate eating, talk positively about food, respond to the child's feeding signals, and do not use coercive techniques. A responsive feeder will wait for their infants' mouth to open before offering food, and they will stop feeding when they show signs of fullness (ex: closing mouth, turning their head away). This feeding style has shown children eating more vegetable, fruit and dairy products and less "junk food".

2. Controlling feeders ignore the child's hunger signals and may use force, punishment or inappropriate rewards to coerce the child to eat. This feeding style has shown children to eat fewer vegetables and fruits and to be at greater risk of under- or overweight.

3. Indulgent feeding styles cater to the child, meaning they tend to feed the child whenever and whatever the child demands. Caregivers tend to make special meals or offer multiple foods to please the child. This result in lower consumption of appropriate foods that contain important nutrients and increased consumption of items high in fat, thereby increasing the risk of becoming overweight.

4. Neglectful feeders abandon the responsibility of feeding the child and may fail to offer food or set limits. Neglectful caregivers ignore both the child's hunger signals and other emotional and physical needs. Parents may have emotional issues, developmental disabilities, depression or other conditions that make it difficult to care for their child, resulting in growth faltering. Neglectful feeding disorders have shown to be associated with increased risk of developing obesity.

Health care providers can identify feeding styles simply by asking parents about meal time, how they perceive their child to eat, how they feel during meal time and how they respond when their child won't eat. Neglectful parents will give vague answers, controlling parents will describe pressuring/forcing their child to eat and indulgent parents will describe pleading, begging and preparing special foods for their child [22]. Once the feeding style is identified, feeding guidelines should be given to caregivers to eliminate counterproductive feeding practices. Some include limiting distractions during mealtime like television, cell phones, toys, books, and maintaining a pleasant neutral attitude throughout the meal. Meals should also be planned to encourage appetite by limiting duration to 20 mins to 30 mins and scheduling 4-6 meals and snacks every day with only water in between. Foods chosen should be age appropriate; new foods, flavors and textures should be introduced regularly; and self-feeding should be encouraged as well as an age-appropriate mess [22].

Child's feeding behaviors and temperament at meal times

Feeding difficulties will often emerge during periods of feeding transition; for example, when the infant moves from breast to bottle/cup, liquids to solids, or when self-feeding begins [22]. Guidance from the health care provider through these transitions may be particularly helpful in avoiding feeding difficulties, which may lead to decreased intake and eventual growth faltering.

Diagnosis of feeding disorders involves health professionals monitoring infants or children during feeding times. Notes on the child's eating behaviors and temperament include a spectrum of behavioral difficulties, including but not limited to, problematic eating behaviors, poor state control, defiance, incorrect feeding behaviors, food fixation including selective food intake, fear of feeding, or food refusal (Table 4) [10,30].

Psycho-social factors

Assessment of psychosocial stressors in the parents, including

poverty, is important to investigate as it is the greatest single risk factor for growth faltering [11,12]. Inquiring whether the inadequate intake is a result of lack of money, allows the health professional to refer the family to a social worker who may direct caregivers to welfare programs or food-bank services meant for impoverished families. Alongside low-socioeconomic status, the parent(s) and child relationship and family dynamic should be evaluated. Observing the child's responsiveness to the parent and vice versa, the extent to which the child refers to the parent for support, the parents comfort in holding the infant, how they encourage feeding, and their responsiveness to the infant's feeding cues are a few demonstrations of the child-parent relationship [12]. Careful observation of interactions that demonstrate abuse or neglect is necessary in this population as children who are growth faltering are four times more likely to be abused or neglected than children who are not [11,12]. In these cases, social service agencies should be contacted.

Treatment of non-organic growth faltering

The first goal of treatment is to provide adequate nutrition to support optimal growth, which can be achieved by giving age-appropriate nutritional counseling to the parents. Re-educating caregivers may be necessary. For example, reinforcing that for toddlers, it is recommended to avoid excessive fluid intake such as juice or milk because it can interfere with appetite [11]. Parents may also need education on how to add energy-dense foods such as infant cereal, butter, gravies, or cream sauces. This education must be tailored to the family's socioeconomic status, and working with the social worker may be necessary to connect low-income families with social welfare programs. Examples of interventions are summarized in Table 5.

Outcomes and Complications of Malnutrition and Growth Faltering

Untreated malnutrition that results in growth faltering within sensitive time periods, such as infancy and childhood, results in poor growth and development [33]. Multiple studies state that growth faltering infants or children are found to be significantly shorter and lighter [9,11,33] and to have smaller heads than controls [9,34]. They are also vulnerable to long-term deficits in intellectual, social and psychological functioning [9,10,12,34]. There are few longitudinal studies that follow these children into later childhood, adolescence and even adulthood, therefore the longer-term consequences are not fully understood.

A consensus statement regarding the influence of fetus, infant and pediatric malnutrition on health by Kaput et al. [14] gathers a body of evidence that demonstrates the effects of malnutrition on cognitive development. Throughout pregnancy, lactation, and early infancy, malnutrition can lead to epigenetic changes resulting in permanent effects on metabolism and susceptibility to disease, defective DNA replication, repair processes or the ability to grow new cells. These epigenetic changes contribute to low birth weight, stunting, underweight, and inadequate cognitive development [14]. Protein and micronutrient malnutrition have been shown to impair cognitive development through infant cognitive function tests. These tests include the Visual Event-Related Potentials (VERP) and MRI technologies.

Immune dysfunction is common in malnourished infants and children, especially in poor and unhygienic environments, and is a significant contributor to increased mortality. Malnutrition impacts immunological function in a variety of ways. Deficiencies may impact the innate and adaptive immune system and efficiency of oral vaccines. Lack of oral feeding results in minimal gastrointestinal stimulation and therefore decreases in function and integrity allowing for bacterial overgrowth and translocation resulting in infections [14].

Other evidence has accumulated linking low birth weight to an increased risk for both cardiovascular disease (CVD) and Type 2 Diabetes. Known as the Fetal Origins Hypothesis or the Barker Hypothesis, this increased risk is hypothesized to be a result of nutrient restrictions in utero and subsequent epigenetic changes that have significant influence over metabolism, blood pressure, and glucose regulation.

Future Research

As this was not a systematic review, we cannot conclude or confirm one definition or perfect measure of pediatric malnutrition. Although, a study as such would be helpful for healthcare practitioners in terms of standard measuring procedures, to allow for easy identification of infants or children most at risk for failure to thrive. Deciding on a uniform definition and measures for growth faltering would assist in the:

1. Early identification of those at risk for malnutrition
2. Gathering and comparison of malnutrition prevalence
3. Development of universal screening tools
4. Development of thresholds for intervention
5. Collection of meaningful nutrition data to increase understanding of this phenomenon
6. Formal collection of evidence-based analysis of the impact of malnutrition and its treatment on patient outcomes [7].

Identifying high-risk patients earlier, and correcting malnutrition sooner growth and cognitive deficits may be lessened. Furthermore, transitioning to similar language across the literature would help reduce confusion when comparing FTT, growth faltering, growth failure, and so on. This review did not fully investigate the long-term consequences of pediatric malnutrition and growth faltering but a longitudinal cohort study investigating these effects would increase understanding of the influence and magnitude of early malnutrition.

Conclusion

Growth faltering remains a contentious, thought-provoking topic. The trend over time has seen feeding disorders categorized separately as either organic or non-organic. Recent research suggests that both be considered during assessment, as they commonly co-exist. It is crucial that health care providers have a thorough understanding of both organic and non-organic red flags, symptoms, and management strategies to ensure that all aspects of the malnutrition are addressed.

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