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ORIGINAL CONTRIBUTION

Association between yogurt consumption, dietary patterns, and cardio-metabolic risk factors

Hubert Cormier[1,2] · Élisabeth Thifault[1] · Véronique Garneau[1] · Angelo Tremblay[3] · Vicky Drapeau[4] · Louis Pérusse[1,3] · Marie-Claude Vohl[1,2]

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Abstract

Purpose To examine whether yogurt consumption is associated with a healthier dietary pattern and with a better cardio-metabolic risk profile among healthy individuals classified on the basis of their body mass index (BMI).

Methods A 91-item food frequency questionnaire, including data on yogurt consumption, was administered to 664 subjects from the INFOGENE study. After principal component analysis, two factors were retained, thus classified as the Prudent and Western dietary patterns.

Results Yogurt was a significant contributor to the Prudent dietary pattern. Moreover, yogurt consumption was associated with lower body weight, waist-to-hip ratio, and waist circumference and tended to be associated with a lower BMI. Consumers had lower levels of fasting total cholesterol and insulin. Consumers of yogurt had a positive Prudent dietary pattern mean score, while the opposite trend was observed in non-consumers of yogurt. Overweight/obese individuals who were consumers of yogurts exhibited a more favorable cardio-metabolic profile characterized by lower plasma triglyceride and insulin levels than non-consumers within the same range of BMI. There was no difference in total yogurt consumption between normal-weight individuals and overweight/obese individuals. However, normal-weight subjects had more daily servings of high-fat yogurt and less daily servings of fat-free yogurt compared to overweight/obese individuals.

Conclusions Being a significant contributor to the Prudent dietary pattern, yogurt consumption may be associated with healthy eating. Also, yogurt consumption may be associated with lower anthropometric indicators and a more beneficial cardio-metabolic risk profile in overweight/obese individuals.

Keywords Yogurt · Nutrition · Cardio-metabolic risk factors · Insulin · Triglycerides · Dietary patterns

Abbreviations

BMI	Body mass index
CVD	Cardiovascular diseases
FFQ	Food frequency questionnaire
LABSAP	Laboratory of physical activity of Laval University

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✉ Marie-Claude Vohl
marie-claude.vohl@fsaa.ulaval.ca

Hubert Cormier
hubert.cormier.1@ulaval.ca

Élisabeth Thifault
elisabeth.thifault@fsaa.ulaval.ca

Véronique Garneau
veronique.garneau@fsaa.ulaval.ca

Angelo Tremblay
angelo.tremblay@kin.ulaval.ca

Vicky Drapeau
vicky.drapeau@fse.ulaval.ca

Louis Pérusse
louis.perusse@kin.ulaval.ca

1 Institute of Nutrition and Functional Foods (INAF), Laval University, Quebec City G1V 0A6, Canada

2 School of Nutrition, Laval University, Quebec City G1V 0A6, Canada

3 Department of Kinesiology, Laval University, Quebec City G1V 0A6, Canada

4 Department of Physical Education, Laval University, Quebec City G1V 0A6, Canada

HDL-C	High-density lipoprotein cholesterol
LDL-C	Low-density lipoprotein cholesterol
ApoB100	Apolipoprotein B-100
HOMA-IR	Homeostasis model assessment of insulin resistance
CRP	Plasma C-reactive protein
GLM	General linear model
DGAI	Dietary Guidelines Adherence Index

Introduction

Dairy food consumption is generally associated with better health. Most dietary guidelines, including Canadian guidelines, recommend the consumption of milk and dairy products as an important part of a healthy, well-balanced diet [1]. Observational studies have shown that dairy product consumption is inversely related to the incidence of cardiovascular diseases (CVD) and could improve features of the metabolic syndrome [2–4], which is a constellation of traditional and non-traditional CVD risk factors including dyslipidemia, insulin resistance, increased blood pressure, and abdominal obesity [5]. Moreover, dairy food intake could potentially have an effect on weight management, but results remained unclear [6–8].

Among dairy foods, yogurt is particularly interesting due to added active bacterial cultures, the high protein content including specific peptides and amino acids, and the presence of micronutrients such as calcium, magnesium, potassium, phosphorus, and vitamin D [9]. Given the healthy status attributed to yogurt, new findings in the literature emerged with a specific focus on yogurt consumption and health. Epidemiological studies have shown that yogurt consumption alone was associated with reduced body weight gain over time [10]. There is strong evidence that yogurt consumption may prevent CVD via several mechanisms including the associations with calcium and saturated fat intakes as well as the high content of milk-derived bioactive peptides [11].

Yogurt is a nutrient-dense food associated with healthy eating and is often categorized as one of the healthiest food choices alongside with fruits and vegetables [12]. Therefore, increasing yogurt intake may offer an interesting avenue for promoting good health among populations.

The aim of the present study was to examine whether yogurt consumption is part of a healthy dietary pattern and is associated with cardio-metabolic risk profile in individuals classified on the basis of their body mass index (BMI). We hypothesized that yogurt consumption is associated with a healthier dietary pattern and cardio-metabolic risk profile, independently of the BMI status.

Methods

Study population

The INFOGENE study database was used, and all the findings in the present paper are drawn from a secondary analysis of the data. Six hundred and sixty-four unrelated subjects from the Quebec City metropolitan area (Canada) were recruited between May 2004 and April 2006 through advertisements in local newspapers and radio stations, and by electronic messages sent to university and hospital employees. Subjects had to be aged between 18 and 55 years. BMI ranged from 16 to 49 kg/m^2 with a mean of 27.6 kg/m^2. All study participants completed a questionnaire on socio-demographic characteristics and a validated food frequency questionnaire (FFQ) administered by a registered dietitian [13]. Individuals who have consumed yogurt according to the validated FFQ data were classified as “consumers of yogurt,” and those reporting no consumption of yogurt were classified as “non-consumers of yogurt.” All participants signed an informed consent form to participate in this study, which has been approved by the Ethics Committee of Laval University.

Anthropometric measurements

Body weight, height, and waist circumference were measured according to the procedures recommended by the Airlie Conference [14]. Weight was measured to the nearest 0.1 kg, and height was measured to the nearest 0.5 cm. BMI was computed as weight in kilograms divided by height in meters squared (kg/m^2). The “normal weight” category was defined as having a BMI < 25 kg/m^2, while the “overweight or obese” category was defined as having a BMI ≥ 25 kg/m^2.

Assessment of dietary patterns

Dietary intake was assessed by a 91-item validated FFQ over 12 months [13] based on food habits of Quebecers, administered by a registered dietitian at the Laboratory of physical activity of Laval University (LABSAP) in Quebec City (Canada). Data obtained from FFQ were analyzed using the Nutrition Data System for Research software v2011, developed by the Nutrition Coordination Center (University of Minnesota, Minneapolis, MN). Yogurt consumption was divided into three categories on the basis of their fat content: fat-free yogurt (0 % M.F.); low-fat yogurt < 2 % M.F.); and high-fat yogurt (≥2 M.F.). All the information was compiled, and similar food items from the FFQ were grouped, thus forming thirty-eight food groups. Food groups were previously described by Paradis et al. [15], but yogurt was disseminated into two different categories (fat-free and low-fat yogurts were under the "reduced- or low-fat dairy products," and high-fat yogurts were under "regular dairy products"). In order to be able to see more realistic assumptions between yogurt consumption and metabolic health, all yogurt categories were grouped together, thus forming a brand new food group. To determine the number of factors to retain, components with an eigenvalue ≥1, scree test, and the interpretability of the factors were considered. Looking at the rotated solution (rotation method: varimax), food groups with absolute factor loadings ≥0.3 were considered as significant contributors to the pattern. Dietary pattern scores were determined using principal component analysis and calculated by summing food groups by their respective factor loading, thus giving the degree to which each subject conformed to the given dietary pattern.

Biochemical parameters

Blood samples were collected from an antecubital vein into vacutainer tubes containing EDTA after 12 h overnight fast and 48 h alcohol abstinence and were immediately centrifuged. Plasma was separated by centrifugation, and samples were aliquoted and frozen for subsequent analyses. Total cholesterol and fasting triglyceride concentrations were determined in plasma and lipoprotein fractions using OLYMPUS AU400e (Olympus America Inc., Melville, NY, USA). The high-density lipoprotein cholesterol (HDL-C) fraction was obtained after precipitation of very low-density lipoprotein and low-density lipoprotein particles in the infranatant (d > 1.006 g ml^{-1}) with heparin-manganese chloride [16]. Low-density lipoprotein cholesterol (LDL-C) was calculated with the Friedewald formula [17]. Apolipoprotein B-100 (ApoB100) concentrations were measured in plasma by the rocket immunoelectrophoretic method of Laurell, as previously described [18]. Fasting insulin was measured by radioimmunoassay with polyethylene glycol separation [19]. Fasting glucose concentrations were enzymatically measured [20]. Homeostasis model assessment of insulin resistance (HOMA-IR) was calculated using the following formula: (fasting glucose x fasting insulin)/22.5 [21]. Plasma C-reactive protein (CRP) was measured by nephelometry (Prospec equipment Behring) using a sensitive assay, as described previously [22].

Statistical analyses

Data were analyzed with SAS statistical software v9.2 (SAS Institute, Cary, NC, USA). Chi-square tests were performed to compare the tallies of categorical responses between independent groups and were used especially to describe the study sample. The other statistical tests used to compare within-group means included the general linear model (GLM) procedure with the type-III sum of squares (for unbalanced study design) and the least-squares means to identify which groups are different from each other when the effects of confounding factors such as age, sex, BMI, physical activity, dietary pattern scores, or energy intake are included in the model. Analyses were stratified on the basis of yogurt consumption (consumers vs. non-consumers) and BMI status (normal-weight individuals vs. overweight/obese individuals). Continuous variables were tested for normality of distribution, and $\log_{10}$-transformation of skewed variables was used in subsequent analyses. Statistical significance was defined as $P \leq 0.05$.

Results

Characteristics of study participants are presented in Table 1. The population was stratified into two groups based on their yogurt consumption (consumers of yogurt vs. non-consumers of yogurt) as shown in Fig. 1. Therefore, the cohort consisted of 564 consumers (211 normal-weight individuals and 353 overweight/obese individuals) and 100 non-consumers of yogurt (29 normal-weight individuals and 71 obese/overweight individuals). The mean consumption of yogurt was 0.47 ± 0.48 servings/day (82.3 g/day) among consumers (Table 1). There were significantly more women as part of the consumer group as shown in Table 1.

The average energy intake from yogurt is presented in Table 2. Consumers of yogurt had less than one serving/day of yogurt, resulting in a mean intake of 79.4 kcal from yogurt daily [3.4 ± 3.1 % of total energy intake (TEI)]. There were no significant differences in total energy or nutrient daily intakes between consumers and non-consumers of yogurt with the exception of carbohydrate intakes that were higher in consumers of yogurt (absolute difference of 8.6 g/day, P = 0.045). Yogurt consumption comprises over 0.47 ± 0.16, 2.24 ± 1.68, and 0.72 ± 0.65 % of TEI for lipids, carbohydrates, and proteins, respectively.

After principal component analysis on food groups, two factors were retained and further classified as the Prudent and Western dietary patterns. Table 3 reports food groups associated with both factors. Yogurt was part of the Prudent dietary pattern also characterized by higher intakes of vegetables, fruits, nuts, non-hydrogenated fats, yogurt, legumes as well as fish and other seafood, while the Western dietary pattern was rather characterized by higher intakes of fried foods, condiments, processed meats, refined grains, snacks, red meats, pizza, beer, high-fat dairy products (ice cream, cheese, whole milk, cream), regular soft drinks, mayonnaise, and hard liquor.

When the effects of age and sex are taken into account, significant differences were observed between consumers

Table 1 Subjects' characteristics of the INFOGENE study on the basis of their yogurt consumption

	Non-consumers of yogurt ($n = 100$) Mean ± SD	Consumers of yogurt ($n = 564$) Mean ± SD	P^a
Age (years)	37.6 ± 11.2	37.7 ± 11.3	0.93
Yogurt consumption			
Daily servings (175 g)	0	0.47 ± 0.48	
	n (%)		P^b
Sex			
Men	53 (8.0)	219 (33.0)	0.008
Women	47 (7.0)	345 (52.0)	
Education			
High school	17 (2.6)	65 (9.8)	0.31
College	30 (4.5)	186 (28.0)	
University	53 (8.1)	312 (47.0)	
Matrimonial status			
Single	46 (6.9)	219 (33.0)	0.16
Married/common law	42 (6.4)	297 (44.7)	
Divorced/separated/widowed	11 (1.7)	47 (7.3)	
Personal income			
<$12,000	30 (4.5)	136 (20.5)	0.89
$12,000 to < $20,000	12 (1.8)	65 (9.8)	
$20,000 to < $30,000	8 (1.2)	56 (8.4)	
$30,000 to < $40,000	18 (2.7)	111 (16.7)	
$40,000 to < $50,000	10 (1.5)	63 (9.5)	
$50,000 and up	22 (3.4)	126 (19.0)	

[a] ANOVA non-adjusted

[b] Chi square

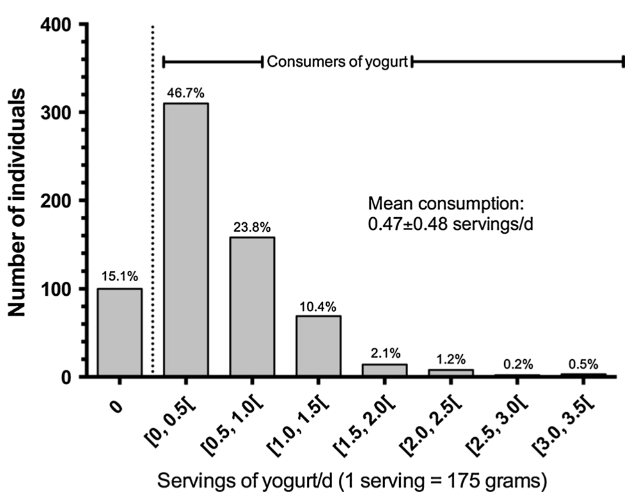

Fig. 1 Histogram of yogurt consumption in the INFOGENE study ($n = 664$)

and non-consumers of yogurt for all anthropometric indicators (Table 4) with the exception of the BMI. Anthropometric indicators were considerably lower for consumers than for non-consumers with an absolute between-groups difference of 6.5 kg of body weight (marginal adjusted means are presented in Supplementary Table 1). Prudent dietary pattern mean scores were significantly different between consumers and non-consumers of yogurt; consumers reported positive Prudent dietary pattern mean score, while non-consumers had negative scores (Table 4). Moreover, consumers had significantly lower levels of fasting plasma total cholesterol ($P = 0.03$), triglyceride ($P = 0.03$), insulin ($P = 0.005$) as well as lower HOMA-IR values ($P = 0.02$) than non-consumers (Table 4). After further adjustment for BMI and physical activity, only differences observed for the Prudent dietary scores, total cholesterol, and fasting insulin levels remained statistically significant (Model 2 and 3, Table 4, $P < 0.05$ for all). When adding the effects of the Prudent and Western dietary pattern scores to the previous statistical model, only a trend for total cholesterol was observed.

We further verified dietary pattern scores in an analysis of variance where subjects were classified on the basis of yogurt consumption (non-consumers vs. consumers) and then on the basis of BMI (BMI < 25 vs. BMI ≥ 25 kg/m^2).

Table 2 Total daily intakes and intakes from yogurt of subjects from the INFOGENE study on the basis of their yogurt consumption

	Non-consumers of yogurt (n = 100) Mean ± SD	Consumers of yogurt (n = 564) Mean ± SD	P^{a}
Total daily intake			
Energy (kcal[b])	2466 ± 806	2440 ± 700	0.36
Lipids (g)	96.1 ± 38.7	90.6 ± 32.9	0.56
Carbohydrates (g)	291.6 ± 95.4	300.2 ± 87.9	0.045
Proteins (g)	99.9 ± 36.1	101.7 ± 32.4	0.08
Cholesterol (mg)	342.9 ± 146.5	314.0 ± 135.5	0.28
SFA (g)	33.0 ± 13.4	30.7 ± 12.6	0.45
MUFA (g)	40.1 ± 16.9	37.5 ± 14.4	0.46
PUFA (g)	15.5 ± 7.2	15.3 ± 6.2	0.59
Intake from yogurt			
Energy (kcal)	–	79.4 ± 74.3	
% of TEI	–	3.37 ± 3.14	
Lipids (g)	–	1.3 ± 1.9	
% of TEI	–	0.47 ± 0.16	
Carbohydrates (g)	–	13.2 ± 12.3	
% of TEI	–	2.24 ± 1.68	
Proteins (g)	–	4.2 ± 3.8	
% of TEI	–	0.72 ± 0.65	
Cholesterol (mg)	–	4.9 ± 6.2	
SFA (g)	–	0.8 ± 1.2	
MUFA (g)	–	0.4 ± 0.5	
PUFA (g)	–	0.05 ± 0.07	

TEI total energy intake

[a] ANOVA adjusted for age, sex, and energy intake

[b] ANOVA adjusted for age and sex

No such differences were observed in regard to the Western dietary pattern mean score. Using the same statistical model, differences were also observed in plasma triglyceride and fasting insulin levels between overweight/obese consumers and overweight/obese non-consumers of yogurt (Table 5). Overweight/obese individuals who were consumers of yogurts exhibited a more favorable cardio-metabolic profile characterized by lower plasma triglyceride and insulin levels than non-consumers of yogurt within the same range of BMI. No difference in the cardio-metabolic profile of normal-weight individuals was observed between consumers and non-consumers of yogurt (Table 5).

In consumers of yogurt, there was no difference in total yogurt consumption (in daily servings or in % of TEI) between normal-weight individuals and overweight/obese individuals. However, as shown in Table 6, normal-weight subjects had more daily servings of high-fat yogurt (0.20 ± 0.41 vs. 0.13 ± 0.32, $P = 0.001$) and less daily servings of fat-free yogurt compared to overweight/obese individuals (0.20 ± 0.33 vs. 0.32 ± 0.46, $P = 0.002$). No significant differences were reported between normal-weight individuals and overweight/obese individuals in the low-fat yogurt subcategory.

Discussion

In this observational study using dietary intake data from a 91-item FFQ, yogurt consumption is an important contributor to the Prudent dietary pattern along with other healthy items such as fruits, vegetables, and nuts. Moreover, yogurt consumption among obese/overweight individuals is associated with a better cardio-metabolic profile characterized by decreased fasting triglyceride and insulin levels as well as a better anthropometric profile characterized by a lower weight, waist-to-hip ratio, and waist circumference. Consumers of yogurt have a positive Prudent dietary pattern mean score, while non-consumers have a negative mean score, thus reflecting differences in ways to eat among these two groups. Significant differences in yogurt choices based on their fat content are observed between normal-weight and overweight/obese individuals.

In the present study, yogurt consumers were more likely to be women. It is reported that there are gender differences in food choices that may be partly attributable to women's greater weight control involvement and partly to their stronger beliefs in healthy eating [23]. This phenomenon

Table 3 Rotated factor loading matrix for the Prudent and Western dietary patterns for the INFOGENE study ($n = 664$)

Food groups (servings/day)	Factor 1 (Western dietary pattern)	Factor 2 (Prudent dietary pattern)
French fries and fried foods	**0.66**	−0.19
Condiments	**0.64**	−0.05
Processed meats	**0.59**	0.03
Refined grains	**0.54**	−0.17
Snacks	**0.48**	−0.01
Red meats	**0.46**	−0.12
Pizza	**0.46**	−0.25
Vegetables	−0.16	**0.68**
Fruits	−0.17	**0.65**
Nuts	0.02	**0.53**
Non-hydrogenated fats	0.13	**0.47**
Legumes	−0.21	**0.38**
Fish and other seafood	−0.06	**0.37**
Wine	−0.01	0.08
Coffee	−0.19	0.07
Beer	**0.38**	−0.10
Sweets	0.11	−0.06
Desserts	0.18	−0.05
High-fat dairy products	**0.31**	0.20
Low-fat dairy products	0.20	−0.04
Yogurt	−0.17	**0.40**
Diet soft drinks	0.22	−0.07
Regular soft drinks	**0.32**	−0.21
Fruit juices	0.24	−0.20
Whole grains	−0.14	0.19
Vegetable juices	0.06	−0.04
Butter	0.16	−0.09
Eggs	0.13	0.10
Potatoes other than French fries	0.18	−0.16
Poultry	0.02	0.06
Organ meats	0.04	0.03
Tea	−0.21	0.28
Soups, broth, or bouillons	−0.005	0.10
Cream-based soups	0.07	0.02
Meat pies	0.10	−0.08
Hydrogenated margarine/shortening	−0.01	−0.05
Mayonnaise	**0.37**	0.12
Hard liquor	**0.31**	0.08

Factor loading ≥0.30 is marked in bold

could potentially explain the difference in the sex distribution observed in yogurt consumers.

According to a review by Jacques and Wang [24] on yogurt and weight management, little is known about the specific role that yogurt might play in weight maintenance and whether any beneficial effects of yogurt are unique to its specific properties or merely attributable to the fact that it is a dairy food. Yogurt is an excellent source of high-quality protein, which helps maintain satiety better than fat or carbohydrates [25, 26] and also a good source of calcium, which is known to help body weight control.

It has been reported in the literature that low-fat and fat-free yogurts play a key role in attaining the recommendations for the dairy food group and help to achieve a more nutrient-dense diet, thus directly impacting on anthropometric indicators and nutritional status [27]. However, in the present study, overweight/obese individuals consumed more fat-free yogurts than normal-weight individuals, who

Table 4 Differences in anthropometric indicators and cardio-metabolic risk factors between non-consumers and consumers of yogurt

	Non-consumers of yogurt ($n = 100$) Mean[c] ± SD	Consumers of yogurt ($n = 564$) Mean[c] ± SD	Model 1	Model 2	Model 3	Model 4
BMI (kg/m^2)	28.7 ± 5.9	27.4 ± 5.6	0.06	–	–	–
Weight (kg)	83.5 ± 20.2	77.0 ± 17.6	0.01	–	–	–
Waist-to-hip ratio	0.88 ± 0.13	0.84 ± 0.12	0.002	–	–	–
Waist circumference (cm)	95.2 ± 16.3	88.9 ± 15.4	0.001	–	–	–
Prudent dietary pattern score	−0.54 ± 0.96	0.10 ± 0.98	<0.0001	<0.0001	<0.0001	–
Western dietary pattern score	0.20 ± 1.18	−0.04 ± 0.96	0.14	0.25	0.23	–
Total cholesterol (mmol/L)	4.79 ± 1.00	4.57 ± 1.00	0.03	0.04	0.04	0.07
Triglycerides (mmol/L)[a]	1.41 ± 0.92	1.19 ± 0.77	0.03	0.13	0.14	0.33
LDL-cholesterol (mmol/L)	3.02 ± 0.90	2.86 ± 0.97	0.16	0.15	0.15	0.17
HDL-cholesterol (mmol/L)	1.32 ± 0.40	1.41 ± 1.35	0.33	0.85	0.88	0.75
Fasting glucose (mmol/L)[a]	5.76 ± 0.96	5.74 ± 1.10	0.96	0.96	0.98	0.94
Fasting insulin (ρmol/L)[a]	96.7 ± 83.3	75.3 ± 52.8	0.005	0.04	0.05	0.16
HOMA-IR[a,b]	25.0 ± 23.7	19.9 ± 17.2	0.02	0.10	0.13	0.30
C-reactive protein (mmol/L)[a]	2.17 ± 2.10	2.06 ± 2.21	0.64	0.87	0.89	0.92
Systolic blood pressure (mm Hg)	121.4 ± 10.4	118.9 ± 10.9	0.17	0.40	0.40	0.80
Diastolic blood pressure (mm Hg)	78.6 ± 8.60	77.4 ± 8.5	0.43	0.62	0.66	0.87

Model 1: *P* values derived from a general linear model adjusted for age and sex

Model 2: *P* values derived from a general linear model adjusted for age, sex, and BMI

Model 3: P values derived from a general linear model adjusted for age, sex, BMI, and physical activity

Model 4: P values derived from a general linear model adjusted for age, sex, BMI, physical activity and for the Prudent and Western dietary pattern scores

[a] Data were $\log_{10}$-transformed

[b] HOMA-IR = Fasting insulin (ρmol/ml) × Fasting glucose (mmol/L)/22.5

[c] Unadjusted means

consumed more high-fat yogurts. This may be part of their strategies to manage their body weight. Kratz et al. [28] did not support the hypothesis that dairy fat or high-fat dairy foods contribute to obesity or cardio-metabolic risk, and have suggested that high-fat dairy consumption within typical dietary patterns is inversely associated with obesity risk. However, for yogurt, the classification of "high fat" versus "low fat" is arbitrary, and the fat content remains low compared to other dairy products such as cheese or ice cream. A prospective population-based cohort study with two surveys 12 years apart has shown that a high intake of dairy fat was associated with a lower risk of central obesity, while a low dairy fat intake was associated with a higher risk of central obesity, defined as a waist-to-hip ratio ≥1 [29]. Moreover, in a Korean population with relatively low intake of dairy products, high consumption of dairy products, including yogurt, was associated with a lower prevalence of obesity and it is suggested that calcium content of dairy products may be one of the components contributing to the association [30]. Another study in Korean adults reported that higher consumption of milk or yogurt was significantly associated with a lower risk for the metabolic syndrome [31].

There are several proposed mechanisms by which yogurt could play a role in weight maintenance. Yogurt provides substantial amounts of macronutrients and micronutrients such as calcium that is one of the main underlying assumptions to help control body weight. Zemel et al. [32, 33] were the first to demonstrate that low calcium intake led to fat accumulation via an increase in blood levels of calciotropic hormones (parathyroid hormone and 1,25$(OH)_2D_3$) and intracellular calcium influx, thereby decreasing lipolysis and increasing lipogenesis. Another option worth exploring would be the high protein content of yogurt that promotes satiety. Indeed, yogurt contains a number of bioactive peptides derived from casein [34] in addition to branched-chain amino acids (leucine, isoleucine, and valine) that are involved, respectively, in the inhibition of the production of the angiotensin II [35] and in the stimulation of protein synthesis during weight-loss regimens [36].

Yogurt is often perceived as a healthy food choice. However, both expert opinion on healthy foods and the food consumption patterns of healthy eaters are influenced not only by nutritional characteristics of foods but also by individual, socioeconomic, and cultural considerations [37,

Table 5 Differences in cardio-metabolic risk factors between non-consumers and consumers of yogurt according to their BMI status

	Non-consumers of yogurt ($n = 100$)		Consumers of yogurt ($n = 564$)		Model 1	Model 2	Model 3
	Normal-weight individuals ($n = 29$)	Overweight/obese individuals ($n = 71$)	Normal-weight individuals ($n = 211$)	Overweight/obese individuals ($n = 353$)			
	Mean[3] ± SD	Mean[3] ± SD	Mean[3] ± SD	Mean[3] ± SD			
Prudent dietary pattern score	−0.51 ± 1.12[a]	−0.56 ± 0.89[a]	0.15 ± 0.97[b]	0.06 ± 0.98[b]	<0.0001	<0.0001	–
Western dietary pattern score	0.05 ± 1.19	0.27 ± 1.18	−0.09 ± 0.87	−0.01 ± 1.01	0.15	0.15	–
Total cholesterol (mmol/L)	4.19 ± 1.05[a]	5.02 ± 0.88[b]	4.28 ± 0.90[a]	4.75 ± 1.02[c]	<0.0001	<0.0001	<0.0001
Triglycerides (mmol/L)[1]	0.78 ± 0.43[a]	1.66 ± 0.95[b]	0.87 ± 0.46[a]	1.38 ± 0.85[c]	<0.0001	<0.0001	<0.0001
LDL-cholesterol (mmol/L)	2.60 ± 0.86[a]	3.19 ± 0.87[b]	2.68 ± 0.92[a]	2.96 ± 0.99[ab]	0.02	0.02	0.03
HDL-cholesterol (mmol/L)	1.55 ± 0.34[a]	1.23 ± 0.39[b]	1.59 ± 0.45[a]	1.30 ± 0.36[b]	<0.0001	<0.0001	<0.0001
Fasting glucose (mmol/L)[1]	5.96 ± 0.91[a]	5.68 ± 0.97[b]	5.82 ± 1.34[a]	5.69 ± 0.93[b]	0.02	0.02	0.01
Fasting insulin (ρmol/L)[1]	50.1 ± 14.3[a]	113.8 ± 91.4[b]	50.4 ± 17.7[a]	90.2 ± 60.6[c]	<0.0001	<0.0001	<0.0001
HOMA-IR[1,2]	13.5 ± 5.4[a]	29.2 ± 26.3[b]	13.4 ± 7.4[a]	23.7 ± 20.1[b]	<0.0001	<0.0001	<0.0001
C-reactive protein (mmol/L)[1]	1.42 ± 1.67[a]	2.55 ± 2.21[b]	1.37 ± 1.76[a]	2.53 ± 2.36[b]	<0.0001	<0.0001	<0.0001
Systolic blood pressure (mm Hg)	118.6 ± 7.7[ab]	122.5 ± 11.2[a]	115.1 ± 10.5[b]	121.3 ± 10.5[a]	<0.0001	<0.0001	<0.0001
Diastolic blood pressure (mm Hg)	77.2 ± 7.5[ab]	79.2 ± 9.0[ab]	75.3 ± 8.8[a]	78.7 ± 8.1[b]	0.02	0.06	0.10

Model 1: ANOVA adjusted for age and sex

Model 2: ANOVA adjusted for age, sex, and physical activity

Model 3: ANOVA adjusted for age, sex, physical activity and for the Prudent and Western dietary pattern scores

[1] Data were $\log_{10}$-transformed

[2] HOMA-IR = Fasting insulin (ρmol/ml) × Fasting glucose (mmol/L)/22.5

[3] Unadjusted means

BMI classification: normal weight: BMI < 25 kg/m^2 ; overweight or obese: BMI ≥ 25 kg/m^2

Between-groups comparisons were made using the LS means procedure in SAS statistical software. Results are significantly different from each other if they do not share the same letter

38]. Darmon et al. [12] identified class of foods based on their nutrient profiles, and yogurt was included in "Class 1" containing the healthiest food choices alongside with fruits and vegetables. Paradis et al. [15] have identified two dietary patterns using a 91-item FFQ, the Prudent and the Western dietary patterns, and have identified regular dairy products (including high-fat yogurt) as being part of the Prudent dietary pattern. The same research group has also shown that individuals having a high score of the Prudent pattern were less likely to be obese and in the opposite, those having a high score of Western pattern were more likely to be obese [15]. In the present study, yogurt (all types, independently of their fat content) was a contributor to the Prudent dietary pattern and consumers had a positive Prudent dietary pattern score, while the opposite was demonstrated in non-consumers.

Consumers of yogurt also exhibited a better anthropometric and cardio-metabolic risk profile than non-consumers as shown in Table 4, suggesting that yogurt consumption could help attaining a more favorable Prudent dietary pattern score and, therefore, could represent a positive step toward improving cardio-metabolic outcomes. However, after further adjustments for physical activity and for the Prudent and Western dietary pattern scores, the associations were attenuated suggesting that differences in overall diet quality may have a greater impact on cardio-metabolic risk factors than yogurt consumption per se. Accordingly, Wang et al. [39] have shown that, compared with non-consumers,

Table 6 Differences in yogurt consumption among consumers of yogurt according to their BMI status

	Consumers of yogurt ($n = 564$)		Model 1	Model 2	Model 3
	Normal-weight individuals ($n = 211$)	Overweight/obese individuals ($n = 353$)			
	Mean ± SD	Mean ± SD			
Total yogurt consumption (daily servings)	0.52 ± 0.45	0.58 ± 0.50	0.36	0.23	0.09
Total yogurt consumption (% of TEI)	3.4 ± 3.0	3.4 ± 3.2	0.87	0.73	0.33
Fat-free yogurt (daily servings)	0.20 ± 0.33[a]	0.32 ± 0.46[b]	0.002	0.002	0.002
Fat-free yogurt (% of TEI)	0.9 ± 1.5[a]	1.5 ± 2.2[b]	0.001	0.001	0.0006
Low-fat yogurt (daily servings)	0.12 ± 0.25	0.13 ± 0.32	0.45	0.41	0.49
Low-fat yogurt (% of TEI)	0.9 ± 1.9	0.9 ± 2.5	0.41	0.35	0.45
High-fat yogurt (daily servings)	0.20 ± 0.41[a]	0.13 ± 0.32[b]	0.001	0.002	0.004
High-fat yogurt (% of TEI)	1.5 ± 3.0[a]	0.9 ± 2.5[b]	0.0007	0.001	0.003

Model 1: ANOVA adjusted for age and sex

Model 2: ANOVA adjusted for age, sex, and physical activity

Model 3: ANOVA adjusted for age, sex, physical activity and for the Prudent and Western dietary pattern scores

BMI classification: normal weight: BMI < 25 kg/m^2 ; overweight or obese: BMI ≥ 25 kg/m^2

Results are significantly different from each other if they do not share the same letter

yogurt consumers had higher Dietary Guidelines Adherence Index (DGAI), evaluating the overall quality of the diet based on the results coming from a 126-item FFQ. Thus, yogurt might help developing a better metabolic well-being as part of a healthy dietary pattern [39]. Significant differences in total cholesterol, triglyceride, and fasting insulin levels as well as for HOMA-IR were observed between consumers and non-consumers of yogurt. However, after further adjustment for the effects of the BMI, only associations with total cholesterol and fasting insulin levels remained significant reflecting the well-documented impact of BMI on the cardio-metabolic risk factors measured [40, 41]. Therefore, individuals were further stratified according to their BMI (normal-weight individuals vs. overweight/obese individuals), and significant differences were observed for plasma triglyceride and insulin levels between consumers and non-consumers of yogurt that were overweight or obese. There was no difference in cardio-metabolic risk factors in normal-weight individuals irrespective of their yogurt consumption status. Thus, yogurt consumption among individuals with a BMI ≥ 25 kg/m^2 appears to have a beneficial effect on cardio-metabolic risk factors as evidenced by lower plasma triglyceride and insulin levels. This is concordant with the observed difference in the Prudent score between consumers and non-consumers that lead to more healthy and less unhealthy food consumption, as part of an overall healthier diet. A systematic review by Sherzai et al. [42] underlined the importance of using dietary patterns and concluded that it is difficult to pinpoint specific nutrients such as fat, calcium, or vitamin D as CVD risk factors due to synergistic interaction of nutrients. However, significant associations between dietary patterns and CVD risk factors were observed. Indeed, Fung et al. [43] reported that the Prudent dietary pattern was associated with a reduced risk of total and ischemic strokes, while the Western pattern was associated with an increased risk. The same research group has demonstrated that the Prudent and Western dietary patterns were predictors of both plasma biomarkers of CVD and obesity risk, suggesting that the effect of the overall diet on CVD risk may be mediated through these biomarkers [44].

Associations between yogurt consumption and cardio-metabolic risk factors have been previously reported in the literature. Indeed, Pereira et al. [2] reported an inverse relationship between dairy product consumption and insulin resistance in a prospective study of 3157 young adults with a 10-year follow-up. Accordingly, Wang et al. [39] showed that yogurt consumption was associated with lower levels of circulating triglycerides and glucose in addition to a lower systolic blood pressure and insulin resistance ($P < 0.05$, for all). The mechanisms by which yogurt consumption is associated with improved cardio-metabolic health outcomes are not clearly identified, but could be attributable to milk-derived bioactive peptides that may exert antihypertensive effect and are involved in the regulation of insulinemia, modulation of the blood lipid profile, and the stimulation of the satiety response [45]. A study aimed at examining gene expression in relation with the Prudent and Western dietary patterns have found that gene expression profiles were different with regard to dietary patterns, which could modulate the risk of chronic diseases and CVD among others [46].

Strengths and limitations

Only a limited number of studies have focussed on the impact of yogurt on health. Most of the data supporting the idea that high intake of dairy fat was inversely associated with obesity came from epidemiological or prospective study and are often fulfilled by summing the fat content of dairy food products such as whole milk, cheese, cream, ice cream, and yogurt. These approaches have both strengths and limitations. However, the present study has unique strengths, notably the use of a validated FFQ and subgroups categorizing yogurts according to their fat content (fat-free, low-fat, and high-fat). Yogurt alone was one of the food groups included in the principal component analysis to obtain dietary patterns. However, results from the present study need further replication and must also be confirmed in a randomized controlled trial in order to verify the causal relationship between yogurt consumption, anthropometric indicators, and the cardio-metabolic risk profile.

Conclusion

In light of these results, yogurt consumption seems to be associated with a healthier dietary pattern as being a significant contributor to the Prudent dietary pattern and may potentially be associated with beneficial effects on cardiometabolic risk factors on overweight/obese individuals. Moreover, yogurt consumption was associated with a significantly lower weight, waist-to-hip ratio, and waist circumference. Normal-weight individuals consumed significantly more high-fat yogurts, while overweight/obese individuals consumed more fat-free yogurts. Yogurt consumption should therefore be encouraged irrespective to their fat content with the goal of ensuring a better, more nutrient-dense nutrition and may be one way to achieve dietary recommendations for dairy products. These data are highly relevant from a clinical nutrition perspective and could be used as a lever to adopt nutritional recommendations for yogurt.

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