

# Dietary patterns matter: diet beverages and cardiometabolic risks in the longitudinal Coronary Artery Risk Development in Young Adults (CARDIA) Study<sup>1–3</sup>

Kiyah J Duffey, Lyn M Steffen, Linda Van Horn, David R Jacobs Jr, and Barry M Popkin

## ABSTRACT

**Background:** Although diet beverages are typically consumed to promote weight control, positive associations with increased cardiometabolic risk have been reported.

**Objective:** The objective was to examine the joint and independent association between dietary pattern and diet beverage consumption with 20-y cardiometabolic risk.

**Design:** We analyzed a prospective 20-y cohort of young adults from the Coronary Artery Risk Development in Young Adults (CARDIA) Study. With the use of cluster analysis, we identified 2 baseline (year 0) dietary patterns [Prudent (higher intakes of fruit, whole grains, milk, and nuts and seeds;  $n = 1778$ ) and Western (higher intakes of fast food, meat and poultry, pizza, and snacks;  $n = 2383$ )] and examined the interaction with diet beverage consumption (Consumers compared with Nonconsumers) by using proportional hazards regression models.

**Results:** Among Consumers, 66% were classified as having a Prudent diet. In fully adjusted models, being a Nonconsumer with a Prudent diet was independently associated with a lower risk of the metabolic syndrome through year 20. Lower risk in the Prudent than in the Western dietary pattern was maintained after stratification by diet beverage consumption: Prudent Nonconsumers had the lowest risk of high waist circumference (HR: 0.78; 95% CI: 0.62, 0.97), high triglycerides (HR: 0.72; 95% CI: 0.56, 0.93), and the metabolic syndrome (HR: 0.64; 95% CI: 0.50, 0.82) compared with Western Consumers.

**Conclusions:** Our results suggest that both overall dietary pattern and diet beverage consumption are important, to various degrees, for different metabolic outcomes. This covariation and interaction may partially explain differences in the relation between diet beverage consumption and cardiometabolic health observed in previous studies. *Am J Clin Nutr* 2012;95:909–15.

## INTRODUCTION

Several major longitudinal studies have reported that the consumption of diet beverages was linked to increased cardiometabolic risks (1–3). Currently, the American Diabetes Association and many weight-loss programs suggest these beverages as a means to reduce energy intake and therefore promote weight control and support weight loss, but the data supporting these recommendations are limited. Some corroborative evidence shows that the dietary habits of weight-loss maintainers include higher intakes of artificially sweetened beverages compared with persons who were always of normal weight (4), but there is still no consensus on the usefulness of

substituting artificial sweeteners for sugar in the context of weight control (5, 6).

Short-term laboratory-based studies of the appetitive effects of artificial sweeteners have produced mixed results (7–11), and energy compensation has been shown to be incomplete in some (9, 12–14) but not all (15, 16) studies that used diet food and beverage products. In several widely cited observational epidemiologic studies (noted above), at least daily consumption of diet soda was associated with a greater risk of incident metabolic syndrome (1–3) and type 2 diabetes (3) and almost doubled risk of overweight or obesity (17). In these studies, diet beverage intake may be confounded with food patterns consumed by diet beverage drinkers, because a recent study showed that diet modifies the effect of cardiometabolic risk (18). Our objective was to examine how distinctly different dietary patterns may affect the association of diet beverage consumption with the risk of incident cardiometabolic outcomes, including the metabolic syndrome.

<sup>1</sup> From the Department of Nutrition, Gillings Global School of Public Health (KJD and BMP), and the Carolina Population Center (BMP), University of North Carolina at Chapel Hill, Chapel Hill, NC; the Department of Preventive Medicine, Feinberg School of Medicine, Northwestern University, Chicago, IL (LVH); the Division of Epidemiology and Community Health (LMS) and the Department of Epidemiology (DRJ), School of Public Health, University of Minnesota, Minneapolis, MN; and the Department of Nutrition, University of Oslo, Oslo, Norway (DRJ).

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<sup>3</sup> Address correspondence and reprint requests to KJ Duffey, Department of Nutrition, University of North Carolina at Chapel Hill, University Square, CB 8120, 123 West Franklin Street, Chapel Hill, NC 27516-3997. E-mail: kduffey@unc.edu.

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## SUBJECTS AND METHODS

### Study population

The CARDIA<sup>4</sup> study is a prospective study of the evolution of cardiovascular disease risk. Baseline recruitment procedures were designed to balance age, sex, ethnicity, and education groups within each of 4 study sites (Birmingham, AL; Oakland, CA; Minneapolis, MN; and Chicago, IL). A total of 5115 young adults (aged 18–30 y) completed the baseline survey (1985–1986). Follow-up examinations were conducted 2, 5, 7, 10, 15, and 20 y after baseline with retention rates of 91%, 86%, 81%, 79%, 74%, and 72%, respectively. Detailed descriptions of the sampling plan and cohort characteristics are described elsewhere (19, 20). The data used for this study were from baseline (year 0) for diet and covariates and from all follow-up exams for the outcome variables. The full analytic sample included surviving cohort members who had complete outcome and covariate data ( $n = 4161$ ). Depending on the outcome variable under analysis, we excluded persons whose year 0 data indicated prevalent high WC ( $n = 404$ ), elevated BP ( $\geq 130/\geq 85$  mm Hg or taking medication for elevated BP;  $n = 411$ ), low HDL cholesterol ( $n = 1288$ ), high fasting glucose ( $n = 743$ ), high triglycerides ( $n = 262$ ), and the metabolic syndrome ( $n = 155$ ). The final sample sizes (fully adjusted models) varied by outcome as follows: high WC ( $n = 3524$ ), elevated BP ( $n = 3500$ ), low HDL cholesterol ( $n = 2699$ ), high triglycerides ( $n = 3602$ ), high fasting glucose ( $n = 3664$ ), and the metabolic syndrome ( $n = 3728$ ). CARDIA was approved by the local institutional review board at each center, and all participants provided written informed consent. All analyses were conducted in accordance with the ethical standards of the University of Chapel Hill.

### Measurement of dietary intake and diet beverage consumption

Dietary intake was assessed at baseline by using the validated (21) interviewer-administered CARDIA Diet History questionnaire (22), which asks about general dietary practices. It was followed by a quantitative diet history, which ascertained information about consumption over the previous month. Foods and beverages from the baseline diet history were categorized by using the Nutrition Coordinating Center (Minneapolis, MN) algorithm into 43 food groups (measured as energy per day from food group). We used the “diet beverages” food group (measured as servings per day, because diet beverages have no calories) to identify baseline consumers of diet beverages. Those who consumed diet beverages are hereafter referred to as Consumers, whereas those who did not consume diet beverages are referred to as Nonconsumers. The remaining 42 food groups were converted to continuous standardized  $z$  scores of percentage of energy (kcal) and were used to derive dietary patterns via cluster analysis (23).

### Dietary patterns: cluster development

Cluster analysis was performed in the pooled sample on the 42 baseline food groups, which excluded diet beverages (Stata

CLUSTER, version 11.0; StataCorp). The purpose of cluster analysis is to place individuals into mutually exclusive groups (clusters) as suggested by the data and not defined a priori. Thus, individuals in a given cluster are distinctly similar to one another and distinctly different from individuals in other clusters with respect to the average dietary consumption of the set of food groups. This method has been used in previous studies of dietary and beverage patterns (23–27).

Stata's kmeans partition CLUSTER command uses Euclidean distances to create cluster centroids based on least-squares estimation over 10,000 iterations. Iterations that produced the largest  $r^2$  values indicated the best fit for the data and maximized the inter- to intracluster variability ratio (28).

To determine the most appropriate cluster solution, comparisons of cluster membership were made across increasingly complex cluster solutions: increasing from 2 to 5 clusters. To maintain within-cluster reliability, a cluster could contain no less than 5% of the sample. Increasingly complex cluster solutions (a larger number of clusters) did not break the original 2 clusters into meaningful subgroups, so the 2-cluster solution was favored. These represented the most robust patterns and maximized intercluster variability and intracluster correlation. Interpretation of the clusters was aided by comparing and describing the entire distribution of all food groups in a given cluster. A complete list of variables and  $z$  score values (each computed centered on whole-sample means and divided by whole sample SDs) for clusters is available elsewhere (*see* Supplemental Table 1 under “Supplemental data” in the online issue). Clustering on food groups averaged across exam year 0 and year 7 did not change our results; thus, only baseline clusters are presented herein.

### Definition and components of the metabolic syndrome

The metabolic syndrome was considered present at any examination in which  $\geq 3$  of the following individual components were documented: WC  $> 35$  inches ( $> 88$  cm) for women or  $> 40$  inches ( $> 102$  cm) for men, fasting blood glucose  $\geq 100$  mg/dL ( $\geq 6.1$  mmol/L) or use of diabetes medication, BP  $\geq 130/\geq 85$  mm Hg or use of antihypertensive medication, serum triglycerides  $\geq 150$  mg/dL ( $\geq 1.7$  mmol/L) or use of cholesterol-lowering medication, or HDL cholesterol  $< 50$  mg/dL ( $< 1.3$  mmol/L) in women or  $< 40$  mg/dL ( $< 1.03$  mmol/L) in men or use of cholesterol-lowering medication (29). Standardized methods were used to collect these cardiometabolic variables and are described in detail elsewhere (30–32). Participants were asked to fast for  $\geq 12$  h and to refrain from smoking and physical activity for  $\geq 2$  h before the measurement. We excluded individuals who fasted for  $< 8$  h. Lipids, glucose, and insulin were assayed in fasting blood samples according to standardized CARDIA procedures (19). Glucose was measured by using hexokinase coupled to glucose-6-phosphate dehydrogenase. Measured height (nearest 0.5 cm), weight (nearest 0.1 kg), and WC (average of 2 measures at the minimum abdominal girth; nearest 0.5 cm) were collected by trained technicians. Seated BP (mm Hg) was measured 3 times after a 5-min rest; we used the average of the last 2 measurements. Metabolic syndrome components were assessed at each examination (except at years 2 and 5 for plasma glucose).

<sup>4</sup>Abbreviations used: BP, blood pressure; CARDIA, Coronary Artery Risk Development in Young Adults; WC, waist circumference.

**TABLE 1**Differences in baseline characteristics between subjects with Prudent and Western dietary patterns by diet beverage consumption status<sup>1</sup>

	Diet beverage			
	Consumers		Nonconsumers	
	Prudent (n = 613)	Western (n = 312)	Prudent (n = 1165)	Western (n = 2071)
<b>Sociodemographic characteristics</b>				
Female (%)	75.2 ± 1.7	53.8 ± 2.8 <sup>2</sup>	56.2 ± 1.5 <sup>3</sup>	45.2 ± 1.1 <sup>2,3</sup>
Black (%)	15.2 ± 1.5	35.3 ± 2.7 <sup>2</sup>	41.7 ± 1.4 <sup>3</sup>	72.6 ± 1.0 <sup>2,3</sup>
Age (y)	25.7 ± 0.13	25.1 ± 0.20 <sup>2</sup>	25.3 ± 0.1 <sup>3</sup>	24.2 ± 0.8 <sup>2,3</sup>
<b>Education (%)</b>				
< High school	2.6 ± 0.6	6.7 ± 1.4 <sup>2</sup>	6.0 ± 0.7 <sup>3</sup>	14.5 ± 0.8 <sup>2,3</sup>
High school	15.0 ± 1.4	21.2 ± 2.3 <sup>2</sup>	24.8 ± 1.3 <sup>3</sup>	38.5 ± 1.1 <sup>2,3</sup>
Some college	29.2 ± 1.8	33.7 ± 2.7	33.2 ± 1.4	33.6 ± 1.0
College	53.2 ± 2.0	38.5 ± 2.8 <sup>2</sup>	36.0 ± 1.4 <sup>3</sup>	13.4 ± 0.7 <sup>2,3</sup>
<b>Family structure (%)</b>				
Single	58.5 ± 2.0	62.3 ± 2.8	54.8 ± 1.5	56.7 ± 1.1
Married	24.8 ± 1.8	14.5 ± 2.0 <sup>2</sup>	19.2 ± 1.2 <sup>3</sup>	10.5 ± 0.7 <sup>2</sup>
Single with children	4.8 ± 0.9	6.1 ± 1.4	8.0 ± 0.8 <sup>3</sup>	13.2 ± 0.7 <sup>2,3</sup>
Married with children	12.0 ± 1.3	17.1 ± 2.1 <sup>2</sup>	17.9 ± 1.1 <sup>3</sup>	19.7 ± 0.9
<b>Health behaviors</b>				
Physical activity (EU/wk)	482 ± 11	402 ± 17 <sup>2</sup>	452 ± 9 <sup>3</sup>	398 ± 7 <sup>2</sup>
<b>Smoking status (%)</b>				
Former	20.0 ± 1.6	11.9 ± 1.8 <sup>2</sup>	17.0 ± 1.1	8.5 ± 0.6 <sup>2</sup>
Current	17.6 ± 1.5	31.0 ± 2.6 <sup>2</sup>	24.3 ± 1.3 <sup>3</sup>	37.2 ± 1.1 <sup>2,3</sup>
Never	62.4 ± 2.0	57.1 ± 2.8	58.7 ± 1.4	54.3 ± 1.1 <sup>2</sup>
<b>Anthropometric measures</b>				
BMI (kg/m <sup>2</sup> )	24.4 ± 0.18	26.3 ± 0.31 <sup>2</sup>	24.0 ± 0.14	24.5 ± 0.12 <sup>2,3</sup>
Overweight (%)	25.2 ± 1.8	32.3 ± 2.7 <sup>2</sup>	19.9 ± 1.2 <sup>3</sup>	23.6 ± 0.9 <sup>2,3</sup>
Obese (%)	0.9 ± 1.2	19.7 ± 2.3 <sup>2</sup>	1.0 ± 0.9	12.0 ± 0.7 <sup>2,3</sup>
Waist circumference (cm)	76.0 ± 0.4	82.4 ± 0.7 <sup>2</sup>	76.9 ± 0.3	78.1 ± 0.26 <sup>2,3</sup>
<b>BP and lipids</b>				
Glucose (mg/dL)	84.0 ± 1.0	83.9 ± 1.2	82.8 ± 0.3	82.0 ± 0.3
Triglycerides (mg/dL)	69.8 ± 1.5	91.1 ± 5.0 <sup>2</sup>	70.5 ± 1.2	72.8 ± 1.0 <sup>3</sup>
HDL cholesterol (mg/dL)	55.4 ± 0.6	50.7 ± 0.7 <sup>2</sup>	53.6 ± 0.4	52.7 ± 0.3 <sup>3</sup>
Systolic BP (mm Hg)	107.4 ± 0.4	110.6 ± 0.6 <sup>2</sup>	110.4 ± 0.3	111.6 ± 0.2 <sup>2</sup>
Diastolic BP (mm Hg)	67.8 ± 0.4	69.3 ± 0.5 <sup>2</sup>	68.8 ± 0.3	68.7 ± 0.2

<sup>1</sup> All values are means ± SEs. Consumers reported any consumption of diet beverages, and Nonconsumers reported no diet beverage consumption. BP, blood pressure; EU, exercise units.

<sup>2</sup> Significantly different from Prudent ( $P < 0.05$ , Student's  $t$  test for continuous variables or chi-square tests for categorical variables) within the diet beverage consumption group (ie, Consumers or Nonconsumers) and in the pooled sample.

<sup>3</sup> Significantly different from Consumers ( $P < 0.05$ , Student's  $t$  test for continuous variables or chi-square tests for categorical variables) within dietary pattern (ie, Prudent or Western dietary pattern).

## Covariates

Data on baseline sociodemographic characteristics and selected health behaviors were collected via self-report by using standardized questionnaires. The variables included race, sex, age, smoking status (current, former, or never), and highest education completed (continuous in years). A physical activity score, assessed by using the CARDIA physical activity questionnaire (33), was computed by multiplying the frequency of participation by the intensity of the activity and is reported as exercise units per week (most exercise captured is leisure-time physical activity). Family structure was defined by marital status and whether or not there were children living at home (single/married or with/without children). A measure of total energy intake was calculated by summing calories from all foods and beverages reported on the dietary-history questionnaire.

## Statistical analysis

Baseline sociodemographic and anthropometric characteristics and energy from selected food groups were compared across dietary patterns by using Student's  $t$  tests (continuous variables) or chi-square tests (categorical variables);  $P < 0.05$  indicated statistical significance. We examined the relation between dietary pattern, diet beverage consumption, and health by using 6 separate proportional hazards models of metabolic outcome (high WC, high fasting glucose, high triglycerides, low HDL cholesterol, elevated BP, and metabolic syndrome) on baseline dietary pattern, diet beverage use, or both. Time of occurrence of the outcome variables was set to 2, 5, 7, 10, 15, or 20 y after baseline, depending on when the outcome was first detected; those who never had the outcome condition were censored at the last visit they attended. We adjusted for important baseline covariates, including sex; age; CARDIA exam

**TABLE 2**Association between dietary pattern and diet beverage consumption with 20-y cardiometabolic outcomes<sup>1</sup>

	High WC (n = 3524)	High fasting glucose (n = 3664)	Low HDL-C (n = 2699)	High TGs (n = 3602)	High BP (n = 3500)	Metabolic syndrome (n = 3728)
Prudent compared with Western pattern	0.92 (0.80, 1.06)	0.93 (0.80, 1.09)	0.87 (0.75, 0.99) <sup>2</sup>	0.78 (0.67, 0.92) <sup>2</sup>	0.84 (0.73, 0.98) <sup>2</sup>	0.77 (0.66, 0.91) <sup>2</sup>
Nonconsumer compared with Consumer	0.84 (0.73, 0.97) <sup>2</sup>	1.07 (0.91, 1.26)	1.02 (0.88, 1.18)	0.92 (0.78, 1.08)	1.00 (0.85, 1.17)	0.81 (0.69, 0.95) <sup>2</sup>

<sup>1</sup> All values are HRs (95% CIs) derived from proportional hazards models adjusted for race; sex; CARDIA study center; baseline age, BMI, smoking status, family structure, total energy (kcal/d), and physical activity (exercise units/wk); maximum education reported during the study (in y); and either diet beverage consumption (in dietary pattern model) or dietary pattern (in diet beverage consumption model). BP, blood pressure; CARDIA, Coronary Artery Risk Development in Young Adults; HDL-C, HDL cholesterol; TGs, triglycerides; WC, waist circumference.

<sup>2</sup> Significantly different from zero,  $P < 0.05$ .

center; baseline weight, total physical activity, total energy intake, smoking status, and family structure; and maximum years of education attained ever during the study. Diet cluster membership was interacted with diet beverage consumption by adding a product term, with Consumers with a Western dietary pattern as the common referent group. Effect estimates were also generated comparing Prudent and Western dietary patterns within strata of Consumers and Nonconsumers. No sex-based or racial-ethnicity-based differences in the relations were detected.

## RESULTS

### Clustering

Clustering showed 2 distinct baseline dietary pattern groups: one that consumed foods that are typically considered part of a Prudent diet, such as fruit, fish, and whole grains, and one that consumed foods that typify a less healthy Western diet, such as fast foods, refined grains, and sugar-sweetened soda. Briefly, the meats and poultry group most differentiated the 2 dietary patterns, with an absolute difference in  $z$  scores of 0.935. Next highest was low-fat whole grains, with a difference of 0.819. Eleven food groups had an absolute difference in  $z$  scores of  $\geq 0.500$ , including whole and refined low-fat grains, high-fat refined grains, fats, fast food, fruit, cheese, and regular (nondiet) soda. A full list of  $z$  scores in increasing order of difference is available in the online supporting information (*see* Supplemental Table 1 under “Supplemental data” in the online issue).

The Prudent diet group constituted 42.7% and the Consumers constituted 22.2% of the total sample (total  $n = 4161$ ). Among persons with a Prudent dietary pattern, 34.5% were Consumers compared with 13.1% among the Western dietary pattern group. Consumers were more likely to be in the Prudent (66.2%) than in the Western (36.0%) diet group (*see* Supplemental Table 2 under “Supplemental data” in the online issue). In both dietary patterns, Nonconsumers reported a greater amount of energy from both more healthy (nuts and seeds, vegetables, and milk;  $P < 0.05$ ) and less healthy [high-fat refined grains and regular (sugar-sweetened) soda;  $P < 0.05$ ] food groups. Nonconsumers in the Western dietary pattern also consumed a greater amount of energy from snacks and fast food than did Consumers of the Western dietary pattern, whereas Nonconsumers of the Prudent dietary pattern consumed more energy from fruit and low-fat refined grains (*see* Supplemental Table 2 under “Supplemental data” in the online issue). Total energy intake was higher for

Nonconsumers than for consumers in both the Prudent and Western dietary pattern groups.

In the pooled sample (ie, no regard to diet beverage consumption status), persons with a Prudent dietary pattern were more often female, white, college educated, and smokers and self-reported greater amounts of physical activity. They also tended to have lower BMIs, dramatically lower percentages of overweight and obesity, and higher HDL-cholesterol concentrations than persons in the Western dietary pattern (*see* Supplemental Table 3 under “Supplemental data” in the online issue). Within both dietary patterns, Consumers were more likely to be females who were white, to be older, and to have a college education; tended to be nonsmokers; and had a higher percentage of baseline overweight (**Table 1**). Consumers (compared with Nonconsumers) in the Prudent dietary pattern also had higher levels of self-reported physical activity. Consumers (compared with Nonconsumers) in the Western dietary pattern had higher BMIs, higher percentage baseline obesity, larger WCs, lower triglyceride concentrations, and higher HDL-cholesterol concentrations (Table 1).

### Prediction of outcomes (ever by year 20)

Without consideration of diet beverage consumption, there was a significantly lower risk of the metabolic syndrome and its components (low HDL cholesterol, high triglycerides, and elevated BP) in the Prudent diet group than in the Western diet group, with nonsignificantly lower point estimates of risk of high WC and high fasting glucose (**Table 2**). Without consideration of dietary pattern, Nonconsumers had a significantly lower risk (compared with Consumers) of the metabolic syndrome, but there was no consistency observed among its components (significantly lower risk was observed for high WC only). Analysis of joint dietary pattern and diet beverage consumption found a statistically significant interaction in the prediction of high fasting glucose, low HDL cholesterol, and high BP (**Table 3**).

The predicted patterns for the individual components of the metabolic syndrome are less consistent. Consumers with a Prudent dietary pattern had the lowest risk of high fasting glucose (HR: 0.75; 95% CI: 0.57, 0.99) and low HDL cholesterol (HR: 0.69; 95% CI: 0.54, 0.87), which were significantly different from the Western Consumers. Nonconsumers with a Prudent dietary pattern, on the other hand, had lower risks of high WC and high triglycerides than did Consumers with a Western dietary pattern. Western Consumers and Prudent Nonconsumers were not

**TABLE 3**Joint associations between dietary pattern and diet beverage consumption with 20-y cardiometabolic outcomes<sup>1</sup>

	High WC (n = 3524)	High fasting glucose (n = 3664)	Low HDL-C (n = 2699)	High TGs (n = 3602)	High BP (n = 3500)	Metabolic syndrome (n = 3728)
Western Consumers	1.0	1.0	1.0	1.0	1.0	1.0
Western Nonconsumers	0.85 (0.70, 1.04)	0.92 (0.74, 1.16)	0.85 (0.70, 1.05)	0.93 (0.74, 1.18)	1.21 (0.97, 1.53)	0.85 (0.69, 1.07)
Prudent Consumers	0.93 (0.73, 1.17)	0.75 (0.57, 0.99) <sup>2</sup>	0.69 (0.54, 0.87) <sup>2</sup>	0.80 (0.61, 1.05)	1.14 (0.87, 1.51)	0.84 (0.64, 1.10)
Prudent Nonconsumers	0.78 (0.62, 0.97) <sup>2</sup>	0.92 (0.73, 1.18)	0.81 (0.65, 1.01)	0.72 (0.56, 0.93) <sup>2</sup>	0.92 (0.72, 1.19)	0.64 (0.50, 0.82) <sup>2</sup>
<i>P</i> -interaction	0.943	0.066	0.017	0.851	0.010	0.460

<sup>1</sup> All values are HRs (95% CIs) derived from proportional hazards models of cardiometabolic outcome on dietary pattern, diet beverage consumption status, and the interaction of dietary pattern with diet beverage consumption, adjusted for race; sex; CARDIA study center; baseline age, BMI, smoking status, family structure, total energy (kcal/d), and physical activity (exercise units /wk); and maximum education reported during the study (in y). BP, blood pressure; CARDIA, Coronary Artery Risk Development in Young Adults; HDL-C, HDL cholesterol; TGs, triglycerides; WC, waist circumference.

<sup>2</sup> Significantly different from the Western Consumer group, *P* < 0.05.

statistically different with respect to high fasting glucose, low HDL cholesterol, and high BP (Table 3).

Findings were similar for unadjusted (**Figure 1**) and adjusted (Table 3) relations. Generally, Consumers with a Western dietary pattern had the highest percentage of the sample with the outcome ever by year 20, whereas the Prudent dietary pattern had the lowest (with the lowest percentage varying between Consumers and Nonconsumers by metabolic outcome). The largest exception was that the nearly identical unadjusted percentages (rates) of elevated BP between Consumers and Nonconsumers with a Prudent dietary pattern were altered with adjustment, such that the Consumers with a Prudent dietary pattern had a higher HR of elevated BP than did Nonconsumers.

## DISCUSSION

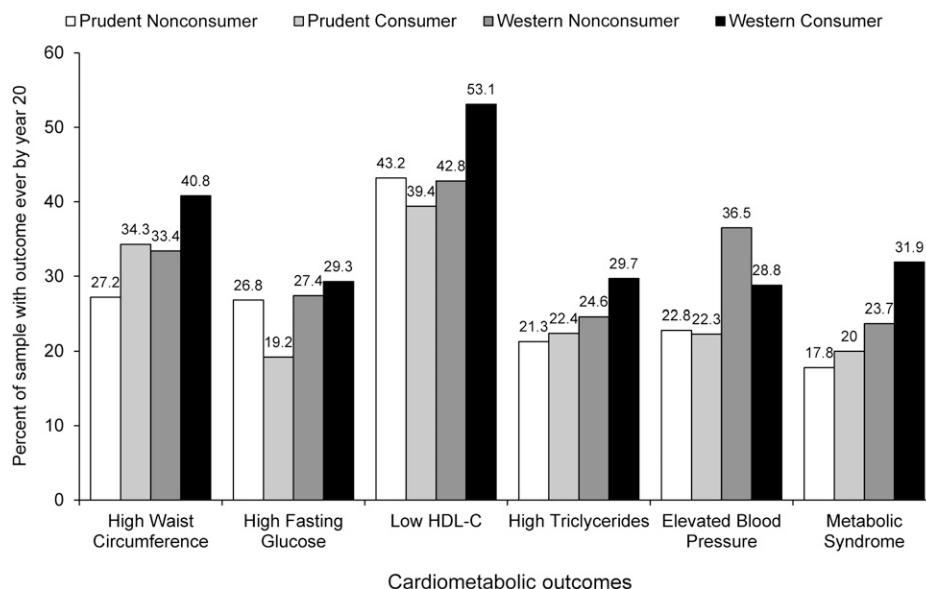
To our knowledge this is the first study to specifically examine the interplay between dietary patterns and diet beverage consumption in prospective prediction of cardiometabolic health outcomes. Overall, a Prudent dietary pattern showed a lower risk of incident metabolic syndrome and each of its components than did a Western dietary pattern. Nonconsumers (compared with consumers) also had a lower risk of incident metabolic syndrome, but associations with the components of the metabolic syndrome were inconsistent. Furthermore, persons with a Prudent dietary pattern were more likely (compared with persons with a Western dietary pattern) to consume diet beverages. Looking jointly at dietary pattern and diet beverage consumption, it is clear that a Prudent dietary pattern is consistently associated with lower risk and being a diet beverage Nonconsumer sometimes, but not always, additionally lowers that risk.

Specifically, we found that persons with a Western dietary pattern who were diet beverage Consumers had a higher risk of cardiometabolic outcomes, except for elevated BP, than did the other 3 groups. Nonconsumers with a Prudent dietary pattern had a lower risk of the metabolic syndrome, a high WC, and high triglycerides (compared with Consumers with a Western dietary pattern), but Consumers with a Prudent dietary pattern had a lower risk of high fasting glucose and low HDL cholesterol. Although both a Prudent dietary pattern and being a diet beverage Nonconsumer were associated with a lower risk of incident metabolic syndrome, our results suggest that dietary pattern and diet beverage consumption interact in predictions of cardiometabolic risks and should be examined jointly.

Previous studies have examined the relation between consumption of diet beverages and cardiometabolic outcomes (1, 3). Nettleton et al (3) reported that at least daily consumption of diet beverages was associated with an increased risk of incident metabolic syndrome (HR: 1.36; 95% CI: 1.11, 1.66) in an older sample of adults (3). Similarly, there was a 53% increase in the odds of incident metabolic syndrome (OR: 1.53; 95% CI: 1.10, 2.15) among older men and women in the Framingham Study (1). Each of these studies, however, had minimal control for confounding by diet: models adjusted for total energy intake (kcal) (3) or total energy intake (kcal) plus consumption of saturated fat, *trans* fat, and fiber (1). None of these studies considered the possibility of interaction.

An important new study by de Koning et al (18) found that an observed association between intake of artificially sweetened beverages and an increased risk of type 2 diabetes is attenuated and no longer statistically significant after multivariate adjustment for detailed measures of family history, previous weight change, dieting, Healthy Eating Index score, and total energy intake in a comparison of the top with the bottom quartile of intake (HR: 1.09; 95% CI: 0.98, 1.21; *P*-trend = 0.13). Although de Koning et al addressed possible confounding by diet more completely than did other studies, their results still could have missed important interactions between dietary pattern and diet beverage consumption, as our study shows. Inclusion of diet beverages in the creation of dietary patterns in our study would likely have resulted in an attenuation of the influence of eating a Prudent diet on cardiometabolic outcomes, which suggests that dietary pattern and diet beverage consumption should be examined independently from one another.

Our study is not without limitations. First, the use of observational, self-reported dietary data precluded us from ruling out residual confounding or making conclusive statements about a possible causal relation between overall dietary patterns and cardiometabolic risk among consumers of diet beverages. Retrospective self-report data are also subject to recall and response bias, which can lead to differential misclassification of dietary intake and is particularly problematic if subgroups of the sample (ie, blacks and whites) differentially report intake. It is also well known that overweight individuals are prone to underreporting energy intake and overreporting physical activity (34). Second, it is possible that persons meeting just 2 baseline criteria for metabolic syndrome were advised to make dietary changes. Because we did not exclude these persons from our analyses, it is



**FIGURE 1.** Age-adjusted cumulative distributions of year 20 cardiometabolic outcomes stratified by dietary pattern and diet beverage consumption status. The values represent the percentage of persons with the outcome shown ever by year 20. The number of observations in age-adjusted distributions varied by outcome as follows: high waist circumference ( $n = 3524$ ), high fasting glucose ( $n = 3664$ ), low HDL cholesterol ( $n = 2699$ ), high triglycerides ( $n = 3602$ ), elevated blood pressure ( $n = 3500$ ), and the metabolic syndrome ( $n = 3728$ ). HDL-C, HDL cholesterol.

possible that our results are slight underestimations of the association between dietary pattern, diet beverage consumption, and cardiometabolic risk. This would be an interesting question to examine with a little larger sample size; <10% of this sample met just 2 criteria (results not reported elsewhere). Finally, our group of Nonconsumers included persons who consume beverages that have been negatively associated with several of the metabolic outcomes examined (eg, sugar-sweetened beverages) and beverages that are arguably healthier (eg, water). This likely had a small effect on our results; however, because most of the Nonconsumers consumed these healthier beverages. For example, at baseline, 53% of the sample consumed water but not sugar-sweetened soda, 6.3% consumed sugar-sweetened soda but not water, and 7.3% consumed both (data not shown elsewhere).

Although the CARDIA Diet History and food-frequency questionnaire have been shown to be valid and reliable instruments, nutrient and energy estimates had larger variability among blacks than among whites (21, 22). Finally, our analyses are limited to the baseline (1985–1986) measure of Consumers; thus, our numbers are small compared with recent estimates, which show considerable increases in diet beverage consumption in the United States over the past decade (5). However, this is also a strength, because it shows that a behavior that was in place by age 18–30 y predicted metabolic outcomes as far as 20 y into the future. Furthermore, there was considerable stability in dietary patterning and diet beverage consumption across time (73% of the baseline sample consumed the same dietary pattern at year 7, 78% of whom consumed the same dietary pattern at year 20; data not shown elsewhere), which suggests that baseline measures are relatively good proxies for later behaviors.

In conclusion, our study found that dietary pattern and diet beverage consumption were each independently associated with incident metabolic syndrome and high WC. Consumption of diet beverages in the context of a Western dietary pattern was gen-

erally associated with a higher risk of metabolic outcomes compared with all other groups. Our results suggest that both overall dietary pattern and diet beverage consumption status are important, to various degrees, for different metabolic outcomes. Their covariation and interaction partially explain differences in the relation between diet beverage consumption and metabolic health, which has been observed in previous studies. Further research is needed to more completely understand the dietary patterns and consumption decisions of diet beverages consumers; especially important is research that can help elucidate the motivation of diet beverage consumption among persons with less healthy food patterning.

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