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Is higher dairy consumption associated with lower body weight and fewer metabolic disturbances? The Hoorn Study[1–3]

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ABSTRACT

Background: Dairy consumption has been postulated to reduce the risk of obesity and metabolic disturbances.

Objective: The aim of this study was to evaluate the associations of dairy consumption with body weight and other components of the metabolic syndrome.

Design: We used cross-sectional data for 2064 men and women aged 50–75 y who participated in the Hoorn Study. The metabolic syndrome was defined according to the National Cholesterol Education Program Expert Panel. Dairy consumption was assessed by using a semiquantitative food-frequency questionnaire.

Results: The median consumption of total dairy products was 4.1 servings/d. After adjustment for potential confounders (ie, dietary factors, physical activity, smoking, income, educational level, and antihypertensive medication), total dairy consumption was significantly associated with lower diastolic blood pressure ($\beta \pm$ SE: -0.31 ± 0.12 mm Hg/serving) and higher fasting glucose concentrations (0.04 ± 0.02 mmol/L per serving), but not with body weight or other metabolic variables (ie, lipids, postload glucose, or insulin). When different dairy products were distinguished, borderline significant ($P < 0.10$) inverse associations were observed for dairy desserts, milk, and yogurt with systolic (-1.26 ± 0.58, -0.57 ± 0.34, and -1.28 ± 0.74 mm Hg/serving, respectively) and diastolic (-0.58 ± 0.31, -0.57 ± 0.18, and -0.35 ± 0.40 mm Hg/serving, respectively) blood pressure, whereas cheese consumption was positively associated with body mass index (0.15 ± 0.08/serving).

Conclusion: In an elderly Dutch population, higher dairy consumption was not associated with lower weight or more favorable levels of components of the metabolic syndrome, except for a modest association with lower blood pressure. *Am J Clin Nutr* 2007;85:989–95.

KEY WORDS Dairy consumption, body weight, metabolic syndrome, cross-sectional study, elderly

INTRODUCTION

The prevalence of overweight and obesity has increased enormously, and it is strongly associated with cardiovascular disease risk factors such as hyperglycemia, high blood pressure, and dyslipidemia (1). The clustering of these risk factors is often referred to as the metabolic syndrome and is associated with elevated risk of cardiovascular morbidity and mortality (2).

Dairy consumption has been postulated to reduce the risk of obesity and metabolic disturbances. Inverse relations between dairy consumption and body weight (3–7) and between dairy consumption and the risk of type 2 diabetes, the metabolic syndrome, and blood pressure (8–12) have been shown in observational studies. These associations are usually attributed to a higher calcium intake, which has also been reported to be associated with lower body weight and less weight gain (13, 14) and lower blood pressure (15, 16). However, given the high correlation between calcium and dairy consumption, the observed associations for calcium may also have reflected effects of other dairy components.

Various components of dairy products have been suggested as explanations for dairy products' possible beneficial effects. First, an increased intake of calcium could reduce 1,25-dihydroxyvitamin D [1,25-(OH_2)D] and thus intracellular calcium, which in turn may stimulate lipolysis and inhibite lipogenesis in adipocytes (15) and increase insulin sensitivity in adipocytes and muscle cells (17). In addition, decreased intracellular calcium concentrations may reduce blood pressure by lowering vascular smooth muscle tone and peripheral vascular resistance (15). Other suggested mechanisms include insulinotropic effects of whey proteins (18) and beneficial effects of magnesium on insulin sensitivity (19). Specific types of dairy products could have different effects on metabolic traits (8, 10) because of such factors as differences in absorbability that result from variations in the amount of lactose (20).

Although a beneficial effect of dairy consumption has repeatedly been reported, other important observational studies have not supported these favorable effects of dairy consumption (21–

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23). In addition, small intervention studies with dairy supplementation showed inconsistent results (24–28), and secondary review of randomized dairy supplementation trials, although they were not specifically designed to investigate the effect on body weight, did not find that they showed any effect on body weight (29). Such inconsistency of results may have been caused by the heterogeneity of the various study populations and differences in the methods used.

Many of the previous studies on dairy consumption were performed mainly in women (4, 21, 25, 26, 28), in men only (8, 23), or in children or young adults (3, 5–7, 10, 11, 21, 22, 28). In the present study, we investigated the association between dairy consumption and components of the metabolic syndrome using cross-sectional data from the population-based Hoorn Study cohort, which comprised elderly men and women who were extensively examined with respect to their dietary intake and metabolic risk factors.

SUBJECTS AND METHODS

Study population

The Hoorn Study is a population-based cohort study of glucose tolerance in 2484 white men and women aged 50–75 y, begun in 1989, that has been described in detail elsewhere (30). Subjects who had missing data for dietary intake ($n = 78$), body mass index (BMI; ($n = 7$), waist circumference ($n = 12$), systolic or diastolic blood pressure ($n = 2$), HDL cholesterol ($n = 6$), LDL cholesterol ($n = 11$), triacylglycerol ($n = 5$), fasting glucose ($n = 4$), physical activity ($n = 295$), smoking status ($n = 21$), income level ($n = 152$), or educational level ($n = 147$) were excluded from all analyses. Therefore, the analyses were performed in 1896 subjects (852 men and 1044 women).

Written informed consent was obtained from all participants. Ethical approval for the study was obtained from the Ethical Review Committee of the Vrije University Medical Center.

Measurements

Weight and height were measured while subjects were wearing light clothing and no shoes. BMI was calculated as weight (in kg) divided by height (in m^2). Waist circumference was measured at the level midway between the lowest rib margin and the iliac crest. Blood pressure (mm Hg) was measured in the right arm by using a random-zero sphygmomanometer (Hawksley-Gelma Ltd, Lancing, United Kingdom) while subjects were sitting. Systolic and diastolic blood pressures were calculated as the mean of duplicate measurements.

Fasting glucose concentration and 2-h postload glucose concentration after a 75-g oral-glucose-tolerance test (OGTT) were measured in venous plasma (mmol/L) by using the glucose dehydrogenase method (Merck, Darmstadt, Germany). In subjects already known to have diabetes, only a fasting blood sample was taken. Fasting specific insulin concentration was quantified with an insulin-specific double-antibody radioimmunoassay (antibody SP21; Linco, St Louis, MO). Serum lipids and lipoproteins were measured by using enzymatic techniques (Boehringer-Mannheim, Mannheim, Germany) as described previously (31). All blood samples were analyzed at the hematologic clinical chemistry laboratory of the Vrije University Medical Center.

The definition of the National Cholesterol Education Program (NCEP) Expert Panel was used for the presence of the metabolic syndrome and of the 5 individual components of the metabolic syndrome (32). The metabolic syndrome was defined as the presence of ≥3 of the following 5 components: elevated fasting glucose (≥6.1 mmol/L), elevated triacylglycerol (≥1.7 mmol/L), low HDL cholesterol (<1.0 mmol/L in men or < 1.3 mmol/L in women), high blood pressure (≥130/85 mm Hg), and abdominal obesity (waist ≥ 102 cm in men or ≥ 88 cm in women).

Information on lifestyle factors was obtained by a self-administered questionnaire, checked by a personal interview. Smoking status was categorized as current smoker or nonsmoker. Physical activity was expressed in the number of hours of physical activity performed per day. The activities included sports, bicycling, gardening, walking, doing odd jobs, and housekeeping. Four categories of alcohol intake were used: nondrinker, ≤10 g/d, 10–30 g/d, and ≥30 g/d. Level of income was categorized as low, medium, or high. Tertiles of educational level (low, Medium, and high) were created separately for men and women.

Assessment of dairy consumption

A 92-item semiquantitative food-frequency questionnaire was used to assess average food intakes, which included the consumption of dairy products. Participants were asked about the usual frequency of their consumption of dairy products and about their average daily consumption. Answer-options were presented in average household portions. The use of separate questions for winter and summer intakes of milk took seasonal variations in consumption into account. The participants completed the questionnaire at home, and answers were checked for completeness at the research center. Nutrient intake, including calcium and fiber intake, was calculated by using a computerized version of the Dutch Food Composition Table (33).

For all liquid and solid dairy products, one serving was defined as 150 and 20 g, respectively. Total dairy consumption was categorized as low-fat dairy (≤2% fat) or high-fat dairy (>2% fat). Dairy desserts included yogurt, curds, and custard. The variable milk included low-fat, skim, and whole milk. The variable yogurt included all low-fat, skim, and whole yogurts.

Statistical analysis

All statistical analyses were performed by using SPSS for WINDOWS software (version 12.0l; SPSS Inc, Chicago, IL). Baseline characteristics were reported according to quartiles of total dairy consumption. We used a linear regression model to examine linear trends in baseline characteristics across the quartiles of total dairy consumption, modeling the categorical variable of dairy consumption as a continuous independent variable and the specific characteristic as the dependent outcome variable. A chi-square test was performed to test for trend for categorical variables.

To examine independent associations between total dairy consumption (and also high-fat or low-fat dairy consumption and specific dairy product groups) as independent variable and continuous metabolic variables as dependent variables, multiple linear regression analyses were performed, and β and their SEs were reported. To rule out possible bias due to prescribed diets, the analyses for high-fat dairy and low-fat dairy were also performed after the exclusion of subjects with known diabetes mellitus or cardiovascular disease or of subjects who used antihypertensive or lipid-lowering medication. For determination of potential different effects of individual dairy products, additional regression

TABLE 1
Baseline characteristics according to quartile (Q) of dairy intake (servings/d)[1]

	Q1 (n = 474)	Q2 (n = 474)	Q3 (n = 474)	Q4 (n = 474)	P for trend[2]
Dairy intake (servings/d)	0.00–2.90	2.91–4.13	4.14–5.56	5.57–17.24	
Age (y)	62.6 ± 7.1[3]	61.5 ± 7.0	61.7 ± 7.5	61.0 ± 7.4	< 0.01
Men (%)	43.7	42.6	45.6	47.9	0.38
Total energy intake (kcal)	1796 ± 535	1975 ± 524	2100 ± 510	2388 ± 632	< 0.01
Fiber intake (g/d)	24.6 ± 7.9	26.1 ± 6.5	27.5 ± 7.4	30.6 ± 8.5	< 0.01
Saturated fat intake (% of energy)	16.7 ± 3.4	17.0 ± 3.3	17.4 ± 3.1	17.4 ± 3.6	< 0.01
Polyunsaturated fat intake (% of energy)	8.3 ± 3.5	8.0 ± 3.1	7.7 ± 3.1	7.2 ± 2.9	< 0.01
Protein intake (% of energy)	13.9 ± 2.7	14.6 ± 2.7	14.8 ± 2.4	15.9 ± 2.9	< 0.01
Carbohydrate intake (% of energy)	19.1 ± 6.3	20.3 ± 5.8	20.4 ± 5.3	21.8 ± 5.5	< 0.01
Calcium intake (mg/d)	646 ± 164	927 ± 124	1150 ± 123	1630 ± 330	< 0.01
Alcohol consumption (%)					
No alcohol	31.9	29.5	32.1	30.2	0.43
<10 g/d	35.7	39.5	39.5	41.8	
10–30 g/d	23.0	22.4	21.1	22.6	
>30 g/d	9.5	8.6	7.4	5.5	
Sports (%)	21.7	29.5	28.1	32.5	< 0.01
Physical activity (h/d)	4.2 ± 2.6	4.6 ± 2.8	4.2 ± 2.4	4.4 ± 2.8	0.63
Cigarette smoking (%)	38.0	31.2	30.0	25.5	< 0.01
Income (%)					
Low	18.4	18.1	18.1	17.3	0.20
Medium	60.5	54.0	54.6	54.6	
High	21.1	27.8	27.2	28.1	
Educational level (%)					
Low	36.3	34.6	31.0	28.7	0.16
Medium	36.3	37.8	37.8	38.0	
High	27.4	27.6	31.2	33.3	
BMI (kg/m^2)	26.5 ± 3.5	26.7 ± 3.8	26.6 ± 3.4	26.6 ± 3.5	0.98
Waist circumference (cm)	91.0 ± 10.8	91.0 ± 11.4	90.8 ± 10.2	90.8 ± 10.7	0.76
Systolic blood pressure (mm Hg)	138.0 ± 21.2	135.0 ± 20.6	136.2 ± 20.4	133.9 ± 18.7	0.01
Diastolic blood pressure (mm Hg)	82.8 ± 10.2	82.2 ± 10.8	81.9 ± 10.2	81.4 ± 10.1	0.03
LDL cholesterol	4.67 ± 1.16	4.65 ± 1.07	4.62 ± 1.06	4.57 ± 1.08	0.18
HDL cholesterol	1.28 (1.07–1.56)[4]	1.30 (1.07–1.56)	1.26 (1.07–1.50)	1.28 (1.08–1.54)	0.85
HDL:total cholesterol	0.20 ± 0.07	0.20 ± 0.06	0.20 ± 0.06	0.21 ± 0.06	0.52
Triacylglycerol	1.40 (1.10–2.00)	1.40 (1.10–2.00)	1.40 (1.00–2.00)	1.30 (1.00–1.80)	0.02
Fasting glucose	5.73 ± 1.59	5.80 ± 1.57	5.68 ± 1.26	5.78 ± 1.48	0.90
2-h Glucose (mmol/L)	5.98 ± 2.83	6.28 ± 3.28	6.14 ± 2.99	5.92 ± 2.69	0.63
Antihypertensive medication use (%)	21.5	19.2	20.9	19.0	0.71
Lipid-lowering medication (%)	1.5	1.5	2.3	0.4	0.11
Diabetes (%)	8.6	10.3	9.1	12.1	0.28
CVD (%)	19.6	17.7	20.0	17.3	0.63
Metabolic syndrome (%)[5]	33.1	30.6	28.9	28.9	0.45

[1] CVD, cardiovascular disease.
[2] A chi-square test was performed for alcohol consumption, income, and educational level.
[3] $\bar{x}$ ± SD (all such values).
[4] Median; interquartile range in parentheses (all such values).
[5] Presence of the metabolic syndrome was estimated according to the definition of the National Cholesterol Education Program (32).

analyses were performed separately for the consumption of dairy desserts, milk, yogurt, and cheese.

Logistic regression analyses were performed to investigate the association between dairy consumption (independent variable) and presence of the metabolic syndrome and the individual dichotomous variables of the metabolic syndrome (dependent variables). These associations were expressed as odds ratios (ORs) and 95% CIs for a serving of dairy foods.

In case of a skewed distribution, variables were logarithmically transformed before further analyses were performed. All models were adjusted for age and sex. In multivariate models, we further adjusted for possible confounders—total energy intake (EI), alcohol intake, fiber intake, use of antihypertensive medication, smoking status, physical activity, income, and educational level. All P values were 2-sided, and $P < 0.05$ was considered significant.

RESULTS

The median consumption of total dairy products in this population was 4.1 servings/d (interquartile range: 2.9–5.6). The median daily consumption of milk, yogurt, cheese, and dairy desserts was 0.7, 0.5, 1.2, and 0.9 servings, respectively. Baseline characteristics of the population across quartiles of daily servings

TABLE 2
Associations of consumption of total dairy, high-fat dairy, and low-fat dairy (servings/d) with weight and metabolic variables[1]

	Total dairy		High-fat dairy		Low-fat dairy	
	$\beta \pm$ SE	P	$\beta \pm$ SE	P	$\beta \pm$ SE	P
Basic models[2]						
BMI (kg/m^2)	0.03 ± 0.04[3]	0.42	−0.14 ± 0.05	0.01	0.15 ± 0.05	< 0.01
Waist circumference (cm)	0.03 ± 0.10	0.80	−0.38 ± 0.15	0.01	0.34 ± 0.13	0.01
Systolic blood pressure (mm Hg)	−0.34 ± 0.20	0.09	−0.72 ± 0.28	0.01	0.03 ± 0.25	0.89
Diastolic blood pressure (mm Hg)	−0.22 ± 0.11	0.04	−0.32 ± 0.15	0.04	−0.08 ± 0.13	0.53
LDL cholesterol (mmol/L)	−0.01 ± 0.01	0.27	−0.00 ± 0.02	0.94	−0.02 ± 0.01	0.21
HDL cholesterol, ln (mmol/L)	−0.00 ± 0.00	0.77	0.01 ± 0.00	0.07	−0.01 ± 0.00	0.06
Triacylglycerol, ln (mmol/L)	−0.01 ± 0.01	0.09	−0.02 ± 0.01	< 0.01	0.00 ± 0.01	0.58
Fasting glucose (mmol/L)	0.02 ± 0.02	0.18	−0.02 ± 0.02	0.37	0.05 ± 0.02	0.01
2-h Glucose (mmol/L)	0.01 ± 0.03	0.86	−0.01 ± 0.04	0.77	0.02 ± 0.04	0.66
Fasting insulin (mmol/L)	0.14 ± 0.55	0.81	−1.23 ± 0.77	0.11	1.21 ± 0.69	0.08
Adjusted models[4]						
BMI (kg/m^2)	0.06 ± 0.04	0.17	−0.11 ± 0.06	0.06	0.15 ± 0.05	< 0.01
Waist circumference (cm)	0.07 ± 0.11	0.51	−0.39 ± 0.16	0.02	0.36 ± 0.13	0.01
Systolic blood pressure (mm Hg)	−0.23 ± 0.22	0.29	−0.37 ± 0.31	0.23	−0.06 ± 0.25	0.83
Diastolic blood pressure (mm Hg)	−0.31 ± 0.12	0.01	−0.28 ± 0.17	0.09	−0.22 ± 0.14	0.11
LDL cholesterol (mmol/L)	−0.02 ± 0.01	0.17	−0.02 ± 0.02	0.42	−0.01 ± 0.02	0.39
HDL cholesterol, ln (mmol/L)	0.00 ± 0.00	0.94	0.01 ± 0.00	0.05	−0.01 ± 0.00	0.10
Triacylglycerol, ln (mmol/L)	−0.00 ± 0.01	0.69	−0.02 ± 0.01	0.02	0.01 ± 0.01	0.13
Fasting glucose (mmol/L)	0.04 ± 0.02	0.01	0.01 ± 0.02	0.76	0.05 ± 0.02	0.01
2-h Glucose (mmol/L)	0.05 ± 0.04	0.14	0.05 ± 0.05	0.31	0.03 ± 0.04	0.42
Fasting insulin (mmol/L)	−0.22 ± 0.61	0.71	−1.81 ± 0.85	0.03	0.96 ± 0.70	0.17

[1] All values are per serving/d.
[2] Adjusted for age and sex.
[3] $\bar{x} \pm$ SD (all such values).
[4] The basic models were further adjusted for total energy intake, fiber intake, level of physical activity, alcohol intake, smoking status, income, educational level, and antihypertensive medication use.

of total dairy consumption are shown in **Table 1**. Subjects with a higher consumption of dairy products were more likely to have higher total EI, higher fiber intake, higher saturated fat intake, lower polyunsaturated fat intake, higher protein and carbohydrate intake, higher calcium intake, and higher sports activity and were less likely to smoke ($P < 0.05$). Among the metabolic variables, there was a significant trend of lower blood pressure levels and lower triacylglycerol concentration with higher dairy consumption.

After adjustment for age and sex, total dairy consumption was borderline significantly inversely associated with systolic and diastolic blood pressure and with triacylglycerol concentrations but not with BMI or the other components of the metabolic syndrome (**Table 2**, basic models). After adjustment for potential confounders (adjusted models), the association between dairy consumption and lower diastolic blood pressure remained, whereas the association between dairy consumption and higher fasting glucose became significant. Instead of adjustment for total EI in the regression models, we performed analyses using dairy consumption expressed as servings/1000 kcal of EI. These analyses showed similar results, except that a statistically significant positive association of dairy consumption with BMI was also found.

Stratification by the presence of hypertension showed no difference in the associations between subjects with ($n = 1236$) or without ($n = 660$) hypertension, except for the associations with systolic blood pressure (P for interaction = 0.023). The association of dairy consumption with systolic blood pressure was stronger in subjects with hypertension ($\beta \pm$ SE: −0.29 ± 0.23; $P = 0.20$) than in those without hypertension ($\beta \pm$ SE: 0.04 ± 0.17; $P = 0.80$). The association of dairy consumption with diastolic blood pressure was also stronger in hypertensive subjects (−0.34 ± 0.13; $P = 0.01$) than in with subjects without hypertension (−0.19 ± 0.12; $P = 0.12$), but the difference was not significant (P for interaction = 0.445). We tested the dairy consumption × obesity (BMI > 30) interaction for systolic and for diastolic blood pressure, but the interactions were not significant ($P = 0.159$ and 0.339, respectively). Nor were the associations consistently stronger in either of the 2 sexes (P = NS for all). To investigate a possible threshold effect, we selected only subjects with calcium concentrations of < 700 mg/d ($n = 286$) or < 600 mg/d ($n = 176$). In these groups, median dairy consumption (with interquartile range) was 1.75 (1.17–2.20) servings/d and 1.35 (0.77–1.83) servings/d, respectively. No statistically significant associations were found between total dairy consumption and weight or metabolic variables in either low-calcium group, except for a positive association with waist circumference ($\beta \pm$ SE: 1.59 ± 0.75; $P = 0.04$) in the < 700 mg calcium/d group.

When high-fat and low-fat dairy products were distinguished, consumption of high-fat dairy was significantly inversely associated with BMI, waist circumference, triacylglycerol, and insulin and significantly positively associated with HDL-cholesterol concentrations after adjustment for confounders (Table 2, adjusted models). After additional adjustment for BMI, these associations were no longer significant, except for ln-triacylglycerides ($\beta \pm$ SE: −0.01 ± 0.01; $P = 0.05$). In contrast, low-fat dairy was significantly positively associated with BMI,

TABLE 3
Associations of consumption of dairy desserts, milk, yogurt, and cheese (servings/d) with weight and metabolic variables[1]

	Dairy desserts		Milk		Yogurt		Cheese	
	β ± SE	*P*	β ± SE	*P*	β ± SE	*P*	β ± SE	*P*
Basic models[2]								
BMI (kg/m^2)	−0.17 ± 0.11[3]	0.12	−0.03 ± 0.06	0.62	0.05 ± 0.14	0.71	0.12 ± 0.08	0.12
Waist circumference (cm)	−0.66 ± 0.30	0.03	−0.02 ± 0.17	0.93	−0.31 ± 0.39	0.42	0.08 ± 0.21	0.69
Systolic BP (mm Hg)	−1.76 ± 0.57	< 0.01	−0.74 ± 0.33	0.03	−1.52 ± 0.74	0.04	0.20 ± 0.40	0.61
Diastolic BP (mm Hg)	−0.66 ± 0.31	0.03	−0.55 ± 0.18	< 0.01	−0.28 ± 0.40	0.48	0.09 ± 0.22	0.68
LDL cholesterol (nmol/L)	−0.03 ± 0.03	0.30	0.01 ± 0.02	0.56	−0.08 ± 0.04	0.05	−0.02 ± 0.02	0.36
HDL cholesterol, ln (nmol/L)	−0.02 ± 0.01	0.02	0.00 ± 0.00	0.42	−0.01 ± 0.01	0.16	0.01 ± 0.01	0.23
Triacylglycerol, ln (nmol/L)	−0.03 ± 0.01	0.03	0.00 ± 0.01	0.69	−0.03 ± 0.02	0.10	−0.02 ± 0.01	0.07
Fasting glucose (nmol/L)	−0.09 ± 0.04	0.05	0.05 ± 0.03	0.03	−0.01 ± 0.06	0.89	0.00 ± 0.03	0.91
2-h Glucose (nmol/L)	−0.11 ± 0.09	0.23	0.05 ± 0.05	0.37	−0.01 ± 0.12	0.92	−0.01 ± 0.06	0.88
Fasting insulin (nmol/L)	−1.99 ± 1.59	0.21	0.84 ± 0.91	0.36	−1.88 ± 2.04	0.36	−1.52 ± 1.11	0.17
Adjusted models[4]								
BMI (kg/m^2)	−0.10 ± 0.11	0.34	−0.02 ± 0.06	0.73	0.10 ± 0.14	0.48	0.15 ± 0.08	0.04
Waist circumference (cm)	−0.44 ± 0.30	0.14	−0.03 ± 0.17	0.88	−0.05 ± 0.38	0.90	0.14 ± 0.21	0.50
Systolic BP (mm Hg)	−1.26 ± 0.58	0.03	−0.57 ± 0.34	0.09	−1.28 ± 0.74	0.08	0.37 ± 0.42	0.37
Diastolic BP (mm Hg)	−0.58 ± 0.31	0.06	−0.57 ± 0.18	< 0.01	−0.35 ± 0.40	0.37	0.00 ± 0.22	0.99
LDL cholesterol (nmol/L)	−0.03 ± 0.03	0.32	0.00 ± 0.02	0.92	−0.06 ± 0.04	0.18	−0.02 ± 0.02	0.53
HDL cholesterol, ln (nmol/L)	−0.02 ± 0.01	0.04	0.01 ± 0.00	0.09	−0.02 ± 0.01	0.07	0.00 ± 0.01	0.91
Triacylglycerol, ln (nmol/L)	−0.01 ± 0.01	0.38	0.01 ± 0.01	0.51	−0.00 ± 0.02	0.82	−0.01 ± 0.01	0.54
Fasting glucose (nmol/L)	−0.06 ± 0.05	0.22	0.07 ± 0.03	0.01	0.02 ± 0.06	0.69	0.03 ± 0.03	0.41
2-h Glucose (nmol/L)	−0.02 ± 0.09	0.87	0.07 ± 0.05	0.17	0.07 ± 0.12	0.58	0.03 ± 0.06	0.60
Fasting insulin (mmol/L)	−1.79 ± 1.63	0.27	0.35 ± 0.93	0.71	−1.59 ± 2.05	0.44	−2.15 ± 1.15	0.06

[1] BP, blood pressure. All values are per serving/d.
[2] Adjusted for age and sex.
[3] $\bar{x}$ ± SD (all such values).
[4] The basic models were further adjusted for total energy intake, fiber intake, level of physical activity, alcohol intake, smoking status, income, educational level, and antihypertensive medication use.

waist circumference, and fasting glucose concentrations. To exclude possible bias due to prescribed diets, these analyses were repeated after exclusion of subjects with known diabetes mellitus or cardiovascular disease and subjects who used antihypertensive or lipid-lowering medication. These exclusions, however, did not materially change the results (data not shown).

When the relation between 4 main groups of dairy products and metabolic variables were examined, higher intakes of most dairy products (ie, dairy desserts, milk, and yogurt) were associated with lower systolic and diastolic blood pressures (**Table 3**, basic models); these associations were not explained by potential confounders (Table 3, adjusted models). Higher cheese consumption was associated with a higher BMI.

Total dairy consumption was not significantly associated with the presence of the metabolic syndrome, after adjustment for potential confounders. The ORs (95% CI) for the risk of having the MS in the second, third, and fourth (highest) quartile compared with the lowest (first) quartile of total dairy consumption were 0.99 (0.74, 1.32), 0.90 (0.67, 1.21), and 1.01 (0.74, 1.39), respectively. When the 5 individual components of the metabolic syndrome were dichotomized, only the association between total dairy consumption and fasting glucose ≥6.1 mmol/L became significant when the highest (4th) quartile of total dairy consumption was compared with the lowest (1st) [ORs (95% CI) of the second, third, and fourth quartiles were 1.16 (0.83, 1.62), 1.10 (0.78, 1.56), and 1.52 (1.06, 2.18), respectively; *P* for trend = 0.040]. No consistent trends were seen in the relations between total dairy consumption and the other dichotomous variables (data not shown).

DISCUSSION

The results of the present study showed a modest inverse association of the consumption of several dairy products with blood pressure levels but not with BMI or with other metabolic variables. Cheese consumption was positively associated with BMI. High-fat dairy showed inverse associations between BMI and waist circumference, and low-fat dairy was positively associated with BMI and waist circumference. No substantial association was observed between dairy consumption and the presence of the metabolic syndrome.

Some previous studies (3–12) showed an inverse relation between total dairy intake and body weight or metabolic risk, but others (21–23) did not. The heterogeneity of the study populations and differences in the methods used by the various studies may be responsible for the observed differences in results. Our population, on average, was older than those of most other studies. If an association between dairy consumption and body weight or metabolic risk exists, we would expect to see these associations even more clearly in this older population, because of their longer (lifetime) exposure to risk factors (including diet) and have a greater prevalence of metabolic disturbances (greater statistical power). In addition, elderly are more prone to disturbances in calcium metabolism because of vitamin D deficiency. However, we did not find stronger negative associations in our population. We can only speculate that risk factors other than dairy consumption may become more important to metabolic risk in older persons. Furthermore, the mean dairy consumption in the Netherlands may be higher than that in other countries. A

possible threshold effect has been suggested at a calcium intake of 600–700 mg/d (14, 25). However, when only the participants in our study who had a low calcium intake (<700 or <600 mg/d) were selected, no significant negative associations of dairy consumption with BMI or metabolic outcomes were found.

Inverse associations of dairy consumption with blood pressure were observed in earlier studies, as well as in the current study, but the associations with other components of the metabolic syndrome in those studies (10, 12, 24, 26) were weaker. Associations of dairy consumption with metabolic variables other than blood pressure were not found in the population in the current study. A significant, positive association between dairy consumption and fasting glucose concentrations was observed, but the effect was very small and probably not of biological importance. The difference with previous studies may be due to the higher mean intake of dairy in our population. However, selection of subjects with low calcium intake did not reveal considerably different results. It was previously suggested that the effect of calcium on blood pressure is greater in persons who already have hypertension (15), and this may be the case also for dairy consumption. Indeed, in additional analyses, after stratifying for hypertension, we observed slightly stronger associations between dairy consumption and blood pressure in the hypertensive subjects than in those without hypertension. This finding suggests that dairy products may be particularly beneficial in subjects with high risk of hypertension or in subjects who already have elevated blood pressure, which is consistent with the finding that particularly salt-sensitive individuals respond to dietary calcium interventions (15). The subjects in the current study who had elevated blood pressure may represent a selection of salt-sensitive persons, in whom there is a tight relation between sodium and calcium excretion (ie, an increase in either cation increases the excretion of the other). In such subjects, increasing salt consumption increases urinary calcium loss, which may be prevented by increasing dietary calcium. Salt-insensitive persons depend more on intracellular calcium stores and are less likely to respond to dietary calcium (15).

In previous studies, the association between dairy consumption and the risk of type 2 diabetes was stronger for low-fat dairy than for high-fat dairy, possibly as a result of the unfavorable effect of the higher amounts of saturated fat in high-fat dairy (8, 9). This distinction between high- and low-fat dairy was not apparent, however, for the risk of the metabolic syndrome in young, obese adults (10) or in the population of the current study. Our results suggested favorable associations between high-fat dairy (rather than low-fat dairy) and BMI and between high-fat dairy and waist circumference, after adjustment for putative confounders. A beneficial association of particularly dairy desserts, as was found in the current study, was previously observed (10).

The favorable associations for the consumption of dairy desserts and high-fat dairy observed in the current study population could possibly be explained by an increased secretion of the incretin hormone glucagon-like peptide 1 (GLP-1) in the gastrointestinal tract and by that hormone's signaling in the central nervous system (34) in response to saturated fatty acids in dairy products (35, 36). A high concentration of GLP-1 causes an inhibition of gastric emptying (37, 38) and an increase in glucose-induced insulin secretion (39). The time of the day at which dairy products are consumed may be of importance to the effects of GLP-1. Thus, when a dairy product is consumed after a meal, GLP-1 may cause prolonged satiety by direct central nervous system effect and by inhibiting gastric emptying, which may result in a decreased intake of snacks after the meal. The unexpected associations of low-fat dairy with higher BMI and of high-fat dairy with lower BMI may also result from the phenomenon that obese people are more likely to consume low-fat dairy because they are obese (reversed causation). Because of the cross-sectional design of the study, the causality of the associations could not be investigated.

Recent studies observed an inverse association between dairy consumption and the prevalence of the metabolic syndrome (10, 12, 40). This finding was not confirmed by our study. According to the study by Pereira et al (10), the inverse association between dairy consumption and the metabolic syndrome existed only in overweight adults. In the current study population, the associations between dairy consumption and metabolic variables did not different significantly between obese and nonobese subjects.

Some limitations of the current study should be considered. First, the use of self-reports of usual dietary intake has undoubtedly led to some misclassification of dairy consumption. Nevertheless, the food-frequency questionnaire used in the current study was compared with a modified dietary history, and the results suggested reasonable accuracy (33). Second, because all analyses were cross-sectional, causality cannot be proven, and, although we adjusted for lifestyle factors, dairy consumption may simply reflect a healthy diet or lifestyle. Further research into the role of food patterns in the development of obesity and metabolic disturbances, particularly prospective studies, is needed.

In conclusion, a larger consumption of dairy products was associated with modestly lower blood pressure levels but not with body weight or other metabolic traits. These results are in line with the suggested favorable effects of the consumption of dairy products on blood pressure, but they do not support the hypothesis that higher dairy consumption is beneficial for weight.

CDAS, GN, RJH, LMB, and JMD were responsible for the design of the study and for data collection; MBS and AAWAvdH were responsible for analysis of the data; RMvD, CDAS, GJH, GN, RJH, LMB, and JMB contributed to the presentation or interpretation (or both) of the results; MBS and AAWAvdH wrote the draft of the paper; and MBS was responsible for the final version of the manuscript. None of the authors had a personal or financial conflict of interest.

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