

Early Childhood Nutritional Supplementation and the Risk of Excess Weight Gain: Balancing Growth Promotion and Obesity Prevention

Atiqur Rahman Khan, MBBS, DCH, MD PhD (Paediatrics), MRCPS (Glasg), FRCP (UK)

Senior Specialist Paediatrician and Neonatologist

Ministry of Health, Kingdom of Saudi Arabia

Corresponding Author: Dr. Atiqur Rahman Khan

Email: dratiqur@gmail.com

Manuscript Type: Narrative Review Article

DOI: 10.56201/rjfsqc.vol.12.no5.2026.pg22.47

Abstract

Background

Childhood obesity has emerged as a major global public health concern, with increasing prevalence in both developed and developing countries, including the Kingdom of Saudi Arabia. Simultaneously, nutritional supplementation remains an important therapeutic intervention for children with growth faltering, chronic diseases, feeding difficulties, and increased nutritional requirements. This presents a clinical challenge of promoting adequate growth while minimizing the risk of unnecessary excess weight gain.

Objective

This narrative review aims to examine the relationship between early childhood nutritional supplementation and the potential risk of later obesity, with particular emphasis on oral nutritional supplements, early-life nutritional programming, neonatal feeding practices, and individualized growth monitoring.

Methods

A comprehensive narrative review of the available literature was conducted using major medical databases, including PubMed, Google Scholar, Scopus, and the Cochrane Library. Evidence related to childhood obesity, infant feeding practices, developmental metabolic programming, prematurity, neonatal intensive care unit (NICU) nutrition, Ready-to-Feed (RTF) formulations, and Saudi Arabian epidemiological trends was critically reviewed and synthesized.

Results

Current evidence demonstrates that nutritional supplementation offers significant clinical benefits when appropriately prescribed for children with documented undernutrition, chronic illness, increased metabolic demands, or feeding difficulties. However, unnecessary or prolonged use of energy-dense supplements in healthy children with normal growth trajectories may contribute to excessive caloric intake and increased adiposity. NICU nutritional strategies, including human milk fortification and RTF formulas, are essential for vulnerable preterm infants but require individualized follow-up and periodic reassessment to ensure balanced catch-up growth and favorable long-term metabolic outcomes.

Conclusion

Childhood obesity is a complex multifactorial condition influenced by genetic, prenatal, nutritional, behavioral, and environmental factors rather than any single nutritional product or feeding practice. The modern goal of pediatric nutrition should focus on growth optimization rather than growth maximization. Individualized nutritional assessment, regular growth monitoring, parental education, and evidence-based use of nutritional supplements are essential to support healthy growth, neurodevelopment, and lifelong metabolic health.

Keywords: *Childhood obesity; Nutritional supplementation; Early nutrition; Oral nutritional supplements; Breastfeeding; Formula feeding; Catch-up growth; Prematurity; NICU nutrition; Developmental origins of health and disease.*

1. Introduction

Childhood obesity has become a major global public health concern, with increasing prevalence in both developed and developing countries, including the Kingdom of Saudi Arabia. In pediatric clinical practice, obesity is commonly assessed using age- and sex-specific body mass index (BMI) percentiles, with obesity generally defined as a BMI at or above the 95th percentile for age and sex. This trend is particularly concerning because excess weight during childhood is associated with significant long-term metabolic, cardiovascular, and psychosocial complications, including type 2 diabetes mellitus, hypertension, dyslipidemia, non-alcoholic fatty liver disease, and reduced quality of life. Saudi Arabia has experienced rapid social and lifestyle transitions over recent decades. Urbanization, reduced physical activity, increased screen time, and greater consumption of energy-dense processed foods have contributed to a growing burden of overweight and obesity among Saudi children and adolescents. At the same time, Saudi pediatric practice continues to encounter undernutrition, faltering growth, feeding difficulties, and increased nutritional requirements among vulnerable infants and children, particularly those born prematurely or affected by chronic illness. For these children, nutritional supplementation can be a necessary and effective intervention to support growth, improve nutritional status, and prevent complications related to malnutrition. The clinical challenge is therefore not whether children should grow, but how to promote healthy growth without encouraging unnecessary excess weight gain.

Early-life nutrition is especially important because the first 1,000 days of life represent a critical developmental window during which nutritional exposures may influence long-term metabolic health. Evidence suggests that breastfeeding may provide modest protection against later overweight and obesity, whereas rapid infant weight gain is consistently associated with increased future obesity risk. In preterm infants, neonatal nutritional support is essential for survival, neurodevelopment, and catch-up growth; however, ongoing reassessment is required to ensure that nutritional interventions remain appropriate and do not continue beyond clinical necessity.

Saudi Arabia faces a dual nutritional burden in which childhood obesity coexists with undernutrition and growth faltering among medically vulnerable children. Consequently, early childhood nutritional supplementation should be considered an individualized therapeutic strategy guided by growth monitoring, dietary assessment, and long-term health objectives rather than as routine calorie supplementation. This narrative review examines the relationship between early childhood nutritional supplementation and the risk of excess weight gain, with particular emphasis on early-life nutritional programming, infant feeding practices, prematurity, neonatal nutritional care, and obesity prevention. The review highlights the importance of balancing therapeutic nutritional support with healthy long-term growth and metabolic outcomes.

2. Methodology

This review adopted a narrative design to explore the relationship between early childhood nutritional supplementation and the risk of excess weight gain, with particular attention to Saudi Arabia and the broader pediatric context. A narrative approach was chosen because the available evidence includes heterogeneous study designs, populations, nutritional interventions, and outcomes, making direct quantitative pooling inappropriate. The review focused on evidence related to childhood obesity, infant feeding, oral nutritional supplements, prematurity, neonatal nutrition, and growth patterns across infancy and early childhood.

The literature base was drawn from major biomedical databases, including PubMed, Google Scholar, Scopus, and the Cochrane Library, using combinations of terms such as childhood obesity, early nutrition, oral nutritional supplements, breastfeeding, formula feeding, catch-up growth, prematurity, Ready-to-Feed formula, NICU nutrition, metabolic programming, and Saudi Arabia. Priority was given to studies published from 2000 to 2026, while landmark publications were also considered when they provided important theoretical or clinical insight. Relevant international guidelines, systematic reviews, meta-analyses, clinical practice statements, and epidemiological reports were also included where appropriate.

Studies were selected if they addressed pediatric nutrition, obesity risk, early-life feeding practices, or neonatal nutritional management. Articles focused exclusively on adults, studies unrelated to growth or nutrition, and publications with limited scientific relevance were excluded from the synthesis. The findings were then organized into themes, including epidemiology of childhood obesity, developmental programming, infant feeding practices, oral nutritional supplementation, NICU nutrition, and post-discharge growth monitoring.

3. Epidemiology of Childhood Obesity

Childhood obesity has become one of the most significant public health challenges worldwide. According to the World Health Organization (WHO), the prevalence of overweight and obesity among children and adolescents has increased dramatically over recent decades, affecting both developed and developing nations. This trend has important implications because excess body weight acquired during childhood often persists into adulthood, increasing the lifetime risk of chronic non-communicable diseases. The Kingdom of Saudi Arabia has experienced substantial socioeconomic and lifestyle changes during the past few decades. Rapid urbanization, increased consumption of processed and energy-dense foods, reduced physical activity, increased screen exposure, and changing dietary patterns have all contributed to a growing burden of childhood obesity. Recent Saudi studies indicate that overweight and obesity are highly prevalent among school-aged children and adolescents. A systematic review involving more than 63,000 Saudi children and adolescents reported considerable variation in prevalence estimates across different regions; however, the overall trend clearly demonstrates increasing rates of excess weight among young people. Family history of obesity, maternal obesity, unhealthy dietary habits, prolonged sedentary behavior, and inadequate physical activity have been identified as important contributing factors. The consequences of childhood obesity extend beyond excess body weight. Obese children are at increased risk of developing insulin resistance, type 2 diabetes mellitus, hypertension, dyslipidemia, non-alcoholic fatty liver disease, obstructive sleep apnea, orthopedic complications, and psychosocial difficulties. Furthermore, childhood obesity frequently tracks into adulthood, increasing the future burden on healthcare systems.

Saudi Arabia simultaneously faces a dual nutritional burden. While obesity and overnutrition are increasingly common in the general pediatric population, undernutrition, faltering growth, and

feeding difficulties continue to affect vulnerable infants and children, particularly those born prematurely or living with chronic illnesses. Consequently, nutritional interventions must be individualized to ensure appropriate growth without promoting unnecessary excess adiposity. Prevention strategies should begin early in life. Increasing evidence supports the concept that nutritional exposures during fetal life, infancy, and early childhood influence later obesity risk. Therefore, interventions promoting breastfeeding, healthy complementary feeding, family-centered nutritional education, and regular growth monitoring are essential components of obesity prevention programs.

FIGURE 1. Conceptual Pathway Linking Early Nutrition and Childhood Obesity

Prenatal Influences

(Maternal nutrition, obesity, gestational diabetes)

↓
Birth Characteristics

(Term birth, prematurity, low birth weight)

↓
Early Feeding Practices

(Breastfeeding, formula feeding, nutritional supplementation)

↓
Growth Pattern

(Normal growth or rapid catch-up growth)

↓
Metabolic Programming

(Hormonal and epigenetic influences)

↓
Childhood Lifestyle Factors

(Diet, physical activity, sleep, screen time)

↓
Healthy Growth OR Childhood Obesity

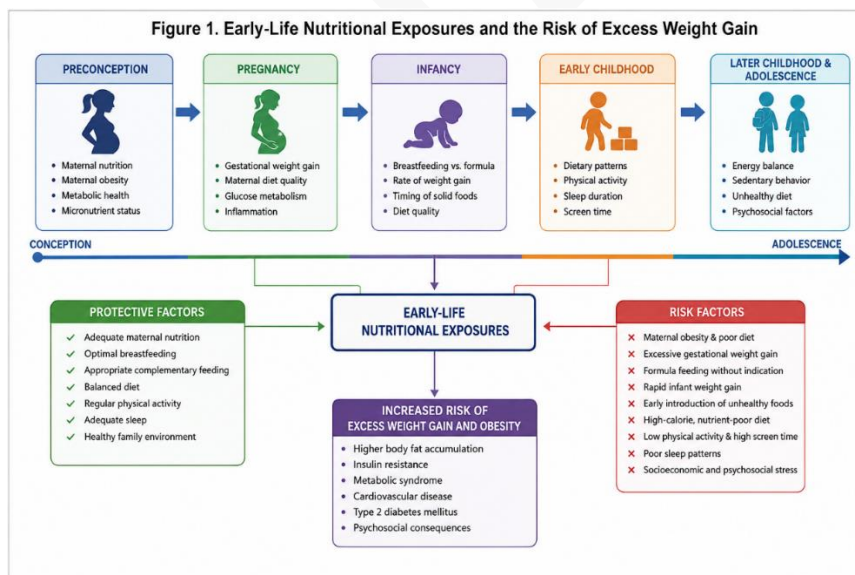


TABLE 1. Major Contributors to Childhood Obesity

Risk Category	Major Contributors	Examples
 Prenatal Factors	Maternal and fetal factors that influence the child's future risk.	• Maternal obesity before and during pregnancy • Gestational diabetes mellitus • Excessive gestational weight gain • Maternal smoking and alcohol use
 Infant Feeding Factors	Early feeding practices that may affect growth and metabolism.	• Lack of breastfeeding or short duration • Formula feeding with high protein content • Overfeeding and large portion sizes • Inappropriate use of energy-dense supplements
 Dietary Factors	Unhealthy eating patterns that increase energy intake.	• High intake of energy-dense foods • Sugar-sweetened beverages and juices • High consumption of fast foods and snacks • Low intake of fruits, vegetables and whole grains
 Lifestyle Factors	Physical inactivity and sedentary behaviors that reduce energy expenditure.	• Sedentary lifestyle and low physical activity • Excessive screen time (TV, computer, mobile) • Reliance on motorized transport • Inadequate sleep duration
 Family Factors	Family-related influences that shape the child's environment and habits.	• Parental obesity and genetic predisposition • Unhealthy family dietary habits • Lack of family meals together • Limited parental support for physical activity
 Environmental Factors	External environment that affects food choices and physical activity opportunities.	• Urbanization and sedentary lifestyle environment • Easy availability of unhealthy foods • Unsafe neighborhoods limiting outdoor play • Marketing and advertising of unhealthy foods
 Biological Factors	Biological and metabolic factors that influence fat storage and energy balance.	• Genetic susceptibility • Hormonal and metabolic influences • Altered gut microbiota • Early life metabolic programming

4. Early Nutritional Programming and Metabolic Health

The concept of Developmental Origins of Health and Disease (DOHaD) proposes that nutritional and environmental exposures during early life may have lasting effects on growth, metabolism, and disease susceptibility. The first 1,000 days of life, extending from conception to approximately two years of age, represent a particularly critical period for metabolic programming.

Both undernutrition and excessive nutrient exposure during this developmental window may influence future obesity risk. Early nutritional experiences can affect appetite regulation, body composition, insulin sensitivity, and long-term cardiometabolic health through complex hormonal and epigenetic mechanisms.

4.1 Breastfeeding and Obesity Prevention

Breastfeeding is widely recognized as the optimal source of infant nutrition. Human milk provides not only essential nutrients but also bioactive substances, including hormones, growth factors, and immunological components that support healthy growth and development.

Several observational studies and meta-analyses suggest that breastfeeding may confer modest protection against later obesity. Proposed mechanisms include improved self-regulation of energy intake, lower protein exposure compared with some infant formulas, favorable modulation of the gut microbiome, and exposure to hormones such as leptin and adiponectin.

Nevertheless, breastfeeding alone cannot completely prevent obesity because genetic predisposition, family lifestyle, dietary habits, and environmental influences also play substantial roles.

4.2 Formula Feeding and Infant Growth Patterns

Infant formula remains an important and safe nutritional alternative when breastfeeding is unavailable or insufficient. However, studies have demonstrated differences in growth trajectories between breastfed and formula-fed infants.

The "early protein hypothesis" suggests that higher protein intake during infancy may stimulate increased insulin and insulin-like growth factor-1 (IGF-1) secretion, potentially promoting accelerated weight gain and adiposity.

The objective should not be to discourage formula use but rather to ensure appropriate formula selection, responsive feeding practices, and careful monitoring of growth patterns.

4.3 Prematurity, NICU Nutrition, and Metabolic Programming

Preterm infants represent a particularly vulnerable population because premature birth interrupts normal fetal nutrient accretion during the third trimester. Consequently, specialized nutritional support is often necessary during neonatal intensive care unit (NICU) admission.

Nutritional interventions commonly include parenteral nutrition, mother's own milk, donor human milk, human milk fortification, preterm formulas, and Ready-to-Feed (RTF) formulations. These strategies are essential for preventing postnatal growth restriction and supporting neurodevelopment. Although catch-up growth is desirable in many preterm infants, excessively rapid weight gain, particularly when characterized by disproportionate fat accumulation, may increase future risk of obesity, insulin resistance, and cardiovascular disease.

4.4 Hormonal and Biological Mechanisms

Several biological mechanisms may explain the relationship between early nutrition and later obesity. Leptin plays a central role in appetite regulation and energy homeostasis. Alterations in early leptin exposure may influence satiety responses and future eating behaviors.

Ghrelin, often described as the "hunger hormone," regulates appetite and energy balance. Early feeding experiences may modify ghrelin responses and appetite regulation.

Insulin and IGF-1 are important mediators of growth. Excess nutrient intake during critical developmental periods may increase adipocyte differentiation and fat deposition.

Emerging evidence also suggests that epigenetic modifications induced by early nutritional exposures may influence gene expression and long-term metabolic outcomes.

Overall, early-life nutrition should aim to promote healthy body composition and optimal neurodevelopment rather than simply maximizing weight gain.

Figure 2. Early Nutritional Programming and Long-Term Metabolic Outcomes

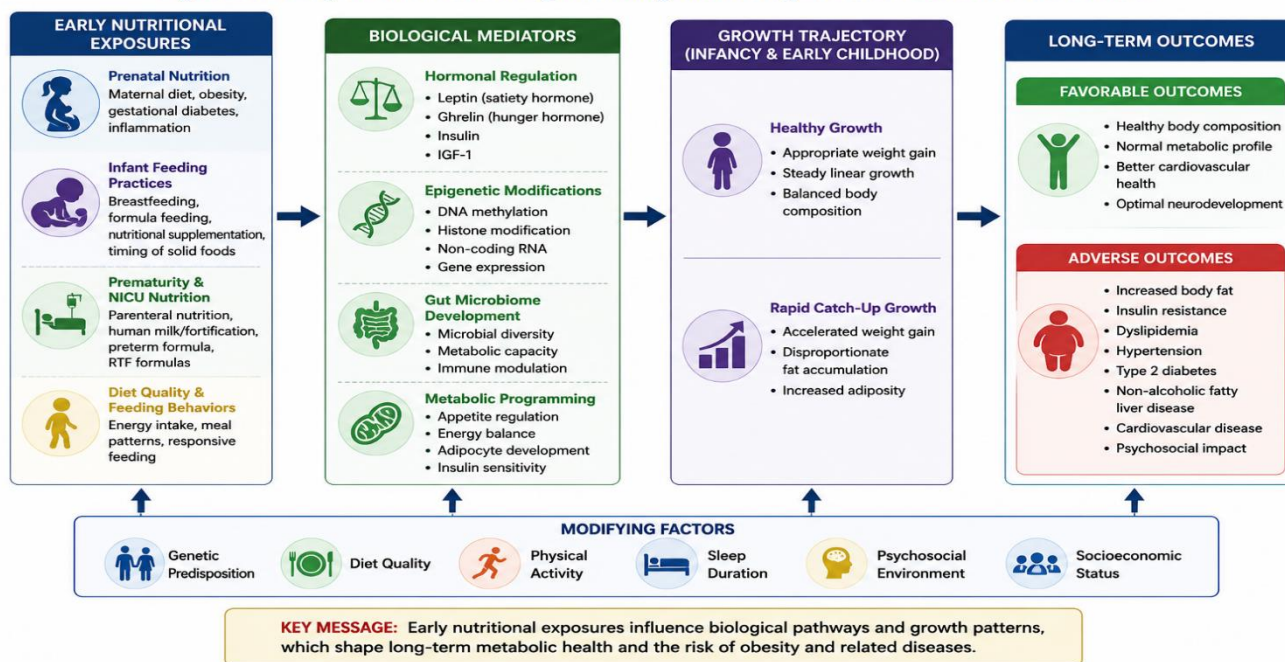


TABLE 2. Comparison of Early Feeding Approaches and Potential Long-Term Implications

Feeding Approach	Description	Key Nutritional Components or Features	Major Benefits	Potential Long-Term Implications
 1. Breastfeeding	Feeding with mother's own milk (exclusive or predominant).	- Optimal balance of macronutrients - Bioactive factors (hormones, enzymes, antibodies) - Human milk oligosaccharides - Lower protein content	- Optimal nutrition and hydration - Immune protection - Supports gut microbiome development - Enhances cognitive development - Promotes mother-infant bonding	- Associated with modestly reduced risk of obesity - Better metabolic programming - Lower risk of infections and some chronic diseases
 2. Standard Infant Formula	Commercial formula designed for full-term infants when breastfeeding is not available or insufficient.	- Balanced macronutrients - Added vitamins and minerals - Higher protein content compared with human milk - Fortified with DHA/ARA in many formulas	- Provides complete nutrition - Safe and convenient alternative - Supports normal growth when used appropriately - Allows shared feeding responsibilities	- Overfeeding and high protein intake may be associated with rapid weight gain - May increase risk of overweight/obesity if overconsumed
 3. Human Milk Fortification	Addition of nutrients (protein, minerals, calories) to human milk, mainly for preterm infants.	- Additional protein, calories - Calcium, phosphorus, zinc, vitamins (A, D, E, K, etc.) - Tailored to preterm needs	- Improves growth in preterm infants - Enhances bone mineralization - Supports neurodevelopment - Allows use of human milk as primary feed	- Appropriate fortification is safe and beneficial - Excessive fortification may contribute to excessive weight gain; requires monitoring
 4. Preterm Formulas / RTF Feeding	Specialized formulas (ready-to-feed or powder) designed for preterm infants when maternal/donor milk is unavailable or insufficient.	- Higher protein and energy - Enriched with minerals (Ca, P, Fe, Zn) - DHA/ARA - Tailored osmolality and nutrient density	- Supports catch-up growth - Meets high nutrient requirements - Convenient and sterile (RTF) - Supports brain and organ development	- Essential for growth but requires regular reassessment - Prolonged use beyond need may increase fat accumulation and obesity risk
 5. Oral Nutritional Supplements	Energy- and nutrient-dense supplements (e.g., Pediasure®, other pediatric products).	- High calories - Protein, carbohydrates, fats - Vitamins and minerals - May contain prebiotics/probiotics	- Improves caloric intake - Supports growth in undernourished children - Useful in chronic illness, recovery, or feeding problems	- Unnecessary use in healthy children may increase total energy intake - Potential risk of excessive weight gain and obesity
 6. Complementary Foods (Healthy Weaning Diet)	Introduction of solid or semi-solid foods along with breast milk or formula at the appropriate age.	- Variety of nutrient-dense foods - Iron-rich foods - Fruits, vegetables, whole grains - Healthy fats	- Provides balanced nutrition - Supports linear growth and immune health - Promotes healthy eating habits	- Healthy dietary patterns support normal growth and lower obesity risk - Poor diet quality increases obesity risk

Key Point: Early feeding practices should be individualized. The goal is healthy growth, optimal development, and long-term metabolic health—not simply maximizing weight gain.

5. Nutritional Supplementation in Early Childhood: Benefits, Challenges, And the Potential Risk Of Excess Weight Gain

Nutritional supplementation has become an integral component of pediatric nutritional management, particularly among children with faltering growth, chronic illnesses, feeding

disorders, or increased metabolic requirements. Commercial oral nutritional supplements, including PediaSure and similar formulations, are widely used in pediatric practice to improve caloric intake, support growth, and enhance nutritional status.

While these products provide important therapeutic benefits in appropriately selected children, concerns have emerged regarding their indiscriminate use in healthy children with normal growth patterns. Consequently, clinicians must carefully balance the potential benefits of supplementation against the possible risk of excessive caloric intake and unhealthy weight gain.

5.1 Appropriate Clinical Indications for Nutritional Supplementation

Oral nutritional supplements may be indicated in several pediatric situations, including:

- Failure to thrive or persistent growth faltering.
- Chronic diseases associated with increased energy requirements, such as congenital heart disease, chronic respiratory disorders, or malignancy.
- Feeding difficulties, oral aversion, and selective eating disorders.
- Gastrointestinal disorders associated with malabsorption.
- Recovery following prolonged hospitalization or severe illness.
- Selected premature infants and NICU graduates demonstrating inadequate post-discharge growth. In such circumstances, supplementation should be regarded as a therapeutic intervention with clearly defined objectives and duration.

5.2 Unnecessary Supplementation in Healthy Children

A growing concern in contemporary pediatric practice is the use of high-calorie nutritional supplements in children who are already growing normally. Parents frequently request these products because of concerns regarding poor appetite, selective eating, or perceived inadequate body size. However, appetite fluctuations are common during infancy and early childhood and do not necessarily indicate nutritional deficiency. Healthy children often exhibit variable food intake depending on developmental stage, activity level, and illness.

The routine uses of calorie-dense supplements in children without documented nutritional compromise may increase total energy intake beyond physiological requirements. Over time, this positive energy balance may contribute to excessive fat deposition and increased obesity risk.

5.3 Growth Monitoring: Beyond Body Weight Alone

Pediatric nutritional assessment should extend beyond simple weight measurement. Comprehensive evaluation includes:

- Weight and height measurements.
- Body mass index (BMI) assessment.
- Growth velocity monitoring.
- Dietary assessment.
- Evaluation of developmental progress.
- Assessment of body composition where feasible.

Children who consistently follow their individual growth trajectory may not require supplementation, even if they appear smaller than peers.

The objective of pediatric nutrition is to support healthy growth rather than to maximize body weight.

5.4 Lessons from Neonatal Follow-Up

Neonatal follow-up clinics provide valuable insight into individualized nutritional care. Preterm infants frequently require nutritional enhancement during early life to achieve catch-up growth and support neurodevelopment.

However, nutritional requirements evolve over time. Prolonged use of energy-enriched formulas or supplements without regular reassessment may result in disproportionate fat accumulation rather than healthy tissue growth.

Accordingly, ongoing clinical review is essential to determine whether nutritional interventions remain appropriate.

5.5 A Personalized Approach to Pediatric Nutrition

Modern pediatric nutrition increasingly emphasizes individualized care. Decisions regarding nutritional supplementation should be based upon:

- Growth trajectory.
- Medical history.
- Nutritional assessment.
- Family feeding practices.
- Developmental status.
- Long-term health objectives.

Supplementation should always be accompanied by periodic reassessment and discontinuation when therapeutic goals have been achieved.

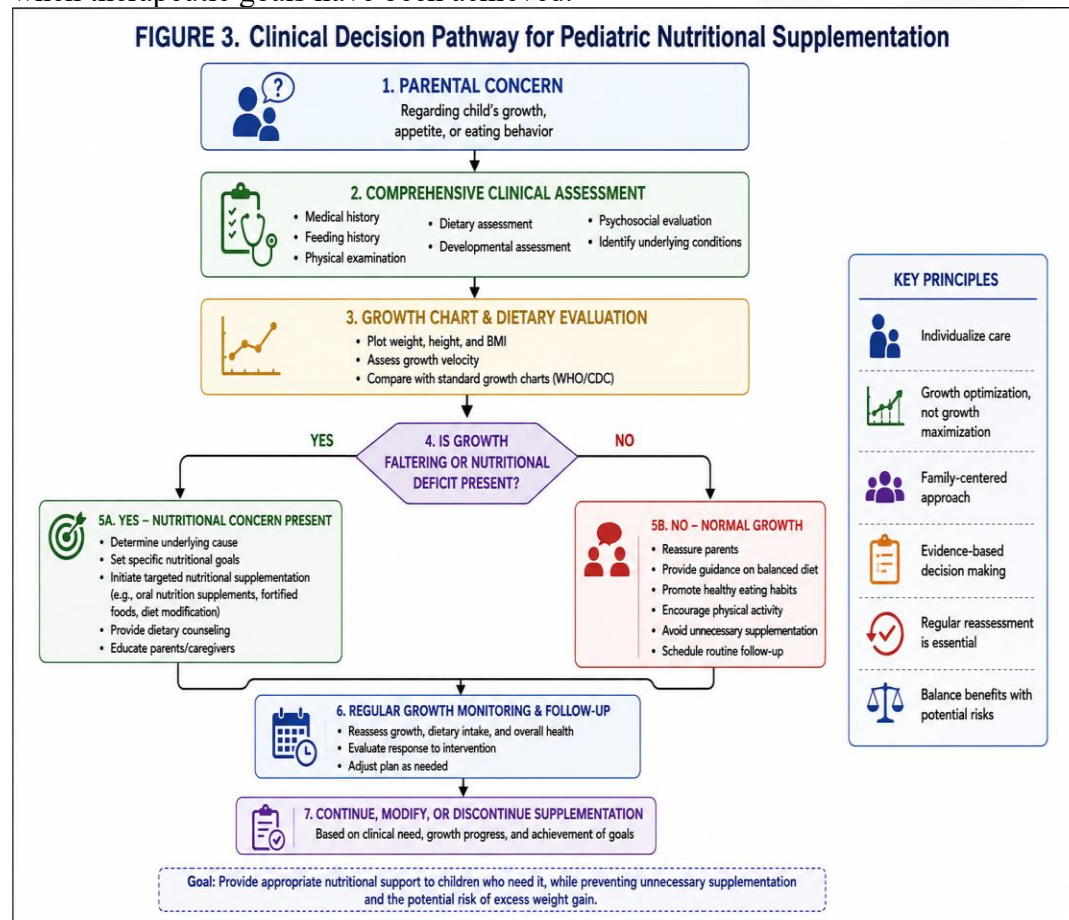


TABLE 3. Common Nutritional Supplements in Pediatrics: Uses, Benefits, and Potential Risks

Supplement Type	Common Examples	Primary Uses / Indications	Potential Benefits	Potential Risks if Unnecessary or Excessive
 1. Oral Nutritional Supplements	- PediaSure® - Pediasure® Grow & Gain - Ensure® Kids - Boost® Kids Essentials	- Poor weight gain - Under nutrition - Chronic illness - Feeding difficulties - Increased nutritional needs	- Increases caloric and nutrient intake - Supports weight gain - Improves micronutrient intake - Supports growth and recovery	- Excess calorie intake - Rapid weight gain - Increased risk of overweight and obesity - Dental caries - Displacement of healthy foods
 2. Infant Formulas	- Standard cow's milk formula - Partially hydrolyzed formula - Extensively hydrolyzed formula - Amino acid-based formula - Soy-based formula	- Infants not breastfed - Growth support - Cow's milk protein allergy - Lactose intolerance - Specific metabolic disorders	- Provides complete nutrition - Supports growth and development - Convenient and safe alternative when needed	- Overfeeding - High protein intake may promote rapid weight gain - Increased risk of obesity if intake exceeds needs
 3. Vitamins	- Vitamin D - Vitamin A - Vitamin C - B-complex vitamins	- Prevention or treatment of deficiency - Specific medical conditions - Increased needs (e.g., prematurity)	- Supports bone health - Enhances immunity - Supports growth and development - Important for metabolism	- Fat-soluble vitamin toxicity (A, D, E, K) - Gastrointestinal upset - Interactions with medications
 4. Minerals	- Iron - Calcium - Zinc - Magnesium	- Treatment/prevention of deficiency - Anemia - Bone health - Immune function - Growth support	- Iron: prevents/treats anemia - Calcium: supports bone development - Zinc: supports immunity and growth - Magnesium: supports neuromuscular function	- Gastrointestinal symptoms - Iron overload - Interference with absorption of other minerals
 5. Probiotics	- Lactobacillus spp. - Bifidobacterium spp. - Saccharomyces boulardii	- Diarrhea (acute or antibiotic-associated) - Irritable bowel symptoms - Immune modulation	- Improves gut microbiota balance - Reduces duration of diarrhea - Supports digestive health	- Generally safe - Rare infections in severely immunocompromised patients - Bloating or gas
 6. Omega-3 Fatty Acids	- Fish oil - DHA supplements - EPA supplements	- Cognitive development - Visual development - Inflammatory conditions	- Supports brain and eye development - May reduce inflammation - Supports cardiovascular health	- Fishy aftertaste - Gastrointestinal discomfort - High doses may affect bleeding risk
 7. Herbal / Other Supplements	- Multivitamin syrups - Appetite stimulants (herbal) - Others (varies)	- Poor appetite - General health support - Cultural or traditional use	- May improve appetite - Provides additional nutrients (if indicated)	- Limited scientific evidence - Possible side effects - Risk of contamination or interactions

6. NICU Nutritional Practices, Ready-To-Feed (Rtf) Formulas, And Long-Term Growth Outcomes

The nutritional management of preterm and critically ill neonates is a cornerstone of modern neonatal care. Premature infants are born with limited nutrient reserves and increased nutritional requirements, necessitating specialized nutritional support during hospitalization.

Advances in neonatal nutrition have contributed substantially to improved survival and neurodevelopmental outcomes among preterm infants. However, attention has increasingly shifted from merely achieving rapid weight gain toward promoting healthy body composition and favorable long-term metabolic health.

6.1 Early Nutritional Strategies in the NICU

Nutritional support in the NICU commonly includes:

- Parenteral nutrition.
- Mother's own breast milk.
- Donor human milk.
- Human milk fortification.
- Specialized preterm formulas.
- Ready-to-Feed (RTF) formulations.

The objective is to prevent postnatal growth restriction while supporting neurodevelopment and organ maturation.

6.2 Ready-to-Feed (RTF) Formulas in Neonatal Practice

Ready-to-Feed formulas provide sterile, standardized nutritional support and reduce the risk of contamination associated with powdered formula preparation.

RTF products are particularly useful for medically fragile infants when maternal breast milk is unavailable or insufficient. Their use should be considered part of evidence-based neonatal nutritional care rather than a contributor to later obesity.

6.3 Human Milk Fortification

Human milk remains the preferred enteral nutrition for preterm infants. Nevertheless, very preterm infants frequently require additional protein, minerals, and calories to meet their nutritional needs. Human milk fortifiers improve growth, bone mineralization, and neurodevelopmental outcomes. Fortification strategies should be individualized according to gestational age, growth pattern, and clinical condition.

6.4 Post-Discharge Nutrition and Catch-Up Growth

Many NICU graduates continue to require nutritional support following hospital discharge. Post-discharge formulas and energy-enriched feeding regimens may benefit selected infants with persistent growth restriction.

However, prolonged use without reassessment may contribute to excessive adiposity. Therefore, regular follow-up evaluating weight, length, head circumference, and developmental progress is essential.

6.5 Growth Optimization Rather Than Growth Maximization

Modern neonatal nutrition emphasizes growth optimization rather than growth maximization. Healthy growth includes:

- Appropriate weight gain.
- Adequate linear growth.
- Favorable body composition.
- Optimal neurodevelopment.

Nutritional strategies should therefore promote balanced growth rather than simply increasing body weight.

FIGURE 4. Nutritional Management Pathway for Preterm Infants to Promote Healthy Growth and Minimize Obesity Risk

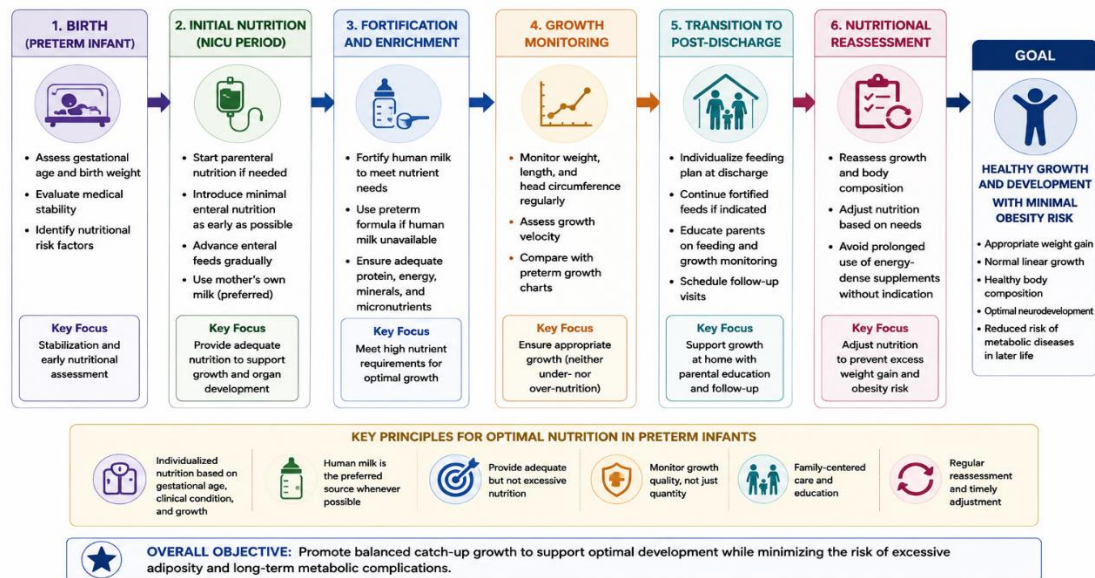


TABLE 4. Key Strategies for Preventing Childhood Obesity: Focus on Early Nutrition

Strategy Area	Key Strategies	Focus in Early Nutrition (0–2 Years)	Expected Benefits	Implementation Considerations	Key Stakeholders
1. Promote Breastfeeding	- Initiate early - Exclusive breastfeeding for 6 months - Continue with complementary foods up to 2 years or beyond	- Colostrum and exclusive breastfeeding - Responsive breastfeeding - Support continuation during illness and maternal return to work	- Lower risk of obesity - Better appetite regulation - Improved metabolic programming - Enhanced immune protection	- Baby-friendly hospital practices - Lactation support services - Community breastfeeding support - Maternity leave policies	- Parents and caregivers - Healthcare providers - Employers - Policy makers - Community organizations
2. Support Healthy Complementary Feeding	- Timely introduction (6 months) - Nutrient-dense, age-appropriate foods - Avoid added sugars, salt, and ultra-processed foods	- Introduce variety of fruits, vegetables, whole grains, and proteins - Encourage self-feeding and texture progression - Respect hunger and fullness cues	- Healthy growth trajectory - Better taste preferences - Reduced risk of obesity and metabolic diseases - Improved digestion and micronutrient status	- Caregiver education - Culturally appropriate guidance - Food safety practices - Access to healthy foods	- Parents and caregivers - Nutritionists/dietitians - Pediatricians - Public health agencies - Food industry
3. Avoid Overnutrition in Infancy	- Avoid excessive calorie intake - Prevent rapid weight gain - Follow appropriate formula preparation	- Avoid overfeeding - Use lower-protein formulas when appropriate - Monitor growth regularly	- Prevents excessive adiposity - Reduces risk of childhood obesity - Supports healthy metabolic programming	- Educate on feeding cues - Proper formula mixing - Regular growth monitoring - Avoid use of food as reward	- Parents and caregivers - Healthcare providers - Formula manufacturers - Public health agencies
4. Encourage Physical Activity and Active Play	- Promote daily movement - Limit sedentary time - Encourage motor skill development	- Tummy time - Free play - Active play appropriate for age	- Healthy weight maintenance - Improved motor development - Better bone and muscle development - Positive behavioral outcomes	- Safe play environments - Limit screen exposure - Parental role modeling - Community spaces for play	- Parents and caregivers - Early childhood educators - Community planners - Policy makers
5. Promote Adequate Sleep	- Establish healthy sleep routines - Ensure adequate sleep duration	- Age-appropriate sleep duration - Consistent bedtime routine - Sleep-friendly environment	- Regulates appetite hormones - Supports healthy growth - Reduces risk of obesity - Improves cognitive function	- Caregiver education - Consistent daily routines - Limit nighttime feeding as age-appropriate	- Parents and caregivers - Healthcare providers - Sleep specialists - Public health agencies
6. Create a Supportive Environment	- Family-based healthy eating habits - Limit marketing of unhealthy foods - Socioeconomic support	- Builds lifelong healthy habits - Limit availability of sugary snacks/beverages - Ensure food security	- Reduces obesity risk - Supports overall well-being - Promotes equity in health	- Nutrition education programs - Regulation of child food marketing - Policies to reduce poverty and improve access to healthy foods	- Families - Schools and childcare centers - Government agencies - NGOs and community groups
OVERALL GOAL: Establish healthy nutritional patterns and supportive environments in early life to promote optimal growth and development and reduce the risk of obesity and chronic diseases across the lifespan.					

7. Current Evidence Linking Early Nutritional Supplementation and Childhood Obesity

The relationship between early nutritional supplementation and later obesity remains complex and multifactorial. Current evidence does not support the notion that any single nutritional product is

solely responsible for childhood obesity. Instead, obesity develops through interactions among genetic susceptibility, prenatal influences, early nutritional exposures, family lifestyle, dietary habits, physical activity, and environmental factors.

7.1 Rapid Infant Weight Gain and Future Obesity Risk

One of the most consistently reported findings in pediatric nutrition research is the association between rapid infant weight gain and subsequent obesity.

Rapid catch-up growth is often desirable among infants born small for gestational age, premature infants, and children recovering from severe illness or malnutrition. However, excessive catch-up growth characterized by disproportionate fat accumulation rather than lean tissue accretion may increase the risk of obesity, insulin resistance, hypertension, and metabolic syndrome later in life. Consequently, growth quality is increasingly considered as important as growth quantity.

7.2 Evidence Regarding Oral Nutritional Supplements

Commercial oral nutritional supplements, including PediaSure and similar products, have demonstrated clear benefits in children with documented undernutrition, chronic illnesses, feeding difficulties, and increased metabolic demands.

Studies have shown improvements in caloric intake, weight gain, and, in some cases, linear growth among appropriately selected children receiving supplementation under medical supervision.

Concerns arise when these products are used routinely in healthy children with normal growth patterns. Long-term use without clinical indication may contribute to excessive caloric intake, particularly when supplements are added to an already adequate diet.

At present, evidence directly linking oral nutritional supplements to obesity in healthy children remains limited. Nevertheless, clinicians should adopt an individualized and cautious approach.

7.3 Formula Feeding and the Early Protein Hypothesis

The "early protein hypothesis" proposes that excessive protein intake during infancy may stimulate insulin and insulin-like growth factor-1 (IGF-1) secretion, promoting accelerated growth and adipogenesis. Randomized studies have demonstrated that lower-protein infant formulas may be associated with slower early weight gain and lower obesity risk compared with higher-protein formulas. Importantly, infant formula remains a safe and essential nutritional option when breastfeeding is not possible. The emphasis should be placed on appropriate formula use, responsive feeding practices, and regular growth assessment.

7.4 Evidence from Preterm and NICU Populations

Preterm infants present unique nutritional challenges. Inadequate nutrition may adversely affect neurodevelopment and survival, whereas excessive nutritional exposure may increase future cardiometabolic risk. Current evidence supports adequate nutritional support for premature infants, including the use of human milk fortification, preterm formulas, and RTF formulations when clinically indicated. Restricting appropriate neonatal nutrition because of concerns regarding future obesity is not recommended. Rather, careful post-discharge monitoring and individualized nutritional adjustment remain the preferred approach.

7.5 Family Feeding Behaviors and Cultural Influences

Family feeding practices strongly influence childhood eating behaviors and growth patterns.

In many societies, including Saudi Arabia, larger body size may still be viewed as a marker of good health and successful parenting. Consequently, parents may seek nutritional supplements for children who are naturally lean but growing normally.

Other important contributors include:

- Frequent consumption of energy-dense foods.
- Sugar-sweetened beverages.
- Reduced physical activity.
- Excessive screen exposure.
- Inadequate sleep duration.

Parental education therefore represents an essential component of childhood obesity prevention.

7.6 Current Clinical Perspective

Current evidence supports an individualized approach to pediatric nutritional supplementation.

Healthcare providers should:

- Assess growth trajectory carefully.
- Evaluate dietary intake comprehensively.
- Identify underlying medical conditions.
- Define specific therapeutic goals.
- Monitor treatment response regularly.

Nutritional supplements should be viewed as therapeutic nutritional tools rather than routine beverages for all children.

FIGURE 5. Pathways Linking Early Nutrition to Later Risk of Obesity and Chronic Diseases

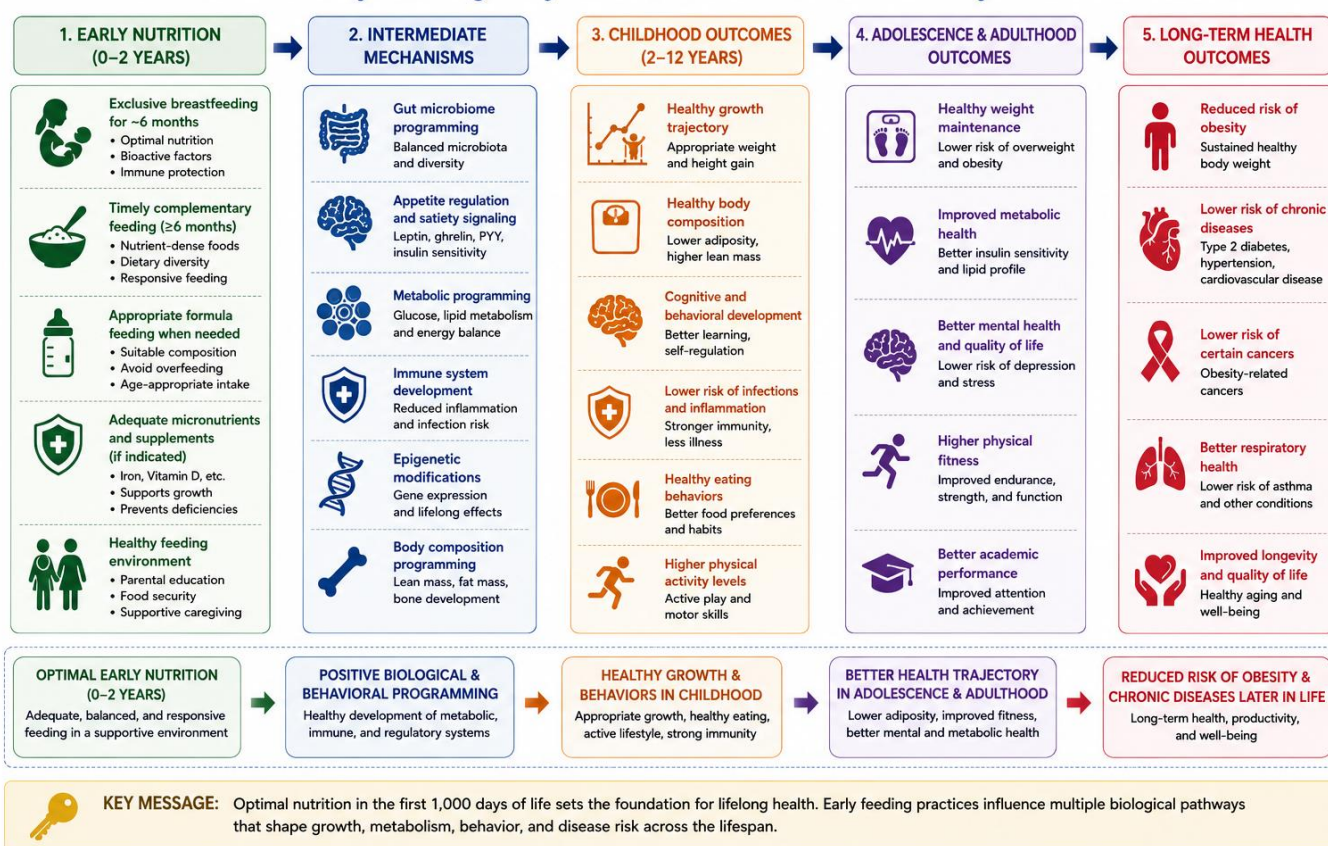


TABLE 5. Stakeholder Roles and Responsibilities in Nutrition-Driven Childhood Obesity Prevention

Stakeholder Group	Key Roles	Specific Responsibilities	Key Actions Related to Early Nutrition	Expected Contributions to Obesity Prevention	Potential Challenges	Enablers / Support Needed
 1. Parents and Caregivers	Primary decision-makers and daily influencers of children's nutrition and lifestyle	- Provide appropriate foods - Practice responsive feeding - Create healthy home environment - Monitor growth and development - Seek health guidance	- Breastfeed exclusively for 6 months - Introduce complementary foods appropriately at 6 months - Offer nutrient-dense, varied diets - Limit sugary drinks and ultra-processed foods - Model healthy eating behaviors	- Healthy growth trajectories - Reduced overnutrition and rapid weight gain - Establishment of lifelong healthy eating habits	- Limited nutrition knowledge - Time and financial constraints - Aggressive marketing of unhealthy foods - Cultural beliefs and myths	- Nutrition education - Access to healthy foods - Parental leave and time support - Social and community support
 2. Healthcare Providers	Advisors, educators, monitors, and advocates for child nutrition and growth	- Assess growth and nutritional status - Provide counseling and education - Screen for risk factors - Recommend appropriate interventions - Coordinate care and referrals	- Promote and support breastfeeding - Guide timely complementary feeding - Counsel on feeding practices and portion sizes - Monitor growth patterns regularly - Address micronutrient deficiencies	- Early identification of risks - Timely interventions - Prevention of overnutrition and deficiencies - Improved health outcomes	- Limited time during visits - Insufficient training - High patient load - Resource constraints	- Training and capacity building - Clinical guidelines and tools - Adequate resources - Strong referral networks
 3. Policy Makers and Government Agencies	Developers of policies, systems, and environments that support healthy nutrition	- Develop nutrition policies - Regulate food environment - Allocate resources - Monitor and evaluate programs - Ensure equity in access	- Enact and enforce codes for marketing to children - Support breastfeeding policies - Fortify staple foods - Fund nutrition programs - Improve food labeling standards	- Healthier food environments - Increased access to nutritious foods - Population-level reduction in obesity risk	- Competing political and economic priorities - Industry lobbying - Limited budgets - Weak enforcement	- Strong political will - Intersectoral collaboration - Sustainable funding - Evidence-based policies
 4. Educators and Schools	Promoters of nutrition education and healthy behaviors in children	- Provide nutrition education - Ensure healthy school meals - Promote physical activity - Create supportive school environments - Engage parents	- Teach healthy eating habits - Provide fruit and vegetables in meals - Limit sugary drinks and snacks - Encourage active play - Support school gardens	- Improved knowledge and skills - Healthier food choices - Increased physical activity - Healthy weight maintenance	- Limited curriculum time - Budget constraints - Availability of unhealthy foods near schools - Varying levels of parental involvement	- Nutrition education resources - Healthy food policies - Trained staff - Partnerships with families and communities
 5. Food Industry	Producers and marketers of foods that influence diets and food environments	- Produce safe, nutritious foods - Reformulate products - Market responsibly - Provide clear labeling - Support public health initiatives	- Reduce sugar, salt, and unhealthy fats in products - Offer affordable, nutritious options for children - Avoid marketing unhealthy foods to young children - Support breastfeeding-friendly workplaces	- Healthier food supply - Reduced exposure to unhealthy marketing - Support for healthier consumer choices	- Profit motives and competition - Resistance to regulation - Marketing pressures - Reformulation costs	- Clear regulations - Incentives for reformulation - Public-private partnerships - Consumer demand for healthy foods
 6. Community and Civil Society Organizations	Mobilizers, advocates, and supporters of community-based nutrition actions	- Raise awareness - Provide support services - Advocate for healthy environments - Monitor community needs - Promote equity and inclusion	- Run breastfeeding support groups - Implement community nutrition programs - Educate on healthy feeding - Advocate for safe play spaces - Support vulnerable families	- Increased community awareness - Improved access to support - Empowered families - Healthier communities	- Limited funding - Volunteer burnout - Coordination difficulties - Reach to marginalized groups	- Sustainable funding - Capacity building - Strong partnerships - Community engagement platforms



OVERALL GOAL: Through coordinated roles and strengthened collaboration, all stakeholders can create supportive environments and practices that promote optimal early nutrition, prevent obesity, and support lifelong health for children.

8. Discussion

The present review highlights the complexity of balancing nutritional support and obesity prevention during infancy and early childhood. The available evidence suggests that early nutritional exposures have important implications for long-term metabolic health. Rapid infant weight gain, prolonged use of energy-dense supplementation in children with normal growth, and excessive catch-up growth following prematurity may increase susceptibility to later obesity and cardiometabolic disease.

Nevertheless, nutritional supplementation remains beneficial and, in many circumstances, essential for children with documented undernutrition, chronic illnesses, feeding difficulties, or increased metabolic demands. The challenge for pediatricians is therefore not to avoid nutritional supplementation, but to ensure that supplementation is used appropriately, individualized to the child's needs, and regularly reassessed.

One of the major themes emerging from this review is the concept of growth optimization rather than growth maximization. Historically, pediatric nutrition focused primarily on achieving rapid weight gain. Contemporary evidence, however, emphasizes that healthy growth should include appropriate body composition, adequate linear growth, favorable neurodevelopment, and long-term metabolic health.

This issue is particularly relevant in Saudi Arabia, where rising rates of childhood obesity coexist with persistent undernutrition among medically vulnerable children. In this setting, healthcare

providers must simultaneously address two nutritional challenges: preventing obesity in the general population while supporting growth in infants and children with genuine nutritional deficits. The neonatal experience offers an important model for individualized nutritional care. During NICU admission, enhanced nutritional strategies such as human milk fortification, specialized preterm formulas, and RTF products are essential to prevent postnatal growth restriction and support neurodevelopment. However, these interventions should not continue indefinitely without reassessment. Parental perceptions also deserve consideration. In many families, a heavier child is often viewed as healthier, leading to unnecessary use of nutritional supplements. Educational interventions should therefore emphasize that healthy growth is determined by appropriate growth velocity, balanced nutrition, physical activity, and overall well-being rather than body weight alone.

Overall, current evidence supports individualized nutritional assessment, regular growth monitoring, parental counseling, and evidence-based nutritional interventions as the cornerstone of pediatric nutritional practice.

FIGURE 6. Conceptual Framework: From Early Nutrition Interventions to Lifelong Health Outcomes

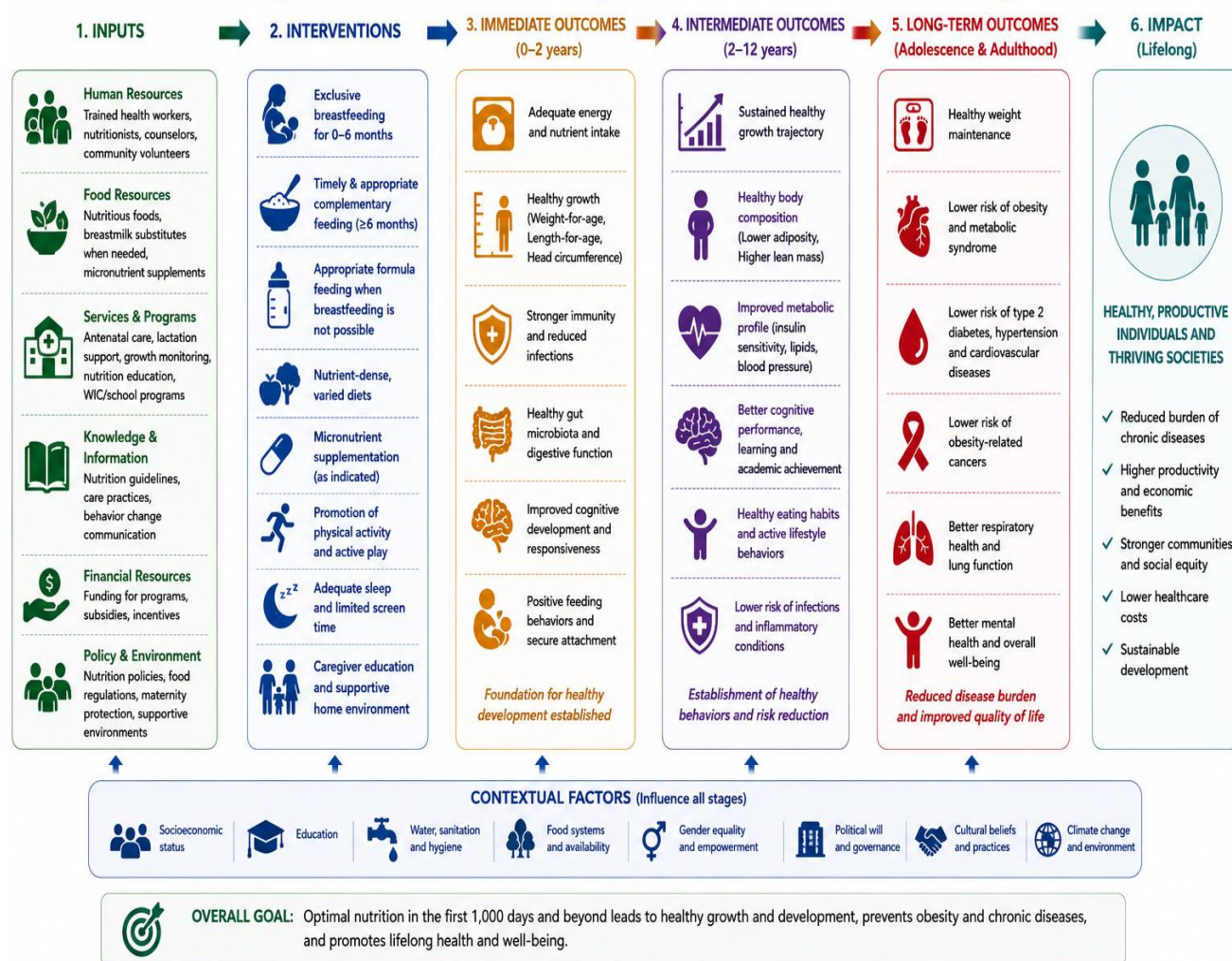


TABLE 6. Major Clinical Challenges and Recommended Approaches

Clinical Challenge	Recommended Approach
Parent concern regarding poor appetite	Evaluate growth charts before recommending supplements
Naturally lean child with normal growth	Reassure parents and monitor growth
Child with failure to thrive	Consider targeted supplementation
Preterm infant after NICU discharge	Individualize nutritional management
Long-term use of supplements	Review indication regularly
Rapid increase in BMI percentile	Assess dietary intake and lifestyle
Misconceptions regarding body size	Provide parental education

9. Clinical Recommendations For Pediatricians, Neonatologists, And Parents

Translating scientific evidence into routine clinical practice is essential to achieving the optimal balance between promoting healthy growth and preventing childhood obesity. Nutritional supplements should be considered therapeutic interventions rather than routine dietary additions.

9.1 Recommendations for Pediatricians and Primary Healthcare Providers

Pediatricians frequently encounter parental concerns regarding poor appetite, selective eating, or inadequate weight gain. Before recommending nutritional supplementation, a comprehensive clinical assessment should be undertaken.

Assessment should include:

- Accurate measurement of weight, height, and BMI.
- Review of growth trajectory using standardized growth charts.
- Detailed dietary assessment.
- Evaluation of feeding behaviors and mealtime practices.
- Assessment of underlying medical conditions.
- Consideration of developmental and psychosocial factors.

Nutritional supplementation should only be initiated when clear clinical indications exist.

9.2 Recommendations for Neonatologists and NICU Follow-Up Clinics

Preterm infants and NICU graduates require individualized nutritional strategies because of their unique nutritional requirements.

Key recommendations include:

- Regular assessment of weight, length, and head circumference.
 - Periodic reassessment of the need for energy-enriched formulas.
 - Promotion and support of breastfeeding whenever possible.
 - Evaluation of body composition and growth quality.
 - Timely transition from specialized nutritional support when clinically appropriate.
- Balanced catch-up growth should remain the primary objective.

9.3 Recommendations for Parents and Caregivers

Parents should be encouraged to:

- Attend regular pediatric growth monitoring visits.
- Offer balanced family meals.
- Avoid forcing children to eat.
- Avoid unnecessary use of high-calorie nutritional supplements.
- Encourage daily physical activity.
- Limit sugar-sweetened beverages and processed foods.
- Restrict excessive screen time.

Families should understand that healthy children often exhibit natural variations in appetite and body size.

9.4 Public Health Considerations in Saudi Arabia

The increasing prevalence of childhood obesity in Saudi Arabia highlights the need for coordinated public health interventions.

Important strategies include:

- Strengthening breastfeeding promotion programs.
- Improving nutritional literacy among parents.
- Encouraging healthy school environments.
- Increasing opportunities for physical activity.
- Promoting early obesity prevention strategies through primary healthcare services.

9.5 Personalized Pediatric Nutrition

Future pediatric nutritional care should increasingly adopt a personalized approach based on:

- Birth history.
- Growth trajectory.
- Medical conditions.
- Family lifestyle.
- Nutritional status.
- Developmental progress.

The objective is to provide the right nutrition, for the right child, at the right time.

FIGURE 7. Clinical Decision Framework for Individualized Pediatric Nutritional Management

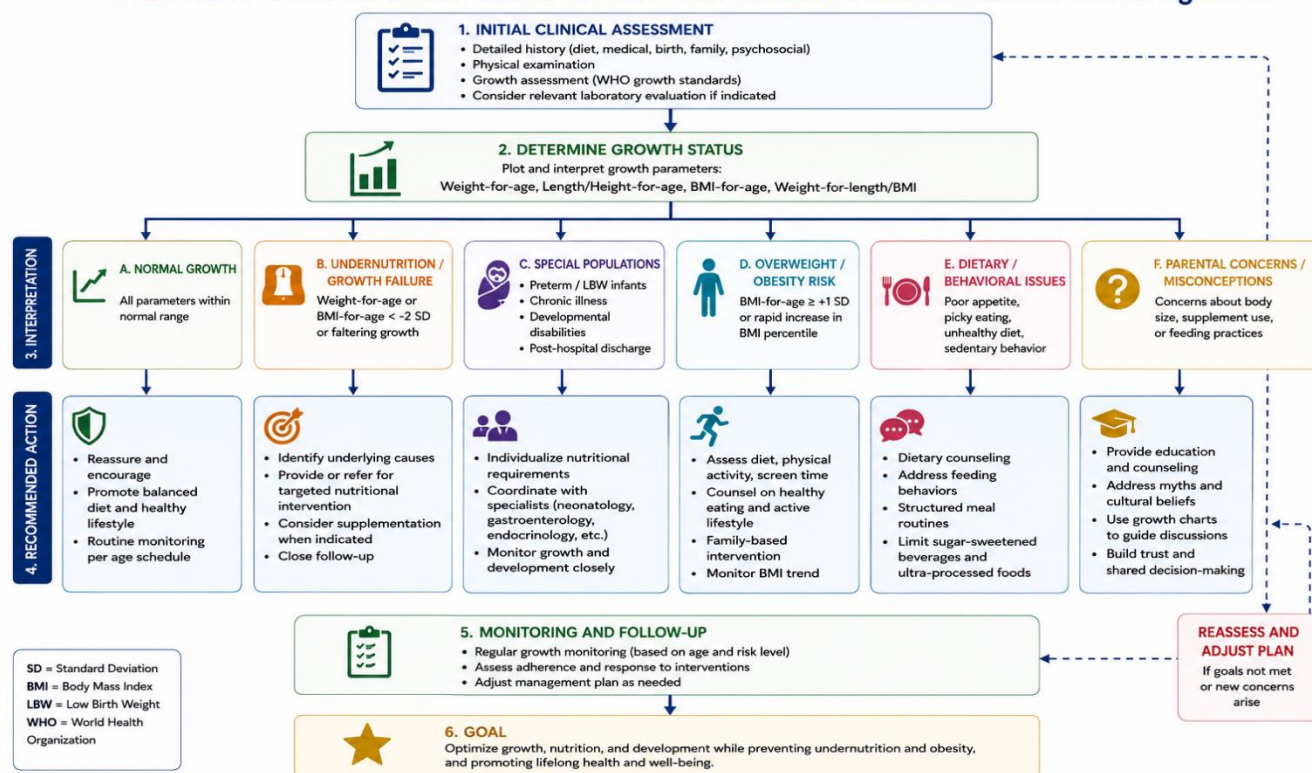


TABLE 7. Practical Clinical Guidance for Nutritional Supplementation

Clinical Situation	Recommended Approach
Failure to thrive	Targeted supplementation with close follow-up
Chronic illness	Individualized nutritional support
Feeding disorder	Multidisciplinary assessment
Healthy child with normal growth	Reassurance and dietary advice
Preterm infant	Individualized follow-up and nutritional reassessment
Long-term supplement use	Review need periodically

10. Future Research Directions

Despite significant advances in pediatric nutrition, several important questions remain unanswered.

Future research should focus on identifying nutritional strategies that optimize growth while minimizing obesity risk.

10.1 Long-Term Outcomes of Oral Nutritional Supplementation

Longitudinal studies are needed to determine the long-term metabolic effects of prolonged nutritional supplementation in healthy children and vulnerable pediatric populations.

10.2 Optimizing Nutrition in Preterm Infants

Future studies should determine how to promote adequate catch-up growth in preterm infants while avoiding excessive adiposity and adverse cardiometabolic outcomes.

10.3 Precision Nutrition

Emerging fields such as genomics, metabolomics, and microbiome science may enable individualized nutritional strategies tailored to each child's biological profile.

10.4 Research Priorities in Saudi Arabia

Additional Saudi-specific research is required to examine:

- Cultural feeding practices.
- Patterns of nutritional supplement use.
- Regional obesity trends.
- Family perceptions regarding child growth.

10.5 Digital Health Technologies

Artificial intelligence, telemedicine, and electronic growth-monitoring systems may improve early identification of children at risk of undernutrition or obesity.

10.6 Moving Beyond Weight Gain

Future research should prioritize healthy body composition, neurodevelopment, and lifelong metabolic health rather than focusing solely on weight gain.

FIGURE 8. Future Directions in Pediatric Nutritional Research

Traditional Focus on Weight Gain

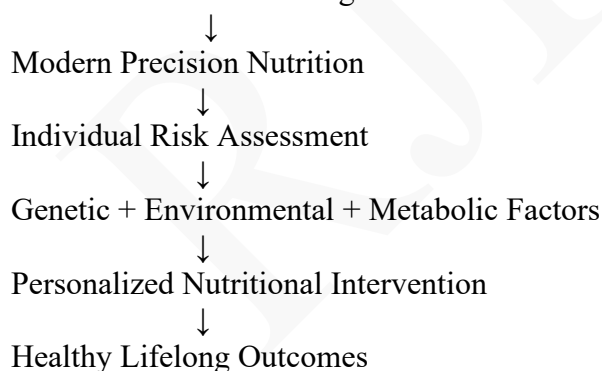


TABLE 8. Priority Areas for Future Research

Research Area	Future Need
Oral nutritional supplements	Long-term metabolic outcomes
Prematurity	Optimal catch-up growth strategies
Precision nutrition	Individualized nutritional interventions

Research Area	Future Need
Saudi Arabia	Epidemiological and behavioral studies
Digital health	AI-assisted growth monitoring
Microbiome research	Understanding metabolic programming

8.1 Limitations

This review has several limitations. First, because this study adopted a narrative review design, quantitative synthesis and meta-analysis were not performed. Second, the included studies were heterogeneous with respect to populations, nutritional interventions, and outcome measures, limiting direct comparison between studies. Third, publication bias and language bias may have influenced the available evidence. Finally, although Saudi Arabia was a major focus of this review, Saudi-specific data on long-term outcomes of pediatric nutritional supplementation remain limited. Nevertheless, the narrative approach enabled comprehensive discussion of clinically relevant issues surrounding childhood nutritional supplementation and obesity prevention.

11. Conclusion

Childhood obesity is a multifactorial disorder influenced by genetic, prenatal, nutritional, behavioral, environmental, and socioeconomic factors. No single nutritional product or feeding practice can be considered solely responsible for excessive weight gain.

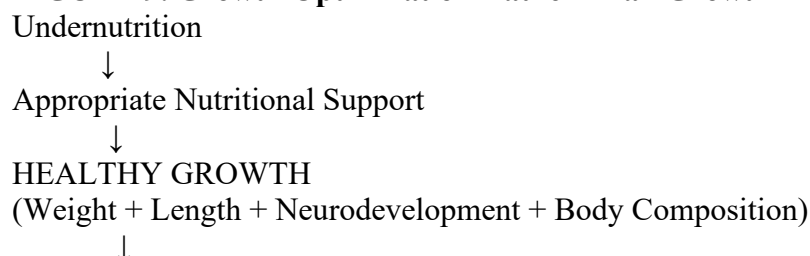
Nutritional supplementation continues to play an essential role in pediatric care, particularly among children with undernutrition, chronic illness, feeding difficulties, and increased nutritional requirements. However, nutritional interventions should always be individualized, evidence-based, and regularly reassessed. The findings of this review support the principle that pediatric nutrition should focus on **growth optimization rather than growth maximization**. Healthy growth encompasses appropriate weight gain, normal linear growth, favorable body composition, optimal neurodevelopment, and long-term metabolic health.

This principle is particularly relevant in Saudi Arabia, where childhood obesity coexists with undernutrition among vulnerable pediatric populations. Clinicians should therefore adopt a balanced approach that promotes healthy growth while minimizing unnecessary excess calorie exposure. Individualized assessment, regular growth monitoring, parental education, breastfeeding support, and evidence-based nutritional supplementation represent the cornerstones of modern pediatric nutritional practice.

Future advances in precision nutrition, microbiome science, and digital health technologies may further improve our ability to provide personalized nutritional care.

In conclusion, successful pediatric nutrition is not defined by how rapidly a child gains weight, but by how appropriately the child grows, develops, and achieves lifelong metabolic health.

FIGURE 9. Growth Optimization Rather Than Growth Maximization



Regular Monitoring



Long-Term Metabolic Health

FIGURE 10. Central Concept of Balanced Pediatric Nutrition

Nutritional Deficit



Individualized Assessment



Evidence-Based Intervention



Regular Reassessment



Healthy Growth and Development



Reduced Risk of Childhood Obesity

TABLE 9. Key Clinical Take-Home Messages

Key Message	Clinical Implication
 1. Growth is the best indicator of adequate nutrition.	Regular growth monitoring is essential and should guide clinical decisions.
 2. Balance is critical.	The goal is optimal growth—not just more weight gain or fear of obesity.
 3. Individualization is essential.	Nutritional management must be tailored to the child's age, health status, growth pattern, and context.
 4. Parental education and reassurance are powerful tools.	Address concerns, correct myths, and empower families to support healthy growth.
 5. Use evidence-based guidelines and growth standards.	Avoid unnecessary supplements and interventions; follow WHO growth standards.
 6. Promote healthy eating and active lifestyles early.	Establish healthy habits in infancy and early childhood to prevent future chronic diseases.
 7. Monitor, reassess, and adjust.	Reevaluate regularly and modify the plan as the child grows and circumstances change.
 8. Collaboration improves outcomes.	Work with families and other healthcare professionals for comprehensive care.
 9. Prevention of both undernutrition and obesity is a shared goal.	Ensure every child has the opportunity for healthy growth, development, and lifelong well-being.

Final Clinical Message

"Successful pediatric nutrition is not defined by how rapidly a child gains weight, but by how appropriately the child grows, develops, and achieves lifelong metabolic health."

Conflict of Interest

The author declares no conflict of interest.

Funding

No external funding was received for the preparation of this manuscript.

Ethical Approval

Ethical approval was not required for this narrative review because no human participants, patient data, or identifiable information were involved.

Data Availability Statement

No new data were generated or analyzed in this study.

Author Contributions

Dr. Atiqur Rahman Khan conceptualized the review, conducted the literature search, synthesized the evidence, drafted the manuscript, critically revised the content, and approved the final manuscript for publication.

Acknowledgments

The author acknowledges all researchers whose work contributed to the evidence discussed in this review.

References

- Agostoni, C., Buonocore, G., Carnielli, V. P., De Curtis, M., Darmaun, D., Decsi, T., Domellöf, M., Embleton, N. D., Fusch, C., Genzel-Boroviczeny, O., et al. (2010). Enteral nutrient supply for preterm infants: Commentary from the ESPGHAN Committee on Nutrition. *Journal of Pediatric Gastroenterology and Nutrition*, 50(1), 85–91. <https://doi.org/10.1097/MPG.0b013e3181adaee0>
- Al-Hussaini, A., Bashir, M. S., Khormi, M., AlTuraiiki, M., Alkhamis, W., Alrajhi, M., & Halal, T. (2019). Overweight and obesity among Saudi children and adolescents: Where do we stand today? *Saudi Journal of Gastroenterology*, 25(4), 229–235. https://doi.org/10.4103/sjg.SJG_617_18
- Alqarni, S. S. (2016). A review of prevalence of obesity in Saudi Arabia. *Journal of Obesity and Eating Disorders*, 2(2), 25.
- American Academy of Pediatrics. (2023). Clinical practice guideline for the evaluation and treatment of children and adolescents with obesity. *Pediatrics*, 151(2), e2022060640. <https://doi.org/10.1542/peds.2022-060640>
- Barker, D. J. P. (2004). The developmental origins of adult disease. *Journal of the American College of Nutrition*, 23(6 Suppl.), 588S–595S.
- Belfort, M. B., Gillman, M. W., Buka, S. L., Casey, P. H., McCormick, M. C., & Preterm Infant Growth Study Group. (2013). Infant growth before and after term: Effects on neurodevelopment and adiposity in preterm infants. *Pediatrics*, 132(4), e899–e905. <https://doi.org/10.1542/peds.2013-0007>
- Baird, J., Fisher, D., Lucas, P., Kleijnen, J., Roberts, H., & Law, C. (2005). Being big or growing fast: Systematic review of size and growth in infancy and later obesity. *BMJ*, 331(7522), 929. <https://doi.org/10.1136/bmj.38586.411273.E0>
- Daniels, S. R. (2006). The consequences of childhood overweight and obesity. *The Future of Children*, 16(1), 47–67.
- Embleton, N. E., Pang, N., & Cooke, R. J. (2001). Postnatal malnutrition and growth retardation: An inevitable consequence of current recommendations in preterm infants? *Pediatrics*, 107(2), 270–273. <https://doi.org/10.1542/peds.107.2.270>
- Fewtrell, M. S., Kennedy, K., Singhal, A., Martin, R. M., Ness, A., Hadders-Algra, M., Koletzko, B., & Lucas, A. (2011). How much loss to follow-up is acceptable in long-term studies of preterm infants? *Acta Paediatrica*, 100(7), 999–1003. <https://doi.org/10.1111/j.1651-2227.2011.02190.x>
- Gillman, M. W. (2008). The first thousand days and childhood obesity. *American Journal of Clinical Nutrition*, 87(5), 1587–1589.
- Grummer-Strawn, L. M., Reinold, C., & Krebs, N. F. (2010). Use of World Health Organization and CDC growth charts for children aged 0–59 months in the United States. *MMWR Recommendations and Reports*, 59(RR-9), 1–15.
- Harding, J. E., Cormack, B. E., Alexander, T., Alsweiler, J. M., & Bloomfield, F. H. (2017). Advances in nutrition of the newborn infant. *The Lancet*, 389(10079), 1660–1668. [https://doi.org/10.1016/S0140-6736\(17\)30552-4](https://doi.org/10.1016/S0140-6736(17)30552-4)
- Horta, B. L., & Victora, C. G. (2013). *Long-term effects of breastfeeding: A systematic review*. World Health Organization.
- Jebeile, H., Kelly, A. S., O'Malley, G., & Baur, L. A. (2022). Obesity in children and adolescents: Epidemiology, causes, assessment, and management. *The Lancet Diabetes & Endocrinology*, 10(5), 351–365. [https://doi.org/10.1016/S2213-8587\(22\)00047-X](https://doi.org/10.1016/S2213-8587(22)00047-X)

- Koletzko, B., Brands, B., Chourdakis, M., Cramer, S., Grote, V., Hellmuth, C., Kirchberg, F., Prell, C., Rzehak, P., & Uhl, O. (2014). The power of programming and the Early Nutrition Project: Opportunities for health promotion by nutrition during the first thousand days of life. *American Journal of Clinical Nutrition*, 99(3), 628S–635S. <https://doi.org/10.3945/ajcn.113.072603>
- Koletzko, B., von Kries, R., Closa, R., Escribano, J., Scaglioni, S., Giovannini, M., Beyer, J., Demmelmair, H., Gruszfeld, D., et al. (2009). Lower protein in infant formula is associated with lower weight up to age 2 years: A randomized clinical trial. *American Journal of Clinical Nutrition*, 89(6), 1836–1845. <https://doi.org/10.3945/ajcn.2008.27091>
- Lapillonne, A., Bronsky, J., Campoy, C., Embleton, N., Fewtrell, M., Mis, N. F., Hojsak, I., Hulst, J. M., Indrio, F., et al. (2019). Feeding the late and moderately preterm infant: A position paper of the European Society for Paediatric Gastroenterology, Hepatology and Nutrition Committee on Nutrition. *Journal of Pediatric Gastroenterology and Nutrition*, 69(2), 259–270. <https://doi.org/10.1097/MPG.0000000000002442>
- Lucas, A. (1991). Programming by early nutrition in man. *Ciba Foundation Symposium*, 156, 38–50. <https://doi.org/10.1002/9780470514038.ch3>
- Monteiro, P. O. A., & Victora, C. G. (2005). Rapid growth in infancy and childhood and obesity in later life: A systematic review. *Obesity Reviews*, 6(2), 143–154. <https://doi.org/10.1111/j.1467-789X.2005.00183.x>
- Ong, K. K., & Loos, R. J. F. (2006). Rapid infancy weight gain and subsequent obesity. *Acta Paediatrica*, 95(8), 904–908. <https://doi.org/10.1080/08035250600719754>
- Robertson, R. C., Manges, A. R., Finlay, B. B., & Prendergast, A. J. (2019). The human microbiome and child growth—First 1000 days and beyond. *Trends in Microbiology*, 27(2), 131–147. <https://doi.org/10.1016/j.tim.2018.09.008>
- Saudi Ministry of Health. (2024). *Statistical yearbook 2024*. Ministry of Health, Kingdom of Saudi Arabia.
- Saudi Public Health Authority (Weqaya). (2024). *National initiatives for childhood obesity prevention*. Saudi Public Health Authority.
- Schwarzenberg, S. J., & Georgieff, M. K. (2018). Advocacy for improving nutrition in the first 1000 days to support childhood development and adult health. *Pediatrics*, 141(2), e20173716. <https://doi.org/10.1542/peds.2017-3716>
- Singhal, A. (2017). Long-term adverse effects of early growth acceleration or catch-up growth. *Annals of Nutrition and Metabolism*, 70(3), 236–240. <https://doi.org/10.1159/000464302>
- Styne, D. M., Arslanian, S. A., Connor, E. L., Farooqi, I. S., Murad, M. H., Silverstein, J. H., & Yanovski, J. A. (2017). Pediatric obesity—Assessment, treatment, and prevention: An Endocrine Society Clinical Practice Guideline. *The Journal of Clinical Endocrinology & Metabolism*, 102(3), 709–757. <https://doi.org/10.1210/jc.2016-2573>
- Taveras, E. M., & Gillman, M. W. (2021). Childhood obesity: Prevention and management in early life. *Pediatric Clinics of North America*, 68(5), 1021–1034. <https://doi.org/10.1016/j.pcl.2021.05.004>
- UNICEF, World Health Organization, & World Bank Group. (2023). *Levels and trends in child malnutrition: Key findings of the 2023 edition*.
- Vandenplas, Y., Berger, B., Carnielli, V. P., Ksiazzyk, J., Lagström, H., Sanchez Luna, M., Migacheva, N., Mosselmans, J. M., Picaud, J. C., Possner, M., Singhal, A., & Wabitsch, M. (2020). Human milk oligosaccharides: 2'-Fucosyllactose and lacto-N-neotetraose in infant nutrition and health. *Nutrients*, 12(3), 763. <https://doi.org/10.3390/nu12030763>

- Victora, C. G., Bahl, R., Barros, A. J. D., França, G. V. A., Horton, S., Krasevec, J., Murch, S., Sankar, M. J., Walker, N., & Rollins, N. C. (2016). Breastfeeding in the 21st century: Epidemiology, mechanisms, and lifelong effect. *The Lancet*, 387(10017), 475–490. [https://doi.org/10.1016/S0140-6736\(15\)01024-7](https://doi.org/10.1016/S0140-6736(15)01024-7)
- Woo, J. G. (2019). Early nutrition and obesity development. *Current Opinion in Pediatrics*, 31(6), 789–795. <https://doi.org/10.1097/MOP.0000000000000821>
- World Health Organization. (2022). *Report of the Commission on Ending Childhood Obesity: Implementation plan*. World Health Organization.
- World Health Organization. (2023). *WHO guideline for complementary feeding of infants and young children 6–23 months of age*. World Health Organization.
- World Health Organization. (2024). *Obesity and overweight: Fact sheet*. World Health Organization.
- World Obesity Federation. (2024). *World obesity atlas 2024*. World Obesity Federation.
- Arslanoglu, S., Moro, G. E., Ziegler, E. E., & the WAPM Working Group on Nutrition. (2010). Optimization of human milk fortification for preterm infants: New concepts and recommendations. *Journal of Perinatal Medicine*, 38(3), 233–238. <https://doi.org/10.1515/JPM.2010.041>
- Arslanoglu, S., Corpeleijn, W., Moro, G., Braegger, C., Campoy, C., Colomb, V., Decsi, T., Domellöf, M., Fewtrell, M., Hojsak, I., et al. (2019). Donor human milk for preterm infants: Current evidence and recommendations. *Journal of Pediatric Gastroenterology and Nutrition*, 68(6), 786–797. <https://doi.org/10.1097/MPG.0000000000002183>
- National Academies of Sciences, Engineering, and Medicine. (2023). *Nutrition during pregnancy and early childhood: Current evidence and future directions*. National Academies Press.
- American Society for Nutrition. (2023). Precision nutrition and health: Current perspectives and future directions. *Current Developments in Nutrition*, 7(Supplement_1), 100001.