

Yogurt consumption and impact on health: focus on children and cardiometabolic risk^{1–3}

André Marette and Eliane Picard-Deland

ABSTRACT

An accumulating body of epidemiologic data, clinical trials, and mechanistic studies suggests that yogurt consumption as part of a healthy diet may be beneficial to cardiometabolic health. This brief review focuses on children and adolescents, introducing new concepts underlying the effect of yogurt consumption on body weight maintenance and the prevention of cardiovascular diseases. Specific properties of yogurt are discussed, which highlight that yogurt is an easy-to-digest, nutrient-dense, and satiating food that contains high-quality protein and specific amino acids. Moreover, the role of yogurt as a modulator of the gut microbiota in infancy is explored. We also propose the idea that the specific matrix of yogurt has bioavailability and metabolic properties that can be exploited to increase the functionality of this dairy product. *Am J Clin Nutr* 2014;99 (suppl):1243S–7S.

INTRODUCTION

The importance of yogurt as part of a balanced and healthy diet is recognized by regulatory authorities and scientific institutions in most countries. Yogurt is defined by The Codex standard as the product of milk fermentation by *Lactobacillus delbrueckii* subspecies *bulgaricus* and *Streptococcus thermophilus* (1). The unique properties of yogurt provided by its living bacteria and its nutrients have captured the interest of the scientific community. An accumulating body of epidemiologic and clinical evidence suggests that yogurt consumption may act beneficially on weight regulation and metabolic risk factors (2–7). However, the effect of dairy products per se and their components on cardiovascular risk is an area of controversy (8). Childhood obesity is one of the most critical public health challenges in the 21st century (9), and poor eating patterns established in childhood may persist throughout adulthood and are an important determinant of obesity and associated diseases later in life (10). This brief review addresses evidence and new research directions involving yogurt and cardiometabolic health in this specific population.

YOGURT IS ACCESSIBLE AND HAS A HIGH NUTRIENT DENSITY

Recent years have been marked by the appearance on the market of an increasing number of yogurts with different tastes, textures, and nutritional values targeting specific consumers, including children. Palatability and accessibility are key factors to be considered for optimizing the consumption of yogurt in different countries. Moreover, the keen interest in yogurt con-

sumption is, at least in part, attributed to its high nutrient content. According to a nutritional quality tool developed in US, plain yogurt has been shown to have a good Nutrient Rich Food score (Fulgoni et al, 2009). Furthermore, a cross-sectional study in individuals participating in the Framingham Heart Study Offspring and Third Generation cohorts has reported that yogurt consumers have a higher diet quality, as measured by the Dietary Guidelines for Americans Index score, and greater intakes of some nutrients, such as potassium, than do nonconsumers (5).

Yogurt contributes to diet quality in children by providing substantial amounts of macronutrients (protein, a wide range of fatty acids, lactose as the predominant carbohydrate) and essential micronutrients (eg, calcium, potassium, zinc, phosphorus, magnesium, vitamin A, riboflavin, vitamin B-5, vitamin B-12). The proteins in yogurt, derived from milk proteins, are of excellent digestibility and nutritional quality (12), and dairy products contribute significantly to protein intake in children, providing growth and maintenance of muscle mass. Moreover, it is recognized that yogurt and dairy products are a rich source of calcium (100 g of plain whole-milk yogurt = ~10% of the Recommended Dietary Allowance for calcium in children) and of phosphorus per unit of energy compared with the average of other typical foods in an adult diet (13). Calcium and phosphorus contribute to the structural integrity and development of bones (14).

There is a growing body of evidence that the contribution of yogurt consumption exerts beneficial effects beyond its impact on healthy growth and development. Indeed, recent studies have shown that some nutrients in yogurt and dairy products, such as proteins/peptides, specific lipids, vitamin D, calcium, magnesium, and potassium, or the combination of these, could have a beneficial

¹ From the Department of Medicine, Faculty of Medicine, Cardiology Axis of the Institut Universitaire de Cardiologie et de Pneumologie de Québec (Hôpital Laval), Quebec City, Canada, and The Institute of Nutrition and Functional Foods, Laval University, Quebec City, Canada (AM and EP-D).

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³ Address correspondence and reprint requests to A Marette, Cardiology Axis of the Institut Universitaire de Cardiologie et de Pneumologie de Québec (Hôpital Laval), Quebec City, Canada G1V 4G5. E-mail: andre.marette@cricuq.ulaval.ca.

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effect on cardiometabolic risk factors (15, 16). For example, clinical trials have investigated the effect of yogurt enriched with vitamin D in individuals with type 2 diabetes and observed an improvement in glycemic status (17, 18), lipid profile, and endothelial biomarkers (18). Yogurt made from milk fortified with vitamin D contains a significant amount of this fat-soluble vitamin. There are also mechanistic studies that explain how yogurt's nutrients may contribute to a negative energy balance and the maintenance of a healthy body weight. Weight-loss studies in low calcium consumers have shown that low calcium intake is a risk factor for overweight and obesity, and that this effect may be explained by an increase in fat oxidation, facilitation of appetite control, and fecal loss (19). Studies investigating the effect of calcium and vitamin D intakes on cardiometabolic health are of particular interest because several age groups within populations, including children, do not reach the recommended levels of those nutrients in the United States and other countries (20–22).

In the past few years, an increasing number of cohort studies have emerged to evaluate the association between dairy product intake and body weight and have yielded conflicting results. Louie et al (23) performed a comprehensive literature search of prospective cohort studies to examine the relation between dairy consumption and overweight/obesity risk in adults and in children and adolescents. Of the 10 studies in children and adolescents (aged 2–14 y, follow-up 8 mo to 10 y), 3 found a protective association, 6 reported no significant association, and 1 reported an increased risk. There was a higher proportion of studies in adults showing a protective effect (5 of 9 studies). The authors concluded that the evidence for a protective effect of dairy consumption on risk of overweight and obesity is suggestive but not consistent in adults and in children/adolescents.

Until now, few studies have assessed the specific effect of yogurt consumption on weight variables and cardiovascular risk in children and adolescents. Abreu et al (6) performed a cross-sectional study in 903 Azorean adolescents and showed a protective association between ≥ 2 servings of milk and yogurt and abdominal obesity in boys. Furthermore, the relation between dairy intake and weight variables and cardiovascular disease risk factors was evaluated recently in adolescents from 8 European countries [Healthy Lifestyle in Europe by Nutrition in Adolescence (HELENA) project]. Waist circumference and the sum of skinfold thicknesses were inversely associated with the consumption of yogurt and milk (and milk- and yogurt-based beverages), and dairy consumption was inversely associated with cardiovascular disease risk score in girls only (7).

Additional research and clinical trials are needed to better understand the relation and the mechanisms between yogurt and weight management and obesity-related diseases in youth. Dairy products, such as yogurt, provide important nutrients to children's diet that could contribute to its potential beneficial effects on weight management and cardiometabolic risk.

YOGURT PROVIDES HIGH-QUALITY PROTEIN AND SPECIFIC AMINO ACIDS

Milk proteins include a casein fraction ($\sim 80\%$) and a soluble protein fraction commonly named whey proteins ($\sim 20\%$). The fermentation and proteolytic activity throughout the shelf-life of yogurt generates bioactive peptides and amino acids (24, 25) with potential health benefits (26). Whey is an inexpensive source of high

nutritional quality and, compared with other food proteins, contains the highest concentration of the branched-chain amino acids (BCAAs), especially L-leucine (27). Whey protein could affect both short-term and long-term food intake regulation by providing satiety signals (27). Interestingly, it has been shown that leucine could stimulate protein synthesis and preserve lean body mass during weight-loss regimens (28). Moreover, studies have shown that whey proteins and their bioactive components, such as lactalbumin, angiotensin-converting enzyme inhibitor, and BCAAs, can have muscle-sparing, hypolipidemic, and insulinotropic effects (28, 29). However, conflicting results have been reported concerning the effects of BCAAs in the regulation of insulin resistance. Indeed, recent studies using metabolomic profiling have suggested that elevation of circulating BCAAs concentrations could predict the development of insulin resistance and type 2 diabetes in adults (30, 31). McCormack et al (32) reported in a cross-sectional cohort that there are increased concentrations of BCAAs already present in young obese children and that increased baseline BCAA concentration is associated with later insulin resistance. In contrast, it has been observed in animal models that increasing dietary leucine intake reduces diet-induced obesity and improves glucose homeostasis (33, 34). One site for BCAA action is the mammalian target of rapamycin (mTOR) and its downstream kinase S6k1, which are kinases in the insulin signaling cascade (35). Larger well-controlled trials are needed, especially in children, to elucidate if the elevation of BCAAs contributes to insulin resistance or represents a biomarker of the physiologic perturbations driving the development of insulin resistance in obesity.

YOGURT AS A MODULATOR OF GUT MICROBIOTA AND METABOLISM

The intestinal microbiota is now recognized to be an important factor in determining the health status of the host. Its composition and activities are stable over time but may be modulated by several factors including age and diet (36). It has been shown in human infants that genetic and environmental factors determine the characteristics of the microbial community (37).

There is increasing evidence that shows that the modulation of the gut microbiota has an impact on energy storage, obesity, and insulin resistance (38–40). Obesity has been associated with phylum-level changes in the microbiota and alteration of representation of bacterial genes and metabolic pathways (41). Moreover, bacterial diversity of the human gut microbiome has been shown to correlate with markers of obesity-related metabolic disorders (42). There is evidence showing that the gut microbiota differed between obese/overweight children and children with a BMI within the normal range (43) or lean children (44). Furthermore, it has been shown that aberrant compositional development of the gut microbiota in children may predict overweight (45).

The consumption of yogurt may ensure some changes to the balance and metabolic activities of the indigenous microbiota as shown by some authors (46, 47). Moreover, yogurt is a vector for probiotics. Animal and human studies have shown that probiotics could have a hypocholesterolemic effect and a potential beneficial impact on body weight (48). However, there are few studies performed in children and adolescents. Interestingly, it was observed in a 10-y follow-up study that perinatal administration of *Lactobacillus rhamnosus GG* inhibited excessive weight gain in



children (49). Moreover, Safavi et al (50) observed beneficial effects of a synbiotic supplement including *Lactobacillus* spp. and *Bifidobacterium* spp. on weight management and cardiometabolic risk factors in children and adolescents aged 6–18 y. The mechanisms by which probiotics can act on weight management remain to be clearly established but could involve interaction with the resident bacteria in the gut, which may affect metabolic pathways implicated in the regulation of fat metabolism (48).

More well-designed large clinical studies are required to evaluate the effect of different probiotic strains on obesity and cardiometabolic risk. There is also a need to identify microbiota-related biomarkers to improve our understanding of the causal relation between the gut microbiota and cardiometabolic diseases. Noninvasive manipulation of gut microbiota composition by specific foods such as yogurt and probiotics in infancy could offer an interesting approach to manage childhood obesity and related disorders.

YOGURT IS EASY TO DIGEST

Yogurt has also been reported to be easy to digest and to bring essential nutrients to children with lactose intolerance and diarrhea. As stated by the NIH, lactose-intolerant children should consume yogurt and dairy products even when having maldigestion or lactose intolerance (51). Most individuals diagnosed with lactose intolerance or lactose maldigestion can tolerate up to 12 g of lactose in a single dose with few or no symptoms and can tolerate even higher amounts if intakes are spread throughout the day (20–24 g) (52). Interestingly, a cause-and-effect relation has been established between the consumption of live yogurt cultures and improved lactose digestion in individuals with lactose maldigestion (53). In developing countries where the rate of malnutrition is high, yogurt could also be particularly useful for the treatment of acute (54) and persistent (55, 56) diarrhea in children.

YOGURT HAS A UNIQUE MATRIX THAT MAY HAVE BIOAVAILABILITY AND METABOLIC PROPERTIES

Yogurt nutrients are part of a larger medium, a microstructure produced by processing. Several factors influence the bioavailability

of nutrients in foods, such as the release of the nutrient from the food matrix, interactions with other food components, and the chemical state of the nutrient (57). For example, it has been shown that the kinetics of the release of fatty acids from cheese during digestion are mainly driven by the physical characteristics of the cheese (58). Few studies have investigated the impact of the processing of yogurt and its matrix on nutrient bioaccessibility and bioavailability. Data have shown that components such as lactose and casein phosphopeptides may increase calcium absorption and mineral retention (59). Moreover, acidity found in yogurt as a result of the fermentation can also influence the absorption of minerals. For example, intestinal calcium uptake can be enhanced by the low pH of yogurt, which ionizes calcium (60).

Other examples of matrix interactions in yogurt include the association between bioactive peptides with nonpeptidic milk components, such as oligosaccharides, glycolipids, and fats (61). Whey proteins, phosphopeptides, vitamin B-12-binding protein, β -lactoglobulin, α -lactalbumin, and lactoferrin can also interact with minerals and vitamins to influence their absorption (12, 62). Multiple nutritional properties can explain the beneficial effects of the matrix interaction on health in dairy products, and particularly in fermented products such as yogurt (Figure 1). Indeed, yogurt has a unique microstructure and texture, and future research might discriminate between types of dairy products and explore the synergy provided by the food matrix, rather than simply evaluating each component of the food individually.

YOGURT IS A TASTY AND SATIATING SNACK

Unhealthy snacking is frequent in children and teenagers, and many of the available and commonly consumed snacks are nutrient-poor, energy-dense items such as salty snacks and sugar-sweetened beverages (63). Therefore, substituting those products with nutrient-rich foods such as dairy products could have a positive impact on childhood obesity (64). Moreover, as stated in the American Heart Association's scientific statement on sugar and cardiovascular health, even when sugar is added to otherwise nutrient-rich food, such as sugar-sweetened dairy

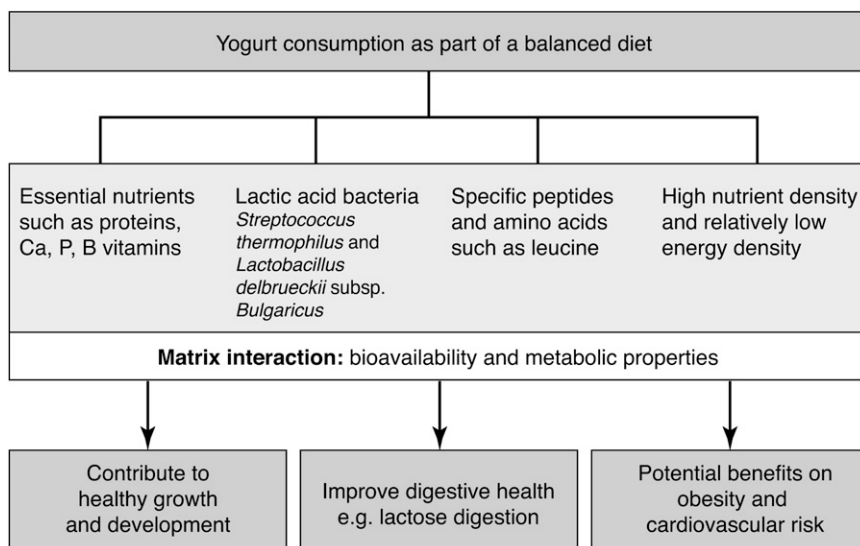


FIGURE 1. Proposed mechanisms by which yogurt consumption as part of a balanced diet exerts beneficial health effects.

products like flavored milk and yogurt, the quality of childhood and adolescent diet is improved. However, if sugars are consumed in excess, deleterious effects may occur (65).

High-protein snacks and meals induce a greater reduction in appetite than do isoenergetic high-fat or high-carbohydrate foods (66, 67). Some of the more frequently consumed high-protein snacks in the United States include dairy products, which usually contain ~10 g of protein/serving (63). The introduction of Greek yogurt into the United States in 2008 may be considered a potentially optimal snack option considering its higher protein content compared with regular yogurt (20–24 g/serving) (68, 69). Interestingly, a study performed in healthy women showed that a 160-kcal afternoon Greek yogurt snack, containing 24 g protein, led to reduced hunger, increased fullness, and delayed subsequent eating compared with snacks containing lower protein amounts (69). This result is in accordance with previous data showing that yogurt has a superior effect on satiety compared with other foods, beverages, and snacks (70, 71). Interestingly, Dougkas et al (72) showed that yogurt has a greater effect on suppressing appetite compared with milk or cheese but did not affect subsequent ad libitum meal energy intake compared with other dairy products.

Furthermore, some studies have shown a potential industrial opportunity to design satiating yogurt. For example, Luch et al (73) observed that low-fat yogurt enriched with protein and fiber can significantly reduce short-term appetite compared with a nonenriched low-fat yogurt. Cognitive and oral factors, post-ingestive factors (eg, gastric emptying and intestinal absorption rates), postprandial circulating amino acids, and endocrine factors (eg, ghrelin) may explain the effects of the test dairy products on appetite in this study. Further studies are warranted to explain the effect of yogurt and its micro- and macronutrients on satiety and body weight regulation, considering factors such as eating patterns, portion sizes, and the substitution of other foods or beverages after the consumption of yogurt.

CONCLUSIONS

Yogurt is an accessible, easy-to-digest, and tasty food that provides important nutrients to children and adolescents and thus forms part of a balanced nutrient-rich diet during development and growth. Recent studies have shown that yogurt consumption may have a beneficial role on body weight regulation and cardiovascular health. However, there is limited evidence in children and adolescents. Dairy products are a source of high-quality proteins, and more studies are needed to evaluate the health effect of specific peptides and amino acids such as BCAAs in youth. Furthermore, epidemiologic studies and clinical trials that consider the interactions of yogurt nutrients and bacteria within the food matrix are warranted to evaluate the effect of yogurt on the modulation of the gut microbiota and the prevention of obesity and cardiometabolic diseases.

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