Dairy Consumption, Obesity, and the Insulin Resistance Syndrome in Young Adults
The CARDIA Study

Mark A. Pereira, PhD

David R. Jacobs, Jr, PhD

Linda Van Horn, PhD, RD

Martha L. Slattery, PhD, RD

Alex I. Kartashov, PhD

David S. Ludwig, MD, PhD

R ISK OF TYPE 2 DIABETES AND cardiovascular disease is affected by a number of medical and lifestyle factors. In recent years, increasing attention has been focused on a constellation of risk factors termed the insulin resistance syndrome (IRS), also known as the metabolic syndrome or syndrome X.[1,2] In this syndrome, obesity, insulin resistance, and hyperinsulinemia are thought to cause glucose intolerance, dyslipidemia (low serum high-density lipoprotein cholesterol (HDL-C), and high serum triglyceride concentrations), hypertension, and impaired fibrinolytic capacity.[3] An increasing incidence of IRS in all racial, ethnic, and social class groups in the United States can be inferred from the increasing prevalence of obesity[4,5] and type 2 diabetes[6-8] over the last 3 decades. Recently, this syndrome has been observed in youth,[9-11] and age-adjusted prevalence among adults has been estimated at 24%.[12] An increase in the prevalence of IRS may partly explain the recent plateau or increase in cardiovascular disease rates, after several decades of decline.[13]

Although various environmental influences, including smoking and physi-

Context Components of the insulin resistance syndrome (IRS), including obesity, glucose intolerance, hypertension, and dyslipidemia, are major risk factors for type 2 diabetes and heart disease. Although diet has been postulated to influence IRS, the independent effects of dairy consumption on development of this syndrome have not been investigated.

Objective To examine associations between dairy intake and incidence of IRS, adjusting for confounding lifestyle and dietary factors.

Design The Coronary Artery Risk Development in Young Adults (CARDIA) study, a population-based prospective study.

Setting and Participants General community sample from 4 US metropolitan areas of 3157 black and white adults aged 18 to 30 years who were followed up from 1985-1986 to 1995-1996.

Main Outcome Measure Ten-year cumulative incidence of IRS and its association with dairy consumption, measured by diet history interview.

Results Dairy consumption was inversely associated with the incidence of all IRS components among individuals who were overweight (body mass index $\geq$25 kg/m^2) at baseline but not among leaner individuals (body mass index <25 kg/m^2). The adjusted odds of developing IRS (2 or more components) were 72% lower (odds ratio, 0.28; 95% confidence interval, 0.14-0.58) among overweight individuals in the highest ($\geq$35 times per week, 24/102 individuals) compared with the lowest (<10 times per week, 85/190 individuals) category of dairy consumption. Each daily occasion of dairy consumption was associated with a 21% lower odds of IRS (odds ratio, 0.79; 95% confidence interval, 0.70-0.88). These associations were similar for blacks and whites and for men and women. Other dietary factors, including macronutrients and micronutrients, did not explain the association between dairy intake and IRS.

Conclusions Dietary patterns characterized by increased dairy consumption have a strong inverse association with IRS among overweight adults and may reduce risk of type 2 diabetes and cardiovascular disease.

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cal inactivity, are known to promote insulin resistance, the effect of dietary composition on IRS is poorly understood. For most of the past 3 decades, the US Department of Agriculture and the American Heart Association have

Author Affiliations: Department of Medicine, Children's Hospital, and Department of Pediatrics, Harvard Medical School (Drs Pereira and Ludwig), and Clinical Research Program, Children's Hospital (Dr Kartashov), Boston, Mass ; Division of Epidemiology, School of Public Health, University of Minnesota, Minneapolis, and Institute for Nutrition Research, University of Oslo, Oslo, Norway (Dr Jacobs); Department of Preventive Medicine, Northwestern University Medical School, Chicago, Ill (Dr Van Horn); University of Utah Medical School, Salt Lake City (Dr Slattery).

Corresponding Author and Reprints: Mark A. Pereira, PhD, Department of Medicine, Children's Hospital, 300 Longwood Ave, Boston, MA 02115 (e-mail: mark.pereira@tch.harvard.edu).

recommended low-fat diets in the prevention and treatment of cardiovascular disease. Recently, however, some have questioned these recommendations out of concern that high-carbohydrate consumption might promote IRS.[14-17] Other dietary factors that have been linked to components of IRS include the ratios of monounsaturated or polyunsaturated to saturated fatty acids,[15,18,19] dietary fiber,[20,21] and glycemic index.[22-24]

Dairy consumption is another dietary factor that might affect IRS. Milk intake has decreased significantly over the past 3 decades[25-27] as the prevalence of obesity and type 2 diabetes has increased. Epidemiologic and experimental studies suggest that dairy products may have favorable effects on body weight in children[28] and adults.[29-31] In addition, dairy and/or calcium may decrease the risk for hypertension,[32,33] coagulopathy,[34] coronary artery disease,[35,36] and stroke.[37,38] An inverse cross-sectional association between dairy intake and IRS was observed in men but not in women although the influence of physical activity, fruit and vegetable intake, and other lifestyle factors was not considered.[39] The purpose of this study was to examine, in a prospective fashion, the independent association between dairy consumption and IRS, after taking into account physical activity level, macronutrient and fiber intake, and other potentially confounding variables.

METHODS

The Coronary Artery Risk Development in Young Adults (CARDIA) Study is a multicenter population-based prospective study of cardiovascular disease risk factor evolution in a US cohort of black and white young adults. The 4 study centers are Birmingham, Ala; Chicago, Ill; Minneapolis, Minn; and Oakland, Calif. Stratification was used to obtain nearly equal numbers of individuals in each race, age group (age ranges, 18-24 and 25-30 years), and educational level (high school diploma and <high school diploma). Participants have been followed up for 15

years, with the present analyses including the first 10 years and 5 clinic examinations beginning with the baseline in 1985 and including 1987, 1990, 1992, and 1995. Fifty-one percent of 5115 eligible participants underwent the baseline examination. Participation has been excellent at approximately 80% through 1995. More details of the CARDIA Study design and its participants have been reported.[40]

Study Participants

From a total sample of 5115, we excluded from our analysis those who had no year 0 or year 7 dietary data (n=1175); had unusually high or low dietary intake values (<800 and >8000 cal/d for men; <600 and >6000 cal/d for women), consistent with CARDIA procedures (n=707); were pregnant at baseline or within 180 days of year 10 clinic examination (n=184); or were taking medications that affect blood lipid levels (n=87). Many participants belonged to more than 1 of these categories, leaving 3563 study participants. Two hundred sixty-five of these individuals had 2 or more components of the IRS at baseline, and 141 had missing IRS data, resulting in a final sample size of 3157. For stratified analyses, 923 of these individuals were overweight (body mass index [BMI] ≥25 kg/m²).

Standard questionnaires were used to maintain consistency in the assessment of demographic (age, sex, race, educational level) and behavioral (physical activity and cigarette smoking) information across CARDIA examination visits. The CARDIA Physical Activity History questionnaire[41] queries the amount of time per week spent in leisure, occupational, and household physical activities over the past 12 months. Physical activity level is summarized as units of total activity averaged from the baseline and year 7 examination. Educational level was quantified as the number of years of school completed by the year 10 examination, and cigarette smoking status as current vs other smoker at the baseline and year 7 examination.

Dietary Assessment

The CARDIA Diet History[42] queries usual dietary practices and obtains a quantitative food frequency of the past 28 days. Starting with the Western Electric dietary history as a model, the list of foods was expanded from 150 to approximately 700 items in the hope of developing a dietary assessment tool that would be suitable across various populations and ethnic groups. Liu et al[43] reported on the reliability and validity of the CARDIA Diet History in 128 young adults. The validity correlations between mean daily nutrient intakes from the CARDIA Diet History and means from 7 randomly scheduled 24-hour recalls were generally above 0.50.[43] The correlations of calorie-adjusted calcium intake ranged from 0.56 to 0.69 across race and sex groups. After correction for within-person variability, they ranged from 0.66 to 0.80.[43]

The University of Minnesota Nutrition Coordinating Center (NCC) tape 10 nutrient database was used at baseline[44] and tape 20 at year 7.[45] Foods containing dairy were identified by matching all CARDIA food codes to the entire NCC code listings for dairy products. We identified dairy products as any items reported during the diet history interview that were either 100% dairy (eg, milk) or included dairy as one of the main ingredients (eg, dips made with sour cream). We did not include mixed dishes or recipes when the contribution of dairy to the weight or caloric content of the item was unclear or likely to be minimal. The most frequently consumed dairy product at the baseline examination was milk and milk drinks, followed by butter, cream, and cheeses. Together these items comprised approximately 90% of dairy intake. Most of the remaining products were yogurts, dips, ice cream, and puddings and other dairy-based desserts. Weekly frequency of consumption for each food (times per week) was used to estimate relative intake per week for each food for each individual. In addition to using specific commonly consumed dairy foods, such as milk, as independent variables in our analyses, we

also performed analyses for various dairy food groups based on type of product and amount of fat. Milk was considered to be reduced fat if it consisted of 2% milk fat whereas cheeses and desserts were considered to be reduced fat if they had less than 15% milk fat (eg, reduced fat sour cream). The summation of dairy intake across all foods in the respective food groups was computed for each individual. To improve the accuracy of estimating habitual intake, we averaged the intake reported during the interviews of the baseline and year 7 examinations. Total dairy intake was classified into 5 categories. To ensure sufficient numbers in each race per dairy category, approximate quintile cut points from the dairy distribution of the total cohort were used. Therefore, when stratified by race or baseline overweight status, we did not have equal numbers of observations per category.

We also considered intake of other food groups that may confound associations between dairy intake and IRS. These food groups included fruits, nonstarchy and starchy vegetables, fruit juices, soft drinks and sugar-sweetened beverages, whole and refined grains, meat, and fish. In attempt to maximize our adjustment for lifestyle factors that may confound associations between dairy intake and IRS, we created a healthy propensity score based on the following lifestyle factors, coded as 0 for unhealthy, and 1 for healthy: cigarette smoking (nonsmoker, 1), physical activity (above median total activity score, 1), fruit and vegetable intake ($\geq$5 servings per day, 1), whole grain intake (above median intake level, 1), and soft drink consumption (below median intake level, 1). Thus, this healthy propensity score had a range of 0 (least healthy) to 5 (most healthy). We also created 2 groups among overweight individuals—those with a healthy propensity score below 3 (490/923) and those with a healthy propensity score of 3 or higher (433/923). Other dietary and nutrient measures from the CARDIA Diet History used in our analyses as potential confounders or mediators of our hypotheses included caloric intake; alcohol; fiber (grams per 1000 cal/d); caffeine (mg/d); percentage of calories from carbohydrates, protein, total fat, saturated and unsaturated fatty acids; and the micronutrients from supplements and foods including calcium, magnesium, sodium, potassium, and vitamin D.

Clinic Measurements

All clinic procedures were conducted in accordance with the CARDIA Study Manual of Operations. Participants were standing and dressed in light clothing without shoes for anthropometric measures. Body weight was measured to the nearest 0.2 kg with a calibrated balance beam scale. Height was measured with a vertical ruler to the nearest 0.5 cm. Body mass index was computed as weight in kilograms divided by height in meters squared. Waist and hips were measured with a tape in duplicate to the nearest 0.5 cm around the minimal abdominal girth and the maximal protrusion of the hips at the level of the symphysis pubica, respectively. Waist-hip ratio (WHR) was computed from the average of the 2 values for each respective measure.

Prior to each CARDIA examination participants were asked to fast and to avoid smoking and heavy physical activity for the final 2 hours. For the patients who did not fast for at least 8 hours prior to clinic examinations, data on triglycerides, insulin, and glucose were considered missing. Blood pressure was measured at each examination on the right arm using a Hawksley random 0 sphygmomanometer (WA Baum Co, Copaigue, NY) with the participant seated and following a 5-minute rest. Three measurements were taken at 1-minute intervals. Systolic and diastolic blood pressures were recorded as phase I and phase V Korotkov sounds.[46] The second and third measurements were averaged. Vacuum tubes containing no preservative were used to draw blood for insulin and glucose. Serum was separated by centrifugation at 4°C within 60 minutes, stored in cryovials and frozen at –70°C within 90 minutes until laboratory analysis. The radioimmunoassay for insulin required an overnight, equilibrium incubation and used a unique antibody that has less than 0.2% cross-reactivity to human proinsulin and its primary circulating split form Des 31,32 proinsulin (Linco Research, St Louis, Mo). Blind analysis of split serum samples resulted in a technical error of 16.6% of the mean, and $r=0.98$. Northwest Lipid Research Clinic Laboratory (Seattle, Wash), which is a participant in the Centers for Disease Control and Prevention standardization program, was used to measure all lipids. Triglyceride levels were estimated using enzymatic procedures, and HDL-C levels were measured according to the method of Warnick et al.[47] Although not a component of IRS, we also included low-density lipoprotein cholesterol as a separate independent variable to include a balanced view of risk factors for cardiovascular disease.

Insulin Resistance Syndrome

Abnormal glucose homeostasis was defined as a fasting plasma insulin concentration of at least 20 µU/mL (approximately the 90th percentile of the fasting insulin distribution), fasting glucose concentration of at least 110 mg/dL (6.1 mmol/L), or use of medications to control blood glucose. Obesity was defined as a BMI of at least 30 kg/m^2 or a WHR of at least 0.85 for women or 0.90 for men. Elevated blood pressure was defined as blood pressure of at least 130/85 mm Hg or use of antihypertensive medications.[48] Dyslipidemia was defined as low HDL-C ($\leq$35 mg/dL [$\leq$0.90 mmol/L]) or high triglyceride ($\geq$200 mg/dL [$\geq$2.26 mmol/L]) concentrations. Insulin resistance syndrome was defined as the presence of 2 or more of the 4 components: abnormal glucose homeostasis, obesity, elevated blood pressure, and dyslipidemia. If 2 components of IRS were positive, the individual was considered to have IRS, even if other components were missing. If 3 components were negative, the individual was not considered to have IRS even if the fourth

Table 1. Dairy Food Intake Medians by Race and Baseline Overweight Status in the Coronary Artery Risk Development in Young Adults (CARDIA) Study*

| | Median Intake Frequency, Times per Week | | | |
| | BMI <25 kg/m^2 | | BMI ≥ 25 kg/m^2 | |
Variables	Blacks (n = 906)	Whites (n = 1328)	Blacks (n = 503)	Whites (n = 420)
All dairy products	16.6	23.2	13.2	21.3
Reduced fat	2.4	9.3	2.3	9.3
High fat	12.2	11.2	8.8	10.4
Milk and milk drinks	5.7	8.2	4.0	7.8
Reduced fat	0.3	5.9	0.5	5.7
High fat	2.4	0.1	1.0	0.0
Cheese and sour cream	2.8	4.7	2.7	4.7
Reduced fat	0.2	1.2	0.1	1.2
High fat	2.3	3.0	2.2	3.0
Butter and cream	3.7	3.9	2.0	2.9
Desserts	1.0	1.0	0.7	0.8
Yogurt	0.0	0.5	0.0	0.3

*BMI indicates body mass index.

was missing. In all other cases of missing components, the IRS status was considered missing and the individual was not included in our analyses. To ensure true incident cases, baseline (year 0) cases of IRS were excluded from all analyses. When the outcome variable was an individual component of IRS (eg, obesity), we excluded from the analysis the baseline cases of this particular component.

Statistical Analysis

All analyses were performed using SAS statistical software version 8 (SAS Institute, Cary, NC). General linear regression models were used to compare the incidence of components of IRS and of IRS itself across categories of dairy intake. We used multiple logistic regression to evaluate associations between dairy consumption and the odds of developing IRS during the 10-year study after excluding all individuals who had IRS at baseline. Odds ratios (ORs) and their 95% confidence intervals (CIs) were computed for the second through fifth category of the respective dairy food group with the first category (lowest intake) as the referent group. A linear trend across categories was tested with contrast statements using orthogonal polynomial coefficients.[49] In addition to assessing the influence of potential confounders, models were constructed to evaluate micronutrients and macronutrients as possible physiologic mediators of the association between dairy intake and IRS. We evaluated whether adding these variables to the final regression models attenuated the strength of the association between dairy intake and risk factors and disease outcomes. We tested 2-way interactions based on a priori hypotheses about potential differences in the association between dairy intake and IRS by race and sex, and by baseline overweight (BMI <25 kg/m^2 vs ≥ 25 kg/m^2) status. Statistical significance was set at $P=.05$.

RESULTS

TABLE 1 presents total dairy intake and specific dairy food groups by race. Dairy intake was higher in whites than in blacks ($P<.001$), and this difference was generally consistent across the dairy subgroups. One exception was when dairy was classified according to amount of fat; whites tended to consume more reduced fat dairy products than blacks, whereas the reverse was true for higher fat dairy products. We also observed differential dairy intake according to baseline BMI, with overweight individuals consuming dairy products at a lower frequency than their

normal-weight counterparts ($P<.001$). These differences were larger for blacks than for whites. We observed a small decline in dairy intake of approximately 13% from the year 0 to the year 7 examination (-3.1 times per week, 95% CI, -3.7 to -2.4]), but change in dairy intake was not associated with baseline BMI (Pearson correlation coefficient, 0.02). Thus, any potential misclassification related to dairy consumption over time should not affect lean and obese individuals differently.

Demographic, lifestyle, and dietary correlates of dairy intake are shown in TABLE 2, with adjustment for age, sex, race, caloric intake, and study center. In comparison, the baseline characteristics of the 1552 participants excluded from the present analyses were generally similar although 64% were black and 46% were white. Higher dairy consumers were much less likely to be black and somewhat more likely to be women. Notably, dairy consumption was positively associated with whole grain, fruit, vegetable, saturated fat intake, and inversely associated with sugar-sweetened soft drink intake.

Ten-year cumulative incidence rates of each IRS component, as well as the IRS itself, are shown in TABLE 3 stratified by race and overweight status (BMI ≥ 25 kg/m^2). Incidence rates for all components were higher for individuals who were overweight at baseline. Blacks have higher rates of each component with the exception of dyslipidemia. The incidence of IRS (developing 2 or more components over 10 years) was nearly 4-fold higher in overweight blacks and nearly 5-fold higher in overweight whites compared with their normal-weight counterparts.

FIGURE 1 shows 10-year cumulative incidence of the 4 components of IRS by dairy categories stratified by baseline overweight status and adjusted for age, sex, race, caloric intake, study center, and baseline BMI as a continuous variable within each BMI category. There was a consistent reduction in incidence for each of the 4 components with increasing categories of dairy intake for overweight individu-

als only. Associations between dairy intake and these IRS components were much weaker and less consistent in normal-weight individuals. Although not part of IRS, we found no association between dairy intake and incidence of high LDL-C ($\geq$140 mg/dL [3.6 mmol/L], data not shown).

With IRS as the dependent variable, there was an interaction between dairy intake and baseline overweight status (P=.03). No association was observed between dairy intake and IRS incidence in those who were not overweight at baseline. Among overweight individuals of either race, incidence of IRS decreased by more than 50% from lowest to highest categories of dairy consumption. This association behaved in a dose-response manner and was monotonic for blacks. Associations between dairy intake and IRS were similar between races and sexes (P value for interaction terms >.10).

TABLE 4 includes ORs for IRS according to categories of total dairy intake. Because of the interaction between dairy intake and overweight status described above, we only present models for individuals who were overweight or obese at baseline. Model 1 includes basic demographic factors and BMI. We observed a substantial reduction in the odds of IRS over the 10-year period with increasing category of dairy intake. The reduction in odds was 71% (OR, 0.29, 95% CI, 0.14-0.58) for the highest category of dairy intake relative to the lowest category (P value for linear trend across all quintiles <.001). Among those who were not overweight or obese at baseline, the OR of IRS for those in the highest category of dairy intake was 0.72 (95% CI, 0.39-1.34, P for trend=.22).

In the adjusted models 2 and 3A involving overweight or obese individuals, we observed little evidence of confounding by other lifestyle and dietary factors. Confidence intervals became wider in model 3A due to the inclusion of many dietary variables, most of which are themselves nonsignificant predictors of IRS. Adjustment for the healthy propensity score revealed very

similar findings (OR for highest vs lowest category of dairy intake, 0.37; 95% CI, 0.18-0.79). In model 3B, we evaluated several macronutrients and micronutrients as possible mediators of the association between dairy intake and IRS. Results for models 2 and 3B are very similar, suggesting that these factors do not explain the inverse association between dairy intake and IRS incidence. Finally, in model 3C, we performed stepwise logistic regression for all dietary variables included in models 3A and 3B while forcing all demographic and nondietary lifestyle factors into the model. Other than dairy, fiber and protein were the only dietary variables with significant associations with IRS. Of particular note is the strong inverse association between dietary fiber intake and IRS (OR for each 3 g/1000–cal increment in fiber [ap-

Table 2. Adjusted Mean Values of Demographic and Dietary Factors by Level of Dairy Intake and Baseline Overweight Status*

	Median Intake Frequency, Times per Week					
	BMI <25 kg/m²			BMI ≥25 kg/m²		
Variables	0 to <10 (n = 366)	16 to <24 (n = 527)	≥35 (n = 463)	0 to <10 (n = 223)	16 to <24 (n = 214)	≥35 (n = 116)
Demographics						
Age, y	25.2	24.7	24.9	25.8	25.1	25.6
Black, %	67.9	41.2	16.4	85.8	41.7	16.3
Women, %	54.9	52.3	60.5	51.5	55.5	65.8
Education, y	14.9	15.2	15.1	14.4	14.8	15.6
Lifestyle						
Physical activity, units	354	402	409	324	381	392
Current smoker, %	27.9	21.8	26.3	26.8	24.7	25.9
Alcohol intake, mL/d	12.7	9.6	9.6	11.5	10.6	11.1
Dietary factors						
Saturated fat, % of daily calories	11.7	13.2	14.7	12.0	13.5	14.6
Carbohydrates, % of daily calories	49.0	48.5	47.3	47.0	46.5	47.0
Protein, % of daily calories	13.8	14.5	14.9	14.4	15.1	15.5
Calcium intake, mg/d	884	1172	1480	877	1133	1500
Soda intake, times/wk	6.5	5.0	3.6	6.4	4.5	3.3
Whole grain intake, times/wk	6.2	8.6	9.5	5.4	7.5	9.9
Fruits and vegetable intake, times/wk	21.4	23.1	23.7	20.4	22.5	23.4

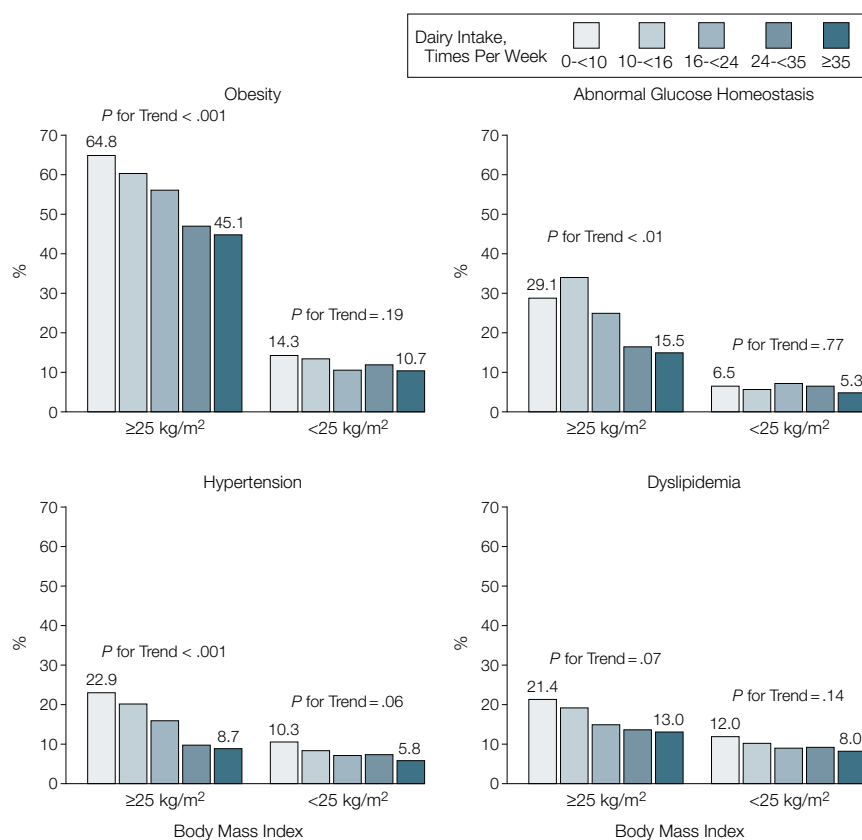*Means are adjusted for age, caloric intake, race, sex, and study center. The second and fourth dairy categories are omitted to conserve space. BMI indicates body mass index.

Table 3. Ten-Year Cumulative Incidence of the Insulin Resistance Syndrome and Its Components by Race and Baseline Overweight Status in the Coronary Artery Risk Development in Young Adults (CARDIA) Study

	No./Total (%)			
	BMI <25 kg/m²		BMI ≥25 kg/m²	
Variables	Black	White	Black	White
Obesity	116/818 (14.2)	129/1237 (10.4)	228/346 (65.9)	146/328 (44.5)
Body mass index ≥30 kg/m²	76/819 (9.3)	39/1237 (3.2)	207/347 (59.7)	121/328 (36.9)
Waist-hip ratio*	60/819 (7.3)	101/1239 (8.2)	69/348 (19.8)	76/328 (23.2)
Abnormal glucose homeostasis	74/646 (11.5)	35/1099 (3.2)	124/393 (31.6)	70/384 (18.2)
Elevated blood pressure	101/779 (13.0)	47/1201 (3.9)	113/545 (20.7)	50/431 (11.6)
Dyslipidemia	65/709 (9.2)	108/1114 (9.7)	58/486 (11.9)	91/385 (23.6)
Insulin resistance syndrome (≥2 components)	85/715 (11.9)	89/1160 (7.7)	170/412 (41.3)	123/367 (33.6)

*Men, ≥0.90; Women, ≥0.85. BMI indicates body mass index.

Figure 1. Ten-Year Cumulative Incidence of Insulin Resistance Syndrome Components by Categories of Total Dairy Intake With Stratification by Baseline Overweight Status

Rates are adjusted for age, study center, caloric intake, race, sex, and baseline body mass index.

proximate interquartile range], 0.66; 95% CI, 0.53-0.80). However, fiber was not a confounder of the association between diary and IRS. The strong and independent joint association of dairy and fiber intake with odds of IRS is shown in **FIGURE 2**. Odds of IRS for individuals in the lowest tertiles of both fiber and dairy were nearly 7-fold higher than those in the highest tertiles of both fiber and dairy intake. Dietary protein demonstrated a positive association with IRS incidence (OR for each 1% caloric increment of protein, 1.12; 95% CI, 1.04-1.21), and this association was due to animal rather than vegetable protein (data not shown). Although dietary calcium appeared to be inversely associated with IRS incidence in a model without dairy intake (OR for each 600-mg increment [approximate interquartile range], 0.79: 95% CI, 0.61-1.03), the association between calcium intake and IRS was entirely explained by adding dairy intake to the model (OR, 0.99; 95% CI, 0.76-1.29).

To examine the extent to which weight gain explains the association between dairy and IRS, we added 10-year weight gain to the final model as a continuous variable. In this model, the OR for the highest category of dairy in-

Table 4. Odds Ratios for Insulin Resistance Syndrome According to Dairy Intake Categories Among Overweight Individuals at Baseline*

	Weekly Dairy Intake, Odds Ratio (95% Confidence Interval)					
Independent Variables	0 to <10 (n = 219)	10 to <16 (n = 201)	16 to <24 (n = 212)	24 to <35 (n = 161)	≥35 (n = 116)	P for Trend
Model 1 Demographics†	1.00	1.15 (0.73-1.80)	0.58 (0.35-0.94)	0.41 (0.24-0.71)	0.29 (0.14-0.58)	<.001
Model 2 Demographics and nondietary lifestyle factors‡	1.00	1.19 (0.76-1.88)	0.62 (0.38-1.01)	0.45 (0.26-0.79)	0.32 (0.16-0.66)	<.001
Model 3A Demographics, nondietary lifestyle factors and dietary factors§	1.00	1.20 (0.75-1.93)	0.64 (0.38-1.08)	0.51 (0.28-0.94)	0.38 (0.17-0.83)	.002
Model 3B Demographics, nondietary lifestyle factors and components of dairy‖	1.00	1.19 (0.75-1.90)	0.59 (0.35-1.00)	0.43 (0.23-0.78)	0.31 (0.14-0.70)	<.001
Model 3C Demographics, nondietary lifestyle factors, and dietary fiber and protein¶	1.00	1.12 (0.71-1.78)	0.56 (0.34-0.92)	0.42 (0.24-0.75)	0.28 (0.14-0.58)	<.001

*Overweight is defined by body mass index of 25 kg/m² or more.
†Demographics include age, sex, race, calorie intake per day, study center, and baseline body mass index.
‡Nondietary lifestyle factors include educational level in years, daily alcohol intake by milliliters per day, current smoking status, units of daily physical activity, and use of vitamin supplement.
§Dietary factors include caloric percentage of daily polyunsaturated fat consumption, milligrams of daily caffeine intake, grams of fiber per 1000 calories, intake frequency of whole and refined grains, meat, fruit, vegetables, soda, and dietary intake of milligrams of magnesium and calcium and micrograms of vitamin D.
‖Components of dairy include caloric percentage of protein and saturated fat and dietary intake of milligrams of magnesium, calcium, and potassium and micrograms of vitamin D.
¶Based on a stepwise procedure with a P≤.10 for inclusion (demographic and lifestyle factors were forced into the model); fiber and protein were the only variables included.

take compared with the lowest category was 0.33 (95% CI, 0.16-0.72). This finding was similar when adjusting for weight gain as quintiles or deciles. We also stratified the sample by 10-year weight gain, based on a median split. In both weight gain strata, the odds of IRS were lowest for those with highest dairy intakes although CIs became wide because of the imbalance in the number of cases between these 2 groups.

As shown in **FIGURE 3**, the association between dairy intake and IRS incidence was very similar for both races and sexes. With the same covariates as in model 3C of Table 4, the odds of IRS associated with an increment of 1 daily eating occasion of dairy was 0.96 (95% CI, 0.73-1.28) for black men, 0.70 (95% CI, 0.54-0.91) for black women, 0.74 (95% CI, 0.59-0.93) for white men, and 0.62 (95% CI, 0.46-0.84) for white women.

In **TABLE 5**, ORs of the components of IRS and of IRS itself are shown for 1 daily increment (7/wk) of total dairy intake and of specific types of dairy. Odds were generally lower, and in most cases considerably reduced, with increasing intake of all types of dairy products. Inverse associations were observed for both reduced-fat and high-fat dairy products. Odds of obesity, abnormal glucose homeostasis, and elevated blood pressure were lower by nearly 20% for each daily eating occasion of total dairy products, and odds of IRS were lower by 21%. When a BMI of 30 kg/m^2 and a WHR of 0.90 for men and 0.85 for women were evaluated separately, odds of both were lower (OR, 0.81 for BMI; OR, 0.89 for WHR) with each daily increment of total dairy. The association between dairy intake and dyslipidemia was somewhat weaker. However, dairy intake appeared to be inversely associated with the odds of elevated triglyceride levels (OR, 0.79 for 1 daily increment of total dairy; 95% CI, 0.67-0.94) but not with low HDL-C (OR, 0.99; 95% CI, 0.87-1.12).
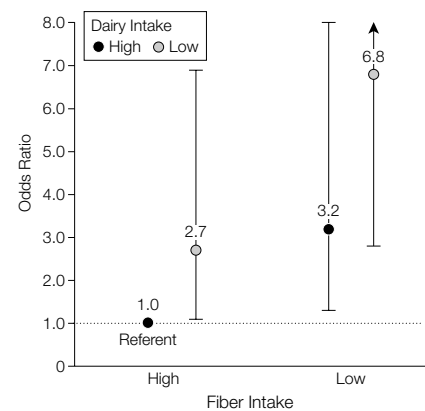
COMMENT

We observed inverse associations between frequency of dairy intake and the development of obesity, abnormal glucose homeostasis, elevated blood pressure, and dyslipidemia in young overweight black and white men and women. The 10-year incidence of the IRS was lower by more than two thirds among overweight individuals in the highest category of dairy consumption (≥5/d) compared with those in the lowest category (<1.5/d). These associations were not confounded by other lifestyle factors or dietary variables that are correlated with dairy intake and did not differ materially by race or sex.

The main limitation of our study is its observational nature. Therefore, we cannot rule out residual confounding, and we cannot conclude that increased dairy intake reduced the incidence of IRS in a causal manner. The strengths of the study include its longitudinal design, allowing us to exclude participants with existing IRS at baseline and to compare the 10-year cumulative incidence of IRS across dairy categories from the average of 2 comprehensive diet history interviews. Self-reported diet averaged over time should be a better estimate of habitual intake than a single measure.[50] Remaining errors in the measure of diet are likely to bias associations toward the null hypothesis (no association), resulting in an underestimation of the true magnitude of the association. Indeed, we observed somewhat stronger associations between dairy intake and IRS incidence when modeling the average dairy intake compared with the year 0 and year 7 dairy intake separately, although these differences were not large and do not materially affect the results or conclusions (data not shown). The diet history method was chosen for use in the CARDIA study because of its comprehensiveness, interviewer-administered format, suitable timeframe for capturing habitual diet without exacerbating recall error, and applicability to populations differing in social and cultural characteristics.
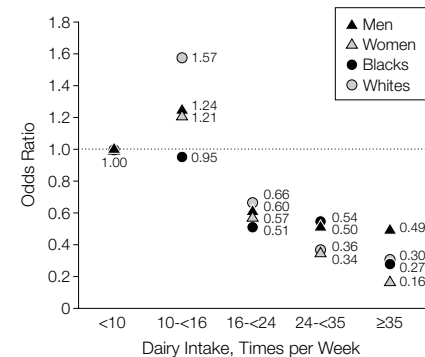
Although saturated fat contained in dairy products may raise LDL-C levels, there are several mechanisms by which dairy intake may protect

Figure 2. Joint Associations of Dairy Intake and Dietary Fiber With Insulin Resistance Syndrome (IRS) Incidence

Odds ratios for IRS are shown for high and low tertiles of the dairy and fiber distributions, after adjustment for age, sex, race, caloric intake, study center, baseline body mass index, educational level (years), alcohol intake, current smoker (yes/no), physical activity, vitamin supplement use (yes/no), and protein intake (% of daily calories). Error bars indicate 95% confidence intervals.

Figure 3. Race- and Sex-Stratified Models of Odds Ratios for Insulin Resistance Syndrome Incidence

Odds ratios are shown after adjustment for age, sex, race, caloric intake (cal/d), study center, baseline body mass index (kg/m^2), educational level (years), alcohol intake (mL/d), current smoker (yes/no), physical activity (units/d), vitamin supplement use (yes/no), fiber (g/1000 cal), and protein intake (% of daily calories).

against insulin resistance, obesity, and cardiovascular disease. Many single-nutrient studies, but not all,[51] suggest that calcium, potassium, and magnesium may lower the risk of hypertension,[32,33] coronary heart disease,[35,36] stroke,[37,38] or type 2 diabetes.[52] Other studies have suggested an intracellu-

Table 5. Odds Ratios for Components of Insulin Resistance Syndrome (IRS) per 1 Daily Eating Occasion of Specific Types of Dairy Products Among Individuals Who Were Overweight at Baseline*

Variables	Odds Ratio (95% Confidence Interval)				
	Obesity	Abnormal Glucose Homeostasis	Elevated Blood Pressure	Dyslipidemia	IRS
All dairy products	0.82 (0.72-0.93)	0.83 (0.73-0.95)	0.81 (0.71-0.93)	0.92 (0.82-1.04)	0.79 (0.72-0.88)
Reduced fat	0.84 (0.70-1.02)	0.95 (0.79-1.14)	0.79 (0.64-0.98)	0.95 (0.80-1.13)	0.78 (0.65-0.93)
High fat	0.84 (0.73-0.97)	0.77 (0.65-0.91)	0.84 (0.71-0.99)	0.91 (0.79-1.05)	0.82 (0.71-0.94)
Milk and milk drinks	0.83 (0.68-1.00)	0.84 (0.70-1.03)	0.80 (0.64-0.99)	0.91 (0.76-1.08)	0.74 (0.62-0.89)
Cheese and sour cream	0.82 (0.55-1.22)	0.96 (0.65-1.42)	0.67 (0.43-1.06)	1.23 (0.85-1.77)	0.64 (0.43-0.94)
Butter and cream	0.85 (0.72-1.02)	0.84 (0.69-1.03)	0.86 (0.70-1.05)	0.91 (0.76-1.08)	0.90 (0.76-1.05)
Dairy-based desserts	0.63 (0.24-1.64)	0.26 (0.09-0.80)	0.37 (0.12-1.13)	0.68 (0.26-1.79)	0.32 (0.13-0.83)
Yogurt	0.47 (0.16-1.43)	0.44 (0.12-1.62)	0.78 (0.22-2.72)	0.51 (0.15-1.72)	0.58 (0.20-1.66)

*Adjusted for all variables listed in Table 4.

lar role of calcium or other components of dairy products in body weight regulation,[30] a hypothesis supported by several,[28-31] but not all,[53] observational and experimental studies. In our study, the inverse association between calcium intake and IRS was entirely explained by dairy intake whereas the association between dairy consumption and IRS was not materially affected by adjustment for the intake of calcium or any other nutrients. It is also possible that the lactose, protein, and fat in dairy foods may enhance satiety and reduce the risk of overweight and obesity relative to other high-carbohydrate foods and beverages. However, adjustment for these nutrients also had no meaningful effect on the associations between dairy intake and the risk factors of the present study.

Alternative explanations for a possible effect of dairy on the development of IRS include alterations in dietary patterns associated with dairy intake (eg, low glycemic index[22-24]), presence in dairy of unrecognized biologically active components, or residual confounding by recognized dietary or lifestyle factors. Further observational and experimental work is needed to examine these possibilities.

The association between dairy intake and IRS was not observed in individuals who were not overweight (BMI <25 kg/m^2) at baseline of this 10-year study, perhaps because these individuals were protected from insulin resistance and obesity by other lifestyle or ge-

netic factors. Other epidemiologic studies of coronary disease or lipid levels have reported similar interactions between overweight status and dietary patterns related to insulin sensitivity.[22]

Changing dietary patterns may play an important role in the epidemics of obesity[4,5] and type 2 diabetes,[6,7] as well as the plateauing or increase in heart disease rates[13] in the United States in recent years. Trends in dietary intake behaviors over the past few decades have revealed decreasing intake of dairy products, especially milk, and increasing amounts of soda consumption and snacking among children and adolescents.[25-27,54] In summary, our study suggests that dietary patterns characterized by increased dairy consumption may protect overweight individuals from the development of obesity and the IRS, which are key risk factors[1,2] for type 2 diabetes and cardiovascular disease. Indeed, other major clinical trials and official nutritional recommendations would appear to be supportive of this dietary pattern.[55,56]

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