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Yogurt consumption is associated with better diet quality and metabolic profile in American men and women

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Abstract

The evidence-based Dietary Guidelines for Americans recommends increasing the intake of fat-free or low-fat milk and milk products. However, yogurt, a nutrient-dense milk product, has been understudied. This cross-sectional study examined whether yogurt consumption was associated with better diet quality and metabolic profile among adults (n = 6526) participating in the Framingham Heart Study Offspring (1998-2001) and Third Generation (2002-2005) cohorts. A validated food frequency questionnaire was used to assess dietary intake, and the Dietary Guidelines Adherence Index (DGAI) was used to measure overall diet quality. Standardized clinical examinations and laboratory tests were conducted. Generalized estimating equations examined the associations of yogurt consumption with diet quality and levels of metabolic factors. Approximately 64% of women (vs 41% of men) were yogurt consumers (ie, consumed >0 servings/week). Yogurt consumers had a higher DGAI score (ie, better diet quality) than nonconsumers. Adjusted for demographic and lifestyle factors and DGAI, yogurt consumers, compared with nonconsumers, had higher potassium intakes (difference, 0.12 g/d) and were 47%, 55%, 48%, 38%, and 34% less likely to have inadequate intakes (based on Dietary Reference Intake) of vitamins B2 and B12, calcium, magnesium, and zinc, respectively (all $P \leq .001$). In addition, yogurt consumption was associated with lower levels of circulating triglycerides, glucose, and lower systolic blood pressure and insulin resistance (all $P < .05$). Yogurt is a good source of several micronutrients and may help to improve diet quality and maintain metabolic well-being as part of a healthy, energy-balanced dietary pattern.

Keywords

Yogurt; Milk; Diet; Nutrition status; Metabolic profile; Human

1. Introduction

The Dietary Guidelines Advisory Committee 2010 identified 10 nutrients that were inadequate in the diet of adult American men and women, including vitamins A, C, D, E,

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and K and choline, calcium, magnesium, potassium, and dietary fiber [1]. Dairy may play an essential role in helping to meet the recommendations for some of these shortfall nutrients [2]. An overall higher diet quality has been observed with increased dairy consumption [3-6]. In addition, although evidence has not been consistent, increasing intake of dairy products may be associated with lower risk of cardiovascular disease and type II diabetes [7-10]. In particular, fat-free or low-fat milk and milk products have been recommended by the Dietary Guidelines for Americans (DGA) as one of the food groups for which consumption should be increased [11]. However, few related epidemiological studies have differentiated between types of dairy products or specifically focused on yogurt.

Yogurt is a dairy product fermented by lactic acid bacteria. Although it generally has a similar micronutrient composition as milk, yogurt is highly concentrated with proteins and vitamins and minerals, such as vitamin B2 and B12, calcium, magnesium, potassium, zinc, and others [12]. For example, low-fat yogurt contains approximately 50% more potassium, calcium, and magnesium per 8-oz serving than low-fat milk [13]. Despite limited evidence, yogurt consumption has been inversely linked to weight gain, common carotid artery intima-media thickness, metabolic syndrome, and type II diabetes [8,14-16]. Therefore, increasing low-fat yogurt intake may be important for improving the diet quality and health among Americans.

The current study aimed to explore the relation of yogurt consumption with diet quality (focusing on shortfall nutrients) and metabolic profile among the adults involved in the Framingham Heart Study (FHS). We hypothesized that yogurt consumers and greater yogurt consumption would be related to better diet quality and healthier metabolic status independent of better diet quality.

2. Methods and materials

2.1. Study population

The current study used data from the FHS Offspring Cohort and Generation Three Cohort. The detailed information about these 2 cohorts can be found elsewhere [17]. Briefly, the FHS, which started in 1948, is a longitudinal population-based study of cardiovascular disease. A total of 5124 offspring (aged 5-70 years) of the original FHS cohort were recruited to participate in the FHS Offspring Cohort Study in 1971. As of 2008, 8 examination cycles had been conducted. The Generation Three Cohort, initiated in 2002, included 4095 adults (aged 19-72 years) with at least 1 parent in the FHS Offspring cohort and their spouses. Two examinations have been conducted among the Generation Three Cohort. At each examination, participants underwent a standardized medical history and physical examination. Dietary intake was assessed among the Offspring Cohort, beginning with examination 5, and the Generation Three Cohort. Study protocols and procedures were approved by institutional review boards for human research at Boston University and Tufts Medical Center and the Massachusetts General Hospital. Written informed consent was obtained from all participants.

For the current cross-sectional study, we combined the data from the Offspring Cohort examination 7 (1998-2001, n = 3539) and the Generation Three Cohort examination 1 (2002-2005, n = 4095). Among these 7634 participants, those with missing (n = 709) or invalid (n = 256) food frequency questionnaire (FFQ) data were excluded from analyses. An *invalid FFQ* was defined as a reported total energy intake of less than 600 kcal/d for all or greater than 4000 kcal/d for women and greater than 4200 kcal/d for men or more than 12 blank food items. The participants with missing data on yogurt consumption (ie, consumption status or percentage of energy contribution from yogurt) (n = 143) were further excluded, leaving 6526 participants (aged 19-89 years) for the analyses. Compared with those who remained in the analyses, participants who were excluded were older and less healthy (data not shown).

2.2. Dietary assessments

Before each examination, a 126-item semiquantitative FFQ [18] was mailed to every participant. Participants were asked to bring the completed FFQ with them at their FHS examination visit. The relative validity of the FFQ has been reported previously [18-20]. Participants were asked how often, on average, during the past year they consumed a standardized serving size of each food (eg, 1 cup yogurt). There were 9 frequency categories ranging from “never or less than one serving per month” to “more than six servings/d.” Separate questions also assessed the use of vitamin and mineral supplements, types of breakfast cereal and cooking oil, and information about certain cooking and eating behaviors. The daily nutrient values were calculated by multiplying the nutrient content of the specific portion size of each food (based on the Harvard nutrient database) by the daily consumption frequency and summing all related food items. Specifically, for the dietary analysis, yogurt was coded as “yogurt with fruit, low-fat, containing 10g protein per 8oz” in the database [18]. The detailed information about the nutrient components in yogurt has been documented [13].

The Dietary Guidelines Adherence Index (DGAI) was created to measure the overall dietary quality according to the adherence of participants to the key dietary recommendations by the 2005 DGA [21]. Detailed information about the development and application of DGAI can be found elsewhere [21]. Briefly, a total of 20 index items were included in the calculation of DGAI score, including 11 items (ie, food intake subscore) assessing adherence to energy-specific food intake recommendations and 9 items (ie, healthy choice subscore) assessing adherence to “healthy choice” nutrient intake recommendations. Each item was scored ranging from 0 to 1 based on the degree of the adherence, so the maximum possible DGAI score is 20 indicating a complete adherence. The DGAI penalizes on overconsumption of discretionary energy and energy-dense foods, which is an important feature of DGAI over other a priori–defined index scores [21].

2.3. Measurements of other variables

All clinical examinations were performed at the NHLBI Framingham Heart Study site in Framingham, Massachusetts. A standardized physical examination was conducted, and questionnaires were used to assess participants' lifestyles (eg, physical activity for a typical day) and medical history. A physical activity index (PAI) score, expressed in metabolic equivalents, was calculated by averaging the number of hours spent on specific activities (ie, sleep, sedentary, slight activity, moderate activity, and heavy activity) and weighting on the oxygen consumption required to perform these activities [22]. Height (to the nearest 0.25 in) and weight (to the nearest 0.25 lb) were measured with the participant standing, shoes off, and wearing only a hospital gown. Body mass index (BMI) was then calculated in kilograms per square meter. Sitting blood pressure was measured twice on the left arm of each participant after a 5-minute rest using a mercury column sphygmomanometer and a standardized protocol, and 2 readings were averaged for the analyses [23].

Fasting (≥8 hours) blood samples were drawn and analyzed in the Framingham Heart Study Laboratory (Framingham, MA) for assessing glucose and lipid levels [17]. A hexokinase/glucose-6-phosphate dehydrogenase method [24] was used to measure serum glucose. Plasma total cholesterol and triglycerides were measured by enzymatic methods [25], and high-density lipoprotein (HDL) cholesterol was measured after dextran-magnesium precipitation [26]. The intra-assay and interassay coefficients of variation were all less than 2% and less than 3%, respectively, for glucose, triglyceride, total cholesterol, and HDL cholesterol. For the Offspring Cohort, fasting insulin concentrations were measured using radioimmunoassay; the intra-assay coefficient of variation was 3.9%, and the interassay coefficient of variation ranged 4.7% to 6.1% [17]. For the Generation Three Cohort, fasting insulin concentrations were measured using enzyme-linked immunosorbent assay; the intra-assay and interassay coefficients of variation were 2.7% and 8.1%, respectively [17]. Fasting insulin values from the Generation Three Cohort were standardized for aggregation with the Offspring cohort to counter the difference in methods [17]. The homeostasis model assessment of insulin resistance (HOMA-IR) was calculated accordingly: HOMA-IR = (glucose [mg/dL] × insulin [mU/L])/405 [27].

2.4. Statistical analyses

All analyses were conducted using SAS statistical software (version 9.2; SAS Institute, Cary, NC). Skewed data were log transformed for the analyses and back transformed to present. Generalized estimating equations (GEEs) were used, as appropriate, to control for the family correlation between Offspring and Generation Three Cohorts.

Participants were grouped as yogurt consumers (>0 servings/week) vs nonconsumers (0 servings/week). Consumers were further divided into 2 groups (ie, low-intake group and high-intake group) using the median amount of (ie, energy contribution [%kcal])) their yogurt consumption as the cut point. Mean values or percentage of participants' characteristics and dietary intakes of selected food groups were calculated and compared across yogurt consumption groups.

To assess the prevalence of nutrient (excluding nutrients from supplements) inadequacy among the current study population, the estimated average requirements (EAR) cutoff method [28] was used. The percentage of the population with usual intakes below the EAR is an appropriate estimate for the prevalence of the group with inadequate intakes, under the assumptions of no correlation between intakes and requirements, greater variance in intakes than in requirements, and the symmetrical distribution of requirements around the EAR [28]. The prevalence of nutrient inadequacy was compared between yogurt consumers and nonconsumers.

The EAR cutoff method may not be appropriate for iron due to the skewed distribution of the requirements of iron [28]. In this regard, the probability method [29] was used for estimating the prevalence of iron inadequacy. In addition, because no EAR was available for the dietary intakes of fiber and potassium, we used the adequate intake (AI) as a reference. Individuals with usual intakes greater than 100% of AI had 0% probability of inadequacy, whereas the prevalence of inadequacy among people whose usual intake of 100% or less of AI could not be estimated [28].

Generalized estimating equation models with Logit link were used to examine whether yogurt consumption (ie, dichotomized or in 3 groups [nonconsumers, low-intake, and high-intake groups]) was associated with a lower likelihood of being inadequate in nutrient intakes, focusing on the “shortfall” nutrients (ie, high prevalence of inadequacy), except for potassium and fiber. Generalized estimating equation models with Identity link assessed the relations of yogurt consumption with the overall diet quality represented by DGAI score, the intake of potassium and fiber, and metabolic profile (including levels of total cholesterol, HDL cholesterol, triglycerides, glucose, blood pressure, and HOMA-IR). Models were adjusted, as appropriate, for participants' age, sex, smoking status, PAI score, total energy intake, DGAI score, BMI, and the use of corresponding dietary supplements (eg, in the analyses of vitamin B6 inadequacy, we adjusted for the use of multiple vitamins, vitamin B6, or B complex vitamins). For the analyses of metabolic profile, the use of any vitamin and mineral supplement was included as a covariate. In addition, the use of cholesterollowering, antidiabetics, or antihypertensive medications was also examined as covariates in the corresponding models. However, the adjustment of these factors did not materially change the results but reduced the sample size due to some missing data on the medication use and thus was not included in the final models. The linear trend across the 3 groups of yogurt consumption was tested by using the median yogurt intake in each group as a continuous variable.

Two sets of sensitivity analyses were conducted. First, we examined the nutrient inadequacy across yogurt consumption groups (ie, consumers vs nonconsumers and nonconsumers vs low-intake group vs high-intake group) using data of total nutrients from foods, supplements, and fortification. Second, all analyses (including first set of sensitivity analyses) described above were repeated while excluding potential outliers of yogurt consumption, that is, the participants whose energy contribution from yogurt was greater than 99th percentile of population distribution.

In addition, we also conducted a cluster analysis to identify the dietary patterns that were associated with yogurt consumption among this FHS population. Generalized estimating equation models were used as appropriate to examine the association between yogurt consumption and the identified dietary patterns among men and women. The details of this cluster analysis are presented as the Supplemental Material

All statistical tests were 2 sided. Statistical significance was set at $P < .05$.

3. Results

There were 41.4% of men and 64.2% women consuming yogurt. The average energy contributions of yogurt among men and women were 1.38% and 2.75%, respectively. Participant characteristics are shown in Table 1. Compared with nonconsumers, yogurt consumers appeared to have better metabolic profile, such as lower BMI, waist circumference, levels of triglycerides, fasting glucose and insulin, and blood pressure but higher HDL cholesterol. Yogurt consumers consumed less percentage of energy from processed meat, refined grains, and beer than nonconsumers. In contrast, the consumption of healthy foods tended to be greater in yogurt consumers vs nonconsumers, such as fruits, vegetables, nuts, fish, and whole grains, and others. This was consistent with our observations in the cluster analysis (Supplemental Material) where we found that yogurt consumers were about twice as likely to have a healthier dietary pattern than nonconsumers.

Yogurt consumers had significantly lower prevalence of nutrient inadequacy than nonconsumers (Table 2), and there were more consumers with usual intake of potassium and fiber above AI (all $P < .01$). After adjusting for age, sex, physical activity, smoking status, BMI, and the use of dietary supplements, yogurt consumption was associated with better overall diet quality as reflected by DGAI score, mean intake of potassium and fiber, or the likelihood of nutrient inadequacy (Tables 3A and 3B). However, further controlling for DGAI score, the relations between yogurt consumption and the inadequacy of fiber; folate; and vitamins B1, B6, C, and E were all eliminated. In contrast, yogurt consumers' (vs nonconsumers') potassium intakes remained higher (difference, 0.12 g/d) and were 47%, 55%, 48%, 38%, and 34% less likely to have inadequate intakes of vitamins B2 and B12, calcium, magnesium, and zinc, respectively (all $P \leq .001$).

As shown in Table 4, compared with nonconsumers, yogurt consumers had lower levels of triglycerides (107.0 [95% confidence interval {CI}, 104.2-109.8] vs 111.2 [108.4-114.0] mg/dL), fasting glucose (97.2 [96.5-97.9] vs 98.7 [98.0-99.5] mg/dL), and insulin (81.4 [79.9-82.9] vs 83.8 [82.2-85.4] pmol/L), systolic blood pressure (120.2 [119.5-120.9] vs 121.7 [121.0-122.3] mm Hg), and HOMA-IR score (3.27 [3.20-3.35] vs 3.42 [3.34-3.50]) (all $P \leq .001$). Despite being attenuated when further controlled for DGAI score and the use of supplements, these inverse associations remained significant for fasting glucose ($P = .02$) and systolic blood pressure ($P = .01$). In addition, people with high intake of yogurt had lower levels of triglycerides ($P_{linear} = .02$), fasting insulin ($P_{linear} = .02$), and HOMA-IR ($P_{linear} = .006$) than nonconsumers. However, there was no association between yogurt consumption and levels of total and HDL cholesterol, and accounting for participants' BMI substantially attenuated many of the associations between yogurt consumption and examined metabolic factors.

The sensitivity analyses generated similar findings as the primary analyses (data not shown).

4. Discussion

Among these 6526 middle-aged to older men and women, as we had hypothesized, yogurt intake was associated with better overall diet quality, greater intakes of several shortfall nutrients, and healthier metabolic profiles independent of overall diet quality.

Yogurt constituted up to 32% of dairy in European diets [30], whereas it only accounted for 5% or less of total dairy intake among men and women and across different ethnic groups in the United States [16]. As a dairy source with high concentration of various nutrients [13,31], increasing yogurt consumption among Americans may lead to more nutrient dense diets and greater adequacy for some of the shortfall nutrients, if substituting for energy-dense foods. However, although the health benefits of yogurt have been widely proposed and investigated in animal models, limited epidemiologic evidence is available, and potential mechanisms are unclear [15,32]. Particularly, different from being fed in animal models, yogurt is generally consumed among free-living human populations in the context of other foods and lifestyles. Therefore, for better elucidating the benefits of yogurt, the dietary patterns and diet quality that are associated with yogurt consumption should be taken into account. Among the FHS adult cohorts, yogurt consumers were more likely to follow a healthier dietary pattern that featured a higher intake of other reduced fat dairy, fruits and vegetables, tofu and beans, nuts and seeds, poultry, fish and other seafood, whole grains, and red wine (shown in Supplemental Material). In concordance, yogurt consumers had significantly higher DGAI score than non-consumers, suggesting that consumers were more likely to have a better overall diet quality by adhering to the key DGA intake recommendations [21]. Because the healthy foods recommended by DGA, including yogurt, tend to be nutrient dense, it is not surprising that we observed a much lower prevalence of nutrient inadequacy among yogurt consumers than nonconsumers. In this regard, our findings were also consistent with the previous report that the dietary variety of nutrient-dense foods was positively associated with nutrient adequacy [6].

Yogurt possesses similar, although more concentrated, micronutrient composition to that of milk. However, none of dietary fiber; folate; and vitamins A, D, E, and C was present in notable quantities in the current studied low-fat yogurt [13]. Therefore, as expected, the associations between yogurt consumption and the adequacy of these nutrients were substantially attenuated after adjusting for the DGAI score. Any of the residual significant associations between yogurt intake and these nutrients may be due to the relatively large study sample size as well as the unmeasured residual confounding that accompanied yogurt consumption.

Based on the amounts of nutrients that are required to meet the EAR and AI [33,34], the low-fat yogurt examined in the current study is an excellent source of calcium, magnesium, potassium, zinc, and vitamins B2 and B12 [13]. Although the current evidence does not suggest that calcium in yogurt is better absorbed than that in milk [35,36], the simple fact that concentrations of some micronutrients are higher in yogurt would result in greater availability of these nutrients for utilization in the body [12]. In addition, yogurt may be well tolerated for lactase-deficient individuals [35,37]. Consistently, we observed that, even after controlling for the DGAI score, yogurt consumption remained robustly associated with lower prevalence of inadequacy for these vitamins and minerals and mostly in a dose-response manner.

In the present cross-sectional analyses, yogurt consumption was inversely related to levels of triglycerides, glucose and insulin, insulin resistance, and blood pressure, when adjusting for demographic and lifestyle factors. Our results were in agreement with some previous evidence [8,14-16]. One more serving of yogurt per day was linked to less 4-year weight gain (−0.82 lb) among 120000 or more American men and women [15] and 60% lower prevalence of metabolic syndrome among US adults in the 1999-2004 National Health and Nutrition Examination Survey [16]. By following a cohort of elderly women for 3 years, Ivey et al [14] reported that participants who consumed more than 100-g yogurt per day had a significantly lower common carotid artery intima-media thickness than did participants with lower consumption. In addition, a meta-analysis of 4 studies targeting yogurt revealed that yogurt consumption was also associated with lower risk of type II diabetes [8].

It should be noted that the significant associations between yogurt consumption and metabolic factors that we found were attenuated after further controlling for the DGAI score and the use of supplements. The association between yogurt consumption and diastolic blood pressure was eliminated, whereas those for triglycerides, fasting glucose and insulin, insulin resistance, and systolic blood pressure remained statistically significant. Additional adjustment for BMI further attenuated these associations, and the relation with triglycerides and insulin was no longer statistically significant. Consequently, the associations with metabolic profile may be due in part to an association between yogurt consumption and BMI suggesting that body weight may be an important mediator of these associations. Nonetheless, combined with the null findings for total and HDL cholesterol, our results suggested that yogurt per se may have health benefits partially by affecting the metabolism of glucose but not lipid metabolism. Systolic blood pressure could also be one important target. Future longitudinal studies are warranted to confirm these findings.

Although it has not been clear, the nutrient-dense property of yogurt may shed great light on the potential mechanisms of its health benefits. Especially, vitamins and minerals are essential factors for many metabolic reactions in human body. For example, the shuttle of calcium ion through cell membrane signals numerous cell activities; calcium is also the primary component for bone mineralization. Zinc is a cofactor for many key enzymes. Potassium is the most abundant cation in cells, which participates actively in energy metabolism, membrane transport, and fluid balance. Magnesium serves as an essential cofactor for more than 300 catalytic reactions. B vitamins have a variety of functions in cell growth, division, and metabolism. Therefore, the inadequacy of these micronutrients can be significantly deleterious for a variety of metabolic functions. Many epidemiologic studies also support the importance of these micronutrients. An average 4.7 g/d of potassium intake has been related to 8.0/4.1 mm Hg lower systolic/diastolic blood pressure, 8% to 15% lower risk of cerebrovascular accident, and 6% to 11% lower risk of myocardial infarction [38]. Higher intake of magnesium has been associated with decreased risk of type II diabetes and metabolic syndrome [39,40]. In this regard, yogurt, as an excellent source of various vitamins and minerals, may be of particular benefit to American diets. On the other hand, the probiotic bacteria in yogurt, although beyond the scope of the current study, may favorably modify the gut micro florae, which play essential roles in energy metabolism, immune function, and metabolic disease [32,41]. In addition, yogurt is a fermented dairy product rich in peptides with in vitro angiotensin-converting enzyme inhibitor effects [42], which may be one explanation for the association between yogurt consumption and lower systolic blood pressure.

Strengths of the present study included its relatively large study size and consideration of the potential influence of diet quality on the associations between yogurt and nutrient adequacy and metabolic profile. However, some limitations should be also noted. The cross-sectional study design does not indicate any causal inference of yogurt consumption on nutrient adequacy and metabolic profile. The generalizability of our results to other populations of different races or young age groups was also limited because participants were mostly adult white Americans. Although our analyses carefully controlled for the yogurt consumption associated diet quality, latent residual confounding could not be ruled out. In addition, the FFQ did not assess the types of yogurt (eg, low fat or fat free, with or without fruits, supplemented with micronutrients or not, etc), whereas yogurt was generalized in the database as being low fat and with fruit [13]. Finally, the participants who were excluded were older and less healthy than those who remained in the analyses. To account for the potential confounding effect of age, we adjusted for age in our analyses. However, it is also possible that the differences in age and health status between those who were included and excluded from these analyses may have biased our findings, although the direction of bias is unknown because we do not know the yogurt consumption of those who were excluded.

Overall, as we had hypothesized, yogurt intake was associated with better diet quality with greater intakes of several shortfall nutrients and healthier metabolic profiles in this FHS adult population. Given the low yogurt consumption among general American adults as compared with the European population, increasing yogurt intake among Americans may be promising in helping to achieve greater adequacy for some of the shortfall nutrients and maintain metabolic well-being as part of a healthy, energy-balanced dietary pattern. Future longitudinal studies are warranted to confirm our findings.

Supplementary Material

Refer to Web version on PubMed Central for supplementary material.

Acknowledgments

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Abbreviations

AI	Adequate intake
BMI	Body mass index
HDL	High-density lipoprotein
DGA	Dietary Guidelines for Americans

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DGAI	Dietary guidelines adherence index
EAR	Estimated average requirements
FFQ	Food frequency questionnaire
FHS	Framingham Heart Study
GEE	Generalized estimating equations
HOMA-IR	Homeostasis model assessment of insulin resistance
PAI	Physical activity index

Table 1

Unadjusted participants' characteristics by yogurt consumption groups: Framingham Heart Study Offspring (1998-2001) and Generation Three Cohorts (2002-2005) (n = 6526)

	Nonconsumers	Consumers	$P_{\text{con vs non-con}}$[a]
n	3016	3510	
Age (y)	52.6 ± 14.0[b]	47.3 ± 13.2	<.001
Physical activity index	37.9 ± 7.5	37.3 ± 6.9	<.001
Body mass index (kg/m^2)	28.0 ± 5.4	26.9 ± 5.5	<.001
Waist circumference (cm)	98.6 ± 14.5	93.7 ± 15.1	<.001
Regular cigarette smokers (%)	17.6	11.6	<.001
Total cholesterol (mg/dL)	196.7 ± 37.2	192.3 ± 36.1	<.001
HDL-cholesterol (mg/dL)	52.3 ± 16.1	56.2 ± 16.8	<.001
Triglycerides (mg/dL)	132.2 ± 90.4	116.5 ± 80.7	<.001
Glucose (mg/dL)	102.2 ± 25.4	96.3 ± 17.9	<.001
Insulin (pmol/L)	92.9 ± 50.5	86.1 ± 43.5	<.001
Systolic blood pressure (mm Hg)	124.5 ± 17.7	119.0 ± 16.6	<.001
Diastolic blood pressure (mm Hg)	75.5 ± 9.8	74.1 ± 9.6	<.001
Dietary intake			
Total energy intake (kcal)	1889 ± 653	2012 ± 647	<.001
Yogurt consumption (servings/wk)	0.00 ± 0.00	2.27 ± 2.56	<.001
Percentage of energy contribution from selected food groups			
Yogurt	0.00 ± 0.00	3.95 ± 4.09	<.001
High fat dairy	5.69 ± 5.04	5.64 ± 4.34	.02
Reduced fat dairy	3.57 ± 4.91	4.05 ± 4.53	<.001
Fruits	4.53 ± 4.50	5.79 ± 4.31	<.001
Nuts and seeds	2.26 ± 3.26	2.56 ± 3.14	<.001
Vegetables	3.46 ± 2.10	3.78 ± 1.98	<.001
Processed meat	2.12 ± 2.27	1.45 ± 1.73	<.001
Meat	9.06 ± 5.67	7.60 ± 4.96	<.001
Fish and other seafood	2.34 ± 2.19	2.67 ± 2.32	<.001
Whole grain cereal	1.72 ± 3.13	1.97 ± 2.97	<.001
Refined grain cereal	0.77 ± 1.77	0.83 ± 1.84	.02
Refined grains	8.17 ± 5.24	7.66 ± 4.64	<.001
Whole grains	3.85 ± 4.09	5.04 ± 3.98	<.001
Beer	3.08 ± 6.70	1.69 ± 3.49	<.001
Red wine	0.88 ± 2.40	0.93 ± 2.00	<.001
White wine	0.61 ± 1.99	0.77 ± 1.91	<.001

[a] *P* values for testing the differences between yogurt consumers and nonconsumers (tests were conducted in GEE Models with Identity Link for continuous variables and Logit Link for categorical variables; skewed continuous data were log transformed before entering the tests).

[b] Means ± SD or percentage.

Table 2

Population distribution of nutrient (excluding supplements) intake status among yogurt consumers vs nonconsumers

	Nonconsumers (n = 3016)	Consumers (n = 3510)
Median energy contribution from yogurt (%kcal)	0	2.07
Prevalence of nutrient inadequacy		
Vitamin B1	24.8[a]	13.1
Vitamin B2	11.2	3.4
Vitamin B6	17.6	8.2
Vitamin B12	6.1	2.4
Calcium	72.5	52.9
Folate	14.8	6.9
Magnesium	65.5	39.1
Vitamin C	25.6	14.1
Zinc	27.8	12.9
Phosphorus	4.1	1.2
Vitamin A	36.7	18.0
Vitamin D	93.4	88.6
Vitamin E	93.2	90.0
Iron	7.6	7.1
Percentage of population with usual intakes above AI[b]		
Potassium	4.7	11.4
Fiber	10.1	22.4

P values were all less than .001 for the difference between groups(tests were conducted in GEE Models with Logit Link).

[a]The percentage of population with inadequate nutrient intake for all such values.

[b]Because EAR are not available for potassium and fiber to define nutrient inadequacy.

Table 3

Table 3A The associations of yogurt consumption with diet quality and the intake of potassium and fiber (nutrients excluding supplements)

		Nonconsumers (n = 3016)	Consumers (n = 3510)	Consumers: Low-intake group[a] (n = 1758)	Consumers: High-intake group[a] (n = 1752)	P_{trend}[b]	$P_{con\ vs\ non\text{-}con}$[c]
Median energy contribution from yogurt (%kcal)		0	2.07	1.11	5.70		
DGAI score[d]		8.05 (7.94, 8.16)[f]	9.14 (9.02, 9.25)	8.78 (8.64, 8.92)	9.53 (9.39, 9.96)		
Potassium (g)	Model 1[e]	2.93 (2.90, 2.96)	3.22 (3.19, 3.25)	3.12 (3.08, 3.15)	3.34 (3.30, 3.38)	<.001	<.001
	Model 2[e]	3.08 (3.06, 3.11)	3.20 (3.18, 3.23)	3.15 (3.13, 3.18)	3.26 (3.23, 3.29)	<.001	<.001
Fiber (g)[g]	Model 1	15.14 (14.89, 15.39)	17.03 (16.78, 17.28)	16.80 (16.51, 17.10)	17.28 (16.95, 17.61)	<.001	<.001
	Model 2	16.65 (16.46, 16.85)	16.83 (16.66, 17.01)	17.21 (16.99, 17.42)	16.34 (16.22, 16.65)	.002	.11

[a] Low-intake and high-intake groups were generated using a cut point of 2.07%kcal from yogurt.

[b] *P* values for testing the linear trends across yogurt consumption (percentage of energy contribution) groups.

[c] *P* values for testing the differences between yogurt consumers and nonconsumers.

[d] For DGAI score, model adjusted for age, sex, PAI score, smoking status, and BMI.

[e] For potassium and fiber, model 1 adjusted for age, sex, total energy intake, PAI score, smoking status, BMI, and the use of corresponding dietary supplements (wherever data were available). Model 2 adjusted for covariates in model 1 and DGAI score.

[f] Means and 95% CI for all such values.

[g] Geometric means and 95% CI were presented

Table 3B The associations of yogurt consumption with the risk of nutrient inadequacy (nutrients excluding supplements)

		Nonconsumers (n = 3016)	Consumers (n = 3510)	Consumers: Low-intake group[a] (n = 1758)	Consumers: High-intake group[a] (n = 1752)	P_{trend}[b]	$P_{con\ vs\ non\text{-}con}$[c]
Median energy contribution from yogurt (%kcal)		0	2.07	1.11	5.70		
Vitamin B1	Model 1[d]	1.00	0.60 (0.50, 0.72)[e]	0.63 (0.51, 0.79)	0.57 (0.46, 0.71)	<.001	<.001
	Model 2[d]	1.00	0.86 (0.71, 1.05)	0.79 (0.62, 1.00)	0.96 (0.75, 1.23)	.99	.14
Vitamin B2	Model 1	1.00	0.45 (0.34, 0.59)	0.62 (0.44, 0.87)	0.32 (0.23, 0.46)	<.001	<.001
	Model 2	1.00	0.53 (0.39, 0.70)	0.70 (0.49, 1.01)	0.38 (0.26, 0.56)	<.001	<.001

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Table 3B The associations of yogurt consumption with the risk of nutrient inadequacy (nutrients excluding supplements)

		Nonconsumers (n = 3016)	Consumers (n = 3510)	Consumers		P_{trend}[b]	$P_{con\ vs\ non\text{-}con}$[c]
				Low-intake group[a] (n = 1758)	High-intake group[a] (n = 1752)		
Vitamin B6	Model 1	1.00	0.65 (0.53, 0.80)	0.78 (0.61, 1.01)	0.54 (0.42, 0.70)	<.001	<.001
	Model 2	1.00	0.94 (0.74, 1.20)	1.01 (0.76, 1.33)	0.87 (0.64, 1.19)	.38	.63
Vitamin B12	Model 1	1.00	0.45 (0.33, 0.62)	0.57 (0.39, 0.85)	0.37 (0.25, 0.54)	<.001	<.001
	Model 2	1.00	0.45 (0.33, 0.61)	0.57 (0.38, 0.84)	0.36 (0.24, 0.54)	<.001	<.001
Calcium	Model 1	1.00	0.44 (0.39, 0.51)	0.67 (0.57, 0.79)	0.27 (0.23, 0.32)	<.001	<.001
	Model 2	1.00	0.52 (0.44, 0.60)	0.74 (0.63, 0.88)	0.32 (0.27, 0.38)	<.001	<.001
Folate	Model 1	1.00	0.62 (0.51, 0.76)	0.72 (0.57, 0.91)	0.53 (0.42, 0.69)	<.001	<.001
	Model 2	1.00	0.86 (0.69, 1.06)	0.89 (0.70, 1.14)	0.81 (0.62, 1.07)	.16	.15
Magnesium	Model 1	1.00	0.41 (0.35, 0.48)	0.48 (0.40, 0.58)	0.34 (0.28, 0.41)	<.001	<.001
	Model 2	1.00	0.62 (0.51, 0.74)	0.60 (0.48, 0.74)	0.64 (0.51, 0.80)	.002	<.001
Vitamin C	Model 1	1.00	0.58 (0.49, 0.67)	0.63 (0.53, 0.75)	0.52 (0.43, 0.63)	<.001	<.001
	Model 2	1.00	0.86 (0.72, 1.01)	0.82 (0.68, 1.00)	0.91 (0.73, 1.13)	.55	.07
Zinc	Model 1	1.00	0.62 (0.51, 0.75)	0.75 (0.59, 0.94)	0.50 (0.40, 0.63)	<.001	<.001
	Model 2	1.00	0.66 (0.55, 0.80)	0.78 (0.62, 0.98)	0.54 (0.43, 0.69)	<.001	<.001
Vitamin A	Model 1	1.00	0.54 (0.47, 0.63)	0.55 (0.46, 0.65)	0.54 (0.45, 0.64)	<.001	<.001
	Model 2	1.00	0.76 (0.65, 0.89)	0.67 (0.56, 0.81)	0.90 (0.74, 1.11)	.65	<.001
Vitamin D	Model 1	1.00	0.65 (0.53, 0.79)	0.68 (0.54, 0.86)	0.61 (0.48, 0.78)	<.001	<.001
	Model 2	1.00	0.78 (0.63, 0.96)	0.77 (0.61, 0.97)	0.78 (0.61, 1.01)	.17	.02
Vitamin E	Model 1	1.00	0.79 (0.64, 0.98)	0.82 (0.64, 1.04)	0.77 (0.60, 0.99)	.08	.04
	Model 2	1.00	1.03 (0.82, 1.29)	0.98 (0.76, 1.25)	1.09 (0.84, 1.42)	.41	.81

[a] Low-intake and high-intake groups were generated using a cut point of 2.07%kcal from yogurt.

[b] *P* values for testing the linear trends across yogurt consumption (percentage of energy contribution) groups.

[c] *P* values for testing the differences between yogurt consumers and nonconsumers.

[d] Model 1adjusted for age, sex, total energy intake, PAI score, smoking status, BMI, and the use of corresponding dietary supplements (wherever data were available). Model 2 adjusted for covariates in model 1 and DGAI score.

[e] Odds ratio (95% CI) for all such values.

Table 4

The associations between yogurt consumption and levels of metabolic factors

		Nonconsumers (n = 3016)	Consumers (n = 3510)	Consumers		P_{trend}[b]	$P_{con\ vs\ non\text{-}con}$[c]
				Low-intake group[a] (n = 1758)	High-intake group[a] (n = 1752)		
Median energy contribution from yogurt (%kcal)		0	2.07	1.11	5.70		
Total cholesterol (mg/dL)	Model 1[d]	196.0 (194.4, 197.7)[e]	194.8 (193.1, 196.5)	195.4 (193.4, 197.4)	194.2 (192.1, 196.3)	.11	.21
	Model 2[d]	194.9 (193.2, 196.6)	194.8 (193.2, 196.5)	195.0 (192.9, 197.0)	194.7 (192.6, 196.8)	.85	.97
	Model 3[d]	194.9 (193.2, 196.6)	195.0 (193.2, 196.6)	195.0 (192.9, 197.0)	195.0 (192.9, 197.1)	.97	.97
HDL cholesterol (mg/dL)	Model 1	53.0 (52.2, 53.7)	53.2 (52.5, 53.9)	53.0 (52.1, 53.8)	53.4 (52.6, 54.3)	.29	.53
	Model 2	53.3 (52.5, 54.0)	53.2 (52.5, 53.9)	53.1 (52.3, 53.3)	53.3 (52.4, 54.2)	.91	.85
	Model 3	53.2 (52.5, 53.8)	53.0 (52.3, 53.7)	53.1 (52.3, 53.9)	52.9 (52.1, 53.7)	.53	.70
Triglycerides (mg/dL)[f]	Model 1	111.2 (108.4, 114.0)	107.0 (104.2, 109.8)	109.5 (106.1, 113.0)	104.3 (101.0, 107.7)	<.001	.01
	Model 2	109.4 (106.6, 112.3)	107.1 (104.3, 109.9)	108.8 (105.5, 112.3)	105.1 (101.8, 108.6)	.02	.16
	Model 3	109.9 (107.2, 112.6)	107.8 (105.2, 110.6)	108.8 (105.6, 112.1)	106.8 (103.5, 110.1)	.10	.20
Glucose (mg/dL)[f]	Model 1	98.7 (98.0, 99.5)	97.2 (96.5, 97.9)	97.9 (97.0, 98.7)	96.5 (95.7, 97.4)	<.001	<.001
	Model 2	98.2 (97.5, 99.0)	97.3 (96.6, 98.0)	97.8 (96.9, 98.6)	96.8 (95.9, 97.6)	.002	.02
	Model 3	98.4 (97.7, 99.1)	97.5 (96.8, 98.2)	97.8 (96.9, 98.6)	97.1 (96.3, 98.0)	.01	.02
Insulin (pmol/L)[f]	Model 1	83.8 (82.2, 85.4)	81.4 (79.9, 82.9)	83.2 (81.4, 85.1)	79.4 (77.6, 81.3)	<.001	.009
	Model 2	82.3 (80.7, 83.9)	81.5 (80.0, 83.1)	82.8 (81.0, 84.6)	80.1 (78.3, 82.0)	.02	.42
	Model 3	82.8 (81.4, 84.2)	82.1 (80.8, 83.4)	82.8 (81.2, 84.3)	81.4 (79.8, 83.1)	.12	.40
Systolic blood pressure (mmHg)	Model 1	121.7 (121.0, 122.3)	120.2 (119.5, 120.9)	120.5 (119.7, 121.3)	119.8 (118.9, 120.7)	<.001	<.001
	Model 2	121.3 (120.6, 122.0)	120.2 (119.5, 120.9)	120.4 (119.6, 121.2)	120.0 (119.1, 120.9)	.03	.01
	Model 3	121.3 (120.6, 122.0)	120.4 (119.7, 121.0)	120.4 (119.6, 121.2)	120.3 (119.5, 121.2)	.12	.02
Diastolic blood pressure (mmHg)	Model 1	75.1 (74.6, 75.5)	74.4 (74.0, 74.9)	74.6 (74.1, 75.1)	74.2 (73.7, 74.8)	.01	.02
	Model 2	74.7 (74.2, 75.1)	74.4 (74.0, 74.9)	74.5 (73.9, 75.0)	74.4 (73.8, 75.0)	.43	.34
	Model 3	74.7 (74.3, 75.2)	74.6 (74.1, 75.0)	74.5 (74.0, 75.0)	74.6 (74.1, 75.2)	.91	.49
HOMA-IR[f]	Model 1	3.42 (3.34, 3.50)	3.27 (3.20, 3.35)	3.37 (3.28, 3.45)	3.17 (3.09, 3.27)	<.001	.001
	Model 2	3.34 (3.26, 3.42)	3.28 (3.21, 3.36)	3.35 (3.26, 3.43)	3.21 (3.12, 3.30)	.006	.19
	Model 3	3.37 (3.30, 3.43)	3.31 (3.25, 3.37)	3.34 (3.27, 3.42)	3.28 (3.20, 3.36)	.04	.15

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[a] Low-intake and high-intake groups were generated using a cut point of 2.07%kcal from yogurt.

[b] *P* values for testing the linear trends across yogurt consumption (percentage of energy contribution) groups.

[c] *P* values for testing the differences between yogurt consumers and nonconsumers.

[d] Model 1: adjusted for age, sex, PAI score, total energy intake, and smoking status. Model 2: model 1 + DGAI score and the use of supplements. Model 3: model 2 + BMI.

[e] Mean (95% CI) for all such values;

[f] Triglycerides, glucose, insulin, and HOMA-IR are presented in geometric means (95% CI).