NCC Pediatrics Continuity Clinic Curriculum:
Nutrition III: School-Age & Adolescent
Faculty Guide

Goal:
To understand the nutrition recommendations and key issues for school-age children and adolescents, and to be able to translate them into practical, anticipatory guidance for parents.

* Note: This module does not cover obesity.

Pre-Meeting Preparation:

- Read "School-Age & Adolescent Nutrition" *(Excerpts from HealthyChildren.org)*
- Skim "The Role of Diet, Nutrition, and Exercise in Preventing Disease" *(PIR, 2022)*
- Skim "Nutritional Deficiencies in Vegetarian, Gluten-Free, and Ketogenic Diets" *(PIR, 2022)*
- **Be prepared to provide a case-example or FAQ related to School-Age & Adolescent Nutrition from your clinic experience.** Discuss how you approached the case/ question.

Conference Agenda:

- *Review* Nutrition III Quiz
- Complete Nutrition III Cases
- Round table discussion of *resident* School-Age & Adolescent cases

Post-Conference: *Board Review Q&A*

Extra Credit:
Please review the following enclosures, related to the practical guidelines, above:

- The 2022 Child Nutrition Reauthorization — An Opportunity to Advance Children's Health *(NEJM, April 2022)*
- Planning Well-Balanced Vegetarian Diets in Infants, Children, and Adolescents: The VegPlate Junior *(Journal of the Academy of Nutrition and Dietetics, July 2019)*
- Organic Food: Nutritional and Environmental Considerations *(PIR, 2021)*
- Vegetarian Diets in Children and Adolescents *(PIR, 2009)*
- Vitamin Deficiency & Overdose Chart *(helpful for Board Review questions)*
- Nurturing Children's Healthy Eating: Position statement *(Appetite, 2019)*
- USDA Dietary Guidelines for Americans 2020-2025 *(starting at page 69 for infants, 83 for children)*
- Screen and Intervene: A Toolkit for Pediatricians to Address Food Insecurity
- *Links to* SNAP *and* WIC

Edited by J. McDonnell, 2016. Updated C. Carr, 2023.

School-Age Nutrition

Material adapted from: http://www.healthychildren.org/English/ages-stages/

Calories & Servings

As the middle years progress, children's total energy needs will increase and thus their food intake will rise, especially as they approach puberty. Between ages 7 and 10, both boys and girls consume about **1,600 to 2,400 calories per day**. Most girls experience a significant increase in their growth rate between ages 10 and 12 and will take in about 200 calories more each day, while boys go through their **growth spurt** about 2 years later and increase their food intake by nearly 500 calories a day.

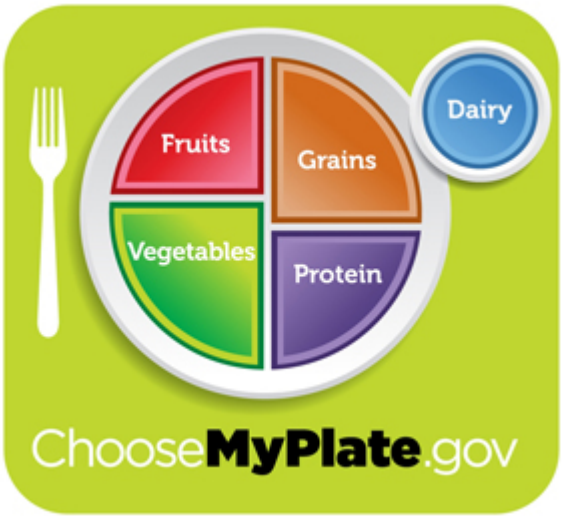
Some parents worry that throughout the school age years, there seems to be no rhyme or reason to their children's appetite. **Appetites can vary**, even from day to day, depending on factors like activity levels. A child who spends the afternoon doing homework, for example, may have fewer caloric needs than one who plays outdoors after school.

At the same time, children in this age group eat for a lot of reasons besides hunger. They could be upset or tired and relying on food for comfort. When your youngster says that he's hungry and it's not a regular meal or snack time, try to determine whether food might be serving some other purpose. Then help him find an activity that will keep him occupied doing something productive.

Ultimately, children in early to middle adolescence should be gaining **4 to 7 lbs per year**. As long as your child is growing normally, keep your focus on serving a variety of healthy foods.

Variety & Nutrients

Your child should consume a variety of foods from the five major food groups that make up the **"Food Plate"** developed by the U.S. Department of Agriculture in July 2011, to replace the "Food Pyramid".



Vegetables: 3-5 servings/day. Serving = 1 cup of raw leafy vegs, 3/4 cup of veg juice, or 1/2 cup of other vegs, chopped raw or cooked.

Fruits: 2-4 servings/day. Serving = ½ cup sliced fruit or a medium-size whole fruit.

Bread, cereal, or pasta: 6-11 servings/day. Serving = 1 slice of bread, ½ cup of rice/pasta, or 1 oz of cereal.

Protein foods: 2-3 servings of 2-3 oz of cooked lean meat, poultry, or fish per day. Serving also = ½ cup of cooked dry beans, 1 egg, or 2 TBSPs of peanut butter for each oz lean meat.

Dairy products: 2-3 servings/day of 1 cup of low-fat milk or yogurt, or 1.5 oz of natural cheese.

Foods to Reduce:

- **Fat:** High fat intake, particularly saturated fats (solid at room temp), can increase cholesterol and lead to coronary artery disease. *After age 2*, children should be served foods lower in saturated fats (e.g. poultry, fish, lean meat—not fried; low-fat dairy; low-saturated-fat oils; soft margarine —not butter; limited eggs). In general, **fats should make up <30% of calories in a child's diet**, with >2/3 of those fat calories coming from *un*saturated fats (liquid at room temp—e.g. corn, safflower, sunflower, soybean, and olive oil).

- **Sugar:** Many children consume sugar in great quantities, usually at the expense of healthier foods (e.g. sodas and juice, instead of milk or water). Keep consumption at moderate levels.
- **Salt:** The habit of using extra salt is acquired. Thus, as much as possible, serve a child food low in salt, to decrease the risk of high blood pressure. Use herbs, spices, or lemon juice to flavor foods and avoid processed foods such as cheese, instant puddings, canned vegetables and soups, hot dogs, salad dressing, pickles, and potato chips.

Vitamins

Supplements are rarely needed in middle childhood, since a balanced diet contains sufficient quantities for the essential vitamins and minerals. However, children with poor appetite, erratic eating habits, or highly selective diets (e.g. vegetarian or vegan) may need vitamin supplements.

Over-the-counter supplements (e.g. Flintstones chewables or gummies) are generally safe; however, if taken in excessive amounts or combined, some—particularly fat-soluble vitamins (ADEK)—can be toxic. Of note, **"mega-vitamin therapy"** or "orthomolecular medicine"— in which vitamins are given in extremely large doses for conditions ranging from the common cold to hyperactivity— has no proven scientific validity and may pose risks.

Following are some of the vitamins and minerals necessary for normally growing children, and some of the foods that contain them. *(Review this **"Vitamin Deficiency & Overdose Chart"** chart for a more complete list of vitamins and the conditions associated with deficiency or excessive intake).*

- ***Vitamin A*** promotes normal growth, healthy skin, and tissue repair, and aids in night and color vision. Rich sources include yellow vegetables, dairy products, and liver.
- ***B vitamins*** promote red blood cell formation and assist in a variety of metabolic activities. Found in meat, poultry, fish, soybeans, milk, eggs, whole grains, and enriched breads and cereals.
- ***Vitamin C*** hastens the healing of wounds and increases resistance to infection. Found in citrus fruits, strawberries, tomatoes, potatoes, Brussels sprouts, spinach, and broccoli.
- ***Vitamin D*** promotes tooth and bone formation and regulates calcium absorption. Sources include fortified dairy products, fish oils, fortified margarine, and egg yolks. Sunlight also contributes to dietary sources of vitamin D, stimulating the conversion in the skin.

Adolescent Nutrition

Material adapted from: http://www.healthychildren.org/English/ages-stages/

Calories & Servings

The body demands more calories during early adolescence than at any other time of life. On average, **boys require about 2800 calories per day; and girls, 2200 calories per day**. Typically, the ravenous hunger of adolescence starts to wane once a child has stopped growing, though not always. Kids who participate in physical activity will still need increased amounts of energy into late adolescence.

Serving sizes for teenagers should still be about the same as they are for adults. Please review the chart on the following page to see the number of servings and sizes recommended for the average teen. The USDA "Food Plate" can still be used as a visual guide.

Food Group	Number of Servings Per Day	
	Females	Males
Calories	Aged 11-24 Total Calories: 2,200	Aged 11-14 Total Calories: 2,500
		Aged 15-18 Total Calories: 3,000
		Aged 19-24 Total Calories: 2,900
Bread, Cereal, Rice and Pasta Group 6-11 servings	9 servings	11servings
Milk, Yogurt and Cheese Group 4-5 servings	4 or 5 servings	Aged 11-18: 4 or 5 servings Aged 19-24: 2-3 servings
Vegetable Group 3-5 servings	4 servings	5 servings
Fruit Group 2-4 servings	3 servings	4 servings
Meat, Poultry, Fish, Dry Beans, Eggs and Nuts 2-3 servings	6 ounces total	7 ounces total
Total Fat	73 grams	Aged 11-14: 83 grams Aged 15-18: 100 grams
Total Added Sugar	12 teaspoons	18 teaspoons

Variety & Nutrients

There are a number of obstacles to balanced adolescent nutrition:

- **Skipping meals:** According to a recent poll, about ½ of boys and girls aged 9-15 years said that they didn't eat breakfast on school mornings. Breakfast-to-go options include a bagel and peanut butter, a hard-boiled egg, nuts & raisins, a yogurt, or an apple.
- **Snacking:** 1/3 of the caloric intake of adolescents comes from snacks—particularly unhealthy ones. It's therefore important to keep the refrigerator and pantry stocked with healthy options like low-fat cheeses, applesauce, air-popped popcorn, and baked potato chips.
- **Eating away from home:** At school, adolescents will often settle for a stop at the vending machine for lunch. After school, they may decide that fitting in with their peers at a fast-food restaurant or pizza shop is more important than making healthy food selections. Brainstorm healthy alternatives and/or other activities to do with their peers.
- **The lure of fad diets:** As teenagers "hopscotch" from one fad diet to another, good nutrition may fall by the wayside. Reinforce that these diets are too restrictive and unhealthy and bad for weight loss in the long run.

The guidance in the above section for "Foods to Reduce" still applies to adolescents. Also remember, each gram of protein and carbohydrates supplies 4 calories, whereas **fat contributes 9 calories/gram**.

Vitamins

Adolescents—particularly girls, who eat roughly 25% fewer calories per day than boys— tend to fall short of their daily quotas of vitamins and minerals. Calcium, iron and zinc are most vulnerable.

Calcium:

Adolescence provides a window of opportunity for avoiding osteoporosis later in life. During the teenage years, the growing bones absorb more calcium from the blood than at any other time of life. By early adulthood, our bones stop accepting deposits, and not long after, the gradual loss of calcium begins.

In a clinical study sponsored by the National Institute of Child Health and Human Development, one group of teenage girls received daily supplements containing extra 500 mg calcium; the other group's calcium came strictly from food. The girls who were given supplements saw their bone density improve by 14%. Each 5% increase in bone mass reduces the risk of suffering a bone fracture by 40%.

The American Academy of Pediatrics recommends the following daily intake of calcium:

Age	Calcium Need (mg per day)	Servings of Milk to Meet Need
4–8 years	800	3 servings
9–18 years	**1,300**	**4 servings**
19–50 years	1,000	3–4 servings

Milk and milk products provide ¾ of the calcium in the American diet. Other foods contain calcium, like broccoli and collard greens. However, these vegetables also contain substances that impair the body's ability to absorb calcium, so that a teen would need to eat approximately 9 cups of broccoli a day to meet the recommended intake. Also consider calcium-fortified juice (no more than 8-12 oz/day!) and cereals.

Unfortunately, 2/3 of adolescent girls in the US fail to meet the daily requirement for calcium. The NIH supports the use of supplements for young people who don't get sufficient calcium through their diet. For optimal absorption, no more than 500mg should be taken at one time.

Also remember that other factors can decrease calcium and impair bone health: excessive soda intake; vegan diets; caffeine, alcohol, and tobacco; certain medications (e.g. diuretics) and GI diseases (e.g. IBD).

Iron:

According to a national survey conducted by the USDA, three in four teenage girls' diets are deficient in this essential mineral, as compared to just one in five of their male counterparts. Adolescent girls are also prone to iron-deficiency due to menstrual losses.

Foods rich in iron include meats (beef, pork, lamb, liver); poultry (especially dark meat); fish; dark-green leafy vegetables (kale, collards, broccoli); legumes (lima beans, peas, dry beans); dried fruit (prunes, apricots, raisins); potatoes with skin; seeds (sunflower, pumpkin, squash); and whole-wheat breads.

Other points to keep in mind are, as follows: (1) the iron in meat, poultry, and fish is more readily absorbed than the iron in vegetables, beans, and grains; (2) vitamin C & citric acid in fruits promotes absorption of iron; (3) the tannins in tea can interfere with metabolism of non-heme (i.e. non-meat) iron.

Please review "Screening for Iron Deficiency" *(see Health Maintenance II)* for more information about the pathophysiology, evaluation, and treatment of iron-deficiency anemia.

The Role of Diet, Nutrition, and Exercise in Preventing Disease

Neal S. LeLeiko, MD, PhD,* Sally Dorfzaun, MS, RD, CDN,* Joseph Picoraro, MD*

*Columbia University Irving Medical Center, New York, NY

EDUCATION GAP

Dietary Reference Intakes contribute to our ability to plan or assess nutritional adequacy in groups and individuals. However, they contribute only a portion to what today's pediatric clinician needs to know about nutritional status and, perhaps more importantly, to guiding children's lifestyles toward healthy adult living. Various recommendations for physical activity, exercise, and cardiorespiratory fitness are largely consistent but lack a rigorous scientific basis. Concerns regarding implementing child nutrition and fitness recommendations now increasingly focus on the very significant impact of social determinants of health and on the reality that the nutrition-related habits and probably activity-related habits developed in childhood may have a lifelong effect on individual well-being.

OBJECTIVES *After reading this article, readers should be able to:*

1. Understand the role of diet and nutrition in preventing disease.
2. Recognize how nutrition-related health disparities can impact vulnerable patients.
3. Identify areas in need of nutritional improvement in our pediatric population.
4. Understand the use and significance of current physical activity–related guidelines.

AUTHOR DISCLOSURE Drs LeLeiko and Picoraro and Ms Dorfzaun have disclosed no financial relationships relevant to this article. This article does not contain a discussion of an unapproved/investigative use of a commercial product/device.

ABBREVIATIONS

AAP	American Academy of Pediatrics
AHA	American Heart Association
AI	adequate intake
AND	Academy of Nutrition and Dietetics
CDC	Centers for Disease Control and Prevention
CRF	cardiorespiratory fitness
DRI	Dietary Reference Intake
EAR	estimated average requirement
EER	Estimated Energy Requirement
FDA	Food and Drug Administration
HEI	Healthy Eating Index
NCD	noncommunicable disease
PA	physical activity
RD	registered dietitian
RDA	Recommended Dietary Allowance
SDOH	social determinant of health
UL	tolerable upper intake level
USDA	US Department of Agriculture
WHO	World Health Organization

INTRODUCTION

Proper diet, nutrition, and exercise are necessary to reduce the morbidity and mortality associated with noncommunicable diseases (NCDs) such as cardiovascular disease and diabetes. All NCDs (which also include cancer and chronic respiratory disease) account for 71% of deaths (41 million) globally. (1) Poor diet, nutrition, and related lifestyle habits likely account for 40% of those NCD-related deaths. (2) The roots of the comorbidities associated with many of the bad outcomes in adults with coronavirus 2019 have, in large measure, been attributed to diet and lifestyle habits developed in childhood.

The challenge of identifying the mechanisms to prevent or treat the nutrition- and activity-related diseases may be formidable but may be overshadowed by the challenge of identifying how to fix the frequently associated social determinants of these diseases. Concern related to addressing social determinants of health (SDOHs) is very relevant but not novel. More than 150 years ago, Rudolf Virchow is said to have coined the aphorism "Medicine is a social science, and politics is nothing but medicine on a grand scale." (3) In 1847, writing as a member of a commission investigating a devastating outbreak of relapsing fever, Virchow noted that the causes of the epidemic were social as much as, if not more than, medical. (4) He noted that the conditions under which the workers were forced to live made them vulnerable to the disease.

The Centers for Disease Control and Prevention (CDC) defines SDOHs as conditions in the places where people live, learn, work, and play that affect a wide range of health risks and outcomes. (5) Healthy People 2030 (6) considers that addressing SDOH is among our most important national health objectives for this decade. The 5 key SDOHs (5) outlined are 1) health-care access and quality, 2) education access and quality, 3) social and community context, 4) economic stability, and 5) neighborhood and built environment.

According to the CDC, in the United States, 6 of 10 adults have a chronic disease, and 4 of 10 have 2 or more chronic diseases. (7)

From 1976 to 1980, 7% of children 6 to 11 years old and 5% of adolescents 12 to 19 years old were obese. By 2015 to 2016, the prevalence of obesity had increased 2 to 4 times; for 2- to 5-year-olds it was 13.9%; 6- to 11-year-olds, 18.4%; and adolescents, 20.6%. (8) In addition, between 2002 and 2015, the overall incidence of type 2 diabetes in young people significantly increased. (9) Healthy eating combined with appropriate activity will result in better health outcomes. Precisely defining healthy eating, appropriate activity, and an optimal mix of the two is a challenge, but among our most important challenges.

HISTORICAL CONTEXT

Beginning in 1941 the US Food and Nutrition Board of the National Academy of Sciences published the first of what would be 10 editions of the Recommended Dietary Allowances (RDAs). The RDAs were "… levels of essential nutrients considered in the judgement of the Committee on Dietary Allowances of the Food and Nutrition Board of the Institute of Medicine of the National Academy of Sciences, on the basis of available scientific knowledge, to be adequate to meet the known nutritional needs of practically all healthy persons." The 10th and final edition of the RDAs appeared in 1989.

At around the same time as the 10th edition of the RDA was being prepared (1988), the first "Surgeon General's Report on Nutrition and Health" focused on the health concerns and benefits of our diets and concluded that the overconsumption of certain foods had become a major health concern for Americans. The report endorsed the following recommendations: eat a variety of foods; balance the food that you eat with physical activity (PA); choose a diet with plenty of grain products, vegetables, and fruits; choose a diet low in fat, saturated fats, and cholesterol; choose a diet moderate in sugars; and choose a diet moderate in salt and sodium.

The report occurred as nutritional concerns related to specific nutrient deficiencies were receding, while being replaced by increased attention to the excess and/or inappropriate consumption of other dietary constituents. There are still some concerns regarding some specific nutrient deficiencies. According to the Dietary Guidelines for Americans 2020–2025 report, (10) there are 4 nutrients of public health concern for children, teenagers, and adults: calcium, potassium, fiber, and vitamin D. The guidelines also mention iron as a nutrient of concern in children up to age 1 year and in women of reproductive age. More information on food sources for these nutrients can be found in the dietary guidelines. (11)

By the mid-1990s, public health concerns related to nutrient deficiencies were receding as it had become increasingly clear that certain diets and nutrients were linked to serious chronic diseases, including heart disease, diabetes, and cancer. In place of the RDAs used in the United States and the recommended nutrient intakes used in Canada, a joint approach resulting in the publication of Dietary Reference Intakes (DRIs) (12)(13) was pursued under the auspices of the Institute of Medicine (now integrated into the National Academies of Sciences, Engineering, and Medicine) and Health Canada.

The DRIs were intended to be used for determining the adequacy of intake of populations and individuals with an increasing focus on preventing chronic nutrition-related diseases. Today, *DRIs* is the general term used for a set of reference values, established collaboratively by the US Food and Nutrition Board and Health Canada, that can be used to assess (and plan) nutrient intakes of healthy people. (12)(13)

The DRIs rely on 4 principal types of nutrient reference values, each with different uses:

1. Estimated average requirement (EAR): The EAR is the daily nutrient intake value that is reliably estimated to meet the requirement of half of the healthy individuals in a population. It is used to calculate the RDA and can be used to plan for providing adequate intake (AI) for groups.
2. RDA: The RDA is set at 2 SD above the EAR. It is intended to identify an average daily dietary intake level that is sufficient to meet the nutrient requirement of nearly all (95%) healthy individuals. There is no RDA for energy (calorie) requirements. Instead, there is the Estimated Energy Requirement or (EER). The EER is estimated to be at the midpoint of the range of the population requirements. It will, therefore, exceed the needs of the 50% of the population below the midpoint and be insufficient for the 50% above the midpoint. The EER is used for groups of people.
3. AI: If there is inadequate data to identify an EAR, the RDA cannot be derived and instead an AI is estimated based on available observed or experimental approximations of nutrient intake. A nutrient has either an RDA (based on sufficiently available data) or an AI based on less reliable available evidence. The AI can be used for groups of people, as well as for individuals, but it is not the equivalent of an RDA.
4. Tolerable upper intake level (UL): The UL is the highest level of daily nutrient intake that is likely to pose no risk of adverse health effects to almost all individuals in the general population. As intake increases above the UL, the risk of adverse effects increases. It is not a recommended level of intake. The UL is used to protect individuals.

The DRIs also include an acceptable macronutrient distribution range, which does not relate to specific nutrients but rather to the expressed percentage of total energy (kilocalories) in the diet that is supplied by the amount of protein, fat, and carbohydrate in the diet.

The DRIs are used to set policies and formulate programs that provide nutritional benefit for all. (12)(13)(14) For individuals with special needs, DRIs can assist in decisions related to optimizing an individual's potentially suboptimal intake.

The DRIs are the basis for many federal programs and policies. (13)(14) The process of updating the DRIs is expensive and lengthy, and as a result many consider that the DRIs are not being consistently reviewed on an optimal schedule. US and Canadian DRI committees have created principles and processes for further evaluation of the DRIs and have established a committee to identify key elements necessary to include chronic disease end points in future DRI reviews. (15)

DIETARY GUIDELINES

Dietary Guidelines for Americans 2020–2025

The Dietary Guidelines for Americans (11) are published every 5 years by the US Department of Agriculture (USDA) to aid Americans in making healthier choices in their day-to-day lives and ultimately to help them prevent chronic diseases. Overall, the dietary guidelines provide the information that is necessary for health professionals to guide the American population into making healthier choices.

The key recommendations that highlight what a healthy eating pattern should include are summarized in Table 1. The new guidelines, published under the auspices of the USDA, for the most part do not deviate from the previous recommendations published 5 years earlier. In general, the report encourages healthy eating. The guidelines are used to help formulate food programs for the military, prisons, and school-age children and, therefore, directly impact a substantial number of Americans.

Feeding Infants and Children from Birth to 24 Months

The National Academies of Sciences, Engineering, and Medicine convened an ad hoc committee to review and assess publicly available guidance on feeding practices for infants and children up to 2 years of age. Their 331-page report (16) identified 26 topic areas related to what and how to feed infants and young children. Not surprisingly, the committee found that many of the recommendations from the various organizations were consistent or generally consistent. The committee did, however, comment that it found considerable variability in the wording of recommendations. They also emphasized the importance of harmonizing the development and dissemination of recommendations.

Healthy Eating Index

The Healthy Eating Index (HEI) (17) is used to evaluate "how well a set of foods aligns with key recommendations of the Dietary Guidelines for Americans." The HEI scores (18) range from 0 to 100, with 100 being ideal. (18)(19) The total HEI-2015 score for Americans was 59 of 100. This disappointing result indicates how far Americans must improve to align with current dietary guideline recommendations and to begin to reduce the risk of developing diet-related chronic diseases such as heart disease, type 2 diabetes, and cancer. (18)

Although the average HEI score for all Americans was 59, children 6 to 17 years old had the lowest HEI score at 53. Fruit and vegetable consumption was very low, and added sugar consumption was very high. A report published in 2017 titled "Added Sugars Intake of Americans: What We

Table 1. Dietary Guidelines for Americans Summary of Key Recommendations (10)

1. Focus on every life stage—It is never too early or too late to eat healthfully.	
Birth to 6 mo	Exclusive human milk and continue human milk throughout at least the infancy stage; if desired, breastfeeding can continue beyond this period
	When breastfeeding/breast milk is unavailable, feed iron-fortified infant formula to infants
	A vitamin D supplement should be given soon after birth
6 mo to 1 y	Begin nutrient-rich complementary foods
	Introduce potentially allergenic foods
	Encouraging a variety of foods is key for infancy and toddler years; good food sources of iron and zinc are highly recommended, especially for children who were breastfed.
	Foods/beverages with added sugars are not recommended
	Foods/beverages that contain high levels of sodium should be restricted
	Avoid honey as well as unpasteurized foods and drinks
1 y through adulthood	Follow a healthy dietary plan across the life cycle, choose nutrient-dense (high in nutrients for number of calories contained) food and drinks, attain a healthy body weight to decrease the risk of chronic conditions
2. Personalize nutrient-dense food and beverage options to individual requirements and cultural preferences.	
3. Prefer nutrient-dense foods and beverages. A healthy dietary pattern consists of the following elements: vegetables, fruits (prefer whole fruit versus fruit juices), grains (make half of your grain intake whole grains), dairy (fat-free/low-fat versions, cheeses, fortified soy drinks), lean proteins (also pulses, nuts, seeds, among others), and oils.	
4. Limit the quantity of foods and drinks that have a higher content of added sugars, saturated fats, and sodium.	
Added sugars <10% of calories per day starting at age 2 y	
Saturated fats <10% of calories per day starting at age 2 y	
Sodium <2,300 mg/d, and even less for children aged <14 y	

Eat in America, NHANES 2013-2014" demonstrated that only 42% of our population met the Dietary Guidelines for Americans recommendations for added sugars. (20)

The CDC reports that the average intake of added sugars for those older than 2 years is more than twice the recommendation and that "6 in 10 young people aged 2 to 19 years and 5 in 10 adults consume a sugary drink on a given day. Processed foods and sugary drinks add unneeded sodium, saturated fats, and sugar to many diets, increasing the risk of chronic diseases." (21)

DENTAL CAVITIES AND BEVERAGE CONSUMPTION

The problem of dental cavities warrants specific attention as it relates to diet. The consumption of any sugary food promotes the coating of the teeth with sugar, and this sugar serves as a substrate for cavity-forming bacteria.

Caries are preventable but, unfortunately, are also very common in children. The CDC estimates that more than 50% of children aged 6 to 8 years had a cavity in their baby teeth and closer to 60% of teens had experienced cavities in their permanent teeth. (22) In addition, a significant disparity exists among low-income households, where children have double the risk of cavities than children in higher-income families. (22)

Consensus recommendations indicate that babies should never be put to bed with a bottle of milk or other drink. Even during the day, water is preferable to sugar-containing drinks. At age 6 months it is recommended to teach babies to drink from cups. The American Dental Association points out that not only does the food eaten matter, but also the form of the food eaten (ie, liquid, solid, sticky, or slow to dissolve) affects the development of cavities. It is recommended to rinse with water and brush after eating foods such as lollipops and taffy, as well as to floss regularly for foods that might get trapped between teeth. Also, the frequency as well as amount of sugary and acidic foods and beverages eaten are a concern. Many snacks aimed at children are high in sugars. It is preferable to encourage foods such as cheeses, fruits, vegetables, and (when age appropriate) nuts because they reduce the constant exposure to foods that can lead to dental problems.

Eliminating unhealthy beverages and providing healthy substitutes should be an appealing target for improving diets. Clearly, the evidence demonstrates that overconsumption of unhealthy beverages is widespread, resulting in a markedly increased risk of obesity, type 2 diabetes, and/or dental caries. The potential immediate effect on our youngest children and infants makes this objective a priority. The elimination of unhealthy beverages is a critical target for improving the health and well-being of infants and young children. During September 2019, the Healthy Eating Research program gathered experts from the Academy of Nutrition and Dietetics (AND), American Academy of Pediatrics (AAP), American Academy of Pediatric Dentistry, and American Heart Association (AHA) to develop recommendations on healthy beverage consumption for children younger than 5 years. The panel of

experts recommended that children should meet their fruit intake requirements preferably choosing whole fruits, fresh, canned, or frozen. However, for some families 100% juice is an important part of their diet and is how they can meet part of their fruit intake requirements. If that is the case, then no more than 4 oz of 100% juice has been set as the upper limit (no minimum requirements) for children 1 to 3 years old, and no more than 6 oz has been included for children 4 to 5 years old. For infants, juice is not recommended. Additional recommendations include drinking only plain, not flavored milk for children 1 to 5 years old. Sugar-sweetened beverages, beverages with low-calorie sweeteners, and caffeinated beverages were not recommended for children 0 to 5 years old. (23) Regarding foods that are good for teeth, the American Dental Association recommends those that are a good source of calcium (dairy products, calcium-fortified tofu, leafy greens) and phosphorus (meat, poultry, eggs, fish). Also, vegetables and fruits are considered important for dental health due to their water and fiber content as well as their micronutrient content that aids in keeping healthy gums and building tooth enamel. The CDC also publishes recommendations for caries prevention. (24) The AAP recommends the first dental visit by the child's first birthday.

The interaction between excessive sugary beverages, cavities, and the widespread use of fluoridated water is hard to quantitate. The preponderance of data on water fluoridation is before 1975. Although the precise quantitative effect of water fluoridation might be difficult to know, the fluoridation of water to prevent tooth decay has resulted in the CDC naming water fluoridation as 1 of the 10 great public health achievements of the 20th century. (25)(26)

FOOD ADDITIVES

There are more than 3,000 food additives in our diets. Approximately 450 are generally regarded as safe. How items achieve this status is not always clear. Additives to our diet are generally considered to represent a component of food processing; however, the definition of food processing is quite variable. There is currently no mechanism to even encourage the collection of data on the safety of these additives at any stage of the life cycle.

Among the definitions for "processed" are those provided by the AND, which identifies a range from minimally processed to heavily processed foods, described as follows (27):

- Minimally processed foods include foods such as freshly bagged spinach, cut vegetables, and roasted nuts. These foods have been described as preprepared for consumer convenience.
- Foods processed at their peak. Food in this category is expected to preserve freshness and, therefore, quality. Included in this group are frozen fruits and vegetables as well as some canned foods such as canned tomatoes and tuna fish.
- Foods to which sweeteners, spices, oils, colors, and preservatives may have been added to enhance flavor and texture. This category includes pasta sauces in a jar, jarred prepared salad dressing, some yogurts, and some cake mixes.
- Among the more heavily processed foods are the so-called ready-to-eat foods. In this category are crackers, chips, and deli meat.
- The most heavily processed foods include frozen and premade meals, such as frozen pizza and microwaveable dinners.

In a 2018 policy statement and technical report titled "Food Additives and Child Health," the AAP (28) expressed concern regarding the chemicals in our foods, both the indirect food additives (bisphenols, phthalates, among others) and the direct food additives (artificial food colors, nitrates, and nitrites) and the possible repercussions that these additives may have on children's well-being. The AAP identified elements used in polycarbonate plastic containers/food cans/packages/plastic wrapping that may contain bisphenols, phthalates, perfluoroalkyl chemicals, and perchlorate. The AAP expressed concerns focused on these elements' connection to endocrine disruption and immunosuppression, as well as problems with metabolism of certain macronutrients and with fetal development. The AAP stated that it recognizes the difficulty of decreasing chemical exposure, but the committee expressed the following concerns: prefer fresh or frozen fruits and vegetables, select glass or stainless steel over plastic containers, avoid use of the microwave to heat up foods and beverages in plastic containers, do not load dishwashers with plastic containers, and check recycling codes on products to avoid those with codes 3, 6, and 7 (unless they have a "biobased," "greenware" legend). (28) Recommendations for pediatricians are listed in Table 2.

A high consumption of ultra-processed foods seems to be associated with negative effects to general well-being and with harmful repercussions in the public health sector as well. According to the AND, to decrease the consumption of highly processed foods one should choose to prepare more homemade meals, as well as increase more consumption of wholesome foods, such as fruits, vegetables, and whole grains, and limit the quantity of foods high in added sugars and sodium. (27)

Table 2. Summary of Recommendations for Pediatricians from the American Academy of Pediatrics Policy Statement on Food Additives (28)

Prioritize consumption of fresh or frozen fruits and vegetables. Support efforts to develop a list of low-cost sources.
Avoid processed meat, especially during pregnancy.
Wash plastic food containers and utensils by hand rather than in the dishwasher. Heat can cause plastics to leak bisphenols and phthalates into food.
Avoid microwaving food or beverages, including infant formula and breast milk, in plastic containers if possible.
Use glass and stainless steel. Especially when cooking or serving hot foods, use alternatives to plastic, such as glass or stainless steel, when possible.
Use the recycling code on the bottom of plastic bottles to guide avoidance of codes 3 (phthalates), 6 (styrene), and 7 (bisphenols), unless labeled as "biobased" or "greenware," which should indicate that they are made from corn and do not contain bisphenols.
Wash your hands. Because chemicals from plastics are so common in items we touch throughout the day, encourage hand washing before handling foods and/or drinks, and wash all fruits and vegetables that cannot be peeled.

POSITIVE FOOD ENVIRONMENT

The importance of maintaining a positive food environment seems to be critical to promoting our children's development as healthy adults. The AAP places emphasis on a total and overall healthy lifestyle and not on any numerical value, such as a number on a scale. (29)(30)

The AAP Committee on Nutrition, Committee on Adolescence, and Section on Obesity have jointly (31) published on the prevention of obesity and eating disorders in adolescents using evidence-based guidance to help identify behaviors that may adversely impact teens dealing with weight concerns and emphasizing the importance for adolescents to develop a healthy lifestyle.

There is strong evidence (29)(30)(31)(32) demonstrating the damaging consequences when parents/caregivers try to control the children's ability to self-regulate caloric intake. The findings indicate that parents must, through the use of anticipatory guidance, encourage moderation and emphasis on healthful food choices rather than promote restrictive eating patterns. Parents and other caregivers should be role models. Furthermore, a position paper from the AND in 2014 (30) discusses the importance of the food environment in children and the impact the food environment has on aiding children to regulate their caloric intake. The AND acknowledges that feeding approaches such as food restriction can create negative repercussions in children's hunger cues.

More specific recommendations regarding the home environment include (30) limiting screen time, involving the whole family in enjoyable activities, promoting a positive body image while avoiding judging your child's body or your own body, focusing on maintaining overall health not weight, avoiding food prohibition/forbidden foods/food as reward, disregarding the "clean plate" approach, and encouraging family mealtimes.

FOOD PRODUCT LABELING AND CLAIMS

Food labeling is complex but important for anyone trying to understand our food environment. The Food and Drug Administration (FDA) provides a guide titled "How to Understand and Use the Nutrition Facts Label." (33) Examining the FDA's current (2013) "Guidance for Industry" can be informative. (34) The FDA also publishes a 6-page food-labeling guide that contains nonbinding recommendations and guidance for industry use of the term *healthy*. (35)

The word *healthy* on a label takes into account only the overall nutrition labeling regarding distribution of caloric intake and not the ingredients list, that is, "... the food meets the conditions for total fat, saturated fat, cholesterol, and other nutrients."

Another term that many people tend to confuse with *health* or *healthy* is the word *natural*. The FDA has not provided a clear explanation but considers the term *natural* to mean that nothing artificial or synthetic (including all color additives regardless of source) has been added that would not normally be expected to be in that particular food. The FDA did not consider whether the term *natural* should describe any specific nutritional or other health benefit. Natural does not equal healthy, healthier, or nutritious, and neither does it mean to indicate that consumption will grant greater health benefits compared with other products not labeled as natural. Many food products in the market contain high amounts of sugar, are low in fiber, or include questionable ingredients and still contain the term *natural* on their label. Gluten-free labeling also may mislead the general population. Many gluten-free products contain high amounts of sugars and food additives and are highly processed as well as more expensive than similar gluten-containing products. A gluten-free diet is essential and is the only treatment for people with celiac disease, but whomever is on such a diet should seek expert dietary guidance from a registered dietitian (RD) or an RD nutritionist (see later herein).

The term *organic* on a food label requires that the food be grown and handled with relatively stringent restrictions. The USDA conducts on-site inspections that document every aspect of the organic process.

The USDA has posted a series of informative articles on how an organic food may be grown and processed, including "What the USDA Organic Label Means," (36) "What Organic Farming (and Processing) Doesn't Allow," (37) and "Allowed and Prohibited Substances." (38)

RDS AND RD NUTRITIONISTS

In general there are few restrictions on use of the term *nutritionist*. Use of the term is not regulated by any certified national agency, and it is variously defined in different states. When an individual or a physician needs nutritional expertise to assist in patient care, the professional level of expertise is best provided by an RD.

The AND defines an RD as an individual who has met specific minimum (baccalaureate) academic requirements and completed specified didactic education and supervised practice experiences and has successfully completed the registration examination for dietitians. In addition, an RD must meet periodic recertification requirements. The AND has approved the optional use of the credential RD nutritionist by RDs. Additional information regarding the qualifications of RDs is available on the AND website (https://www.eatright.org/food/resources/learn-more-about-rdns/qualifications-of-a-registered-dietitian-nutritionist).

ROLE OF EXERCISE (EXERCISE, PA, AND CARDIORESPIRATORY FITNESS) IN THE PREVENTION OF DISEASES

The idea that all individuals, regardless of age, disability, or state of health, will benefit from obtaining adequate PA is widely accepted. There does not seem to be a significant amount of disagreement on the general concepts of the importance of PA, but there is inadequate reliable data on the specifics of what constitutes a prescription of maximal benefits achievable.

The World Health Organization (WHO) published its Global Action Plan on Physical Activity 2018–2030 to provide guidance to support actions that would reduce the global prevalence of physical inactivity in adults and adolescents. (39)

A scholarly review of the plan concluded that substantial inconsistencies throughout the available data resulted in widely varying estimates of the levels of PA of children and adolescents at the global, regional, and national levels. They cited the need to develop a reliable tool to assess the status and progress more accurately in the field. (40)

The WHO defines PA as "all movement including during leisure time, for transport to get to and from places, or as part of a person's work. Popular ways to be active include walking, cycling, wheeling, sports, active recreation and play, and can be done at any level of skill and for enjoyment by everybody." (41)

The AHA points out that the 3 terms PA, exercise (42), and cardiorespiratory fitness (CRF) are associated but distinct concepts. (43) Furthermore, regarding the prevention of disease, the most important of the 3 is CRF. "CRF refers to the ability of the circulatory and respiratory systems to provide oxygen to skeletal muscle mitochondria for energy production needed during physical activity." (43) CRF is an objective measure of health that can be followed longitudinally. The AHA has suggested that CRF be assigned as a vital sign because of its power in predicting adult mortality. There are different tests that may be used to assess CRF. The gold standard is the cardiopulmonary exercise test. The development of a reliable measure of CRF that can be used in any medical office or clinic is a priority but does not seem imminent.

The actual beneficial effects of PA were described approximately 70 years ago (44)(45) in studies in adult populations. The focus of the studies was the effect of PA on coronary heart disease. Regarding the well-being of children and adolescents, the international community accepts that PA is beneficial for their health and well-being. (46)(47) PA recommendations for infants and children aged 0 to 4 years (47) and for children and adolescents aged 5 to 17 years to improve health have been published by the WHO and reviewed. (46)

Carson et al (47) reviewed 96 studies of PA in infants and children (0–4 years old). Poitras et al (46) performed a systematic review of the relationships between objectively measured PA and health indicators in school-age children and adolescents (5–17 years old). Both studies had significant limitations. For the 0- to 4-year-olds it was not possible to identify the specific frequency and duration of PA needed to produce a measurable health benefit. But across the 96 studies it was consistently observed that more PA (in terms of frequency or duration) was better for health. Among the 162 studies of 5- to 17-year-olds, the heterogeneity of the studies precluded a proper meta-analysis, but the authors provided a narrative synthesis. They concluded that total PA was favorably associated with physical, psychological/social, and cognitive health indicators. All patterns of activity (sporadic, brief bouts, continuous) provided benefit. The authors felt that their findings support the importance of at least 60 min/d of moderate to vigorous PA for disease prevention and health promotion in children and youth but also highlight the potential benefits of even limited PA.

Most recently, Wu et al (48) attempted a systematic review and meta-analysis of the effect of intensity, duration, and amount of PA in children and adolescents. The authors emphasized that the major limitation of their analysis was the "low quality" of the available studies. (48) The authors provided several very general conclusions regarding the impact of various training approaches on muscle function but could not provide enough specific information to translate their findings into specific recommendations.

A review of the current literature reveals that there are substantial inconsistencies in the studies reported (and probably ongoing) that have resulted and are still causing varying estimates of the PA status of children and adolescents at the global, regional, and national levels. The development of a validated measuring instrument that would harmonize the many ongoing efforts to understand the significance and status of PA among children everywhere is a WHO priority.

Adequate studies of PA will have to broaden their analyses to include behavioral and dietary effects of PA. A study of food choices of gym goers before and after exercise reported that the food choices made after exercise were less healthy than those made before exercise. (49) The report raised the complication of the impact of exercise on dietary intake. It seems that the interaction of exercise and diet involves unexplored behavioral elements.

There is considerable interest in using wearable mobile devices to monitor various body functions. Initial reports are providing the basis for improving future research protocols. (50) As the use of monitoring devices expands in PA research, the lack of uniformity in obtaining reliable measures will need to be addressed. (51)

PA and Bone Density

There is a clear relationship between childhood and adolescent PA and adult bone density and the occurrence of osteoporosis later in life. Most of the literature is extrapolated from studies in adults and emphasizes the importance of calcium absorption and exercise without providing specific data on how dietary calcium and exercise specifically translate into increased bone mineral content and bone density. (52) There is no validated exercise program for children and adolescents that provides specific data on exercise effect on bone mass. The WHO guidelines on PA and sedentary behavior suggest that PA provides benefits for bone health in children and adolescents, but the studies on which they base their recommendation have significant limitations. (53) The lack of definitive studies does not, however, invalidate the current recommendations reflecting the importance of a healthy diet combined with PA.

PA in Chronic Disease

Children with cancer, chronic respiratory diseases, metabolic diseases, cardiac disease, psychiatric and emotional disorders, and other serious life-altering conditions should not be excluded from exercise regimens. Clearly, each individual must be evaluated by the appropriate physician in charge. It is important not to automatically consider that the metabolic impact will be negative. Requesting specific PA limitations as well as options from the physicians in charge of the child's care can provide benefits to some children.

A Weight-Neutral Strategy for Treating Complications of Obesity

Gaesser and Angadi (54) proposed a "weight-neutral" strategy for obesity treatment to replace what they see as a "weight-centric" approach. The weight-neutral strategy would focus on PA and improving CRF. Their rationale includes the following points:

1. Weight-centric approaches to obesity (and obesity-related morbidities) have been largely ineffective.
2. The obesity-associated risk of death is lessened by moderate to high levels of CRF or PA.
3. Exercise training, unrelated to dietary management, can improve obesity-related cardiometabolic risk markers. The improvements found are independent of weight loss and of a similar magnitude to that observed with weight-loss programs.
4. Intentional weight loss is less effective in reducing mortality risk than is increasing CRF or PA.
5. The cycle of losing and regaining weight is by itself associated with numerous adverse health outcomes, including increased mortality.
6. The task of shifting the primary focus on preventing the bad outcomes of obesity from weight loss to increased fitness via increased PA will be challenging, but given the tremendous personal costs and economic costs of the increasing incidence of obesity, it could be worthwhile.

PA Guidelines for Americans

The authors of the US Department of Health and Human Services Physical Activity Guidelines for Americans (55) state that "physical activity fosters normal growth and development and can make people feel better, function better, sleep better, and reduce the risk of a large number of chronic

Table 3. US (55) and Canadian (56) PA Guidelines

AGE GROUP, Y	CANADA	UNITED STATES
0–4	Infants: Daily (tummy time/playing on the floor/ crawling) Toddlers and preschoolers: total of 180 min daily accumulative (any intensity)	—
3–5	—	• Preschool-age children should be physically active throughout the day
		• Adult caregivers of preschool-age children should encourage active play that includes a variety of activity types
5–11	Minimum of 60 min of moderate to vigorous intensity a day (3× a week vigorous activity strengthens muscles and bones)	Minimum of 60 min of moderate- to vigorous-intensity PA daily
		• Aerobic: Most of the ≥60 min per day should be either moderate- or vigorous-intensity aerobic PA and should include vigorous-intensity PA ≥3 d/wk
	—	• Muscle-strengthening: As part of their ≥60 min of daily PA, children and adolescents should include muscle-strengthening PA on at least 3 d/wk
		• Bone-strengthening: As part of their ≥60 min of daily PA, children and adolescents should include bone-strengthening PA on ≥3 d/wk
12–17	—	Minimum of 60 min of moderate to vigorous intensity a day (3× a week vigorous activity strengthens muscles and bones)

—, not applicable.

diseases. Health benefits start immediately after exercising, and even short episodes of physical activity are beneficial."

The document discussed health benefits related to a substantial number of health-related conditions. It also provides new guidance for preschool-aged children (ages 3–5 years).

The guidelines along with related guidelines from Canada (56) are summarized in Table 3.

Although the 118-page document is extensive, the level of evidence in support of much of what it contains is not adequate. Based on consensus, the findings are likely largely acceptable, but these findings need to be questioned and revised.

Finally, we focused on the role of diet, nutrition, and exercise on preventing disease. Future contributions on this subject will likely have to expand to include the impact of food production on our environment and on global climate change, a subject that is beyond the scope of this review.

Summary

- Based on strong evidence, the terrible toll that the coronavirus 2019 pandemic has taken on adults resulted in large part from coexisting morbidities associated with nutrition-related (and, therefore, preventable) diseases, including type 2 diabetes and cardiovascular disease.
- Based on strong epidemiologic data and consensus, concerns regarding child nutrition now increasingly focus on the very significant effect of social determinants of health and on the reality that the nutrition- and exercise-related habits developed in childhood have a lifelong effect on individual well-being.
- Based on sound statistical analysis, Dietary Reference Intakes contribute greatly to our understanding of how to plan or assess nutritional adequacy in groups and individuals.
- Based on consensus, Dietary Reference Intakes contribute only a portion to what today's pediatric clinician needs to know about guiding children toward healthy adult lives.
- Based on strong evidence and consensus, the role of diet, nutrition, and adequate exercise in preventing disease is acknowledged.

References and teaching slides for this article can be found at https://doi.org/10.1542/PIR.2021-005174.

Nutritional Deficiencies in Vegetarian, Gluten-Free, and Ketogenic Diets

Erik Andrewski, MD,* Katherine Cheng, MD,† Charles Vanderpool, MD*

*Riley Hospital for Children and Indiana University School of Medicine, Indianapolis, IN
†UCSF Benioff Children's Hospital, San Francisco, CA

EDUCATION GAPS

Pediatricians should be aware of the increased prevalence of infants, children, and young adults on restrictive diets, including vegan, ketogenic, and gluten-free diets. Although inadequately monitored vegetarian and gluten-free diets can lead to poor growth, the ketogenic diet carries severe risks, including hypoglycemia and cardiomyopathy, if not managed properly.

OBJECTIVES *After completing this article, readers should be able to:*

1. Understand medical indications for a gluten-free or ketogenic diet.
2. Recognize presenting signs and symptoms of nutritional deficiencies associated with the vegetarian, gluten-free, and ketogenic diets.
3. Gain knowledge regarding dietary changes and common foods or fortified products that can help reduce the risk of deficiency.

ABSTRACT

Previously, medical diets, including the ketogenic and gluten-free diets, were rare outside of their target population. Subspecialists more familiar with risks and benefits often managed nutrition and any associated shortcomings. With more patients electively following a gluten-free or ketogenic diet for nonmedical needs, as well as the increasing prevalence of vegetarian diets, general pediatricians are seeing more followers of restrictive diets with general well-child care. Increasingly, general pediatricians can be the first provider to witness presenting signs or symptoms of associated nutritional deficiencies. This article reviews signs and symptoms of possible nutrient deficiencies seen with the vegetarian, ketogenic, and gluten-free diets.

AUTHOR DISCLOSURE Drs Andrewski, Cheng, and Vanderpool have disclosed no financial relationships relevant to this article. This commentary does not contain a discussion of an unapproved/investigative use of a commercial product/device.

ABBREVIATIONS

AA	amino acid
AED	antiepileptic drug
CD	celiac disease
DHA	docosahexaenoic acid
DRI	dietary reference intake
GF	gluten-free
GFD	gluten-free diet
KD	ketogenic diet

INTRODUCTION

Adults and children can follow restrictive diets for various reasons, including medical necessity, perceived health benefits, trendiness, animal rights, environmental impact, or a desire for weight loss. Nearly half of American adults and 40% of teens report attempted weight loss annually. (1)(2) Various diets come in

and out of favor, with some originating as medical therapies for specific ailments or disease states. Ketogenic (KD), gluten-free (GFD), and vegetarian diets are generally safe when closely supervised by trained health-care providers. Patients adapting these diets regardless of reason could unknowingly place themselves at risk for nutrient deficiency without proper monitoring and supplementation. In contrast to vegetarian and GF diets, the KD is additionally associated with serious, and potentially lethal, adverse effects, including cardiac arrhythmia, growth failure, and nephrolithiasis, necessitating close supervision by a trained medical expert. (3) This article reviews common restrictive diets, with a focus on medical evidence for need and potential deficiencies that can be encountered with each diet.

KETOGENIC DIET

The KD was developed in the 1920s for treatment of seizures; although effective, the rigidity of the diet led to a steep drop in popularity after the introduction of antiepileptic drugs (AEDs) in the mid-20th century. (4) The KD enjoyed a recent resurgence in popularity after being found efficacious for seizure reduction or cessation in epileptic patients with seizures refractory to multiple frontline medications. The KD is also effective treatment for pyruvate dehydrogenase deficiency and glucose transporter type 1 deficiency. (5) Recently, the KD has been investigated for weight loss and management of type II diabetes mellitus. (3)

Diet

The KD consists of low carbohydrate intake, leading to ketosis; multiple regimens exist and are based on varying lipid-to-nonlipid ratios by weight, commonly 4:1 g, 3:1 g, or less. These ratios provide high fat, low carbohydrate, and adequate protein, with the ultimate goal to imitate a fasting state. (6) In the classic KD, nearly 90% of daily calorie intake is from fat. (7) Some patients may opt for an initial fast to achieve ketosis more quickly. Medium-chain triglycerides can be used and are more ketogenic than their long-chain counterparts, allowing for a more flexible ratio, but can be associated with increased rates of diarrhea, vomiting, and abdominal pain. (8) The Atkins diet, originally devised for weight loss, offers a less restrictive path to ketosis that is often equally effective for seizure management. (9) Children are allowed up to 30% of caloric intake from protein, 10% from carbohydrates, and the remaining 60% from fat. The increased protein and carbohydrate allowance is more palatable, and the increased flexibility allows consumption of school lunches or dining out. (9)(10) Irrespective of ratio, children on a KD are at increased risk for kidney stones due to hypercalciuria as a result of serum acidosis. (11)

Nutritional Deficiencies

Due to a decreased variety of food options, nutritional deficiencies, including thiamine, vitamin D, magnesium, phosphorous, copper, zinc, selenium, and carnitine, can be associated with the KD. Studies have shown the stricter the lipid-to-nonlipid ratio, the higher the likelihood of nutrient deficiencies, with children on a 4:1 ratio meeting only 3 of 28 daily dietary reference intakes (DRIs) and those on a 1:1 ratio meeting 12 of 28 DRIs. (5) KD plans can include specialty commercial formulas, solid foods, or a mixture of both. Typically, a multivitamin is prescribed with the diet, but none have been specifically designed to treat KD deficiencies, and supplementation varies among institutions. (12)

Selenium, a trace element found in high quantity in meats and grains, especially if grown in areas with high soil concentration, is required for the production of more than 25 proteins in humans and can be protective against some forms of cancer. (13)(14)(15) The typical KD is selenium-deficient, and without proper supplementation, serum levels can be depressed within a few months of KD initiation. Keshan disease, a cardiomyopathy, is a rare but serious complication of selenium deficiency. (16) Selenium-associated cardiomyopathy is caused by decreased action of the antioxidant enzyme glutathione peroxidase, leading to inflammation and tissue damage. (17) Restoration of appropriate levels can help prevent progression of the disease but will not reverse the damage. (18) Those with concurrent gastrointestinal disease are especially at risk.

Other minerals, including magnesium, phosphorous, and zinc, can be deficient in patients on a KD, with hair loss, diarrhea, or poor growth being notable symptoms of zinc deficiency. (7)(19)

Carnitine, a cofactor responsible for moving acyl–coenzyme A from the mitochondria to peroxisomes in long-chain fatty acid metabolism, is another possible deficiency associated with the KD. Nearly three-quarters of required daily value is obtained via diet, mostly from meat and dairy. (20) A carnitine deficiency would be particularly concerning for children on the KD due to its critical role in fatty acid oxidation. Studies of carnitine deficiency on a KD are sparse and limited by small sample size. When starting a KD, carnitine levels should be checked because

deficiency has been associated with hypoglycemia during the initial fast. During the maintenance phase, symptoms associated with secondary carnitine deficiency from a KD include mild muscle weakness, hypotonia, apathy, listlessness, anorexia, nausea or vomiting, and constipation. (21) In a prospective study, Coppola et al (22) found 11 patients who were simultaneously on carnitine-reducing AEDs and KD therapy and showed no deficiency after 3 and 12 months. The remainder of their cohort was exclusively on AED therapy, and carnitine deficiency was primarily associated with valproate use. In a second study, Berry et al (6) found that 18% of patients on a KD became carnitine-deficient, but no patients became symptomatic or had elevated alanine aminotransferase levels. Those who were deficient responded quickly to supplementation. Carnitine deficiency can be a rare complication of KD therapy, and serum levels likely do not need to be monitored unless patients become symptomatic. (21) Reassuringly, cardiomyopathy does not seem to be associated with secondary carnitine deficiency from a KD, unlike primary carnitine deficiency syndromes. (23)

Other possible deficiencies include a case report of pureed, homemade KD with insufficient copper causing neutropenia, which resolved with appropriate replacement therapy. (24) Two reports of optic neuropathy secondary to thiamine deficiency have also been reported. (25)

Interestingly, fat-soluble vitamin D deficiency has been found in patients on a KD and shown via imaging to lead to bone demineralization in this population. (26) Complicating these findings, most children on a KD are also treated with AEDs, a known cause of vitamin D deficiency. A lack of sufficient calcium, phosphorous, and magnesium in the KD can exacerbate the effects of low vitamin D. (5) Further study is needed to establish what proportion of deficiency can be attributed to diet alone.

VEGETARIAN DIET

Veganism, or avoidance of all animal products, is on the rise, with an estimated 2% of all Americans and 1% of children ages 8 to 18 years following this strict diet. (27)(28)(29) Vegetarians avoid all meat products, although some subtypes can eat fish, eggs, dairy, or honey (Fig 1). Although not strictly vegetarian, most macrobiotic dieters avoid red meats, poultry, butter, lard, eggs, and dairy entirely, and some followers allow rare consumption of fish. They also emphasize avoidance of genetically

FIGURE 1. Subtypes of vegetarian diets. Green denotes no restrictions; yellow, limited consumption; pink, general avoidance; and red, total avoidance.

modified organisms and local sourcing of foods. (30) Their combined number is anticipated to grow as climate change, animal rights concerns, and perceived nutritional benefits lead more Americans to cease consuming some, or all, animal products. These diets have been described as safe for all life stages, including pregnancy, infancy, childhood, and adolescence, so long as they are "well-balanced." (31)

Nutritional Deficiencies and Adverse Effects

Vitamin, mineral, and macronutrient deficiencies have been reported in patients limiting animal product consumption.

Vitamin B_{12} is produced exclusively by microorganisms and found in high concentrations in animal product. Vitamin B_{12} deficiency is a well-known complication of veganism but can also be seen in nonvegans with low egg, dairy, fish, or meat intake; without adequate supplementation, deficits occur and can cause macrocytic anemia and neurologic deficits of the dorsal column. (32) One study followed strict macrobiotic vegan infants into adolescence; even after animal dietary product was reintroduced as teens, more than one-third continued to have depressed cobalamin levels, showing that transition in diet alone might not replete serum vitamin B_{12}. (33) Deficiency of vitamin B_{12} can also be seen in the breastfeeding infant of a vegan mother, and infant supplementation of vitamin B_{12} should be considered.

Vitamin D is essential for bone health, with fortified cow milk serving as a great source for children. This is not universally true of soy and nondairy milks, and the vitamin D content of cow milk substitutes should be confirmed (Table 1). A Polish study found that vegan patients had average vitamin D levels 50% under the lower limit of normal. (35) Another study comparing standard vegetarians and macrobiotic vegetarians stratified by animal food intake found stricter macrobiotic tendencies associated with lower vitamin D intakes. Overall, the macrobiotic group was severely vitamin D–deficient, averaging less than 50 IU of a recommended 400 IU daily intake. Eighty-eight percent consumed less than 100 IU per day, the minimum necessary for rickets prevention, compared with 18% of the control vegetarian group. (36) Cases of rickets in vegans consuming homemade formula or unfortified milk alternatives are not uncommon, with children at greatest risk in winter and early spring, when they are unable to synthesize vitamin D via sunlight exposure. (36)(37)(38)

Retinol, the active form of fat-soluble vitamin A, is exclusive to animal products; however, humans can convert other carotenoids, or members of the vitamin A family, to the active form. For those avoiding animal products, good sources of carotenoids include spinach, carrots, sweet potato and other yellow and orange fruits or vegetables. Provitamin carotenoids are measured in retinol activity equivalents and require a larger intake to meet daily goals than retinol. Vitamin A is essential for vision, skin health, immune function, and the developing embryo. (39)(40) If dietary intake of yellow and orange vegetables is low, supplementation should be considered.

Mineral deficiencies can arise from inadequate intake, decreased bioavailability, and high concentrations of oxalate and phytate. Phytate is a storage molecule commonly found in cereals, oil seeds, legumes, and nuts that acts as a reservoir of phosphorous, calcium, and magnesium. (41) Oxalate, a known contributor to kidney stones, is found in especially high concentration in taro root, beets, spinach, rhubarb, and sweet potato. (42) In the digestive tract, phytate and oxalate can complex with divalent cations, rendering them poorly absorbable and leading to potential deficiencies of calcium, iron, and zinc. (43)(44) Absorption is most adversely affected when calcium-, iron-, or zinc-rich foods are eaten in the same meal as high phytate or oxalate foods. Although zinc absorption is decreased in

Table 1. Milk and Milk Substitute Nutrition Information (34)

MILK TYPE	VITAMIN D, % DRI	CALCIUM, % DRI	PROTEIN, g	CALORIES
Whole milk	10–25	20–30	8	150
Skim milk	10–25	25–30	8	80
Almond	10	30	1–5	30–40
Cashew	25	10–45	0–1	25
Coconut	10	10–45	0–1	40–45
Flax	30	30	0–7	55–80
Hemp	10	20–40	2–4	60
Oat	0–25	2–35	1–4	70–80
Pea	30	35–45	8	70
Rice	25	25–30	0–1	70
Soy	15–30	20–40	6–7	80–90

Content per 8-oz serving; the unsweetened versions of milk substitutes were used for nutrition information. Ranges are provided when significant variation was found between brands. DRI=dietary reference intake.

patients on vegetarian diets, it is currently unclear whether serum concentrations are reduced enough to precipitate any adverse effects.

Dairy products provide up to two-thirds of total calcium intake in the United States. (45) A study using computer-generated diets concluded that nonfortified foods in a vegan diet could not meet the DRIs of calcium without producing other nutrient deficiencies or caloric excess. Including calcium-fortified foods, the same study examined real diet logs of 127 dairy-free 9- to 18-year-olds; only 1 had adequate intake, and on average consumption was less than 40% of DRIs. (46) In addition to decreased intake, high oxalate contents of leafy greens and cruciferous vegetables inhibit calcium absorption. This can be mitigated by combining calcium-rich foods with a source of vitamin C. If intake is still below recommended levels, daily supplementation is recommended.

Adult vegans have been found to have lower iron stores but typically do not have increased rates of anemia. Similar data are not available for the pediatric population. Caution should be taken because even children reaching 100% of the DRI of iron may be deficient due to lower bioavailability of nonheme iron, a phytate-heavy diet, and decreased dietary vitamin C, which has a synergistic effect on iron absorption.

Both absolute intake and composition of protein should be closely monitored in a vegetarian diet. Although animal products are a complete source of essential amino acids (AAs), a mixture of nonanimal products is required to obtain all essential AAs. Legumes and fruits provide adequate threonine, an essential AA lacking in most grains, but are deficient in methionine and cysteine. Plant-based protein is often less bioavailable as well. For these reasons, increased protein intake with a vegetarian diet by up to 35% of daily recommended value is suggested. (47)

Protein deficiency from inappropriate milk substitute is well documented. Certain milk substitutes, such as rice milk and almond milk, have little to no protein. Some cases of Kwashiorkor have been reported secondary to milk substitution. In these specific instances, dairy avoidance was related to perceived milk allergy or parental choice to avoid animal products. (27) If dairy substitutes are used, close attention should be given to protein content (Table 1).

In terms of overall growth, no studies have shown vegan children to be at increased risk for failure to thrive, but mildly decreased weight and stature among teenage boys has been demonstrated. (48) In particular, The Farm Study examined more than 400 children, with vegans' average height 0.7 cm less than that of their omnivorous peers. Of note, participants in The Farm Study cohort were supplemented with multiple vitamins and minerals, possibly lessening the growth suppression that could be seen with less vigilant intake. (49)

A final concern is children who choose vegetarian diets while their families remain omnivorous. Teens pursuing a vegan or vegetarian diet can do so for weight loss with overly restrictive eating, limiting nutritional variety and increasing the risk of deficiency.

Special Considerations in Infants and Toddlers

Vegan diets can begin at birth, with breast feeding by a vegan mother or exclusive soy formula use. Vitamin and mineral concentrations in human milk are dependent on maternal levels. (50)

Concentrations of vitamins A, C, D, and the B group in human milk are especially maternal diet–dependent. (51)(52) Although vitamin B_{12} is frequently supplemented in vegans, nursing mothers can have borderline levels. Case reports have found symptomatic vitamin B_{12} deficiency in both breastfed infants of vegan mothers and those who have started weaning. In its most severe form, prolonged vitamin B_{12} deficiency can cause irreversible neurologic damage from decreased myelination. (50)(53) To ensure adequate vitamin B_{12}, mothers should take an approved supplement or infants should be supplemented directly. In addition, low maternal iron stores in vegan or vegetarian mothers can lead to deficiency in breastfed infants. Guez et al (54) described a case of normocytic anemia, hepatosplenomegaly, and developmental delay secondary to severe iron deficiency and vitamin B_{12} deficiency in a strict vegan mother not actively supplementing. Term infants born to iron-deficient vegetarian mothers are not only more likely to become deficient but also onset of deficiency can occur as early as 6 months of age, or 3 months sooner than infants born to moms with adequate iron stores. (55)

Lack of docosahexaenoic acid (DHA) in vegan mothers' milk has become a concern, with studies showing a lower human milk concentration than in their nonvegan peers. DHA is critical for the developing retina and brain in preterm infants, although benefit to term infants is less clear. (56)(57) Some studies support that higher early consumption correlates with better long-term developmental outcomes. Note that although omnivorous mothers have higher concentrations of DHA, until recently DHA was not added to formula, which had a lower level than vegan human milk. (27)(58)(59)

Standard soy formulas available on the market are nutritionally complete and appropriate for use in healthy

term infants. However, soy formulas are not appropriate for use in preterm infants, especially infants with weight less than 1,800 g, due to concerns regarding reduced calcium and phosphorous absorption, bone mineralization, and growth. (60) There is a lack of preterm or completely hydrolyzed vegan formulas on the market, leading some parents to use home mixtures that might not be nutritionally appropriate. Families might also look to using formulas outside of their country of location, leading to the potential for limited quality and safety monitoring and limited recall notification for quality concerns.

Finally, weaning to standard soy milk and vegan diet places infants at risk for insufficient caloric intake. Soy milk contains many of the same vitamins and minerals as whole milk, but fat content is more comparable with that of 2% milk. (59) Other milk substitutes have varying nutritional profiles (Table 1). High-fiber foods, including fruits, vegetables, and whole grains, the cornerstone of a vegan diet, are filling but have poor energy density. A vegan diet can easily exceed the 0.5 g/kg of daily fiber recommended by the American Academy of Pediatrics, leading to early satiety, caloric insufficiency, and poor growth. Until the child is age 2 years, parents should provide adequate energy by offering nut butters, avocado, legumes, and refined grains to meet daily caloric goals. (59)

GF DIET

Gluten, a family of proteins high in glutamine and proline residues known as prolamins, is a viscoelastic substance that enhances the flavor and texture of baked goods. Many gastrointestinal disorders require partial or total gluten avoidance. Nearly 1% of Americans and Europeans are affected by celiac disease (CD), an autoimmune enteropathy triggered by gluten. The GF diet (GFD) was discovered in 1953; it consists of strict avoidance of wheat, barley, and rye and is the only known treatment for CD (Fig 2). (61)(62)

Wheat, barley, and rye all contain high concentrations of gluten and must be strictly avoided by patients with CD on a GFD. Oats are less clear cut; aside from frequent contamination by other grains during processing, a small subset of patients with CD might have a reaction to a protein contained in oats that is structurally similar to gluten. Oats should be avoided after initial diagnosis of CD and reintroduced only after presenting symptoms have resolved. After reintroduction of oats, patients should be clinically and serologically monitored. (63)

Other gastrointestinal diseases for which patients can follow a GFD include wheat allergy, nonceliac gluten sensitivity, and irritable bowel syndrome. Wheat allergy, mediated by an IgE reaction to various proteins found in wheat, affects up to 0.5% of the population. Wheat allergy typically requires elimination of only wheat products rather than a true GFD, although some portion of patients can have cross-reactivity to proteins in other grains (Fig 3). (65)

The number of Americans following a strict GFD is increasing, with patients without CD now composing most of those purchasing GF foods. (66) Many nonceliac purchasers of GF products are nonwhite individuals, have

VITAMIN	VEGAN	KETOGENIC	GLUTEN-FREE	SOURCES	SIGNS AND SYMPTOMS OF DEFICIENCY
B_1 (thiamine)				Whole grains, pork	Neuropathy, confusion, heart failure, weight loss
B_9 (folate)				Leafy greens, oranges, nuts, beans, peas	Megaloblastic anemia, fatigue, headaches, palpitations
B_{12} (cobalamin)				Animal product	Macrocytic anemia, neuropsychiatric symptoms
Vitamin D				Fish liver, fortified dairy	Osteomalacia, rickets, hypocalcemia
Vitamin A				Animal product, orange/yellow vegetables (as carotene)	Xeropthalmia, vision changes, night blindness
Calcium				Dairy, fortified foods, leafy greens	Osteopenia, osteoporosis arrhythmia, numbness, tingling
Iron				Heme: fish, poultry, meat; nonheme: iron-fortified cereals/breads	Anemia, fatigue
Magnesium				Leafy vegetables, whole grains, legumes	Nausea, vomiting, seizures, arrhythmia
Phosphorous				Dairy, breads, vegetables	Osteopenia, muscle weakness
Copper				Oysters, chocolate, potatoes	Anemia, neutropenia, abnormal hair, osteopenia, muscle weakness
Zinc				Seafood, meat, poultry, whole grains	Poor growth, hypogonadism dysgeusia, diarrhea, alopecia, dermatitis (especially perioral and perianal), poor wound healing
Selenium				Seafood, organ meats, beans, Brazil nuts	Cardiomyopathy, skeletal muscle deficiency
Carnitine				Meat	Cardiomyopathy, weakness, hypoglycemia
Docosahexaenoic acid				Human milk	Poor neurodevelopment
Fiber				Fruits, vegetables, grains	Constipation, elevated cholesterol

FIGURE 2. Deficiencies associated with the ketogenic, vegan, and gluten-free diets. Shading denotes increased risk of deficiency.

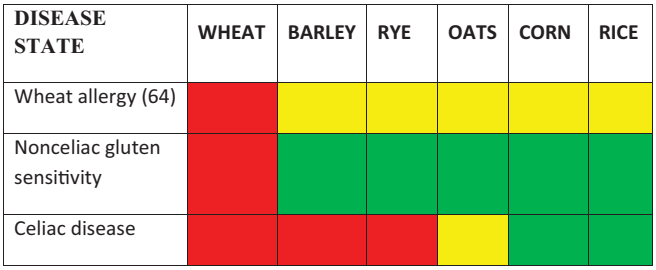


FIGURE 3. Grain avoidance in gluten-limiting disease states. Red denotes need for avoidance; yellow, potential avoidance based on individual symptoms; and green, no restrictions.

a high school diploma or less, and earn less than $30,000 a year, which are all groups that may have decreased access to medical care relative to the general population and thus potentially are more prone to nutrient deficiency. (67)

The decision to avoid gluten in patients without CD is multifold, with more than 1 in 5 US consumers viewing "gluten-free" as important when selecting food. (67) In some international areas, up to 5% of children avoid it entirely. (68) Reasons for adopting a GFD include perceived healthiness, trendiness, concerns over genetically modified wheat, behavioral changes in children, or nonspecific symptoms such as chronic abdominal pain, fatigue, and headaches that patients might relate to gluten.

A GFD can be nutritionally incomplete due to avoidance of wheat, rye, and barley. These products naturally contain vitamins, minerals, and fiber, and many wheat products have government-mandated micronutrient fortification that is not required of their GF equivalents.

Many studies report concern about low fiber and, to a lesser extent, decreased protein intake with a GFD. (69)(70) Wheat, barley, rye, and oats are naturally good sources of fiber; GF substitutes for breads, pastas, and baked goods are often heavily refined, which entails removing the bran and mill and substantially decreasing fiber content. (71) One study looked specifically at adolescent fiber intake and found lower daily intakes in the GFD group relative to their peers. (72) Although most studies still support inadequate intake, some newer papers report increasing fiber content of packaged GF foods. (73) Non–gluten-containing pseudocereals such as amaranth, buckwheat, and quinoa are also becoming increasingly popular and have high fiber content.

Use of refined flours and lack of mandatory fortification also contribute to vitamin and mineral deficiencies with a GFD. In many Western countries, including the United States, governments mandate that wheat-based products be fortified, as evidenced by packaging listing "enriched wheat flour." The Food and Drug Administration (FDA) requires the addition of thiamine, niacin, riboflavin, folate, and iron to enriched grain products. (74) For products listing calcium-fortified, the FDA has also set minimum standards. Nonwheat flours are not held to the same controls, with only 5% of GF breads having the mandatory amount of calcium, iron, niacin, and thiamine present. (75) Thiamine is of particular concern, with one study showing that serum levels actually decreased in patients with CD after initiation of a GFD and mucosal healing, likely due to the low thiamine content of the GFD. (76) Packaged GF goods have also been shown to have lower folate levels than their gluten-based equivalents, with deficiency being found in up to 20% of patients with CD on a GFD. (76)

Concerns for vitamin B_{12} deficiency have also been well-documented in the GF population, with up to 40% having inadequate serum levels. (75) Vitamin B_{12} is essential for the production of methionine from homocysteine. If vitamin B_{12} levels are low, homocysteine levels can rise. (77) A multicenter trial compared 2 groups of patients with CD on a GFD using homocysteine levels as a proxy for adequacy of intake; 1 group received vitamin B_{12}, folic acid, and vitamin C supplementation, and the control group received only placebo. With the vitamin B_{12} regimen, serum homocysteine levels dropped, and patients reported an overall improved sense of wellness. (78) Megaloblastic anemia, psychiatric symptoms, and thromboemboli should all raise suspicion for vitamin B_{12} deficiency in patients on a GFD. (79) Interestingly, one study also found increased rates of vitamin A deficiency in some subsets of patients with CD after GFD initiation, but those results have not yet been replicated elsewhere. (80)

Mineral deficiencies associated with GFD include selenium and magnesium, which are consumed in significantly smaller amounts on a GFD. (69) Selenium is known to be high in wheat products, and intake is inadequate by DRIs with a GFD, but evidence of serum deficiency is lacking. Serum levels of magnesium remained depressed after initiation of a GFD. With evidence of mucosal healing after GFD initiation, this seems likely to

be related to inadequate intake with packaged GF foods and naturally GF grains, both being poor sources. (76)

In children, inadequate iron intake raises concerns for anemia, and zinc is crucial for adequate growth and is involved in protein synthesis. Studies on patients with CD suggest that iron and zinc intake is decreased on a GFD relative to the general population but mixed regarding whether true deficiency occurs. Iron data range from normal serum levels to up to 40% of patients with CD having an iron deficiency. (69)(73)(75) Impaired absorption of iron in the duodenum in patients with active CD enteropathy complicates interpretation of results and extrapolation to nonceliac patients. For calcium, adult intake was higher on a GFD compared with that of their gluten-consuming counterparts, but still only 18% to 32% of women met calcium DRIs. (69) In a cohort of children, 3.6% were calcium-deficient when adherent to a GFD. (81)

Many limitations exist in studies of potential GFD-associated nutritional deficiencies in children. Most available data focus on adult populations, which might not be accurately extrapolated to children. Studies looking at nonceliac patients on a GFD are also sparse. Studies focused only on patients with CD might artificially increase the number of observed deficiencies of a GFD due to complicating factors from CD, including impaired absorption from chronic mucosal injury, that would not be generalizable to non-CD populations. Other authors suggest that the literature's focus on patients with CD might actually underestimate GFD nutrient deficiencies in the nonceliac population, as patients without CD might be more likely to avoid multiple food groups for perceived health benefits. Finally, many studies examined cohorts outside of the United States, who likely have different dietary patterns, access to different brands of GF foods, and varying laws regarding mandatory fortification.

Summary

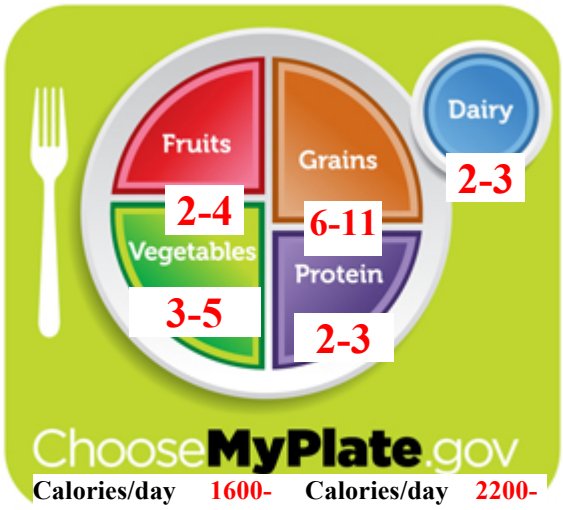
- The ketogenic diet (KD) is an effective therapy for antiepileptic drug–refractory seizure disorders, pyruvate dehydrogenase deficiency, and glucose transporter type 1 deficiency. Currently, there is no standardized KD multivitamin available, and the stricter the lipid-to-nonlipid ratio in a KD, the higher the risk of nutrient deficiencies, with selenium being of particular concern. (5)(12)(26) (Evidence quality D)
- If well-balanced or supplemented, vegan and vegetarian diets can be safe for all ages, including pregnancy, infancy, and childhood. However, patients who are highly restrictive in eating might be at increased risk for micronutrient and macronutrient deficiency, with vitamin B_{12}, iron, folate, and zinc deficiency being of particular concern. (82) (Evidence quality B)
- In the pediatric population, vegetarian diets should be closely monitored for fiber and protein content. The American Academy of Pediatrics recommends no more than 0.5 mg/kg per day of fiber to promote increased intake of energy-rich foods that promote growth. Plant-based protein is less bioavailable than that of animal origin, with vegetarian children requiring varying amounts above the standard recommended daily allowance depending on patient age. (47)(82) (Evidence quality D)
- Plant-based milks are not universal in nutritional status and often are not a suitable replacement for cow milk; in particular, protein, calcium, and vitamin D content can be of concern. (34) (Evidence Quality D)
- Strict avoidance of gluten is the only known treatment for celiac disease. Patients following a gluten-free diet, whether for medical needs or personal preference, can be at increased risk for micronutrient deficiency, including iron, folate, and B vitamins, with monitoring decisions made on a patient by patient basis. (83) (Evidence Quality B)

To view teaching slides that accompany this article, visit **https://doi.org/10.1542/pir.2020-004275.**

References for this article can be found at https://publications.aap.org/pediatricsinreview/43/2.

Nutrition III Quiz

1. Please fill-in the serving ranges for the **"Food Plate"** of an early-to-middle adolescent:



Calories/day (school-age):	**1600-2400**	**Calories/day (adolescent)**	**2200-2800**

** Remember—these are recommended ranges and not absolute rules.

2. What are the most common nutritional deficiencies in **adolescent females**, and how might they present? **Calcium**— osteopenia. **Iron**— anemia. **Zinc**— hair/skin/nail changes.

3. What nutritional components are particularly critical for **vegetarians**? How do their deficiencies present?

- **Vitamin B12**: aid in growth and development of brain and nervous system; in older children and adolescents, may present as megaloblastic anemia.
- **Folate**: aid in growth and development of brain and nervous system; in older children and adolescents, may present as megaloblastic anemia.
- **Omega-3-fatty acid**: assist in brain and retinal development; in older children and adolescents, may present as fatigue, poor memory, dry skin, mood swings or depression, and poor circulation.

Other important vitamins/minerals that may be lacking are protein (malnutrition → kwashiorkor & marasmus); iron (anemia); calcium (osteopenia); and zinc (hair/skin/nail changes).

4. What are the indications for a gluten-free diet, and what are its potential complications?

Indications: **Celiac disease**, wheat allergy, non-celiac gluten sensitivity, irritable bowel syndrome

Complications: Deficiencies of B1, B9, B12, vitamin A, calicium, iron, magnesium, zinc, selenium. Inadequate fiber (constipation, lack of satiety, excess caloric intake). Gluten free products tend to be highly processed/ refined. Some concern for lower protein intake.

5. What are the indications for a ketogenic diet, and what are its potential complications?

Indications: Epilepsy, pyruvate dehydrogenase deficiency, glucose transporter type 1 deficiency

Complications: Deficiencies of thiamine, vitamin D, magnesium, phosphate, copper, zinc, selenium, and carnitine. Cardiac arrhythmia, nephrolithiasis, growth failure.

Nutrition III Cases

Case 1: Ms. Lang presents with her 11 year old son Danny for his 11-year well visit. Danny has no past medical history, is tracking at approximately the 50th percentile on his height, weight, and BMI growth curves, and has been well since his last well visit. Ms. Lang's main concern today is that Danny eats a large amount of highly processed foods. Danny notes that he prefers a variety of flavors of Pop Tarts and a glass or two of juice for breakfast, Ham and Cheddar Lunchables for lunch, and either Pepperoni Bagel Bites or Kraft Mac N' Cheese for dinner. Most days Danny has a morning and afternoon snack of gummy snacks made from real juice or some baked potato chips. Ms. Lang is happy to know that Danny is growing well. She is wondering if this is a battle worth having, or if it is okay to keep things the way they are. What do you tell her?

It doesn't have to be a "battle," but helping Danny to improve his diet will have significant positive impact on his health, both now and in to adulthood. His current diet is **high in sugar, sodium, saturated fat**, direct food additives such as **artificial colors, nitrites, and nitrates** AND indirect additives such as **bisphenols, phthalates, perfluoroalkyl chemicals, and perchlorate.**

These components increase the chance of **obesity, hypertension, type two diabetes, and other chronic diseases**. They provide excess calories and relatively little fiber and micronutrients. Indirect additives are suspected of **endocrine disruption, immune suppression, and problems with macronutrient metabolism**.

Ms. Lang thanks you for the information. She knows the foods Danny prefers are really bad for him, she just doesn't know how to get him to stop eating them! Do you have any suggestions?

Answers will vary. Motivational interviewing techniques may help with parent and patient buy-in. In general, it may be best to focus on ways to encourage and make time for meals that incorporate fresh fruits and vegetables, whole grains, and lean protein sources, rather than focusing on what not to do. Encourage family grocery store trips with a goal of "shopping the perimeter" and avoiding the central part of the store where more of the highly processed foods are kept. Discuss ways to make fresh fruits and vegetables more appealing and snackable. Involving Danny is key. He should be encouraged to join in the shopping trip, help decide which healthy options to try, and help prepare the foods in a way he finds easy and appealing.

On the way out the door, Ms. Lang thanks you for all the great information and mentions that she is considering some "healthy" and "natural" options for prepared foods. She is seriously considering switching to a gluten-free or organic diet, but her husband is in favor of the Atkins diet products. She would like to know your "take" on these options?

- **"Healthy"** = a food with this label meets the conditions for caloric distribution of total fat, saturated fat, cholesterol, and other nutrients. It does not take in to account micronutrient content or direct and indirect additives.
- **"Natural"** = a product without synthetic or artificially derived ingredients. Products labeled "natural" are **not necessarily healthy or nutritious** and often have high sugar content and low fiber.
- **"Gluten-Free"** diets are medically indicated for individuals with celiac disease and select other diagnoses. GF diets are not appropriate for most people. The GF diet tends to be relatively low in protein, fiber, and many micronutrients. GF products tend to be highly processed, contain high amounts of sugar and additives, and higher in calories than gluten-containing equivalents. GF products are generally expensive too.

- **"Organic"** = foods that are grown and handled and inspected by the USDA under certain stringent conditions. Artificial, synthetic colors, flavors, and preservatives are prohibited as well as antibiotics, synthetic herbicides, irradiation, sewage sludge, and genetic engineering. Organic foods are more expensive and organic diets have not been shown to be more nutritious or have better health outcomes than diets high in conventionally grown produce.
- **"Atkins"** = a ketogenic diet with 10% of calories from carbohydrates, 30% of calories from protein, and 60% from fat. May be indicated for children with poorly controlled epilepsy. In general, ketogenic diets are not appropriate for children and are associated with increased risk of micronutrient deficiencies, inadequate fiber intake, kidney stones, and constipation. **Any child requiring a ketogenic diet should be followed in a multidisciplinary ketogenic diet clinic**. Atkins products are highly processed and contain high-intensity sweeteners, and excessive saturated fat sodium, and synthetic additives.

Case 2: Vegan/Vegetarian Eating

PO3 Smith presents with his pregnant wife and son, age 4, and daughter, Kimberly, age 13, for their school physicals. In taking a dietary history, you learn that the 13 year-old has decided to become "vegan", after watching a vintage rerun of "The Vegan Challenge" episode on Oprah. She also DVR'd the episode for her mother and convinced her to start cooking vegan for the entire family. Mrs. Smith proudly reports that, for the last year, the entire family has been eating vegan, and she has noticed that she and her children have been healthier and more energetic. PO3 Smith, who has been missing his steak dinners, asks you to explain to his wife and strong-willed Kimberly why a vegan diet is unhealthy.

What is eliminated in a vegan diet versus a vegetarian diet?

- Vegan diets eliminate ALL animal and fish products, to include eggs and dairy.
- Lacto-vegetarians include milk products. Lacto-ovo vegetarians include milk and egg products.
- Pescatarians include fish.

Can you make an argument to support Mrs. Smith? What are the benefits of a vegan or vegetarian diet?

Studies have shown that when "well-informed" parents raise vegetarian children, their growth parameters compare with that of non-vegetarian children. In addition, they tend to be leaner, with lower relative body weights and skin-fold thicknesses. Studies show that children and adolescents who follow a vegetarian diet have a lower intake of cholesterol, saturated fat, and total fat and a higher intake of fruit, vegetables, and fiber than their non-vegetarian counterparts. Vegetarian adults have a decreased risk for several chronic diseases such as diabetes, coronary artery disease, hypertension, obesity, and some types of cancer.

PO3 Smith seems even more distressed by this explanation. To diffuse the situation, you ask the others to step out the room, so that you can do your HEADSS exam for Kimberly.

Regarding her choice to become vegan, what sorts of questions and counseling do you want to address to Kimberly?

- Understand Kimberly's reason for a vegetarian diet, recognizing that the rationale may be ideological rather than health-related, including: ethical opposition to killing animals; disgusted by animal processing; and influence of friends.
- Evaluate weight concerns, body image, frequency of dieting for weight loss, and exercise patterns (a vegetarian diet may be an attempt to camouflage an eating disorder)
- Assess knowledge base and provide targeted education, including how to read food labels and *healthy* vegetarian options at school or out with friends.
- Recommend supplementation as necessary with calcium and vitamin B12

Nutrition III Board Review

1. You are evaluating a 2-year-old daughter of strict vegan parents. Her birth weight at term was 3.5 kg. Since weaning at 12 months of age, the child's diet has included a homemade, macrobiotic-based formula. In your office today, the girl's weight is 11.2 kg.

Of the following, the child's diet MOST likely is deficient in
A. essential amino acids
B. linoleic acid
C. vitamin A
D. vitamin B12
E. vitamin C

Strict vegan diets include foods that come solely from plant sources. Such diets generally contain adequate amounts of vitamins A and C as well as essential fatty acids (including linoleic acid). However, a strict vegan diet instituted after weaning contains very little vitamin B12, a nutrient primarily found in meats, eggs, and dairy products, unless supplements are provided.

Breastfed infants of vegan mothers may develop vitamin B12 deficiency, but only if maternal stores are low. Although the vitamin composition of human milk is directly related to dietary intake of vitamins A, C, D, and the B group, studies comparing the vitamin content of human milk from vegan compared with nonvegan mothers have not demonstrated any significant micronutrient differences. Commercial soy-based formulas are alternatives for vegan mothers who do not breastfeed. In most cases, therefore, the greatest potential nutritional risks for both breastfed and soy formula-fed infants of vegan parents occur after weaning. This is particularly the case when a homemade weaning formula is given. Conversely, commercially available soy milks are supplemented with vitamins.

Studies in both the United States and the United Kingdom have shown that vegan children exhibit small but significant differences in growth variables (height and weight percentiles) compared with children eating mixed diets. This observation most likely is the consequence of group differences in total energy consumption, although other studies have demonstrated that the calcium and zinc content of the vegan diet also may be low, indicating the requirement for supplementation.

Conversely, the essential amino acid and total protein intake of vegan children has been shown to be adequate to support normal growth. Despite the lower mean height and weight of vegan children compared with children eating mixed diets, a large British study found no evidence of growth failure (weight or height less than the 5th percentile) in vegan children, and no between-group differences were noted in terms of muscle strength and overall health.

A routine health assessment of any child should include a careful dietary history. Information about specific cultural or family customs permits identification of patients at nutritional risk and aids the clinician in determining whether caregivers require education regarding appropriate nutrition for growing children. For example, in industrialized countries, vitamin D deficiency rickets is an emerging nutritional problem. Such deficiency is particularly prevalent for dark-skinned infants living in temperate or northern climates, those whose cultural/religious customs may include extensive covering of body surfaces, and in infants and children who receive little direct sunlight exposure (ie, less than 30 minutes to the face and hands three times per week).

2. A 7-month-old child presents for a follow-up office visit after undergoing a Kasai procedure for biliary atresia at 6 weeks of age. The mother states that the boy is irritable when his right arm is moved. On physical examination, the infant is jaundiced. You detect tenderness in the anterior radial head. Radiography of the affected region demonstrates metaphyseal fraying and a fracture.

Of the following, the MOST appropriate laboratory studies to obtain next are
A. calcium and phosphorus measurement and bone densitometry (DEXA scan)
B. calcium and phosphorus measurement and urinary calcium-to-creatinine ratio
C. calcium, phosphorus, and 25-hydroxyvitamin D measurement
D. calcium, phosphorus, and magnesium measurement
E. magnesium, phosphorus, and parathyroid hormone measurement

Chronic cholestasis due to biliary atresia results in decreased bile flow into the intestine. The absence of intraluminal bile acids, in turn, causes decreased digestion of lipids, leading to fat malabsorption. In addition, absorption of fat-soluble vitamins (A, D, E, and K) is impaired, which may lead to clinical sequelae of fat-soluble vitamin deficiency. Finally, steatorrhea may impair calcium absorption because intraluminal free fatty acids may bind calcium.

The clinical presentation of the patient in the vignette strongly suggests the presence of rickets from vitamin D deficiency. Therefore, the most helpful initial laboratory testing is determination of calcium, phosphorus, and 25-hydroxyvitamin D concentrations. The 25-hydroxyvitamin D assay is the best measure of hepatic stores of vitamin D and is a better marker of vitamin D status than either serum vitamin D or 1,25-dihydroxyvitamin D. Although bone density testing, measurement of serum magnesium and parathyroid hormone, and determination of the urinary calcium-to-creatinine ratio may provide useful additional information, they will not help establish the diagnosis of vitamin D-deficient rickets.

Rickets is a potentially preventable complication of biliary atresia, but requires monitoring of calcium, phosphorus, and 25-hydroxyvitamin D concentrations two to four times a year. Infants who have biliary atresia routinely receive supplementation with approximately 8,000 IU of ergocalciferol (vitamin D2) daily. This dose of vitamin D is approximately 20 times the recommended dietary allowance for a healthy toddler. If rickets develops or the vitamin D concentration cannot be maintained within the normal range, the patient should receive either calcitriol (1,25-dihydroxyvitamin D3) or intramuscular vitamin D.

3. A 12-year-old boy has had cholestasis since infancy from Alagille syndrome. He has been lost to medical follow-up for the last several years. He now presents to your office with pain in his right upper thigh after a fall. His thigh is intensely tender, and ultrasonography demonstrates a large hematoma in his quadriceps. The parents state that he has tended to bruise easily in the past few months.

Of the following, the condition MOST likely to account for this patient's symptoms is
A. factor VIII deficiency
B. idiopathic thrombocytopenic purpura
C. vitamin C deficiency
D. vitamin K deficiency
E. von Willebrand disease

Alagille syndrome is characterized by cardiac disease (especially peripheral pulmonary stenosis), vertebral anomalies, ocular anomalies (posterior embryotoxon), facial dysmorphism (triangular facies, macrocephaly, large ears), and paucity of the intrahepatic bile ducts. The hepatic manifestations of this syndrome account for much of the medical morbidity. Specifically, impaired bile flow results in chronic cholestasis, which leads to severe pruritus, jaundice, malabsorption of nutrients, and malabsorption of fat-soluble vitamins. Although most affected children have their jaundice improve as they grow older, a subset progresses to cirrhosis and requires liver transplantation.

Patients who have hepatic disease must have their nutritional status monitored carefully. Chronic anorexia, recurrent illnesses, and fat malabsorption may result in caloric deficiency and growth failure. Caloric supplementation by nasogastric tube or gastrostomy may be necessary to ensure adequate caloric intake. In addition, patients who have cholestasis are at risk for fat-soluble vitamin deficiency.

Vitamin D deficiency typically causes osteopenia and rickets, vitamin E deficiency causes peripheral neuropathy and ataxia, and vitamin A deficiency may cause night blindness or corneal lesions. The bruising described for the patient in the vignette most likely is due to vitamin K deficiency. Vitamin K is a cofactor essential in posttranscriptional carboxylation of the clotting factors II, VII, IX, and X. Thus, vitamin K deficiency leads to prolonged prothrombin and partial thromboplastin time, which predisposes to bruising. Although factor VIII deficiency, vitamin C deficiency, von Willebrand disease, and idiopathic thrombocytopenia purpura also may cause bruising, the patient who has Alagille syndrome is not at increased risk for developing these conditions.

In addition to supplementing patients who have chronic liver disease with fat-soluble vitamins, the clinician caring for these patients also must supply adequate calories. Patients who have advanced chronic liver disease may have both anorexia and increased caloric requirements. In addition, patients who have portal hypertension and ascites may

need to have total fluid intake restricted, which, in turn, means that they may require a more concentrated and less palatable formula. For these reasons, nasogastric or gastrostomy feedings sometimes are necessary to achieve optimal growth, especially when preparing a patient for liver transplantation.

4. A 16-year-old boy in your practice has cystic fibrosis. As a complication of his illness, he has developed cirrhosis and cholestasis. He now complains of shaky hands. Neurologic examination demonstrates hyporeflexia and tremor with hands outstretched.

Of the following, the patient's symptoms are MOST consistent with deficiency of
A. vitamin A
B. vitamin B1 (thiamine)
C. vitamin C
D. vitamin D
E. vitamin E

Because the young man described in the vignette has chronic cholestasis, he is at risk for developing deficiency of any of the fat-soluble vitamins, including vitamins A, D, E, and K. His neurologic symptoms of tremor and hyporeflexia most strongly suggest vitamin E deficiency. Vitamin E (tocopherol) is an important factor in stabilizing the lipid membrane of the red blood cell and the lipids in the myelin sheath of neurons. Therefore, the most common presenting features of hypovitaminosis E are hemolysis (primarily reported in preterm infants) and peripheral neuropathy (identified in infants and children who have chronic cholestasis, pancreatic insufficiency, or malabsorption).

Supplementation of formulas and parenteral nutrition with vitamin E has reduced substantially the incidence of hemolysis in the vitamin E-deficient preterm infant. However, patients who have cystic fibrosis or cholestatic liver disease require both monitoring of vitamin E concentrations and supplementation with vitamin E. Because vitamin E is a fat-soluble vitamin, those who have cholestasis may have difficulty absorbing alpha-tocopherol, the form of vitamin E available in most dietary supplements. For this reason, d-alpha-tocopheryl polyethylene glycol 1,000 succinate, a water-soluble form of vitamin E, should be given to patients who have significant cholestatic liver disease. The recommended dose for a patient who has cholestatic liver disease is 15-25 IU/kg/day.

Deficiency of vitamin A, B1, C, or D would not be expected to cause such a clinical presentation. Vitamin A deficiency causes impaired vision ("night blindness") and corneal ulcers; vitamin B1 deficiency can cause myopathy and heart failure ("beriberi"); vitamin C deficiency causes irritability, bone lesions, and bruising (scurvy); and vitamin D deficiency causes osteopenia or rickets.

5. A medical student rotating in your clinic tells you about a 5-month-old infant he has evaluated. He reports that the infant is fed goat milk exclusively and asks you if this is adequate nutrition at this age.

Of the following, the MOST likely deficiency in this infant is of
A. folate
B. iron
C. niacin
D. vitamin A
E. vitamin D

Goat milk is used exclusively for infant nutrition in some countries and has been used occasionally in the United States for infants who have cow milk allergies, but its routine use in the United States is not recommended. Although its fat may be digested more easily than fat found in cow milk preparations, it is deficient in several important nutrients, such as iron, vitamin D, and especially folate. Folate is a cofactor required in nucleoprotein synthesis, and deficiency ultimately results in ineffective erythropoiesis and megaloblastic anemia. Macrocytosis and hypersegmented neutrophils are typical findings on complete blood count, and if the anemia is severe, pancytopenia also can occur. Mothers who feed their infants goat milk exclusively should be counseled to switch to cow milk formula to avoid these complications. Niacin and vitamin A are sufficiently present in goat milk to avoid deficiency of these nutrients.