British Journal of Nutrition (2017), 117, 148–160
doi:10.1017/S000711451600444X

Dairy consumption is associated with a lower incidence of the metabolic syndrome in middle-aged and older Korean adults: the Korean Genome and Epidemiology Study (KoGES)

Dasom Kim and Jihye Kim*

Department of Medical Nutrition, Graduate School of East-West Medical Science, Kyung Hee University, Yongin 446-701, Republic of Korea

(Submitted 11 May 2016 – Final revision received 10 November 2016 – Accepted 6 December 2016 – First published online 18 January 2017)

Abstract

This cohort study examined the association between total and individual dairy products and the risk of developing the metabolic syndrome (MetS) and its components in Korean adults from the Korean Genome and Epidemiology Study. We prospectively analysed 5510 participants aged 40–69 years without the MetS at baseline during a 10-year follow-up period. Dairy consumption was assessed with a semi-quantitative FFQ at baseline and after 4 years. The MetS was defined according to the criteria by the National Cholesterol Education Program Adult Treatment Panel III. The Cox's proportional hazard model was used to examine the association between consumption of total dairy products, milk and yogurt in servings per week and the risk of incident MetS or individual components. A total of 2103 subjects developed the MetS (38·2 %) during an average follow-up of 67·4 months (range 17–104 months). Frequent dairy consumption (>7 servings of total dairy and milk/week, ≥4 servings of yogurt/week) was associated with a reduced risk of incident MetS and its components. In the multivariable adjusted model, hazard ratios for the MetS were 0·51 (95 % CI 0·43, 0·61) for total dairy products, 0·50 (95 % CI 0·38, 0·66) for milk and 0·67 (95 % CI 0·57, 0·78) for yogurt in frequent consumers compared with non-consumers. An inverse association between milk/yogurt and low HDL-cholesterol was shown only in women. In conclusion, high consumption of individual dairy products including milk and yogurt as well as total dairy were associated with a reduced risk of incident MetS and individual components in Korean adults.

Key words: **Dairy consumption: Milk: Yogurt: Metabolic syndrome: Korean Genome and Epidemiology Study**

The metabolic syndrome (MetS) is a cluster of conditions, including abdominal obesity, elevated blood pressure, hypertriacylglycerolaemia, hyperglycaemia and low HDL-cholesterol, which together increase the risk of CVD and type 2 diabetes[1]. The prevalence of the MetS has rapidly increased worldwide[2,3], and diet plays an important role in the prevention and management of the MetS[4]. A number of studies have explored the association between dairy consumption and the risk of the MetS. However, the relationship remains controversial because of the inconsistency of the results. Some cross-sectional[5,6] and prospective studies[7,8] have shown an inverse association, whereas others have shown no association[9,10].

Although most studies propose the favourable effects of dairy products on the risk of developing the MetS in Western populations, there is little evidence to draw a cause–effect relationship between dairy consumption and the incidence of the MetS in the Asian population. Generally, dairy consumption is much lower in Asians, especially in Koreans because dairy foods are not a part of the traditional Korean diet and 75 % of Koreans have lactose intolerance[5,11]. Recommendation for dairy food intake is one serving per day for Korean adults[12]. According to the data from the Korea National Health and Nutrition Examination Survey, Korean adults consuming ≥1 serving of dairy food/d was 27 %[13] and Korean adults consume milk (2·7 servings/week) more frequently than yogurt (1·3 servings/week) or cheese[14]. Furthermore, different types of dairy products with a varying nutrient composition may have contributed to these controversial results[15,16]. Only one prospective study reported an inverse association between total dairy products with the risk of the MetS in Korean adults[17]. However, the study did not examine the effect of individual dairy products on the risk of developing the MetS and the follow-up period was relatively short. Furthermore, the effect of sex on the association between dairy food intake and the risk of incident MetS has not been investigated although some evidences have suggested sex differences on the association between dietary factors and the risk of chronic diseases including the MetS[18,19]. Therefore, the present study explored the sex-stratified association of individual dairy products such as milk and yogurt, with the risk of the MetS and its components in middle-aged and older Korean

Abbreviations: HR, hazard ratio; MetS, metabolic syndrome.

* **Corresponding author:** J. Kim, fax +82 31 204 8119, email kjhye@khu.ac.kr

adults using data from the Korean Genome and Epidemiology Study (KoGES), a large community-based cohort study. We hypothesised that frequent consumption of dairy products may be associated with a reduced risk of the MetS and individual components.

Methods

Study population

This study is a prospective, community-based cohort study with data collected from the KoGES. KoGES began in 2001 and sought to assess the effects of dietary, environmental and lifestyle determinants on the incidence of chronic diseases such as diabetes mellitus, hypertension and the MetS in the general Korean population. Detailed information on the study procedure was described in a previous report[20]. In brief, 10 030 Korean adults aged 40–69 years who lived in Ansan (urban) and Ansung (rural) were recruited at baseline between 2001 and 2002. All participants completed interviewer-administered questionnaires on demographic information, lifestyle including dietary habits, their health condition, and medical history, and also anthropometric measurements were acquired and biochemical tests were conducted biennially. The study protocol was approved by the Institutional Review Board of the Korea Centers for Disease Control and Prevention, and informed written consent was obtained from all participants. The present study was based on the data from baseline through the fourth follow-up examination between 2009 and 2010.

Of the original 10 030 participants, 2977 participants had the MetS at baseline, 747 participants refused to participate in the follow-up examinations, 137 participants had CVD or cancer and 659 participants did not complete the baseline or follow-up FFQ; these participants were excluded from the study. In our data, the ninety participants had very low or high energy intake (<2092 or 20 920 kJ/d (<500 or >5000 kcal/d)). We included the participants with unusually low or high energy intake in our analysis because the exclusion of ninety subjects did not affect the results. Thus, 5510 participants (2859 men and 2651 women) were entered into the analysis during the 10-year period from 2001 to 2010, and a follow-up rate of 66 % was achieved, resulting in 30 947 person-years accrued. The average follow-up period was 67·4 months.

Dietary assessment

At baseline and the second follow-up examination, dietary intake was assessed by trained dietitians with a 103-item semi-quantitative FFQ, which has been validated[21]. Total dairy products included milk, yogurt and cheese. Participants were asked to report usual frequency and portion size of dairy consumption during the past year. The answer for frequency had nine options for each food (never or almost never, once per month, two to three times per month, one to two times per week, three to four times per week, five to six times per week, once per day, two times per day, three times per day). The answer for portion size had three options for each food (1/2 serving, 1 serving (standard), ≥2 servings). To enhance the accuracy of serving size, pictures of dairy products and cup models marked with 50, 100, 150 and 200 ml were used as reference materials for serving sizes. One serving was equal to 200 ml of milk, 130 ml of liquid yogurt, 150 ml of solid yogurt and 20 g of cheese[12]. For analysis, dairy consumption was converted to weekly frequencies and then multiplied by the reported portion sizes of each food. To estimate whether consuming more than a recommended level of dairy food group (>7 servings/week) affect the incidence of the MetS compared with consuming non-dairy food. Finally, dairy consumption was categorised into five groups (never, <1, 1 ≤ to <4, 4 ≤ to ≤7, >7 servings/week) for total dairy and milk and four groups (never, <1, 1 ≤ to <4, ≥4 servings/week) for yogurt because the number of subjects consuming yogurt frequently was very small. The effect of cheese consumption on the incidence of the MetS was not examined because most of the participants never or rarely consumed cheese. For subjects who acquired the MetS or were censored between baseline and the second follow-up examination, intake of dairy products was evaluated based on the FFQ at baseline; for those who acquired the MetS or were censored after the second follow-up examination, intake of dairy products was evaluated based on the average of FFQ at baseline and FFQ at the second follow-up.

Measurements

Height (cm) and body weight (kg) were measured to the nearest 0·1 cm or 0·1 kg in light clothes without shoes. BMI was calculated as weight (kg) divided by height squared (m^2). Waist circumference was measured to the nearest 0·1 cm at the narrowest point between the lowest rib and iliac crest, and the average of three repeated measurements was used in the analysis. Blood pressure was measured with a Baumanometer mercury sphygmomanometer (W.A. Baum) after subjects had rested for 5 min in a sitting position. Systolic and diastolic blood pressures were measured at phases I and V Korotkoff sound, respectively, and were determined as the average of the both arm readings. The blood samples were collected after at least 8 h of fasting state and plasma was separated for biochemical measurements. The concentrations of glucose, TAG and HDL-cholesterol in plasma were measured enzymatically using an autoanalyzer (ADIVA 1650; Bayer HealthCare).

Definition of the metabolic syndrome

We used the diagnostic criteria for the MetS based on the National Cholesterol Education Program Adult Treatment Panel III definition modified by the American Heart Association and the National Heart Lung and Blood Institute[22]. According to the criteria, the MetS was defined as the presence of three or more of the following: abdominal obesity (waist circumference ≥90 cm in men or ≥80 cm in women); elevated blood pressure (systolic blood pressure ≥130 mmHg or diastolic blood pressure ≥85 mmHg or on antihypertensive medication or physician's diagnosis of hypertension); hyperglycaemia (fasting blood glucose ≥5·6 mmol/l, current use of insulin, oral hypoglycaemic medication or physician's diagnosis of diabetes mellitus); hypertriacylglycerolaemia (TAG ≥ 1·7 mmol/l); low

HDL-cholesterol (HDL-cholesterol < 1·0 mmol/l in men or <1·3 mmol/l in women).

Covariates

Educational levels were categorised into three groups: ≤6 years (elementary school graduates), 7≤ to ≤12 years (high school graduates) and >12 years (college graduates or more). Average monthly household income was categorised into four groups: <1 million KRW (approximately <850 USD at 2016), 1≤ to <2 million KRW (approximately 850≤ to <1700 USD), 2≤ to <3 million KRW (approximately 1700≤ to <2500 USD) and ≥3 million KRW (approximately ≥2500 USD). Smoking status was classified as non-smoker, former smoker or current smoker. Alcohol consumption was classified into three groups: non-drinker, former drinker and current drinker. Physical activity was assessed using metabolic equivalent of task (MET) hours per day. To obtain MET, participants reported hours spent on sleep and five types of activities classified according to activity intensity including sedentary, very light, light, moderate and heavy. Total MET-hours per day were calculated by multiplying the reported hours spent by the MET values that were determined based on each type of activity[23]. Daily nutrient intakes such as energy, Ca and fibre were obtained from the semi-quantitative FFQ, and calculated on the basis of the fifth edition of *Food Composition Table* developed by Rural Development Administration of Korea[24].

Statistical analysis

Statistical analysis were performed with SAS version 9.3 (SAS Institute). Baseline characteristics are expressed as percentage (categorical) or as means and standard deviation (continuous). Comparisons of variables at baseline across total dairy product consumption were analysed by the χ^2 test for categorical data and by the generalised linear models with *post hoc* Tukey's HSD (honestly significant difference) test for continuous data. Multivariate adjusted Cox's proportional hazard models were conducted as a method for survival analysis to assess the hazard ratios (HR) and 95 % CI for incident MetS and its components during follow-up according to the consumption of total dairy products, milk and yogurt either in categorical form or in continuous form (dairy consumption as servings/week). We used an average of dairy products intake calculated from the two dietary measures instead of single measurement to minimise within-subject variation in diet and well represent long-term diet during follow-up[25]. The proportional hazard assumption that the ratio of hazards is proportional and constant over time was confirmed graphically using log-log plots[26] and statistically based on Schoenfeld's residuals[27] with no major violation of the assumption. In multivariable adjusted model, model 1 was adjusted for age, sex, BMI, residential location, educational level, household income, smoking status, alcohol intake and physical activity as covariates and model 2 was adjusted for covariates included in model 1 plus nutrient intakes such as energy and energy-adjusted Ca and fibre using the residual method because dietary Ca and fibre have been suggested to be associated with the risk of the MetS[28,29]. Sex-stratified analyses were conducted to investigate the association between dairy consumption and the risks of the MetS and individual components of the MetS. To assess the statistical significance for trends of the MetS risk across categories, the median consumption values for each category were used as a continuous variable in the Cox's proportional hazard models.

Results

Among the 5510 participants, 2103 subjects developed the MetS during the 10-year follow-up.

The baseline characteristics of the study participants according to total dairy consumption is shown in Table 1. Compared with non-dairy consumers, frequent dairy consumers (>7 servings/week) were more likely to be younger male residents of Ansan (urban area), be educated, to have higher income and were less likely to be current smokers and be physically active. Frequent dairy consumers had a lower waist circumference, systolic and diastolic blood pressures, and TAG level and a higher concentration of HDL-cholesterol compared with non-dairy consumers. In addition, frequent dairy consumers had a higher intake of non-dairy food group such as vegetables, fruits and meat as well as nutrient such as energy, energy from fat, Ca and fibre, and a lower intake of energy from carbohydrates.

The associations between total dairy consumption and incidence of the MetS and its components are summarised in Table 2. Frequent dairy consumers had a 39 % lower risk of the MetS than non-dairy consumers after adjusting for potential confounders such as age, sex, BMI, residential location, educational level, income, smoking status, alcohol intake and physical activity (HR 0·61; 95 % CI 0·52, 0·71, $P_{\text{for trend}}$ < 0·0001). The inverse association became even stronger after further adjustment for nutrient intake such as energy, Ca and fibre (HR 0·51; 95 % CI 0·43, 0·61, $P_{\text{for trend}}$ < 0·0001). Frequent total dairy consumption was associated with a reduced risk of individual MetS components (HR 0·51; 95 % CI 0·42, 0·63, $P_{\text{for trend}}$ < 0·0001 for elevated blood pressure; HR 0·54; 95 % CI 0·45, 0·66, $P_{\text{for trend}}$ < 0·0001 for hypertriacylglycerolaemia; HR 0·51; 95 % CI 0·43, 0·61, $P_{\text{for trend}}$ < 0·0001 for hyperglycaemia) compared with that of non-dairy consumers after adjusting for all confounding factors. We analysed sex-stratified association of total dairy consumption with the risk of MetS components. Frequent total dairy consumption was associated with lower risk of incident abdominal obesity (HR 0·49; 95 % CI 0·36, 0·65, $P_{\text{for trend}}$ <0·0001 for men; HR 0·45; 95 % CI 0·33, 0·60, $P_{\text{for trend}}$ < 0·0001 for women) and low HDL-cholesterol (HR 0·81; 95 % CI 0·65, 1·00, $P_{\text{for trend}}$ = 0·0438 for men; HR 0·44; 95 % CI 0·35, 0·54, $P_{\text{for trend}}$ < 0·0001 for women) in both sexes. Except for abdominal obesity and low HDL-cholesterol, no sex difference between total dairy consumption and the risk of other MetS components was found (range of P values < 0·0001–0·0054).

We also observed associations between individual dairy products such as milk or yogurt and the risk of incident MetS and its components (Tables 3 and 4). Frequent milk consumers (>7 servings/week) had a 50 % reduction in the risk of

Table 1. Baseline characteristics of participants according to total dairy consumption (*n* 5510)
(Mean values and standard deviations; percentages)

	Total dairy consumption (servings/week)*										
	None		<1		1≤ to <4		4≤ to ≤7		>7		
	Mean	SD	Mean	SD	Mean	SD	Mean	SD	Mean	SD	*P*
n	649		906		1503		1199		1253		
Age (years)	54·6^{a}	9·4	52·6^{b}	9·1	50·3^{c}	8·4	50·0^{c}	8·2	50·2^{c}	8·3	<0·0001
Sex (% of female)	58·4		57·2		55·8		50·6		41·2		<0·0001
Residential location (%)											
Ansan (urban area)	33·1		38·1		54·5		62·4		62·8		<0·0001
Ansung (rural area)	66·8		61·9		45·5		37·6		37·2		
Educational level (%)											
≤6 years	48·0		35·9		26·1		20·7		20·6		<0·0001
7≤ to ≤12 years	44·2		52·6		58·0		60·9		62·3		
>12 years	7·8		11·6		15·9		18·4		17·1		
Household income (KRW/month) (%)											
<1 million	49·1		41·6		30·2		23·6		22·4		<0·0001
1≤ to <2 million	27·3		30·6		30·8		28·8		33·4		
2≤ to <3 million	13·1		15·1		20·6		23·0		21·3		
≥3 million	10·6		12·7		18·4		24·6		22·9		
Smoking status (%)											
Never	45·5		51·8		54·8		58·7		65·3		<0·0001
Former	18·4		15·6		17·5		18·1		13·6		
Current	36·1		32·6		27·7		23·2		21·1		
Alcohol intake (%)											
Never	39·9		43·5		39·4		42·6		46·2		0·0024
Former	7·1		7·7		5·7		6·0		4·7		
Current	53·0		48·8		54·9		51·4		49·1		
Physical activity											
MET-h/d	27·3^{a}	16·6	25·5^{a}	16·4	22·9^{b}	14·9	22·1^{b}	14·2	22·0^{b}	14·1	<0·0001
BMI (kg/m^2)	23·8	3·0	23·7	3·0	23·8	2·9	23·8	2·8	23·8	2·8	0·9118
Waist circumference (cm)	82·0^{a}	7·8	80·9^{b}	7·9	80·2^{b,c}	7·9	79·8^{c,d}	7·9	79·1^{d}	8·0	<0·0001
Systolic blood pressures (mmHg)	122·5^{a}	19·3	118·4^{b}	16·9	117·4^{b,c}	17·0	115·3^{d}	15·8	116·1^{c,d}	16·1	<0·0001
Diastolic blood pressures (mmHg)	80·5^{a}	11·6	78·6^{b}	10·2	78·1^{b,c}	10·8	76·9^{d}	10·5	77·2^{c,d}	10·6	<0·0001
Fasting blood glucose (mmol/l)	4·9	0·8	4·9	0·8	4·9	0·8	4·9	1·0	4·9	1·0	0·8430
TAG (mmol/l)	1·6^{a}	1·2	1·5^{b}	1·0	1·4^{b}	1·0	1·3^{b,c}	0·9	1·3^{c}	0·8	<0·0001
HDL-cholesterol (mmol/l)	1·3^{a,b}	0·3	1·3^{a,b}	0·3	1·3^{b}	0·3	1·3^{a,b}	0·3	1·4^{a}	0·3	0·0270
Food intake (servings/day)											
Grains	3·2^{a}	1·3	3·3^{a}	1·4	3·2^{a}	1·3	3·1^{a}	1·1	3·1^{a}	1·3	0·0421
Vegetables	3·2^{a,b}	2·7	3·0^{a}	2·3	3·6^{b,c}	2·7	3·9^{c}	2·7	4·6^{d}	4·2	<0·0001
Fruits	1·6^{a}	2·0	1·8^{a,b}	2·6	2·0^{b}	2·7	2·1^{b}	2·6	2·6^{c}	3·4	<0·0001
Meat	0·5^{a}	0·6	0·5^{a}	1·1	0·6^{a,b}	0·6	0·7^{b}	0·6	0·8^{c}	1·1	<0·0001
Nutrient intake											
Energy (kJ/d)	7317·8	2405·4	7383·9	2631·7	7999·8	2782·3	8455·9	2556·4	9430·7	3857·7	
Energy (kcal/d)	1749·0^{a}	574·9	1764·8^{a}	629·3	1912·8^{b}	665·1	2021·2^{c}	611·2	2254·9^{d}	922·0	<0·0001
Percentage from energy											
Carbohydrate	74·4^{a}	7·8	74·6^{a}	6·9	72·0^{b}	6·5	70·0^{c}	6·7	68·5^{d}	6·9	<0·0001
Fat	12·6^{a}	5·7	12·7^{a}	5·1	14·5^{b}	4·8	15·9^{c}	5·0	17·0^{d}	5·2	<0·0001
Protein	13·0^{a}	2·5	12·7^{b}	2·2	13·5^{c}	2·2	14·0^{d}	2·2	14·4^{e}	2·2	<0·0001
Ca (mg/d)	331·2^{a}	181·4	329·6^{a}	173·6	421·7^{b}	200·9	534·0^{c}	217·4	706·3^{d}	345·3	<0·0001
P (mg/d)	866·5^{a}	338·8	842·9^{a}	314·4	972·0^{b}	357·3	1087·4^{c}	345·5	1283·7^{d}	565·8	<0·0001
Na (mg/d)	3111·0^{a,b}	1589·8	2914·0^{a}	1633·7	3090·9^{a}	1593·8	3278·5^{b}	1587·0	3595·3^{c}	1884·5	<0·0001
K (mg/d)	2146·1^{a}	948·2	2080·4^{a}	986·5	2407·7^{b}	1077·2	2662·7^{c}	1070·9	3194·1^{d}	1576·9	<0·0001
Fibre (mg/d)	6·5^{a,b}	3·0	6·3^{b}	3·2	6·8^{a,c}	3·4	7·2^{c}	3·4	8·0^{d}	4·3	<0·0001

MET, metabolic equivalent of task.
a,b,c,d,e Mean values with unlike superscript letters indicates difference of variables among categories were examined by a generalised linear model (Tukey's test of multiple comparisons).
* One serving was equal to 200 ml of milk, 130 ml of liquid yogurt, 150 ml of solid yogurt and 20 g of cheese.

developing the MetS (HR 0·50; 95 % CI 0·38, 0·66, $P_{for\ trend}$ < 0·0001) and individual components of the MetS such as elevated blood pressure (HR 0·45; 95 % CI 0·32, 0·62, $P_{for\ trend}$ < 0·0001) hypertriacylglycerolaemia (HR 0·51; 95 % CI 0·38, 0·69, $P_{for\ trend}$ <0·0001) and hyperglycaemia (HR 0·44; 95 % CI 0·33, 0·59, $P_{for\ trend}$ < 0·0001) after adjustment for confounding factors compared with non-milk consumers. In sex-stratified analysis, frequent milk consumption was associated with a reduced risk of abdominal obesity only in men (HR 0·64; 95 % CI 0·40, 1·02, $P_{for\ trend}$ = 0·0115) and of low HDL-cholesterol only in women (HR 0·56; 95 % CI 0·42, 0·76, $P_{for\ trend}$ < 0·0001) compared with that of non-milk consumers.

British Journal of Nutrition

Table 2. Hazard ratios (HR) for incident metabolic syndrome (MetS) and its components according to total dairy consumption*
(HR and 95 % confidence intervals)

	Total dairy consumption (servings/week)†										
	None		<1		1≤ to <4		4 ≤ to ≤7		>7		
	HR	95 % CI	HR	95 % CI	HR	95 % CI	HR	95 % CI	HR	95 % CI	$P_{\text{for trend}}$
MetS (*n* 5510)											
n	649		906		1503		1199		1253		
n of cases	325		376		568		405		429		
Model 1	1·00		0·63	0·54, 0·74	0·67	0·58, 0·77	0·62	0·53, 0·72	0·61	0·52, 0·71	<0·0001
Model 2	1·00		0·63	0·54, 0·74	0·65	0·56, 0·75	0·59	0·50, 0·69	0·54	0·45, 0·64	<0·0001
Men											
n	379		518		839		607		516		
n of cases	168		190		306		185		159		
Model 1	1·00		0·68	0·55, 0·84	0·73	0·60, 0·89	0·62	0·50, 0·77	0·67	0·54, 0·84	0·0011
Model 2	1·00		0·68	0·55, 0·4	0·71	0·58, 0·86	0·59	0·47, 0·74	0·60	0·47, 0·78	<0·0001
Women, *n* (*n* of cases)											
Model 1	1·00		0·58	0·46, 0·72	0·62	0·50, 0·76	0·63	0·51, 0·79	0·60	0·49, 0·74	0·0039
Model 2	1·00		0·57	0·45, 0·71	0·60	0·49, 0·74	0·60	0·48, 0·75	0·53	0·42, 0·68	0·0002
Abdominal obesity (*n* 4702)											
Total											
n	542		773		1286		1042		1059		
n of cases	226		235		394		309		311		
Model 1	1·00		0·67	0·49, 0·90	0·67	0·51, 0·89	0·86	0·65, 1·15	0·74	0·54, 1·00	0·5217
Model 2	1·00		0·69	0·51, 0·94	0·68	0·51, 0·91	0·87	0·65, 1·16	0·72	0·52, 0·99	0·2896
Men											
n	381		537		846		635		537		
n of cases	128		130		221		134		115		
Model 1	1·00		0·65	0·51, 0·84	0·73	0·59, 0·92	0·61	0·47, 0·78	0·62	0·48, 0·80	0·0009
Model 2	1·00		0·66	0·51, 0·84	0·69	0·55, 0·87	0·53	0·41, 0·69	0·48	0·36, 0·65	<0·0001
Women											
n	161		236		440		407		522		
n of cases	98		105		173		175		196		
Model 1	1·00		0·61	0·46, 0·81	0·54	0·41, 0·70	0·66	0·50, 0·85	0·50	0·38, 0·65	0·0002
Model 2	1·00		0·60	0·45, 0·80	0·53	0·41, 0·69	0·64	0·49, 0·84	0·47	0·35, 0·62	<0·0001
Elevated blood pressure (*n* 4335)											
n	440		707		1178		1000		1010		
n of cases	226		291		390		331		318		
Model 1	1·00		0·63	0·52, 0·75	0·60	0·50, 0·71	0·66	0·55, 0·78	0·62	0·51, 0·74	0·0006
Model 2	1·00		0·63	0·53, 0·75	0·58	0·49, 0·69	0·62	0·51, 0·74	0·54	0·44, 0·67	<0·0001
Men											
n	239		368		567		437		378		
n of cases	123		158		205		163		137		
Model 1	1·00		0·68	0·53, 0·86	0·63	0·50, 0·79	0·66	0·52, 0·84	0·67	0·52, 0·87	0·0176
Model 2	1·00		0·68	0·54, 0·87	0·60	0·48, 0·76	0·63	0·49, 0·80	0·61	0·46, 0·81	0·0016
Women											
n	201		339		611		563		632		
n of cases	1030		133		185		168		181		
Model 1	1·00		0·56	0·43, 0·74	0·55	0·42, 0·70	0·64	0·50, 0·83	0·58	0·45, 0·75	0·0269
Model 2	1·00		0·56	0·43, 0·74	0·53	0·41, 0·68	0·60	0·46, 0·79	0·50	0·37, 0·67	0·0009
Hypertriacylglycerolaemia (*n* 4930)											
n	576		814		1307		1054		1179		
n of cases	277		298		473		358		385		
Model 1	1·00		0·58	0·49, 0·69	0·60	0·51, 0·70	0·57	0·79, 0·68	0·56	0·47, 0·66	<0·0001
Model 2	1·00		0·58	0·49, 0·69	0·60	0·51, 0·70	0·58	0·49, 0·69	0·55	0·46, 0·67	<0·0001
Men											
n	282		363		598		469		397		
n of cases	136		128		542		166		148		
Model 1	1·00		0·58	0·45, 0·74	0·70	0·56, 0·87	0·60	0·47, 0·76	0·67	0·52, 0·85	0·0158
Model 2	1·00		0·58	0·45, 0·74	0·70	0·56, 0·87	0·60	0·47, 0·76	0·63	0·48, 0·84	0·0054
Women											
n	294		451		709		585		782		
n of cases	141		170		228		192		237		
Model 1	1·00		0·57	0·45, 0·71	0·51	0·41, 0·64	0·55	0·44, 0·69	0·49	0·39, 0·61	<0·0001
Model 2	1·00		0·57	0·45, 0·72	0·52	0·41, 0·65	0·56	0·44, 0·71	0·51	0·39, 0·66	<0·0001
Hyperglycaemia (*n* 6351)											
n	740		1151		1733		1293		1434		
n of cases	331		402		532		381		393		
Model 1	1·00		0·58	0·49, 0·69	0·60	0·51, 0·70	0·57	0·49, 0·68	0·56	0·47, 0·66	<0·0001
Model 2	1·00		0·65	0·56, 0·76	0·61	0·52, 0·70	0·60	0·51, 0·70	0·54	0·45, 0·64	<0·0001

Table 2. *Continued*

	Total dairy consumption (servings/week)†										
	None		<1		1≤ to <4		4 ≤ to ≤7		>7		
	HR	95 % CI	HR	95 % CI	HR	95 % CI	HR	95 % CI	HR	95 % CI	$P_{for\ trend}$
Men											
n	401		564		840		577		515		
n of cases	205		228		312		211		171		
Model 1	1·00		0·64	0·53, 0·78	0·59	0·49, 0·71	0·62	0·51, 0·76	0·58	0·47, 0·72	<0·0001
Model 2	1·00		0·64	0·53, 0·78	0·57	0·47, 0·68	0·58	0·47, 0·71	0·50	0·39, 0·63	<0·0001
Women											
n	339		587		893		716		919		
n of cases	126		174		220		170		222		
Model 1	1·00		0·68	0·54, 0·87	0·68	0·54, 0·85	0·67	0·53, 0·86	0·69	0·54, 0·87	0·0330
Model 2	1·00		0·66	0·52, 0·5	0·66	0·52, 0·83	0·63	0·49, 0·82	0·60	0·46, 0·79	0·0023
Low HDL-cholesterol (*n* 4896),											
Total											
n	662		844		1304		1016		1070		
n of cases	434		513		747		554		625		
Model 1	1·00		0·66	0·58, 0·75	0·66	0·58, 0·74	0·63	0·55, 0·72	0·63	0·55, 0·72	<0·0001
Model 2	1·00		0·66	0·58, 0·75	0·65	0·57, 0·74	0·62	0·54, 0·71	0·61	0·52, 0·71	<0·0001
Men											
n	402		521		819		575		522		
n of cases	223		267		422		256		258		
Model 1	1·00		0·69	0·58, 0·83	0·74	0·63, 0·87	0·63	0·52, 0·76	0·77	0·64, 0·93	0·0162
Model 2	1·00		0·69	0·57, 0·82	0·75	0·63, 0·89	0·65	0·54, 0·79	0·82	0·66, 1·01	0·0542
Women											
n	260		323		485		441		548		
n of cases	211		246		325		298		367		
Model 1	1·00		0·63	0·52, 0·76	0·56	0·47, 0·68	0·59	0·79, 0·71	0·52	0·43, 0·62	<0·0001
Model 2	1·00		0·62	0·51, 0·75	0·55	0·45, 0·66	0·56	0·46, 0·68	0·47	0·38, 0·58	<0·0001

* Model 1: adjusted for age, (sex), BMI, residential location, educational level, household income, smoking status, alcohol intake and physical activity; model 2: further adjusted for nutrient intakes such as energy and energy-adjusted Ca and fibre.
† One serving was equal to 200 ml of milk, 130 ml of liquid yogurt, 150 ml of solid yogurt and 20 g of cheese.

Similarly, frequent yogurt consumption (≥4 servings/week) was associated with a 33 % reduction in the risk of developing the MetS (HR 0·67; 95 % CI 0·57, 0·78, $P_{for\ trend}$ < 0·0001), and individual components such as abdominal obesity (HR 0·64; 95 % CI 0·50, 0·81, $P_{for\ trend}$ < 0·0001), elevated blood pressure (HR 0·70; 95 % CI 0·59, 0·84, $P_{for\ trend}$ < 0·0001), hypertriacylglycerolaemia (HR 0·68; 95 % CI 0·58, 0·80, $P_{for\ trend}$ < 0·0001) and hyperglycaemia (HR 0·72; 95 % CI 0·62, 0·84, $P_{for\ trend}$ < 0·0001) compared with non-yogurt consumers. In sex-stratified analysis, the risk of low HDL-cholesterol decreased significantly according to increasing yogurt consumption only in women (HR 0·61; 95 % CI 0·51, 0·73, $P_{for\ trend}$ < 0·0001).

When dairy consumption was included in the analysis as a continuous form, total dairy consumption was associated with a reduced risk of incident MetS (HR 0·95; 95 % CI 0·90, 0·99, $P_{for\ trend}$ = 0·0231), but it was not significantly associated with individual components of the MetS (range of *P* values 0·0667–0·9674, data not shown).

Discussion

In this community-based prospective study with a 10-year follow-up period, we found that frequent consumption of total dairy products or milk (>7 servings/week) were inversely associated a lower incidence of the MetS and all individual components of the MetS including abdominal obesity (only significant in men for milk), elevated blood pressure, hypertriacylglycerolaemia, hyperglycaemia and low HDL-cholesterol (only significant in women for milk) after adjustment for age, sex, BMI, residential location, educational level, income, smoking status, alcohol intake, physical activity and nutrient intakes such as energy, Ca and fibre. Furthermore, increased consumption of yogurt (≥4 servings/week) was associated with a lower incidence of all MetS components (only significant in women for low HDL-cholesterol) as well as the MetS. The results suggest the beneficial effects of milk and yogurt as well as total dairy products on the risk of the MetS.

Our findings are in line with those of other prospective studies indicating an inverse association between dairy consumption and the risk of the MetS. In a prospective study conducted in Australian adults aged 49 years and over, higher consumption of regular-fat dairy products was associated with a 59 % reduction in the risk of the MetS after adjustment for age, sex, smoking status, physical activity, family history of type 2 diabetes, dietary glycaemic load and nutrient intakes including energy, Ca and fibre[15]. Fumeron *et al.*[8] found that dairy consumption was negatively associated with a lower incidence of the MetS in a 9-year follow-up cohort of 3435 French adults aged 30–65 years. Likewise, a prospective study of 1868 Mediterranean participants aged 55–80 years showed that subjects in the highest tertile of low-fat dairy, low-fat milk and yogurt consumption had a lower risk of incident MetS compared with those in the lowest tertile after adjustment for risk factors during a median follow-up of 3·2

https://doi.org/10.1017/S000711451600444X Published online by Cambridge University Press

Table 3. Hazard ratios (HR) for incident metabolic syndrome (MetS) and its components according to milk consumption*
(HR and 95 % confidence intervals)

	Milk consumption (servings/week)†										
	None		<1		1≤ to <4		4≤ to ≤7		>7		
	HR	95 % CI	HR	95 % CI	HR	95 % CI	HR	95 % CI	HR	95 % CI	$P_{for\ trend}$
MetS (*n* 5510)											
n	1441		1154		1595		1073		247		
n of cases	660		435		543		386		79		
Model 1	1·00		0·74	0·65, 0·83	0·70	0·62, 0·79	0·84	0·74, 0·96	0·63	0·49, 0·80	<0·0001
Model 2	1·00		0·72	0·64, 0·82	0·68	0·60, 0·77	0·77	0·66, 0·89	0·53	0·40, 0·70	<0·0001
Men											
n	765		680		829		476		109		
n of cases	315		238		275		146		34		
Model 1	1·00		0·68	0·57, 0·80	0·73	0·62, 0·87	0·76	0·62, 0·92	0·71	0·50, 1·02	0·0031
Model 2	1·00		0·67	0·56, 0·80	0·72	0·60, 0·85	0·71	0·57, 0·89	0·64	0·42, 0·97	0·0004
Women											
n	676		474		766		597		138		
n of cases	345		197		268		240		45		
Model 1	1·00		0·86	0·71, 1·04	0·73	0·62, 0·87	0·98	0·82, 1·17	0·61	0·44, 0·85	0·0374
Model 2	1·00		0·83	0·69, 1·01	0·70	0·59, 0·84	0·88	0·72, 1·08	0·51	0·35, 0·74	0·0034
Abdominal obesity (*n* 4702)											
Total											
n	1193		1004		1388		926		191		
n of cases	424		285		428		285		53		
Model 1	1·00		0·82	0·63, 1·06	0·85	0·67, 1·07	1·21	0·94, 1·56	0·90	0·55, 1·59	0·4052
Model 2	1·00		0·83	0·64, 1·08	0·86	0·67, 1·09	1·20	0·92, 1·58	0·84	0·49, 1·44	0·6247
Men											
n	766		698		862		501		109		
n of cases	222		162		204		115		25		
Model 1	1·00		0·70	0·57, 0·86	0·79	0·65, 0·96	0·83	0·66, 1·04	0·76	0·50, 1·16	0·0999
Model 2	1·00		0·69	0·56, 0·85	0·76	0·62, 0·93	0·75	0·58, 0·97	0·61	0·38, 1·00	0·0083
Women											
n	427		306		526		425		82		
n of cases	202		123		224		170		28		
Model 1	1·00		0·84	0·66, 1·06	0·90	0·74, 1·10	0·84	0·68, 1·04	0·67	0·44, 1·03	0·0598
Model 2	1·00		0·84	0·66, 1·06	0·90	0·73, 1·11	0·82	0·64, 1·04	0·64	0·40, 1·01	0·0717
Elevated blood pressure (*n* 4335)											
n	1054		930		1298		852		201		
n of cases	468		332		409		292		55		
Model 1	1·00		0·71	0·61, 0·82	0·70	0·61, 0·80	0·87	0·75, 1·01	0·60	0·45, 0·79	0·0010
Model 2	1·00		0·70	0·61, 0·81	0·66	0·57, 0·76	0·78	0·66, 0·9	0·46	0·33, 0·63	<0·0001
Men											
n	511		492		568		339		779		
n of cases	234		191		203		132		26		
Model 1	1·00		0·73	0·60, 0·88	0·70	0·57, 0·84	0·88	0·71, 1·10	0·65	0·43, 0·97	0·0278
Model 2	1·00		0·72	0·59, 0·88	0·67	0·55, 0·82	0·81	0·64, 1·03	0·54	0·34, 0·86	0·0013
Women											
n	543		438		730		513		122		
n of cases	234		141		206		160		29		
Model 1	1·00		0·68	0·55, 0·85	0·70	0·58, 0·86	0·88	0·71, 1·08	0·59	0·40, 0·88	0·0316
Model 2	1·00		0·67	0·53, 0·83	0·64	0·52, 0·79	0·76	0·60, 0·97	0·42	0·26, 0·67	0·0003
Hypertriacylglycerolaemia (*n* 4930)											
n	1286		1003		1437		969		265		
n of cases	565		336		49		333		65		
Model 1	1·00		0·61	0·53, 0·70	0·65	0·57, 0·74	0·73	0·63, 0·84	0·54	0·41, 0·70	<0·0001
Model 2	1·00		0·60	0·52, 0·69	0·65	0·57, 0·74	0·71	0·61, 0·84	0·52	0·38, 0·70	<0·0001

https://doi.org/10.1017/S000711451600444X Published online by Cambridge University Press

Table 3. *Continued*

	Milk consumption (servings/week)†										
	None		<1		1≤ to <4		4≤ to ≤7		>7		
	HR	95 % CI	HR	95 % CI	HR	95 % CI	HR	95 % CI	HR	95 % CI	$P_{for\ trend}$
Men											
n	554		467		638		371		79		
n of cases	240		172		247		135		29		
Model 1	1·00		0·65	0·53, 0·79	0·73	0·61, 0·87	0·79	0·64, 0·99	0·69	0·47, 1·03	0·0219
Model 2	1·00		0·64	0·52, 0·78	0·72	0·60, 0·87	0·76	0·60, 0·97	0·62	0·39, 0·98	0·0067
Women											
n	732		536		799		598		156		
n of cases	325		164		245		198		36		
Model 1	1·00		0·59	0·48, 0·71	0·61	0·51, 0·72	0·70	0·58, 0·84	0·46	0·32, 0·65	<0·0001
Model 2	1·00		0·58	0·48, 0·71	0·61	0·51, 0·73	0·69	0·56, 0·86	0·47	0·31, 0·70	<0·0001
Hyperglycaemia (*n* 6351)											
n	1734		1379		1806		1141		291		
n of cases	653		437		532		352		65		
Model 1	1·00		0·72	0·63, 0·82	0·73	0·65, 0·83	0·91	0·79, 1·04	0·54	0·42, 0·70	0·0002
Model 2	1·00		0·72	0·64, 0·82	0·70	0·62, 0·79	0·82	0·70, 0·95	0·45	0·33, 0·60	<0·0001
Men											
n	799		718		819		459		102		
n of cases	353		271		301		174		28		
Model 1	1·00		0·68	0·58, 0·80	0·69	0·59, 0·81	0·88	0·73, 1·07	0·49	0·33, 0·72	0·0011
Model 2	1·00		0·69	0·59, 0·1	0·66	0·56, 0·77	0·80	0·65, 0·98	0·40	0·26, 0·63	<0·0001
Women											
n	935		661		987		682		189		
n of cases	300		166		231		178		37		
Model 1	1·00		0·80	0·66, 0·98	0·82	0·68, 0·99	0·97	0·80, 1·19	0·62	0·44, 0·88	0·0948
Model 2	1·00		0·80	0·65, 0·97	0·79	0·65, 0·5	0·87	0·70, 1·09	0·51	0·34, 0·77	0·0110
Low HDL-cholesterol (*n* 4896)											
Total											
n	1364		985		1393		933		221		
n of cases	859		564		781		536		133		
Model 1	1·00		0·73	0·66, 0·82	0·75	0·68, 0·83	0·79	0·71, 0·89	0·78	0·65, 0·94	<0·0001
Model 2	1·00		0·73	0·65, 0·81	0·75	0·68, 0·83	0·80	0·70, 0·90	0·78	0·63, 0·98	<0·0001
Men											
n	773		655		828		474		109		
n of cases	409		336		410		211		60		
Model 1	1·00		0·80	0·69, 0·93	0·81	0·71, 0·94	0·81	0·68, 0·96	0·93	0·71, 1·23	0·0348
Model 2	1·00		0·80	0·69, 0·93	0·84	0·73, 0·97	0·86	0·72, 1·04	1·06	0·77, 1·46	0·1485
Women											
n	591		330		565		459		112		
n of cases	450		228		371		325		73		
Model 1	1·00		0·66	0·56, 0·78	0·69	0·60, 0·80	0·75	0·65, 0·88	0·65	0·51, 0·85	<0·0001
Model 2	1·00		0·65	0·55, 0·77	0·68	0·58, 0·79	0·72	0·61, 0·86	0·60	0·44, 0·81	<0·0001

* Model 1: adjusted for age (sex), BMI, residential location, educational level, household income, smoking status, alcohol intake and physical activity; model 2: further adjusted for nutrient intakes such as energy and energy-adjusted Ca and fibre.

† One serving was equal to 200 ml of milk.

https://doi.org/10.1017/S000711451600444X Published online by Cambridge University Press

Table 4. Hazard ratios (HR) for incident metabolic syndrome (MetS) and its components according to yogurt consumption*
(HR and 95 % confidence intervals)

	Yogurt consumption (servings/week)†								
	None		<1		1≤ to <4		≥4		
	HR	95 % CI	HR	95 % CI	HR	95 % CI	HR	95 % CI	$P_{\text{for trend}}$
MetS (*n* 5510)									
n	1471		1627		1589		823		
n of cases	677		602		545		279		
Model 1	1·00		0·68	0·60, 0·76	0·67	0·60, 0·76	0·70	0·60, 0·81	<0·0001
Model 2	1·00		0·68	0·60, 0·76	0·67	0·59, 0·75	0·68	0·58, 0·79	<0·0001
Men									
n	875		882		744		358		
n of cases	355		299		249		105		
Model 1	1·00		0·72	0·62, 0·85	0·71	0·60, 0·84	0·69	0·55, 0·86	<0·0001
Model 2	1·00		0·72	0·61, 0·84	0·70	0·59, 0·82	0·67	0·53, 0·84	<0·0001
Women									
n	596		745		845		465		
n of cases	322		303		296		174		
Model 1	1·00		0·63	0·54, 0·75	0·65	0·55, 0·76	0·72	0·59, 0·88	0·0003
Model 2	1·00		0·64	0·54, 0·75	0·65	0·55, 0·77	0·71	0·58, 0·87	0·0001
Abdominal obesity (*n* 4702)									
Total									
n	1270		1379		1372		681		
n of cases	495		373		413		194		
Model 1	1·00		0·56	0·45, 0·70	0·48	0·38, 0·60	0·76	0·57, 1·01	<0·0001
Model 2	1·00		0·56	0·45, 0·70	0·47	0·37, 0·60	0·73	0·55, 0·99	<0·0001
Men									
n	896		903		776		361		
n of cases	290		182		190		66		
Model 1	1·00		0·57	0·47, 0·69	0·64	0·53, 0·77	0·54	0·41, 0·71	<0·0001
Model 2	1·00		0·56	0·46, 0·68	0·61	0·51, 0·74	0·48	0·36, 0·64	<0·0001
Women									
n	374		476		596		320		
n of cases	205		191		223		128		
Model 1	1·00		0·60	0·49, 0·73	0·56	0·46, 0·69	0·65	0·52, 0·82	<0·0001
Model 2	1·00		0·60	0·49, 0·73	0·55	0·45, 0·68	0·64	0·51, 0·81	<0·0001
Elevated blood pressure (*n* 4335)									
n	1079		1269		1321		666		
n of cases	486		438		421		211		
Model 1	1·00		0·66	0·58, 0·76	0·71	0·62, 0·82	0·73	0·62, 0·87	<0·0001
Model 2	1·00		0·67	0·58, 0·76	0·71	0·62, 0·81	0·71	0·59, 0·85	<0·0001
Men									
n	568		604		555		262		
n of cases	263		224		208		91		
Model 1	1·00		0·67	0·56, 0·80	0·74	0·62, 0·90	0·74	0·58, 0·94	0·0048
Model 2	1·00		0·66	0·55, 0·79	0·73	0·61, 0·88	0·73	0·57, 0·94	0·0029
Women									
n	511		665		766		404		
n of cases	223		214		213		120		
Model 1	1·00		0·67	0·55, 0·81	0·67	0·55, 0·82	0·74	0·58, 0·93	0·0041
Model 2	1·00		0·68	0·55, 0·82	0·68	0·55, 0·82	0·70	0·55, 0·90	0·0011
Hypertriacylglycerolaemia (*n* 4930)									
n	1299		1473		1399		759		
n of cases	568		513		464		246		
Model 1	1·00		0·65	0·58, 0·74	0·65	0·57, 0·74	0·66	0·57, 0·78	<0·0001
Model 2	1·00		0·65	0·58, 0·74	0·66	0·58, 0·75	0·68	0·58, 0·81	<0·0001

Table 4. *Continued*

	Yogurt consumption (servings/week)†								
	None		<1		1≤ to <4		≥4		
	HR	95 % CI	HR	95 % CI	HR	95 % CI	HR	95 % CI	$P_{for\ trend}$
Men									
n	643		647		551		268		
n of cases	287		230		211		95		
Model 1	1·00		0·65	0·54, 0·77	0·70	0·58, 0·85	0·70	0·55, 0·89	0·0007
Model 2	1·00		0·65	0·545, 0·77	0·70	0·58, 0·85	0·70	0·54, 0·90	0·0007
Women									
n	656		826		848		491		
n of cases	281		283		253		151		
Model 1	1·00		0·65	0·55, 0·77	0·62	0·52, 0·73	0·65	0·53, 0·80	<0·0001
Model 2	1·00		0·66	0·55, 0·78	0·63	0·53, 0·76	0·69	0·56, 0·86	<0·0001
Hyperglycaemia (*n* 6351)									
n	1632		1949		1813		957		
n of cases	664		595		510		270		
Model 1	1·00		0·66	0·59, 0·74	0·66	0·58, 0·74	0·75	0·65, 0·87	<0·0001
Model 2	1·00		0·66	0·59, 0·74	0·66	0·58, 0·74	0·73	0·62, 0·85	<0·0001
Men									
n	877		910		763		347		
n of cases	410		330		272		115		
Model 1	1·00		0·63	0·54, 0·73	0·63	0·54, 0·74	0·68	0·55, 0·84	<0·0001
Model 2	1·00		0·63	0·54, 0·73	0·2	0·53, 0·73	0·66	0·52, 0·82	<0·0001
Women									
n	755		1039		1050		610		
n of cases	254		265		238		155		
Model 1	1·00		0·70	0·59, 0·84	0·70	0·58, 0·84	0·84	0·68, 1·04	0·0445
Model 2	1·00		0·70	0·58, 0·84	0·70	0·58, 0·84	0·81	0·65, 1·02	0·0195
Low HDL-cholesterol (*n* 4896)									
Total									
n	1469		1421		1324		682		
n of cases	910		814		759		390		
Model 1	1·00		0·72	0·65, 0·79	0·74	0·67, 0·82	0·74	0·65, 0·84	<0·0001
Model 2	1·00		0·72	0·65, 0·79	0·75	0·67, 0·83	0·75	0·66, 0·85	<0·0001
Men									
n	911		862		718		348		
n of cases	471		424		364		167		
Model 1	1·00		0·80	0·70, 0·91	0·84	0·73, 0·97	0·89	0·74, 1·07	0·0851
Model 2	1·00		0·79	0·69, 0·91	0·85	0·73, 0·98	0·91	0·76, 1·11	0·1207
Women									
n	558		559		606		334		
n of cases	439		390		395		223		
Model 1	1·00		0·64	0·56, 0·74	0·63	0·55, 0·73	0·62	0·53, 0·74	<0·0001
Model 2	1·00		0·64	0·55, 0·73	0·63	0·55, 0·73	0·62	0·52, 0·74	<0·0001

* Model 1: adjusted for age, (sex), BMI, residential location, educational level, household income, smoking status, alcohol intake, and physical activity; model 2: further adjusted for nutrient intakes such as energy and energy-adjusted Ca and fibre.

† One serving was equal to 130 ml of liquid yogurt and 150 ml of solid yogurt.

https://doi.org/10.1017/S000711451600444X Published online by Cambridge University Press

years. In addition, high consumption of whole-fat yogurt was associated with a reduced risk of all of the individual components of the MetS as well as the MetS in itself, which is similar to our results[16].

In contrast, the results of some studies are not fully consistent with our findings[30,31]. In a cross-sectional study of Brazilian adults aged >35 years, for example, no association between frequent dairy consumption and the prevalence of the MetS was observed[30]. Pereira *et al.*[31] found an inverse relationship between dairy consumption and incidence of the MetS among overweight subjects, but not among subjects with normal weight. The discordant results from these studies may be attributable to differences in the definition of the MetS, study population and study design.

Several potential mechanisms for the favourable effect of dairy products on metabolic risk factors have been proposed. Various nutrients from dairy products including Ca and dairy protein may synergistically protect against all MetS components. Ca in milk products combine with fatty acids and bile acids in the gut, thereby increasing fecal fat excretion and/or inhibiting fat reabsorption[32]. As a result, this can improve the ratio of HDL-cholesterol:LDL-cholesterol[33,34]. An intervention study reported that unlike Ca from supplements, Ca from milk or yogurt reduced postprandial TAG levels in healthy male subjects aged 18–50 years old, suggesting dairy Ca reduces fat absorption[35]. Dietary Ca also reduces blood pressure via suppression of 1,25-dihydroxyvitamin D, which increases intercellular Ca in vascular smooth muscle cells[36].

Dairy proteins may have antihypertensive properties as well. Casein and whey protein, the major proteins in dairy, may regulate blood pressure via inhibition of angiotensin I-converting enzyme, which converts angiotensin I to angiotensin II, a potent vasoconstrictor[37]. Pal & Ellis[38] showed that supplements with 54 g/d of casein and whey protein for 12 weeks significantly decreased blood pressure compared with the placebo group in overweight and obese subjects. Furthermore, fasting TAG and insulin resistance were significantly decreased at week 12 in the whey protein supplemented group compared with the casein or control group[39]. The insulinotropic effect of whey protein may be associated with specific amino acid composition, in particular branched-chain amino acids such as leucine, isoleucine and valine. A mixture of branched-chain amino acids can result in a glycaemic and insulinaemic response that is similar to those seen after whey ingestion in a healthy person[40]. Dairy protein-derived peptides may play an important role in preventing the MetS by regulating insulinaemia, blood pressure, dyslipidaemia and fat accumulation[41]. Despite beneficial effects of various components, dairy products have a high proportion of SFA, which have been shown to have harmful effects on metabolic health[42]. However, the effect of dairy fat on metabolic risk factors is controversial[43]. Recent studies suggest that dairy fat has different effects depending on the type of dairy products and composition of macronutrients in the meal[44].

In our study, yogurt consumption was inversely associated with the risk of the MetS and all components including abdominal obesity, unlike milk. Although yogurt is nutritionally similar to milk, added ingredients (protein, vitamins and minerals) and fermentation may improve its nutritional value and enhance the bioavailability of some minerals such as Ca, Mg and Zn by inducing an acidic environment[45,46]. Recent studies showed that high consumption of yogurt was associated with a reduced risk of obesity and the MetS[47,48]. Probiotic bacteria from yogurt beneficially influence the balance of gut microbiota. Gut microbiota are considered to play an important role in the development of obesity and obesity-related low-grade inflammation[49]. Bacteria from yogurt ferment indigestible carbohydrates and produce SCFA, which will alter cholesterol synthesis. In addition, some bacteria can bind bile acids to cholesterol and resulting in the excretion of bile acid–cholesterol complexes in the feces[50].

Interestingly, an inverse association between dairy consumption and risk of low HDL-cholesterol was shown only in women regardless of dairy food type. Sex might play a role as an influencing factor on the association between diet and disease risk[51]. The sex difference may be associated with sex hormones. For example, oestrogen enhances fat transport and increases the levels of lipoproteins in the blood, whereas androgen has the opposite effect of oestrogen[52]. Therefore, lipid levels could be differently regulated between men and women. Moreover, the lipid levels may respond more sensitive to dietary changes in women than in men[53]. In this study, changes in lipid metabolism caused by sex hormones might have contributed to a greater association between dairy consumption and the risk of low HDL-cholesterol in women.

Our study has several strengths. The relatively long period of follow-up may be helpful to evaluate the relationship between dairy consumption from the habitual diet and the incidence of the MetS. Furthermore, the use of average consumption in dairy intake from baseline and follow-up FFQ could minimise the random measurement error caused by within-person variation and dietary changes during follow-up. Finally, multiple confounders that might influence the association between dairy consumption and the MetS such as lifestyle factors including nutrient intakes were adjusted for analysis.

The present study has some limitations. First, we could not clarify the effect of dairy subtypes with different fat content on the risk of developing the MetS. Second, this cohort was composed of middle-aged Korean adults, so caution should be used when generalising our findings to other age groups. Third, we have not examined the use of cholesterol medication. Finally, although we extensively adjusted for potential confounding factors of MetS risks, the residual confounding factors which were not considered in the analysis might affect the metabolic risks associated with dairy consumption.

In conclusion, frequent consumption (>7 servings/week) of total dairy products and milk was associated with a lower 10-year incidence of the MetS, abdominal obesity (only significant in men for milk), elevated blood pressure, hypertriacylglycerolaemia, and hyperglycaemia, and increased consumption (≥4 servings/week) of yogurt was associated with a lower incidence of the MetS and all individual components in the middle-aged and older Korean adults. Frequent dairy consumption (milk and yogurt) was associated with lower risk of low HDL-cholesterol only in women. Further studies should be conducted to investigate the effect of dairy subtypes with different fat contents on metabolic risk factors.

Acknowledgements

We thank Korea Centers for Disease Control and Prevention (KCDC) for providing open source data. Epidemiological data used in this study were obtained from the Korean Genome and Epidemiology Study (KoGES; 4851-302) of KCDC, Republic of Korea. This research was supported by the Basic Science Research Program of the National Research Foundation of Korea (NRF), funded by the Ministry of Education, Science, and Technology (NRF2016R1D1A1B03931307). The NRF had no role in the study design, data analysis or writing of this article.

Both authors had a significant role in the project. D. K. contributed to data analysis and writing the manuscript. J. K. contributed to designing the research and writing the manuscript; and also has primary responsibility for the final content. Both authors read and approved the final manuscript.

The authors have no conflicts of interest to declare.

References

1. Saely CH, Rein P & Drexel H (2007) The metabolic syndrome and risk of cardiovascular disease and diabetes: experiences with the new diagnostic criteria from the International Diabetes Federation. *Horm Metab Res* **39**, 642–650.
2. Mozumdar A & Liguori G (2011) Persistent increase of prevalence of metabolic syndrome among U.S. adults: NHANES III to NHANES 1999–2006. *Diabetes Care* **34**, 216–219.
3. Nestel P, Lyu R, Low LP, *et al.* (2007) Metabolic syndrome: recent prevalence in East and Southeast Asian populations. *Asia Pac J Clin Nutr* **16**, 362–367.
4. Chung SJ, Lee Y, Lee S, *et al.* (2015) Breakfast skipping and breakfast type are associated with daily nutrient intakes and metabolic syndrome in Korean adults. *Nutr Res Pract* **9**, 288–295.
5. Kim J (2013) Dairy food consumption is inversely associated with the risk of the metabolic syndrome in Korean adults. *J Hum Nutr Diet* **26**, Suppl. 1, 171–179.
6. Azadbakht L, Mirmiran P, Esmaillzadeh A, *et al.* (2005) Dairy consumption is inversely associated with the prevalence of the metabolic syndrome in Tehranian adults. *Am J Clin Nutr* **82**, 523–530.
7. Lutsey PL, Steffen LM & Stevens J (2008) Dietary intake and the development of the metabolic syndrome: the Atherosclerosis Risk in Communities study. *Circulation* **117**, 754–761.
8. Fumeron F, Lamri A, Abi Khalil C, *et al.* (2011) Dairy consumption and the incidence of hyperglycemia and the metabolic syndrome: results from a French prospective study, Data from the Epidemiological Study on the Insulin Resistance Syndrome (DESIR). *Diabetes Care* **34**, 813–817.
9. Damiao R, Castro TG, Cardoso MA, *et al.* (2006) Dietary intakes associated with metabolic syndrome in a cohort of Japanese ancestry. *Br J Nutr* **96**, 532–538.
10. Lin Y, Chang H, Tseng Y, *et al.* (2013) Characteristics and health behavior of newly developed metabolic syndrome among community-dwelling elderly in Taiwan. *Int J Gerontol* **7**, 90–96.
11. Scrimshaw NS & Murray EB (1988) The acceptability of milk and milk products in populations with a high prevalence of lactose intolerance. *Am J Clin Nutr* **48**, 1079–1159.
12. Ministry of Health and Welfare (2015) *Dietary Reference Intakes for Koreans 2015*. Sejong City: Ministry for Health and Welfare.
13. Lee HJ, Cho JI, Lee HS, *et al.* (2014) Intakes of dairy products and calcium and obesity in Korean adults: Korean National Health and Nutrition Examination Surveys (KNHANES) 2007–2009. *PLoS ONE* **9**, e99085.
14. Korea Centers for Disease Control and Prevention (2011) Korea Health Statistics 2010: Korea National Health and Nutrition Examination Survey (KNHANES V-1). Cheongju City: Korea Centers for Disease Control and Prevention.
15. Louie JC, Flood VM, Rangan AM, *et al.* (2013) Higher regular fat dairy consumption is associated with lower incidence of metabolic syndrome but not type 2 diabetes. *Nutr Metab Cardiovasc Dis* **23**, 816–821.
16. Babio N, Becerra-Tomas N, Martinez-Gonzalez MA, *et al.* (2015) Consumption of yogurt, low-fat milk, and other low-fat dairy products is associated with lower risk of metabolic syndrome incidence in an elderly Mediterranean population. *J Nutr* **145**, 2308–2316.
17. Shin H, Yoon YS, Lee Y, *et al.* (2013) Dairy product intake is inversely associated with metabolic syndrome in Korean adults: Anseong and Ansan cohort of the Korean Genome and Epidemiology Study. *J Korean Med Sci* **28**, 1482–1488.
18. Bedard A, Riverin M, Dodin S, *et al.* (2012) Sex differences in the impact of the Mediterranean diet on cardiovascular risk profile. *Br J Nutr* **108**, 1428–1434.
19. Kang Y & Kim J (2016) Gender difference on the association between dietary patterns and metabolic syndrome in Korean population. *Eur J Nutr* **55**, 2321–2330.
20. Lim S, Jang HC, Lee HK, *et al.* (2006) A rural-urban comparison of the characteristics of the metabolic syndrome by gender in Korea: the Korean Health and Genome Study (KHGS). *J Endocrinol Invest* **29**, 313–319.
21. Ahn Y, Kwon E, Shim JE, *et al.* (2007) Validation and reproducibility of food frequency questionnaire for Korean Genome Epidemiologic Study. *Eur J Clin Nutr* **61**, 1435–1441.
22. Alberti KG, Eckel RH, Grundy SM, *et al.* (2009) Harmonizing the metabolic syndrome: a joint interim statement of the International Diabetes Federation Task Force on Epidemiology and Prevention; National Heart, Lung, and Blood Institute; American Heart Association; World Heart Federation; International Atherosclerosis Society; and International Association for the Study of Obesity. *Circulation* 120, 1640–1645.
23. Ainsworth BE, Haskell WL, Whitt MC, *et al.* (2000) Compendium of physical activities: an update of activity codes and MET intensities. *Med Sci Sports Exerc* **32**, S498–S504.
24. National Institute of Agricultural Sciences (1996) *Food Composition Table*, 5th ed. Jeonju City: Rural Development Administration of Korea.
25. Hu FB, Stampfer MJ, Rimm E, *et al.* (1999) Dietary fat and coronary heart disease: a comparison of approaches for adjusting for total energy intake and modeling repeated dietary measurements. *Am J Epidemiol* **149**, 531–540.
26. Hess KR (1995) Graphical methods for assessing violations of the proportional hazards assumption in Cox regression. *Stat Med* **14**, 1707–1723.
27. Schoenfeld D (1982) Partial residuals for the proportional hazards regression model. *Biometrika* **69**, 239–241.
28. Shin SK, Kim MK, Lee YH, *et al.* (2015) The cross-sectional relationship between dietary calcium intake and metabolic syndrome among men and women aged 40 or older in rural areas of Korea. *Nutr Res Pract* **9**, 328–335.
29. Moreno Franco B, Leon Latre M, Andres Esteban EM, *et al.* (2014) Soluble and insoluble dietary fibre intake and risk factors for metabolic syndrome and cardiovascular disease in middle-aged adults: the AWHS cohort. *Nutr Hosp* **30**, 1279–1288.
30. de Oliveira EP, McLellan KC, Vaz de Arruda Silveira L, *et al.* (2012) Dietary factors associated with metabolic syndrome in Brazilian adults. *Nutr J* **11**, 13.
31. Pereira MA, Jacobs DR Jr, Van Horn L, *et al.* (2002) Dairy consumption, obesity, and the insulin resistance syndrome in young adults: the CARDIA Study. *JAMA* **287**, 2081–2089.

32. Boon N, Hul GB, Stegen JH, *et al.* (2007) An intervention study of the effects of calcium intake on faecal fat excretion, energy metabolism and adipose tissue mRNA expression of lipid-metabolism related proteins. *Int J Obes (Lond)* **31**, 1704–1712.
33. Reid IR, Mason B, Horne A, *et al.* (2002) Effects of calcium supplementation on serum lipid concentrations in normal older women: a randomized controlled trial. *Am J Med* **112**, 343–347.
34. Denke MA, Fox MM & Schulte MC (1993) Short-term dietary calcium fortification increases fecal saturated fat content and reduces serum lipids in men. *J Nutr* **123**, 1047–1053.
35. Lorenzen JK, Nielsen S, Holst JJ, *et al.* (2007) Effect of dairy calcium or supplementary calcium intake on postprandial fat metabolism, appetite, and subsequent energy intake. *Am J Clin Nutr* **85**, 678–687.
36. Zemel MB (2001) Calcium modulation of hypertension and obesity: mechanisms and implications. *J Am Coll Nutr* **20**, 428S–435S; discussion 440S–442S.
37. Choi J, Sabikni L, Hassan A, *et al.* (2012) Bioactive peptides in dairy products. *Int J Dairy Technol* **65**, 1–12.
38. Pal S & Ellis V (2010) The chronic effects of whey proteins on blood pressure, vascular function, and inflammatory markers in overweight individuals. *Obesity* **18**, 1354–1359.
39. Pal S, Ellis V & Dhaliwal S (2010) Effects of whey protein isolate on body composition, lipids, insulin and glucose in overweight and obese individuals. *Br J Nutr* **104**, 716–723.
40. Nilsson M, Holst JJ & Bjorck IM (2007) Metabolic effects of amino acid mixtures and whey protein in healthy subjects: studies using glucose-equivalent drinks. *Am J Clin Nutr* **85**, 996–1004.
41. Ricci-Cabello I, Herrera MO & Artacho R (2012) Possible role of milk-derived bioactive peptides in the treatment and prevention of metabolic syndrome. *Nutr Rev* **70**, 241–255.
42. Bjornshave A & Hermansen K (2014) Effects of dairy protein and fat on the metabolic syndrome and type 2 diabetes. *Rev Diabet Stud* **11**, 153–166.
43. Chowdhury R, Warnakula S, Kunutsor S, *et al.* (2014) Association of dietary, circulating, and supplement fatty acids with coronary risk: a systematic review and meta-analysis. *Ann Intern Med* **160**, 398–406.
44. Visioli F & Strata A (2014) Milk, dairy products, and their functional effects in humans: a narrative review of recent evidence. *Adv Nutr* **5**, 131–143.
45. Wang H, Livingston KA, Fox CS, *et al.* (2013) Yogurt consumption is associated with better diet quality and metabolic profile in American men and women. *Nutr Res* **33**, 18–26.
46. El-Abbadi NH, Dao MC & Meydani SN (2014) Yogurt: role in healthy and active aging. *Am J Clin Nutr* **99**, 1263S–1270S.
47. Martinez-Gonzalez MA, Sayon-Orea C, Ruiz-Canela M, *et al.* (2014) Yogurt consumption, weight change and risk of overweight/obesity: the SUN cohort study. *Nutr Metab Cardiovasc Dis* **24**, 1189–1196.
48. Drehmer M, Pereira MA, Schmidt MI, *et al.* (2016) Total and full-fat, but not low-fat, dairy product intakes are inversely associated with metabolic syndrome in adults. *J Nutr* **146**, 81–89.
49. Verdam FJ, Fuentes S, de Jonge C, *et al.* (2013) Human intestinal microbiota composition is associated with local and systemic inflammation in obesity. . *Obesity (Silver Spring)* **21**, E607–E615.
50. St-Onge MP, Farnworth ER & Jones PJ (2000) Consumption of fermented and nonfermented dairy products: effects on cholesterol concentrations and metabolism. *Am J Clin Nutr* **71**, 674–681.
51. Kang Y & Kim J (2016) Association between fried food consumption and hypertension in Korean adults. *Br J Nutr* **115**, 87–94.
52. Knopp RH, Paramsothy P, Retzlaff BM, *et al.* (2005) Gender differences in lipoprotein metabolism and dietary response: basis in hormonal differences and implications for cardiovascular disease. *Curr Atheroscler Rep* **7**, 472–479.
53. Walden CE, Retzlaff BM, Buck BL, *et al.* (2000) Differential effect of National Cholesterol Education Program (NCEP) step II diet on HDL cholesterol, its subfractions, and apoprotein A-I levels in hypercholesterolemic women and men after 1 year: the beFIT Study. *Arterioscler Thromb Vasc Biol* **20**, 1580–1587.