Yogurt: role in healthy and active aging[1–4]

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ABSTRACT
Yogurt consumption has been associated with health benefits in different populations. Limited information, however, is available on nutritional and health attributes of yogurt in older adults. Yogurt is abundant in calcium, zinc, B vitamins, and probiotics; it is a good source of protein; and it may be supplemented with vitamin D and additional probiotics associated with positive health outcomes. Aging is accompanied by a wide array of nutritional deficiencies and health complications associated with under- and overnutrition, including musculoskeletal impairment, immunosenescence, cardiometabolic diseases, and cognitive impairment. Furthermore, yogurt is accessible and convenient to consume by the older population, which makes yogurt consumption a feasible approach to enhance older adults' nutritional status. A limited number of studies have specifically addressed the impact of yogurt on the nutritional and health status of older adults, and most are observational. However, those reported thus far and reviewed here are encouraging and suggest that yogurt could play a role in improving the nutritional status and health of older adults. In addition, these reports support further investigation into the role of yogurt in healthy and active aging. *Am J Clin Nutr* 2014;99(suppl):1263S–70S.

INTRODUCTION

Yogurt is a nutrient-dense probiotic food, with unique properties that enhance the bioavailability of some of these nutrients and potentially enhancing health. These properties make it worth exploring whether yogurt may be particularly well suited to ameliorate some of the most common nutritional deficits, and their related health risks, in the elderly. So far, few studies have evaluated the effect of yogurt on health outcomes in the elderly. In this review, we summarize the existing evidence and identify gaps in our knowledge that need to be addressed by well-designed studies. Studies of yogurt supplementation in the elderly are compiled in **Table 1**.

NUTRITIONAL VALUE OF YOGURT

Yogurt and diet quality in the elderly

An evaluation of dietary intake showed that yogurt consumption is associated with greater adherence to healthy dietary guidelines, as assessed by the *Dietary Guidelines for Americans* 2005 (1). Those consuming an average of 2.3 servings yogurt/wk were more likely than nonconsumers to eat more healthy foods, including fruit, vegetables, nuts, fish, and whole grains, and had a smaller proportion of their energy intake from processed meat, refined grains, and beer (2). Results further showed that yogurt consumers have significantly reduced prevalence of nutrient deficiencies for riboflavin, vitamin B-12, calcium, magnesium, and zinc (2).

Many factors contribute to malnutrition in the elderly, including chronic and infectious disease, decrease in physical activity and metabolic rate, physical disability, difficulty chewing and ingesting food, polypharmacy, limited income, and decrease in mobility. In addition to the rich nutritional composition of yogurt and its potential effects on health, there are benefits that make it feasible for the elderly to increase yogurt intake. Yogurt has a relatively long shelf-life, and there are no obstacles in consumption for individuals with chewing difficulty. Lactose intolerance, which is prevalent in the older population, is not an issue with yogurt, in contrast to other dairy products. Therefore, increasing yogurt consumption by older adults could represent a convenient and economical strategy to enhance their intake of key macronutrients and micronutrients for this age group.

Consumption and type

Yogurt can be commercially produced with substantial variety in composition, flavors, and additives. These include whole-milk, low-fat, or nonfat forms; plain or flavored; inclusion of fruit; addition of natural or artificial sweeteners; and occasional supplementation with vitamin D. Flavored fermented dairy products cannot exceed 50% (by mass) of nondairy additives such as fruit or sweeteners (3). Yogurt consumption accounts for as much as 32% of dairy intake in Europe, with a range of consumption in different European countries, yet accounts for only 5% in the United States (2). As reported in the National Nutrient Database for Standard Reference (NDBsr26)[5], among the 1000 most

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[5] Abbreviations used: BMD, bone mineral density; CVD, cardiovascular disease; LAB, lactic acid bacteria; NDBsr26, National Nutrient Database for Standard Reference version 26; NK, natural killer.

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TABLE 1
Studies of yogurt consumption in the elderly[1]

Area and first author (ref)	Study design	Population	Key findings
Bone and muscle health			
Bonjour (4)	Randomized, double-blind controlled trial, 2-mo supplementation with vitamin D and calcium-fortified yogurt or nonfortified yogurt control	Institutionalized elderly women (*n* = 89; mean ± SD age: 85.5 ± 6.6 y)	PTH and bone resorption markers decreased after supplementation
Ferrazzano (5)	Cross-sectional in vitro study exploring the effect of CCPs (contained in yogurt) on dental enamel mineralization	Human molars (*n* = 80; unspecified age)	Yogurt CCPs protected molars against demineralization and promoted remineralization
Heaney (6)	Crossover study; subjects consumed a jelled fruit-flavored snack or fruit-flavored yogurt for 7–11 d	Postmenopausal women (*n* = 29; mean ± SD age: 61 ± 4 y)	Decreased bone resorption, as seen by a significant decrease in urinary N-telopeptide
Sahni (7)	Longitudinal study (12-y follow-up)	Framingham Offspring Study (*n* = 3212; mean ± SD age: 55 ± 1.6 y)	Yogurt intake was positively associated with trochanter bone mineral density and was mildly protective against hip fractures; authors stated that this protection needs to be verified further
Cardiometabolic disease			
Goldbohm (8)	Prospective cohort study (Netherlands Cohort Study)	Men and women (*n* = 120,852; age range: 50–69 y)	Fermented milk intake was inversely associated with all-cause mortality in men and women
Margolis (9)	Prospective cohort study (Women's Health Initiative Observational Study)	Postmenopausal women, nondiabetic at enrollment (*n* = 82,076; age range: 50–79 y)	Yogurt intake was associated with a significantly lower risk of type 2 diabetes
Sonestedt (10)	Prospective cohort study (Swedish Malmö Diet and Cancer cohort, 12-y follow-up)	Men and women, no cardiovascular disease on enrollment (*n* = 26,445; age range: 44–74)	Fermented dairy product consumption was inversely related to cardiovascular disease
Immunology			
Makino (11)	Meta-analysis of 2 independent randomized studies in which subjects consumed yogurt or milk for 8 or 12 wk	Healthy elderly subjects (study 1: *n* = 57; median age: 74.5 y; study 2: *n* = 85; median age: 67.7 y)	In the yogurt group there was a significantly lower risk of catching the common cold, and a significant increase in natural killer cell activity
Schiffrin (12)	Observational study with one treatment group consuming yogurt with *Lactobacillus johnsonii* for 1 mo	Elderly men and women with or without hypochlorhydria (positive breath test for hydrogen, *n* = 23; negative breath test, *n* = 13; mean ± SD age: 76.9 ± 7.3 y)	Endotoxemia and leukocyte phagocytosis decreased in both groups after yogurt consumption; monocyte and neutrophil activity (ex vivo production of cytokines or reactive oxygen species, respectively) increased in the positive breath test group after consumption
Cognition			
Crichton (13)	Cross-sectional study	Men and women (*n* = 1183; age range: 39–65 y)	Low-fat yogurt intake was associated with memory recall (self-reported) and social functioning in men

[1] CCP, casein phosphopeptide; PTH, parathyroid hormone; ref, reference.

commonly consumed foods in the United States are low-fat yogurt, plain or with fruit, or plain whole-milk yogurt. They range in protein content from 3.5 to 5.3 g and in caloric energy from 61 to 105 kcal/100-g serving (14). There is also an increasing popularity of strained yogurt, more commonly known as Greek yogurt or *labneh*, where straining the fermented milk after coagulation removes the liquid whey as well as some of the lactose, creating a richer consistency (15), and which is required to contain at least 5.6% protein compared with the minimum of 2.7% for unstrained yogurt (3). Forms of Greek yogurts referenced in the NDBsr26 within a similar range of caloric energy as unstrained yogurt contain these higher protein amounts (ie, 10.2 and 7.5 g for plain or with fruit, respectively, per 100-g serving) (14). Historically, yogurt was strained to decrease its water content and to help delay spoilage, and this condensed form of yogurt is a traditional component of Mediterranean, Middle Eastern, and South Asian cuisines (15).

The nutritional characteristics of yogurt are comparable to the milk from which it was produced, although usually in higher concentration, and certain nutrients are affect by factors such as bacterial strains, heat exposure during the fermentation process, and extra ingredients added (16).

Probiotics

As defined by the 2003 Codex Standard for Fermented Milks, yogurt must contain viable, live, and abundant cultures of the lactic acid bacteria (LAB) *Lactobacillus bulgaricus* and *Streptococcus thermophiles* species at a minimum concentration of 10^7 CFU/g at the time of manufacture (3, 17, 18). It may also be supplemented with additional bacteria that contribute desirable factors (19), and these labeled microorganisms should be present at $\geq 10^6$ CFU/g (3). To qualify for the seal of “live and active culture yogurt” by the National Yogurt Association, amounts of *L. bulgaricus* and *S. thermophiles* at the point of manufacture must be $\geq 10^8$/g (16). Yogurt is considered a probiotic food by virtue of the live microorganisms it contains, which clinical studies have shown to confer various health benefits with consumption (17, 19). It is important, therefore, to consider not only the type of bacterial strains but also the concentrations of live yogurt bacteria at ingestion, and how much remains viable in the ileum and duodenum.

Minerals

Yogurt is a rich source of dietary minerals, and the NDBsr26 reports that a 100-g serving of plain low-fat yogurt includes amounts of calcium at 183 mg, magnesium at 17 mg, potassium at 234 mg, phosphorous at 144 mg, and zinc at 0.9 mg (14). The concentrations of these minerals are higher in yogurt compared with milk by nearly 50% (2). Furthermore, fermentation with LAB to create yogurt results in an acidic environment that can enhance the bioavailability of these minerals. The lower pH maintains calcium and magnesium in their ionic forms, potentially allowing for their greater absorption in the intestine and increasing amounts of soluble zinc bound to ligands that can facilitate transportation across the intestinal wall, which results in enhanced absorption of zinc (16, 20). However, the effect of higher luminal pH on enhancing the status of calcium and magnesium from yogurt needs to be determined in vivo.

Vitamins

Yogurt is also a good source of B vitamins: a 100-g serving of plain low-fat yogurt contains riboflavin, niacin, vitamin B-6, and vitamin B-12 at amounts of 0.21, 0.11, 0.05, and 0.56 mg, respectively (14). However, fermentation, pasteurization, and other production processes can negatively affect the vitamin content. For Greek-style yogurt, the process of straining can lead to the loss of certain micronutrients, particularly the water-soluble vitamins (15). The choice of bacterial strain can further influence vitamin integrity, because some LAB consume B vitamins for growth, whereas others can synthesize them. Commercial processes therefore combine different bacterial strains to mitigate issues of vitamin depletion, with some combinations aimed at restoring or amplifying the amounts of these vitamins in the final yogurt product (16).

Protein

Yogurt is an excellent source of essential amino acids of high biological quality and generally contains a higher protein content than milk. Furthermore, the proteolytic activity of bacterial cultures in yogurt enables some predigestion of milk proteins, resulting in greater amounts of free amino acids that allow for better protein digestibility (16).

HEALTH RISKS AND NUTRITIONAL DEFICIENCIES IN THE ELDERLY THAT COULD BE ADDRESSED WITH YOGURT CONSUMPTION

Musculoskeletal

Bone health and aging

With aging there is a decrease in bone density and an increased requirement for vitamin D and calcium. The physiologic changes leading to poor bone health include decreased calcium absorption, along with increased bone loss and bone remodeling throughout the life span (21). Vitamin D deficiency is common in the elderly because of the age-related decrease in cutaneous vitamin D_3 production, poor nutrition, and lifestyle factors such as prolonged periods spent indoors (22). This, together with an equally large prevalence of calcium deficiency and low protein consumption in the elderly, are significant factors for poor bone health, leading to a higher risk of osteoporosis, muscle weakening, falls, and fractures. Several studies have shown that vitamin D and calcium supplementation have positive effects on bone health, including reduction in falls and fractures and enhanced muscle performance (21, 23, 24). This seems to be the case, especially when focusing on populations that are vitamin D deficient (25). Previous evidence has shown that higher consumption of dairy products, which are rich in calcium, may protect adults against bone loss (26). However, it has not yet been fully established whether calcium supplementation may lead to this effect in the absence of vitamin D supplementation.

Muscle health and aging

The decline in muscle mass that accompanies aging, termed *sarcopenia*, is exacerbated by poor nutrition (27). It has been suggested that, although long-term trials are still needed, a slight short-term increase in protein intake in older individuals may lead to enhanced bone and muscle health without affecting renal function (28).

Potential benefits of yogurt on musculoskeletal health

Yogurt may be an important source of protein and calcium in the elderly that could potentially lead to enhancement in bone and muscle health. An assessment of dairy product consumption and its relation with bone mineral density (BMD) of the hip (at the femoral neck and trochanter) and spine, as well as with incidence of hip fracture, was conducted by Sahni et al (18) among participants in the Framingham Offspring Study. For BMD analysis (n = 2506), it was found that participants in the high-yogurt-consumption group of >4 servings/wk had greater BMD in all bone sites compared with nonconsumers, although the increase was only significant at the trochanter (0.809 ± 0.009 compared with 0.787 ± 0.003 g/cm^2; P = 0.05), and not significant for femoral neck or spine BMD [0.933 ± 0.009 compared with 0.914 ± 0.003 g/cm^2 (P = 0.32) and 1.242 ± 0.016 compared with 1.225 ± 0.005 g/cm^2 (P = 0.27), respectively]. A decrease of 1 SD in femoral neck BMD has previously been shown to be associated with an ∼40% increase in risk of osteoporotic hip fracture (19); however, the difference in hip fracture risk seen in this study in yogurt consumers compared with nonconsumers was not significant (P-trend = 0.10) (7).

Yogurt extract has also been found to protect against demineralization and even enhance remineralization of tooth enamel in vitro (5). In a randomized, double-blind, controlled intervention in which elderly nursing home residents consumed either yogurt fortified with calcium (800 mg/d) and vitamin D_3 (10 μg/d) or a nonfortified yogurt control (280 mg calcium/d) for ∼2 mo, it was found that the group consuming the fortified yogurt experienced a significant reduction in parathyroid hormone and bone resorption markers compared with the control group (4). Similarly, a crossover study in which postmenopausal women consumed either fruit-flavored yogurt or a fruit-flavored jelled snack for 7–11 d showed that there was a significant reduction in N-telopeptide (NTx), a urinary marker of bone resorption, after yogurt consumption compared with after consumption of the jelled snack (6). Lower amounts of bone resorption indicate a more positive bone balance and reflect the potential for better bone health (30). More long-term studies are needed to evaluate the effect of yogurt consumption on bone and muscle health of both community-dwelling and institutionalized elderly individuals. In addition, the optimal nutritional composition of yogurt for enhancement of bone health must be established.

Obesity

The nutritional composition of yogurt, as well as an established correlation between yogurt consumption and increased diet quality (2), may be used to address not only nutritional deficiencies but also weight maintenance in the elderly. The loss of lean muscle tissue and concomitant reduction in muscle function and mobility that are associated with aging lead to a greater proportion of body fat mass, which can result in a tendency toward becoming overweight or obese. Epidemiologic studies indicate that dairy products, and in particular yogurt, may have the potential to reduce the risk of obesity. Lifestyle and dietary factors were assessed for their association with long-term weight gain in ∼120,000 male and female participants from the Nurses' Health Studies and the Health Professionals Follow-Up Study over a period of 12–20 y (31). The authors found that average weight gain across all cohorts was 1.52 kg per 4-y period (95% CI: −1.86, 5.62 kg). However, a significant inverse association was observed between long-term weight gain and higher consumption of certain foods, where an increase in the number of servings per day was associated with less weight gain for yogurt (−0.37 kg), nuts (−0.26 kg), fruit (−0.22 kg), whole grains (−0.17 kg), and vegetables (−0.10 kg) per 4-y period ($P < 0.01$; adjusted for age, baseline BMI at each 4-y period, sleep duration, changes in physical activity, alcohol use, television watching, smoking, and dietary factors). The authors postulated that increased consumption of these foods displaced intake of other foods that may be higher in calories and fat and have lower fiber content but stated that the effect of yogurt could be related to altered gut bacteria as well as other weight-related behavior that was not captured in the study (31). In an analysis conducted on the cross-sectional relation between dairy consumption and metabolic outcomes in data from the NHANES, yogurt was associated with fewer metabolic disorders. Specifically, in men and women, yogurt consumption was inversely related to BMI, waist circumference, systolic blood pressure, and fasting glucose. In women, yogurt consumption was also related to higher HDL cholesterol (32). In a study to assess the cross-sectional association of yogurt with diet quality and metabolic profile in ∼6500 participants in the Framingham Offspring Study, Wang et al (2) found that yogurt consumers, on average, exhibited significantly improved metabolic variables, including lower BMI and blood pressure, reduced concentrations of triglycerides, fasting glucose, and insulin and greater HDL cholesterol compared with nonconsumers, after adjustment for demographic and lifestyle factors that included diet quality.

Evidence from randomized controlled trials in overweight and obese individuals further indicates that dietary calcium, particularly when sourced from dairy, can promote weight and fat loss (33). In a 12-wk isocaloric, energy-restricted dietary intervention that included 400–500 mg calcium supplementation/d, participants in the experimental and control groups (n = 34; aged 18–50 y) were prescribed diets established on the basis of energy needs that included adjustment for activity level records and matched for macronutrient proportions, and which were subsequently monitored weekly by diet records and measures of compliance. The experimental group consumed 3 daily 6-ounce servings of yogurt and showed significantly greater weight reduction than did controls exposed to caloric restriction and 0–1 daily servings of an alternative dairy product (6.63 ± 0.6 compared with 4.99 ± 0.5 kg, respectively; $P < 0.01$), although the control group consumed fewer calories than did the yogurt group, at an average 1303 ± 190 kcal/d compared with 1437 ± 190 kcal/d, respectively. The yogurt group also experienced a significantly higher proportion of abdominal fat loss (yogurt compared with control: −4.43 ± 0.47 compared with −2.75 ± 0.73 kg; $P < 0.005$) and less loss of lean body mass (yogurt compared with control: −1351 ± 156 compared with −1968 ± 212 g; $P < 0.05$). There was a significant increase in circulating glycerol (representing amplified lipolysis) and a reduction in waist circumference among the yogurt group. The participants were not blinded to treatment, and data on tobacco use and physical activity were collected but not reported, although the authors stated that baseline levels were maintained throughout the study (33). To our knowledge, no studies have focused on the effect of yogurt on obesity in the elderly.

Inflammatory and cardiometabolic diseases

A review published by Labonté et al (34) on effects of dairy products on inflammatory biomarkers in randomized controlled trials of a nutritional intervention in overweight or obese adults showed conflicting results, with 4 of the 8 studies showing improvement in inflammatory biomarkers with dairy consumption. However, most of the reviewed studies failed to address yogurt consumption individually. The only one to do so found that yogurt-enriched diets resulted in reduced C-reactive protein and increased adiponectin concentrations compared with controls (33, 34).

Although there are a substantial number of studies that have sought to characterize the relation between dairy products and various long-term health outcomes, few have examined yogurt individually. Nevertheless, those that provided direct analysis of yogurt have generally shown that yogurt is associated with a reduced risk of chronic diseases. Margolis et al (9) found that higher yogurt consumption is linked to a lower risk of diabetes in postmenopausal women. In this prospective cohort study in 82,076 postmenopausal women, aged 50–79 y, from the Women's Health Initiative it was found that there was a significant inverse relation between low-fat dairy food consumption and the risk of developing type 2 diabetes, with an RR of $\sim$0.7 (*P*-trend $<$ 0.0001, after adjustment for age, race, and total energy intake, and with the trend remaining significant after adjustment for additional variables) in the highest quintiles of consumption compared with the lowest quintile. A similar yet weaker trend was observed for total dairy product consumption that included high-fat dairy products, but the association was lost when high-fat dairy foods were examined separately. Although median yogurt consumption was generally low in this population, at 0.5 servings/wk, and 38% of participants reported seldom or never eating yogurt, an increased frequency of yogurt intake was associated with a significantly reduced risk of developing type 2 diabetes. Women with the most frequent yogurt consumption ($\geq$2 servings/wk) had the lowest risk of developing type 2 diabetes (RR: 0.52; $P < 0.0001$, after adjustment for age, race, and total energy intake, and with the trend remaining significant after adjustment for additional variables) compared with those who consumed yogurt less than once per month. Some effect modification by BMI was also observed, because consuming more low-fat dairy foods offered additional protection against diabetes risk among women with a higher BMI compared with leaner women and helped mitigate some of the additional risk of diabetes seen in study participants who were obese. This study suggests that dairy consumption, particularly of low-fat dairy foods and specifically yogurt, may be protective against diabetes in an older population of women, particularly among those who are overweight or obese. Results from the Swedish prospective cohort study in Malmö showed a significant inverse relation between fermented dairy products (yogurt and cultured sour cream) and cardiovascular disease (CVD) in adults aged 44–74 y (10). Higher consumption of fermented milk was associated with lower homeostatic model assessment (HOMA) index (*P*-trend = 0.005), and cheese consumption was associated with higher HDL cholesterol (*P*-trend = 0.002), whereas consumption of other types of dairy products was positively associated with cardiovascular risk factors. There was a significantly lower risk of CVD for individuals in the highest quintiles of consumption of dairy foods compared with those with low consumption [12% decreased risk of CVD (95% CI: 0%, 22%) for the highest quintile; *P*-trend = 0.04], in particular for those with a high consumption of fermented milk products [15% decreased risk of CVD (95% CI: 5%, 24%); *P*-trend = 0.003]. This reduction in CVD risk remained significant after several covariates, including age, race, energy intake, and physical activity, were adjusted for.

In the Italian cohort of the European Prospective Investigation into Cancer and Nutrition (EPIC), dietary intake of yogurt was related to decreased colorectal cancer risk in men and women (35). In a study to evaluate the relation between dairy product consumption and risk of cardiovascular and all-cause related deaths in the Netherlands Cohort Study, fermented milk products were found to have a modest but significant inverse relation with all-cause mortality among men ($RR_{continuous}$: 0.91; 95% CI: 0.86, 0.97 per 100 mL/d) and women ($RR_{continuous}$: 0.92; 95% CI: 0.85, 1.00 per 100 mL/d) within the 10-y follow-up period. Posteriori analysis of yogurt consumption showed that 61% of male study participants consumed yogurt, at an average 66 mL yogurt/d, and 75% of female study participants consumed yogurt, at an average 71 mL yogurt/d. A slight inverse association with mortality was observed among men (*P*-trend =0.039; $RR_{continuous}$: 0.96; 95% CI: 0.92, 1.00 per 100 mL/d), although no association was found among women ($RR_{continuous}$: 1.00; 95% CI: 0.95, 1.05 per 100 mL/d) (8). Although the mechanism of inverse relation between yogurt and all-cause mortality is not known, several publications recently have shown the gut microbiota to play a role in determining the risk of several chronic and metabolic diseases (6). Thus, yogurt's live bacterial content might provide one possible explanation for the reported association between yogurt and lower risk of all-cause mortality reported here.

Immunosenescence

Dysregulation of inflammatory and immune responses occurs with aging, resulting in chronic low-grade inflammation and immunosenescence that puts the elderly at greater risk of infection and development of metabolic and chronic diseases such as type 2 diabetes, CVD, and certain cancers (11, 37). The immune system undergoes several changes throughout the life span that increase the risk of impairment against external and internal dangers in the host. Several reviews have described these changes in depth. Briefly, there is impairment in T cell–mediated immunity, alterations in cytokine production, impaired innate immunity, limited antibody production, a decrease in the percentage of naive cells, and an increase in the percentage of memory cells with impaired response (38–40). Initiating and maintaining an appropriate immune response to pathogenic challenge are also influenced by nutritional status. Protein-energy malnutrition and/or insufficient concentrations of essential micronutrients can impair immune function (41, 42). Lesourd and Mazari (43) observed that among apparently healthy elderly even slight reductions in serum albumin below the normal range of 35–40 g/L indicated diminished nutritional state and were associated with increased age-related alterations in T cell subsets and function and decreased lymphocyte proliferation. Among undernourished elderly individuals, protein-energy malnutrition and deficiencies in zinc, vitamin B-6, and folate are linked to impaired immune response, at least some of which were ameliorated with supplementation of these nutrients (43).

Several diseases are more likely to occur in the elderly because of immunosenescence. Pneumonia is especially prevalent among nursing home and frail elderly populations, and it is associated with low zinc status (44, 45). Vulnerability to tuberculosis, HIV/AIDS, herpes zoster, urinary tract infections, and gastrointestinal infections also increase with aging. Infectious diseases are both associated with and may be exacerbated by nutritional deficiencies that can impair cell-mediated and humoral immunologic function (41). The intestinal flora is also affected by aging, partly as a result from changes in diet, reduced intestinal motility, excessive and, in some cases, chronic use of antibiotics, changes in gastrointestinal architecture, and impairment of gut immunity. Furthermore, the numbers and diversity of protective bacteria species decline with age (46). In recent years, a group in Ireland has been characterizing the gut microbiota of elderly Irish individuals through the creation of the ELDERMET project. A high prevalence of *Clostridium perfingens* (commonly found in fecal samples in elderly and hospitalized patients, especially in individuals in long-term residential care) was inversely correlated with *Bifidobacterium* species (47). These results show that hospitalized elderly subjects may have unhealthy intestinal microflora and suggest a potential benefit for foods supplemented with probiotics.

Yogurt consumption may enhance immune response, thereby reducing infectious disease risk. The components of yogurt that may be involved in enhancing immunity include zinc, vitamin B-6, protein, and bacteria. Evidence supporting this comes from either human and animal studies showing that deficiencies of these vitamins lead to immune impairment or supplementation studies showing immune enhancement. For example, zinc supplementation of zinc-deficient nursing home elderly individuals led to enhancement in lymphocyte proliferation (48). In addition, zinc deficiency, which is highly prevalent in frail elderly individuals, was associated with risk of pneumonia (45, 49). The potential of yogurt in simultaneously providing these nutrients and enhancing immune response warrants further investigation. Probiotic consumption has been associated with enhancement of innate immunity (50), reduction in duration and severity of respiratory infection (51), and enhancement of gut-associated immunity (52).

There are few studies, however, on the effect of yogurt on immunity in humans, and even fewer studies in elderly populations. Double-blind randomized controlled trials of adequate size are needed to determine the effect of yogurt on relevant markers of the immune response and related clinical outcomes, such as incidence of infection and the underlying mechanisms. A study conducted by Schiffrin et al (12) in healthy elderly individuals determined the effect of yogurt with probiotics on gut health, measured as intestinal permeability to macromolecules, innate immunity, and changes in plasma endotoxin concentrations. They compared a group of healthy elderly individuals with hypochlorhydria, measured as low or negative hydrogen in breath, with a group with positive hydrogen breath test measurements. In both groups, there was a decrease in plasma endotoxin concentrations and leukocyte phagocytosis and an increase in monocyte and neutrophil activity measured through ex vivo assays.

Makino et al (11) showed that daily consumption of yogurt with live culture may lead to resistance to respiratory infection, specifically colds, in the elderly. They conducted 2 independent studies in healthy elderly individuals in which a group consuming yogurt daily was compared with a group consuming milk daily for 8 or 12 wk. They showed a significantly lower risk of developing colds in the elderly individuals who consumed yogurt. Although they saw a significant increase in lymphocyte blastoid transformation in both milk and yogurt groups after the consumption period, the increase in the yogurt group was significantly greater than in the milk group. They also conducted cytotoxicity assays by measuring natural killer (NK) cell activity, which they classified into low, normal, or high in relation to the activity range in the study population. Subjects in the yogurt group with low NK cell activity at baseline experienced a significant increase in cytotoxicity after intake. Conversely, the NK cytotoxicity in subjects with above-normal NK cell activity at baseline returned to the normal range after intake. None of these changes were significant in the milk group. The existing evidence on the potential benefits of yogurt on immunity in elderly populations is limited but encouraging, and further investigation is warranted, especially through randomized controlled human trials to confirm and expand on these observations.

Cognition and mental health

Although there is limited assessment of the influence yogurt may have on cognition and long-term mental health, this is an important area to explore because of the rich content of B vitamins in yogurt and evidence of its anti-inflammatory effects that may be protective against cognitive impairment, as well as the recent evidence indicating a connection between the gut microbiota and cognition. In a longitudinal study conducted by Vercambre et al (53) of the relation between dietary habits of ~4800 French women, born between 1925 and 1930, and age-related mental decline assessed in 2006, the odds of reduced capacity for instrumental activities of daily living showed a significant inverse relation with concentrations of riboflavin and vitamins B-6 and B-12. They did not find an association with dairy products, and the specific influence of yogurt is difficult to gauge, because it was grouped with milk in their analysis. However, in a cross-sectional analysis in 1183 men and women in Australia, aged 39–65 y, self-reported measures of memory recall and social functioning were significantly associated with the consumption of low-fat yogurt among men (13). Similarly, a randomized controlled study conducted recently by Tillisch et al (54) compared brain response by using fMRI in women (aged 18–55 y) who consumed a fermented milk product supplemented with several probiotic species compared with women who consumed a nonfermented milk product or undergoing no intervention. They reported that consumption of the fermented milk product led to functional changes in a wide array of regions of the brain that control emotion and sensation. It will be interesting to know whether similar results can be reproduced in older adults (>65 y).

SUMMARY AND CONCLUSIONS

Thus far, the most robust evidence that suggests a potential benefit of yogurt consumption on elderly health outcomes is from observational studies or indirectly from studies that have evaluated the effect of isolated nutrients or probiotics known to be abundant in yogurt on different health outcomes. Few clinical studies have determined the effect of yogurt as a whole food on biological markers of health or diseases in the elderly. The existing studies are encouraging, however, and suggest that yogurt could play an important role in improving the nutritional and health status of the elderly when provided as part of a healthy diet. Furthermore, these studies support the need for additional investigation on the role of yogurt in healthy and active aging individuals. In particular, clinical trials and studies conducted over longer periods are needed to evaluate the sustained effects of yogurt on nutritional status and health of older adults.

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