Nutrition to support optimal growth and development in youth

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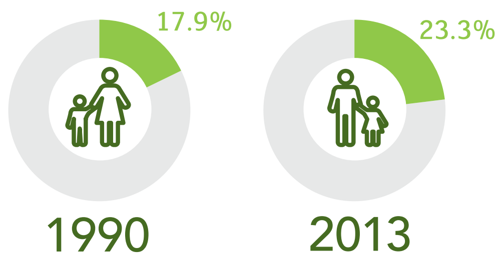
Childhood Obesity Increase Rate

***30%** increase in obesity among children 2-19*
years worldwide from 1990-2013

Childhood Obesity Worldwide



Childhood and adolescence are characterized by periods of rapid physical growth, which can be observed as changes in physique, like height and strength. Simultaneously, astounding development occurs in body systems, such as the nervous system, especially the brain. To achieve optimal growth and development, the diet must provide enough of the essential nutrients to support these processes while keeping energy balance in check to avoid excessive weight gain. Overweight and obesity are of equal concern to nutrient sufficiency due to rapidly increasing prevalence worldwide among children and teens [1].

Since it is estimated that 77% of obese children become obese adults, preventing excess weight gain early in life is a critical step in maintaining health throughout the entire lifespan [2]. Specific recommendations for preventing obesity in children are not detailed here, but interested readers are referred to authoritative body recommendations such as the World Health Organization and the American Academy of Pediatrics [3,4].

This overview summarizes nutrients as they relate to linear growth and development and alludes to the importance of developing food preferences consistent with eating a nutrient-dense diet.

STRONG SUPPORT

Nutrients in GREEN text have established quantified levels for growth and development supported by strong evidence.

Nutrients in ORANGE text have a potential role in growth and development supported by less clear or emerging evidence.

EMERGING POTENTIAL

Nutrition Supports Linear Growth

Linear growth, including bone elongation and muscle mass accretion, occurs rapidly during both childhood and adolescence. Rapid growth relies on adequate supply of the building blocks required to develop these tissues as well as nutrients that regulate and support these processes.

Calories and protein are building blocks.

An average 2-year-old boy's height typically doubles and weight increases 5 times over starting weight by 20 years of age [5]. **Calories and protein** fuel this rapid linear growth. Protein is a major structural component muscle tissue, which grows at an unparalleled rate. *Figure 1* shows the relatively high protein requirements relative to adults [6]. Protein must be present in both sufficient quantity and of high quality to provide the 9 essential amino acids. High quality protein sources include animal (dairy, egg, meat, poultry), and some plant proteins (e.g., soy). Other plant protein sources, like peas or nuts, need to be consumed with complementary protein to provide all 9 essential amino acids.

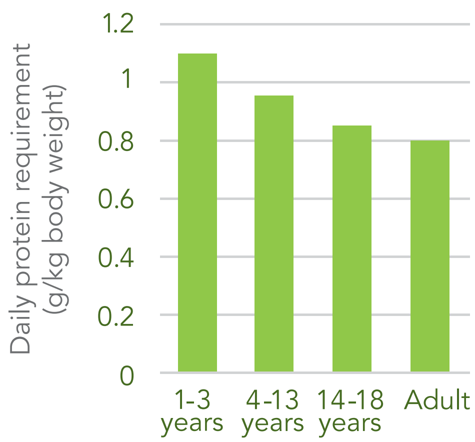
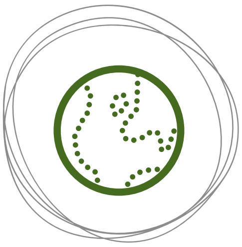


Figure 1: **Protein needs by age group**

Iron Deficiency Around the World



Iron deficiency anemia is the ***most common nutritional disorder in the world,*** prevalent in both industrialized and developing countries.

Iron Deficiency and Child Growth

40%

Iron deficiency can inhibit growth and ***affects about 40% of preschool-aged children*** globally.

Energy (calories) from food is also required to build body tissues. As with protein, calorie needs relative to body weight are much higher during childhood and adolescence than in adulthood [7]. Insufficient calories can delay growth spurts and lead to stunting. In most developed countries, getting enough calories and protein to support adequate growth is rarely a concern. However, protein-energy malnutrition can affect up to a third of children in high prevalence regions of the world [8].

Iron supplies expanding blood volume.

Blood volume increases during growth to transport nutrients to fuel growing tissues. As a major component of blood and muscle tissue, adequate intake of **iron** during growth is essential. Increases in blood volume require iron to build the hemoglobin molecule necessary to carry oxygen in the blood. Additionally, iron supports the myoglobin component of growing muscle [9].

Higher losses of iron due to menstruation translates into teen girls needing more than twice the amount of iron than boys, as shown in *Figure 2* [9].

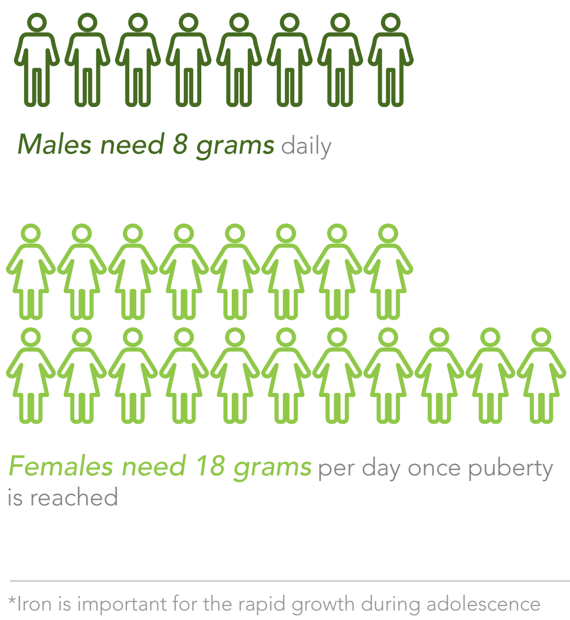


Figure 2: Daily iron (mg/day) needed for adolescent boys compared to girls.

Calcium is the main component of the skeleton, while vitamin D ensures calcium reaches the growing bones.

Ninety-eight percent of the body's **calcium** is found in bone [11]. Childhood and adolescence are a critical window of opportunity to both elongate and build bone mass; up to 90% of peak bone mass is acquired by 20 years of age as shown in *Figure 3* [12, 13]. A study including 20 countries found that inadequate calcium intake is widespread; in adolescents, around half of girls and over one-third of boys are below daily recommended intakes [13].

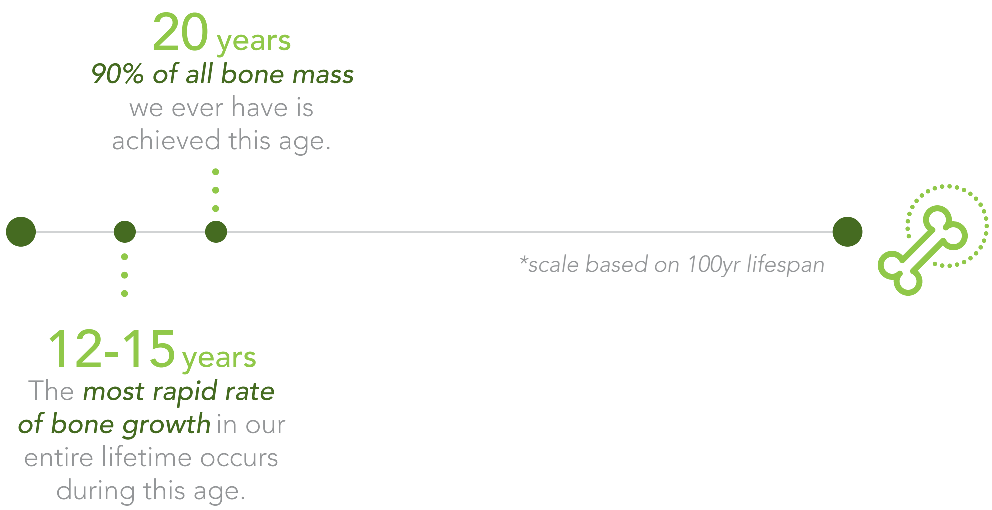


Figure 3: **One fourth of adult bone mass is built in adolescents. Ninety percent of bone mass is achieved by 18-20 years of age.**

Vitamin D is a nutrient that is actually a hormone. It helps the body utilize calcium by increasing absorption from food and helping deposit calcium into the bones. Either too little or too much vitamin D can lead to bone problems in young children and increased risk of fractures [14]. Even though some vitamin D is made on skin exposed to sunlight, it is still an essential component of the diet. The American Academy of Pediatrics recommends that children and adolescents consume natural and fortified food sources of vitamin D [14]. Few foods have been approved for fortification due to the narrow range of safety between too little and too much of this nutrient.

Zinc is required for numerous metabolic reactions essential for growth.

While many nutrients serve as building blocks for growing tissues, others facilitate growth by modifying gene expression or aiding protein formulation so that these growth processes can occur. **Zinc** is an important enabler in the body, acting as a catalyst for dozens of reactions, especially those metabolic processes associated with growth and sexual maturation. As a result, zinc deficiency affects growth [9]. It is also associated with mortality due to diarrhea, pneumonia and malaria among young children [15]. Prevalence of zinc deficiency is estimated to be > 30% worldwide, primarily in developing countries where zinc-rich animal protein foods are limited or not available while dietary compounds that inhibit zinc absorption, such as phytate, are common [15]. Even minor deficiencies are of consequence on growth and development [16]. In some regions, including Africa or South-East Asia, inadequate zinc intakes can affect up to 70% of the population and deficiency poses a serious public health concern [15].

Nutrition to support cognitive and sensory development

The nervous system develops at a tremendous rate during early life stages. The brain grows in size and complexity, facilitating learning and enhancing understanding of our world through our senses. Nerve cells *(see Figure 4)* throughout the body carry out the functions of the nervous system by conducting nerve impulses. Neuron growth (including the important myelin sheath), synthesis of neurotransmitters to relay messages to the brain and development of the eye all rely on nutritional inputs. Just as with linear growth, nutrients serve as both structural building blocks and as factors that regulate development of cognitive and sensory systems.

Structure of a Typical Neuron

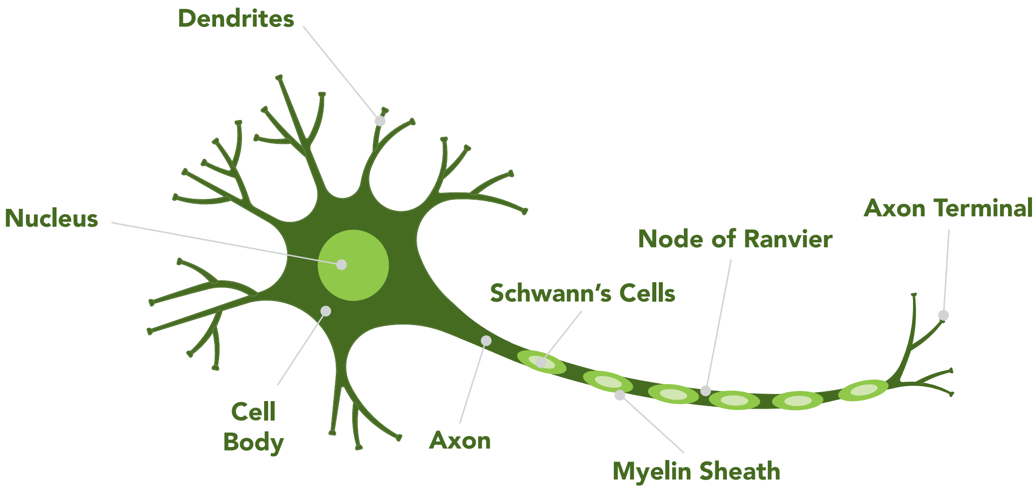
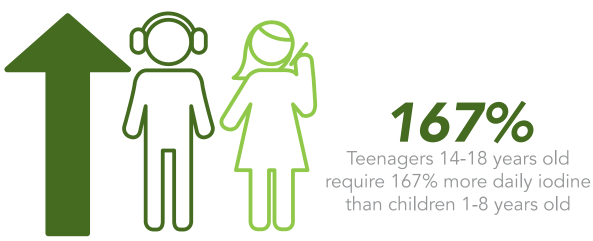


Figure 4: Nerve cells throughout the body depend on nutrients to properly grow and function [17].

Iodine and zinc help regulate development of the brain and nervous system.

The thyroid gland is one of the body's major organs for regulating growth and development. It produces hormones essential for regulating many biochemical processes, especially those related to brain development. **Iodine** is required for synthesis of these hormones, meaning that dietary intake of iodine plays a large role in cognitive development. Dietary requirements for iodine increase as children reach adolescence [9].

Teens Need More Daily Iodine



Important Nutrients to Support the Brain/Nervous System

Iodine deficiency is the most common cause of preventable brain damage in the world with 31.5% of children between ages 6 and 12 estimated to have insufficient iodine intake globally [18]. Deficiency negatively impacts cognitive performance whereas iodine supplementation positively, modestly improves some aspects of physical and mental development in deficient individuals [19, 20].

The importance of **zinc** in dozens of the body's reactions that regulate growth and development was previously mentioned, so it is no surprise that zinc also has a role in cognitive development. It is essential for growth of the nervous system, including formation of neurons and synapses that allow neurons to communicate with each other. Deficiency impairs signal transmission throughout the nervous system, which impacts a variety of functions including motor skills, attention, and learning. Supplementation in high-risk young children is not supported by evidence of benefit for neither physical nor cognitive outcomes, so prevention is key [21].

Iron and omega-3 long-chain polyunsaturated fatty acids are structural components of the developing nervous system.

Our nerves rely on the myelin sheath *(see Figure 4)* to enable nerve signals to travel rapidly across the neuron. **Iron** has a role in developing this myelin sheath as well as in synthesizing neurotransmitters [22]. Iron-deficiency is associated with fatigue and with impaired immunity, so the role of iron in cognition may be a combination of direct and indirect factors. Since iron deficiency is the most common nutritional disorder in the world, special care should be taken to ensure children receive enough iron. Emphasizing dietary sources of iron, management of dietary inhibitors, and selective fortification combined with disease management continue to be public health priorities.

Fatty acids are a primary component of every cell membrane in the body. It is possible that DHA plays a role in cognitive development and performance, because brain cells are enriched in a specific long-chain omega-3 fatty acid called **docosahexaenoic acid (DHA)**. To date, the role of DHA supplementation is undetermined with respect to improving learning and memory. Some evidence suggests that supplementation is most effective in children with previously low intakes of DHA [23]. Effects of DHA supplementation shown in infants are not seen in older children, possibly due to difficulty in effectively measuring changes in cognitive performance [24].

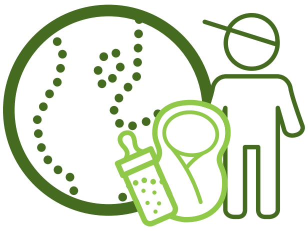
B vitamins and choline are potentially linked to cognitive health.

Vitamin B6, vitamin B12, folate and choline have possible roles in nerve cell myelination, neurotransmitter synthesis, and regulation of gene expression in the central nervous system. Research in some countries show that deficiencies in children can lead to negative implications on cognitive development [22]. However, published evidence from controlled studies for vitamins B6, B12, or folic acid on improving cognitive function in youth is not yet convincing.

Vitamin A and the carotenoid lutein / zeaxanthin are essential components of the eye.

The brain is not the only part of the nervous system developing in early age. Our senses are also developing. When it comes to vision, nutrition plays a critical role. **Vitamin A** is essential for the transduction of light into neural signals in the eye [9].

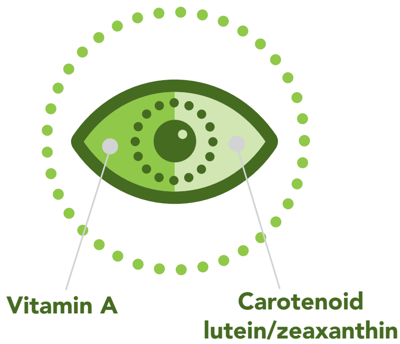
Vitamin A Deficiency in Children



250 mil.

Vitamin A deficiency is the leading cause of preventable blindness globally, especially in young children in developing countries; it is estimated that 250 million preschool-aged children are vitamin A deficient globally (10).

Essential Eye Components



Vitamin A and the carotenoid lutein/zeaxanthin, are essential components of the eye.

Although **lutein and zeaxanthin are carotenoids**, they are not the type converted in the body to vitamin A. Rather they are found in the retina (neural tissue in the back of the eye) and in brain tissue where they may serve as important antioxidant protection. Compared to adult brains, children's brains contain nearly twice the amount of lutein/zeaxanthin relative to the other carotenoids, suggesting that lutein may also play a role in neural development [25]. The role of carotenoids in cognitive health is an emerging area of nutrition science with high potential for human health.

Food preferences are shaped in early life

Knowing which nutrients are important for growth and development is one step in ensuring children's health. But children need to eat nutrient rich foods to realize these benefits. Many children prefer high-calorie snacks or candy to high nutrient dense foods like vegetables. Extra calories, among sedentary youth in particular, contribute to weight gain. It is not surprising that sweet, indulgent foods are preferred by many children; infants are born with innate preferences for sweet or savory flavors compared to bitter, sour, or salty flavors [26]. Considered from an evolutionary perspective, sweet or savory flavors signal calorie-rich foods needed to survive when energy was limited.

However, food preferences can be modified. Young children need to taste a new food somewhere between 6 to 15 times before preference increases [26]. Children exposed to a variety of foods early in life retain a preference for these foods over time. This can be especially important when it comes to vegetables exposure since they are more difficult to promote in later years when peer pressure and availability are added factors. Exposing children to foods in a positive pleasurable environment using behaviors such as modeling parents or peers enjoying vegetables can help children accept new foods. On the other hand, pressure behaviors such as using ice cream as a reward for eating vegetables typically decrease a child's preference for the food being encouraged [27].

Children & New Food

Repeated food exposures can increase children's preference for new foods

Summary

Growth and development is a complex process requiring nutrients used as building blocks for growing tissues, as well as nutrients that regulate intricate development processes. It can be challenging to balance nutrient needs while keeping calorie intakes within a healthy range to prevent weight gain. Certain key nutrients like protein, minerals (iron, iodine, zinc, and calcium), vitamins, lutein/zeaxanthin, and long-chain omega-3 fats are among those of key importance during this life stage. Developing lifelong dietary preferences for nutrient rich sources of these critical nutrients, will help lead to lifelong health. Exposing children to a variety of foods in early life, makes it easier for children to enjoy a health-promoting diet throughout their life.

Disclaimer: The information in this document is intended for informational purposes only; it is not intended for claim guidance.

Barbara Lyle, Ph.D., has over 25 years of experience in the consumer food industry working on and leading cross-functional teams at the fuzzy front end of consumer concept development, new products, science trends, and global platform development. She has client partner experience with the top innovation companies globally and previously served as treasurer for the American Society for Nutrition. Barbara is currently adjunct faculty at Northwestern University, School of Professional Studies. She has co-author numerous scientific publications, patents, and submissions to FDA and USDA addressing labeling regulations.

Reference Citation:

1. Ng, M et al. "Global, regional, and national prevalence of overweight and obesity in children and adults during 1980–2013: a systematic analysis for the Global Burden of Disease Study 2013" *The Lancet.* 2014 384;(9945):766–781.
2. Freedman DS, LK Khan, Dietz WH, Srinivasan SR, and Berenson GS. "Relationship of childhood obesity to coronary heart disease risk factors in adulthood: the Bogalusa Heart Study." *Pediatrics.* 2001 Sep;108(3):712-8.
3. World Health Organization website. "Population nutrient intake goals for preventing diet-related chronic diseases" http://www.who.int/nutrition/topics/5_population_nutrient/en/index3.html
4. Daniels SR, Hassink SG, and Committee on Nutrition. "The Role of the pediatrician in primary prevention of obesity" *Pediatrics* 2015;136(1):e275-e292.
5. CDC growth chart. http://www.cdc.gov/growthcharts/data/set1clinical/cj41c021.pdf
6. Institute of Medicine. "Dietary reference intakes for energy, carbohydrate, fiber, fat, fatty acids, cholesterol, protein, and amino acids." Washington, DC. The National Academies Press. 2005.
7. FAO "Human energy requirements: Report of a Joint FAO/WHO/UNU Expert Consultation." FAO Food and Nutrition Technical Report Series 1. October 2001.
8. UNICEF-WHO-The World Bank: Joint child malnutrition estimates - Levels and trends. Website reports dated December 15, 2015. http://www.who.int/nutgrowthdb/estimates/en/
9. Institute of Medicine. "Dietary reference intakes for vitamin A, vitamin K, arsenic, boron, chromium, copper, iodine, iron, manganese, molybdenum, nickel, silicon, vanadium, and zinc." Washington, DC. The National Academies Press. 2001.
10. World Health Organization website "Micronutrient deficiencies." http://www.who.int/nutrition/topics/micronutrients/en/
11. Institute of Medicine. "DRI dietary reference intakes calcium vitamin D." Washington, DC. The National Academies Press. 2011.
12. National Institute of Health Osteoporosis and Related Bone Diseases National Resource Center website. "Kids and their bones: A guide for parents." http://www.niams.nih.gov/health_info/bone/bone_health/juvenile/default.asp
13. Weaver, CM. "The role of nutrition on optimizing peak bone mass." *Asia Pac J Clin Nutr* 2008;17(S1):135-137.
14. Golden NH, SA Abrams, Committee on Nutrition. "Optimizing Bone Health in Children and Adolescents" *Pediatrics* October 2014;134(4): e1229–e1243.
15. Caulfield, LE and RE Black. "Zinc deficiency." In: World Health Organization "Comparative quantification of health risks: Global and regional burden of disease attribution to selected major risk factors." Current website. http://www.who.int/publications/cra/chapters/volume1/0257-0280.pdf
16. Hambidge M. "Human zinc deficiency" *J Nutr.* 2000;130(5S Suppl):1344S-9S.
17. SEER Training Modules, Nerve Tissue. U. S. National Institutes of Health, National Cancer Institute. 16 December 2015 http://training.seer.cancer.gov/.
18. de Benoist B, E McLean, M Andersson, and L Rogers."Iodine deficiency in 2007: global progress since 2003." *Food Nutr Bull.* 2008;29(3):195-202.
19. Bleichrodt N, RM Shrestha, CE West, JG Hautvast, FJ van de Vijver, and MP Born. "The benefits of adequate iodine intake." *Nutr Rev.* 1996;54(4 Pt 2):S72-8.
20. Angermayr, L, and C Clar. "Iodine supplementation for preventing iodine deficiency disorders in children" Cochrane. April 19, 2004.
21. Gogia, S and HS Sachdev. "Zinc supplementation for mental and motor development in children" Cochrane. October 12, 2012.
22. Bryan J, S Osendarp, D Hughes, E Calvaresi, K Baghurst, and JW van Klinken. "Nutrients for cognitive development in school-aged children." *Nutr Rev.* 2004;62(8):295-306
23. Stonehouse W. "Does consumption of LC omega-3 PUFA enhance cognitive performance in healthy school-aged children and throughout adulthood? Evidence from clinical trials." *Nutrients.* 2014;6(7):2730-58.

Reference Citation:

24. Jiao, J, Q Li, J Chu, W Zeng, M Yang, and S Zhu."Effect of n-3 PUFA supplementation on cognitive function throughout the life span from infancy to old age: a systematic review and meta-analysis of randomized controlled trials. *Am J Clin Nutr.* 2014;100(6):1422-36.
25. Johnson, E. "Role of lutein and zeaxanthin in visual and cognitive function throughout the lifespan" *Nutrition Reviews*. 2014;72(9):605 - 612
26. Ventura, AK and John Worobey J. "Early Influences on the Development of Food Preferences" *Current Biology*. 2013;23(9): R401–R408.
27. Nicklaus, S. "The role of food experiences during early childhood in food pleasure learning." *Appetite*. 2015. Available online 20 August 2015.