Diet Pattern and Respiratory Morbidity in the Atherosclerosis Risk in Communities Study

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Abstract

Rationale: Dietary intake is a potential risk factor for respiratory morbidity in adult populations. Few studies capture the effect of dietary patterns, representative of the combination of nutrients consumed, on self-reported respiratory morbidity in combination with objective measures of lung function.

Objectives: To evaluate patterns of dietary intake in relation to respiratory morbidity and objective measures of lung function in a U.S. population.

Methods: The ARIC (Atherosclerosis Risk in Communities) study investigators enrolled 15,792 participants from four U.S. communities between 1987 and 1989 and collected data using a validated food frequency questionnaire to assess diet. Principal component analysis was applied, and patterns representative of “Western” and “Prudent” diets emerged. We investigated cross-sectional associations between dietary patterns and pulmonary assessments that included asthma and chronic obstructive pulmonary disease (COPD) diagnosis, respiratory symptoms, and lung function. Multivariable Poisson regression models included quintiles of dietary patterns and potential

confounders. Interaction of dietary patterns with obesity, sex, and smoking status was assessed in relation to all outcomes.

Results: Higher scores in the “Western” dietary pattern (quintile 5 vs. quintile 1) were associated with higher prevalence of COPD (prevalence ratio [PR], 1.62; 95% confidence ratio [CI], 1.33–1.97), wheeze (PR, 1.37; 95% CI, 1.11–1.69), cough (PR, 1.32; 95% CI, 1.32–1.59), and phlegm (PR, 1.27; 95% CI, 1.05–1.54) and lower percent predicted forced expiratory volume in 1 second (FEV₁), percent predicted forced vital capacity (FVC), and FEV₁/FVC ratio. Higher scores in the “Prudent” dietary pattern (quintile 5 vs. quintile 1) were associated with lower prevalence of COPD (PR, 0.82; 95% CI, 0.70–0.95) and cough (PR, 0.77; 95% CI, 0.67–0.89) and higher percent predicted FEV₁ and FEV₁/FVC ratio. The prevalence of asthma was not related to dietary intake.

Conclusions: A “Western” dietary pattern was associated with respiratory symptoms, lower lung function, and COPD in ARIC participants.

Keywords: lung; food; spirometry; symptoms; chronic obstructive pulmonary disease

(Received in original form July 19, 2017; accepted in final form February 15, 2018)

Supported by National Institutes of Health (NIH) grant 4KL2TR001077-04 (E.P.B.), NIH grants P50ES018176/EPA RD83615201 and P50MD010431/EPA RD83615001 (G.B.D., N.N.H., and M.C.M.), and the Intramural Research Program of the NIH, National Institute of Environmental Health Sciences (S.J.L.). The Atherosclerosis Risk in Communities study is performed as a collaborative study supported by National Heart, Lung, and Blood Institute contracts HHSN268201100005C, HHSN268201100006C, HHSN268201100007C, HHSN268201100008C, HHSN268201100009C, HHSN268201100010C, HHSN268201100011C, and HHSN268201100012C.

Author Contributions: All authors are included on the basis of substantial contributions to the conception or design of the work; or to the acquisition, analysis, or interpretation of data for the work; and to the drafting of the work or critical revision of it for important intellectual content; and final approval of the version to be published; and agree to be accountable for all aspects of the work in ensuring that questions related to the accuracy or integrity of any part of the work are appropriately investigated and resolved.

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This article has an online supplement, which is accessible from this issue's table of contents at www.atsjournals.org.

Ann Am Thorac Soc Vol 15, No 6, pp 675–682, Jun 2018

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DOI: 10.1513/AnnalsATS.201707-571OC

Internet address: www.atsjournals.org

Respiratory disease is a significant cause of morbidity and mortality in the United States. Chronic obstructive pulmonary disease (COPD) and asthma, the most prevalent respiratory diseases in the United States (1, 2), contribute over \$40 and \$50 billion, respectively, in health care costs and lost productivity annually (3, 4). These two diseases share common features of airflow obstruction and symptoms of wheeze, cough, and often phlegm production. As such, efforts to identify modifiable risk factors are crucial.

Westernization, including radical changes in diet, has been identified as a potential culprit in the global rise in asthma and COPD (5, 6). Early studies examining the effects of diet on respiratory health were focused on the effects of individual micronutrient intake. Although observational studies held promise, randomized controlled trials of micronutrient supplementation demonstrated inconsistent or negative results (7). It is now recognized that a combination and interaction of nutrients, in the form of dietary pattern, may have important predictive value for respiratory morbidity (8, 9). Limited investigations evaluating dietary patterns suggest that the ecologic trends in diet associated with Westernization (higher intake of processed foods high in trans or saturated fats and refined carbohydrates as well as lower intake of fruits and vegetables) may translate to changes at the individual level (10–15). Few studies evaluating these effects included a combination of self-reported respiratory diagnoses and symptoms with objective measures of lung function. Furthermore, though the United States is a hub of Westernization, there is a relative lack of studies examining associations between diet and respiratory health in U.S. populations, where dietary patterns may differ from those identified abroad. There is a need for U.S. population-based cohort studies to provide evidence for the link between diet and respiratory morbidity across populations.

The ARIC (Atherosclerosis Risk in Communities) study, a large, population-based cohort study (Visit 1 completed in 1987–1989) provides a unique opportunity to examine the effects of diet at a critical time point in the United States. This time period is early in the steady rise in fast and convenience foods prepared away from home and falls within the period between 1984 and 1992, when the U.S. Department

of Agriculture released the first Food Wheel and Food Guide Pyramid (16) that were focused on promoting awareness of healthy dietary patterns. The cross-sectional analysis of dietary intake at this significant juncture of change provides historical insight needed to understand contemporary studies of dietary pattern and dietary pattern evolution in relation to lung health. The ARIC data provide a unique opportunity to address our hypothesis that dietary pattern contributes to respiratory morbidity.

Methods

Subjects

The design, objectives, and methods of the ARIC study were reported in detail previously (17). Participants were recruited from four communities in the United States: Forsyth County, North Carolina; Jackson, Mississippi; the northwestern suburbs of Minneapolis, Minnesota; and Washington County, Maryland. A total of 15,792 participants were eligible and completed baseline clinical examinations and questionnaires between 1987 and 1989. Local institutional review boards approved the ARIC protocol, and all subjects gave informed consent.

Assessment of Dietary Intake

At Visit 1 (1987–1989), usual dietary intake over the preceding year was assessed using a 66-item interviewer-administered semiquantitative food frequency questionnaire (FFQ), a modified version of the 61-item instrument developed by Willett and colleagues (18). Briefly, consumption frequency of each food item was noted on a nine-category scale, ranging from never or less than one time per month to six or more times per day, with serving size based on food models provided for reference. Total energy intake was estimated from a combination of serving size, frequency of consumption, and caloric value of individual foods and beverages. The 66 food and beverage items were categorized into 29 subgroups based on similarity of nutrient composition, and subgroups were further organized into five major food groups according to prior methods: meat, dairy, fruits and vegetables, refined grains, and whole grains (19).

Outcome Assessment

Participants were asked questions regarding respiratory symptoms from the American

Thoracic Society/Division of Lung Diseases questionnaire (20). A “yes” response was used to define wheeze (Does your chest ever sound wheezy or whistling apart from colds?), cough (Do you usually have a cough?), and phlegm (Do you usually bring up phlegm from your chest?).

Measures of lung function included forced expiratory volume in one second (FEV_1), forced vital capacity (FVC), and FEV_1/FVC ratio, obtained according to American Thoracic Society criteria (21) and a standardized protocol, with quality control conducted throughout the study as described previously (22). Sex- and race-specific predicted values for FEV_1 and FVC, adjusted for age and height, were computed from prediction equations of Hankinson and colleagues (23).

Participants were classified as having asthma if they reported having current asthma and a doctor’s diagnosis of the disease. Participants were considered to have COPD if they demonstrated both FEV_1/FVC ratio and FEV_1 less than the lower limits of normal (24, 25). A sensitivity analysis, requiring history of smoking for COPD diagnosis, was also performed.

Participant Characteristics

Interviewers collected information on age, ethnicity, sex, smoking, education, and physical activity. Pack-years of smoking was calculated from smoking histories. Participants were also classified as current, former, or never smokers on the basis of self-report. Self-reported physical activity was measured via the Sport Index, referenced previously (26, 27) and derived from the Baecke questionnaire (28). Trained observers measured height and weight using a beam balance scale and stadiometer, respectively. Body mass index (BMI) was calculated as weight in kilograms divided by height in meters squared.

Statistical Analyses

Exclusions were observations with missing diet data, implausible energy intakes, defined as less than 500 or greater than 3,500 kcal/d for women and less than 700 or greater than 4,500 kcal/d for men or for whom total energy intake was not available, those with missing self-reported respiratory diagnosis, or those with missing BMI data (Figure 1). Given the small number of participants of Asian or Native American race, these individuals were also excluded. After exclusions, data from 15,256

Figure 1. STROBE (STrengthening the Reporting of OBservational studies in Epidemiology) diagram. Individuals were sequentially excluded from analysis for missing diet data, missing total caloric intake, implausible total caloric intake, missing self-reported respiratory diagnosis, missing body mass index (BMI), and Asian or Native American race, leaving 15,256 individuals from Visit 1 included in analyses.

participants were included for final cross-sectional analyses. Missing data for covariates of interest are indicated in the footnote of Table 1. Final numbers for analyses in Tables 2 and 3 varied slightly due to these missing data.

Principal component analysis (29) was performed using PROC FACTOR with SAS statistical software version 23 (SAS Institute) to derive dietary patterns from the 29 food subgroups (19). Varimax rotation was performed to enhance interpretability while maintaining uncorrelated factors. After evaluation of eigenvalues, scree plot, and interpretability, two factors were retained (19), with factor 1 explaining 7% of the variability and factor 2 explaining 5% of the variability. Dietary patterns were named according to the highest loading factors in each factor: “Prudent” (healthy) and “Western” (unhealthy) dietary patterns (differing in composition from the “Prudent” and “Western” patterns formerly derived in a smaller subset of the ARIC population [19]), and each individual received a separate score for each dietary pattern.

Summary statistics by quintile of dietary intake were evaluated for statistical trend via one-way analysis of variance (continuous, parametric), Kruskal-Wallis test (continuous, nonparametric) or chi-square test (categorical). Univariate associations between the continuous dietary scores and each outcome were modeled via fractional polynomial predicted models, and predicted curves were used to qualitatively verify the appropriateness of the quintile models. Poisson (for binary outcomes, with robust variance estimation) or linear regression (for pulmonary function metrics) was used to model the association of dietary patterns with the outcomes of interest. Final models were adjusted for age (continuous), BMI (continuous), sex, race, education (less than high school, high school or vocational, college and higher), pack-years of smoking (continuous), smoking status (current, former, or never smoker), total energy intake (kcal/d), and physical activity score (continuous). A sensitivity analysis was performed with additional adjustment for reported secondhand smoke and occupation.

To obtain *P* values for trend, quintiles of dietary intake were modeled as an ordinal variable (e.g., quintile 1 through quintile 5) in regression models, and the associated *P* value was recorded. Interactions

between dietary pattern and obesity (BMI, ≥ 30 kg/m²), sex, and smoking status were evaluated for all outcomes in adjusted models. Regression analyses were performed using STATA software version 13 (StataCorp).

Results

Included participants demonstrated a mean age of 54.2 years (SD, 5.8 yr), were primarily male (55.4%), educated (76.4%), and white (73.3%). Most described a history of smoking (58.2%). The population prevalence of wheeze, cough, and phlegm was roughly 10 to 12%, as was prevalence of COPD. The reported asthma prevalence was low at 3.2%. On average, participants reported daily intake of 4.1 servings of fruit and vegetables, with one to two servings of meat, dairy, refined grains, and whole grains.

Factor 1, identified as the “Prudent” dietary pattern, was characterized by high intake of vegetables, fruit, fish, poultry, and whole grains. Factor 2, identified as the “Western” dietary pattern, was characterized by high intake of refined grains, red and processed meats, french fries, eggs, and soda (see Tables E1 and E2 in the online supplement). The factors were not true inverses, representing unique risk factors. Escalating quintiles of each pattern (Table 1) represent greater degrees of adherence of the self-reported diet to the identified dietary patterns. Consistent with factor loading, with increasing “Prudent” diet score, participants reported greater fruit/vegetable intake, as well as greater whole grain and dairy intake and higher daily caloric values. Little variation was seen in meat or refined grain intake, consistent with low factor loading scores for these variables in the “Prudent” diet. Increase in the “Prudent” diet score was associated with older age, female sex, African American ethnicity, overall higher level of education, and higher BMI. Behaviorally, this pattern was also positively associated with lifelong abstinence from smoking and fewer pack-years among ever smokers. Increasing “Prudent” diet score was associated with lower prevalence of COPD and respiratory symptoms as well as better lung function.

Participants with increasing “Western” diet score tended to report higher intake of meat and refined grain intake, as well as higher dairy intake and higher daily caloric

Table 1. Dietary intake, demographics, and behavioral characteristics of Atherosclerosis Risk in Communities study participants

	Full Cohort	Prudent Diet Quintiles					Western Diet Quintiles				
		Q1 (Low)	Q2	Q3	Q4	Q5 (High)	Q1 (Low)	Q2	Q3	Q4	Q5 (High)
Dietary intake											
Major food groups, mean servings/d											
Meat	1.1	1.0	1.0	1.1	1.1	1.0	0.4	0.7	1.0	1.3	1.9
Dairy	1.6	1.2	1.4	1.6	1.8	2.1	1.4	1.4	1.6	1.7	2.0
Fruit and vegetables	4.1	1.9	2.9	3.8	4.8	7.0	4.2	3.8	3.9	4.1	4.4
Whole grain	1.2	0.6	1.0	1.3	1.5	1.8	1.4	1.3	1.2	1.2	1.1
Refined grain	2.4	2.5	2.4	2.3	2.4	2.3	1.0	1.6	2.1	2.8	4.4
Calories/d, kcal	1,628	1,373	1,486	1,585	1,734	1,963	1,119	1,299	1,530	1,804	2,389
Demographic characteristics											
Mean age, yr	54.2	53.5	54.0	54.4	54.5	54.5	54.4	54.1	54.3	54.3	53.8
Male sex, %	55.4	53.8	47.7	43.9	40.3	37.1	25.1	35.0	42.6	53.0	67.0
African American ethnicity, %	26.7	28.2	26.3	26.1	25.5	27.4	26.2	26.8	27.4	27.1	26.1
Education level, %											
Less than high school	23.6	29.4	24.2	23.0	21.7	19.7	16.8	21.8	22.7	26.0	30.7
High school or vocational	40.8	43.5	42.3	39.5	39.8	38.8	39.8	39.6	41.9	40.8	41.8
College and higher	35.6	27.1	33.5	37.5	38.5	41.5	43.4	38.6	35.4	33.2	27.5
Mean BMI, kg/m ²	27.7	27.4	27.6	27.7	27.9	28.0	27.2	27.7	28.0	27.8	27.8
Behavioral characteristics											
Mean Sport Index*	2.4	2.3	2.4	2.4	2.5	2.6	2.6	2.5	2.4	2.4	2.4
Smoking status, % [†]											
Current	26.0	35.9	27.7	24.4	21.8	20.4	17.1	24.9	25.4	28.7	34.3
Former	32.2	30.1	32.4	33.0	32.7	32.8	33.0	30.9	31.8	32.4	32.8
Never	41.8	34.0	39.9	42.6	45.6	46.8	49.9	44.2	42.9	38.9	32.9
Mean pack-years among ever smokers	27.8	30.5	29.1	27.3	27.0	24.1	22.8	25.0	27.0	29.8	32.5
Respiratory health											
Asthma, %	3.2	3.2	3.1	3.0	3.1	3.6	2.9	3.1	3.0	3.3	3.6
COPD, % [‡]	11.5	14.7	12.7	10.6	10.9	8.8	6.3	8.6	11.6	13.3	17.9
Wheeze, %	10.7	12.0	10.8	10.4	10.3	10.3	7.5	9.4	10.3	11.8	14.6
Cough, %	12.4	15.9	12.7	12.0	11.2	10.1	8.0	11.1	11.5	14.4	16.9
Phlegm, %	12.0	15.0	12.8	10.5	11.3	10.5	8.1	10.9	11.3	13.2	16.7
Lung function [‡]											
FEV ₁ , % predicted, mean	93.4	91.2	92.7	93.7	94.2	95.1	97.4	94.7	93.3	91.8	89.5
FVC, % predicted, mean	100.5	99.2	100.1	100.9	101.0	101.5	103.7	101.5	100.5	99.2	97.7
FEV ₁ /FVC, mean	0.74	0.74	0.74	0.74	0.75	0.75	0.76	0.75	0.74	0.74	0.73

Definition of abbreviations: BMI = body mass index; COPD = chronic obstructive pulmonary disease; FEV₁ = forced expiratory volume in 1 second; FVC = forced vital capacity.

Overall $n = 15,256$.

* $n = 15,234$.

† $n = 15,243$.

‡ $n = 15,142$.

values. Little variation was noted with whole-grain intake, and there was no consistent directionality with fruit and vegetable intake, consistent with factor loading. Increase in score was associated with younger age, male sex, white ethnicity, overall lower level of education, and higher BMI. Behaviorally, this pattern was associated with higher prevalence of smokers and higher pack-years among ever smokers, as well as an increase in prevalent COPD and respiratory symptoms and worse lung function.

Multivariable analyses of respiratory diagnoses (Table 2) were consistent with the univariate associations demonstrated in Table 1. “Western” and “Prudent” dietary patterns were associated with COPD prevalence ($P < 0.001$). Increasing “Western” diet score was associated with increasing prevalence of COPD, with a prevalence ratio (PR) of 1.62 (95% confidence interval [CI], 1.33–1.97) for quintile 5 versus quintile 1. Increasing “Prudent” diet score demonstrated a

protective effect, with a prevalence ratio of COPD of 0.82 (95% CI, 0.70–0.95) for quintile 5 versus quintile 1 (Table 2). No change in these associations occurred when COPD diagnosis was limited to those with a history of smoking. No relationship was found between dietary pattern and asthma prevalence. Addition of occupation and secondhand smoke to multivariable models did not change effect estimates. Tests for effect modification revealed a significant interaction between smoking status and

Table 2. Relationship of quintile of dietary intake pattern to obstructive lung disease and respiratory symptoms

	Quintile of Dietary Intake Pattern					<i>P</i> _{trend} Value
	Q1	Q2	Q3	Q4	Q5	
Asthma						
Western diet	1.00	1.02 (0.76–1.37)	0.98 (0.72–1.34)	1.06 (0.76–1.49)	1.13 (0.75–1.70)	0.606
Prudent diet	1.00	0.93 (0.70–1.24)	0.89 (0.66–1.19)	0.91 (0.67–1.22)	1.01 (0.74–1.38)	0.990
COPD*						
Western diet	1.00	1.15 (0.97–1.37)	1.41 (1.19–1.67)	1.37 (1.15–1.63)	1.62 (1.33–1.97)	<0.001
Prudent diet	1.00	0.99 (0.88–1.12)	0.90 (0.79–1.03)	0.93 (0.81–1.06)	0.82 (0.70–0.95)	0.007
Wheeze						
Western diet	1.00	1.09 (0.92–1.29)	1.19 (1.01–1.41)	1.25 (1.05–1.49)	1.37 (1.11–1.69)	0.002
Prudent diet	1.00	0.98 (0.85–1.12)	0.96 (0.84–1.11)	0.96 (0.83–1.11)	0.96 (0.82–1.12)	0.539
Cough						
Western diet	1.00	1.15 (0.98–1.34)	1.16 (1.00–1.36)	1.30 (1.11–1.53)	1.32 (1.10–1.59)	0.001
Prudent diet	1.00	0.90 (0.80–1.01)	0.89 (0.79–1.01)	0.84 (0.74–0.96)	0.77 (0.67–0.89)	<0.001
Phlegm						
Western diet	1.00	1.15 (0.99–1.35)	1.12 (0.95–1.31)	1.18 (1.00–1.39)	1.27 (1.05–1.54)	0.031
Prudent diet	1.00	0.96 (0.85–1.08)	0.81 (0.71–0.92)	0.92 (0.81–1.05)	0.89 (0.77–1.03)	0.080

Definition of abbreviation: COPD = chronic obstructive pulmonary disease.

Prevalence ratios (95% confidence intervals) were obtained via Poisson regression with robust variance estimation. Data were adjusted for age, sex, race, education, center, smoking (status and pack-years), physical activity, total energy intake, and body mass index ($n = 14,938$). *P* values are in bold typeface when statistically significant.

* $n = 14,829$.

COPD, such that the association between increasing intake of the “Western” diet and prevalence of COPD was greater among never smokers than among ever smokers ($P_{\text{intx}} = 0.046$) (Table E3). A statistically significant interaction was also noted between obesity status and “Western” diet for the outcome of asthma prevalence, though neither stratum-specific *P* value was statistically significant (Table E4).

Multivariable analyses likewise revealed positive associations between increasing adherence to a “Western” dietary pattern and prevalence of wheeze, cough, and phlegm (Figure 2, Table 2). For example, individuals in quintile 5 versus quintile 1 of

the “Western” diet demonstrated 32% higher prevalence of cough (PR, 1.32; 95% CI, 1.10–1.59), with a *P* value for trend across quintiles of 0.001. This relationship was inverse for the “Prudent” diet, where individuals with increased adherence to this dietary pattern were less likely to report symptoms of cough ($P = 0.001$), though neither wheeze nor phlegm was significantly associated. No interactions were noted between sex and diet or obesity and diet for symptom outcomes (Tables E4 and E5). The addition of occupation and secondhand smoke as covariates in multivariable models did not change effect estimates. An interaction was present between smoking

status and “Prudent” diet score for the outcome of wheeze, though neither stratum-specific *P* value was significant (Table E3).

Associations between dietary patterns and COPD and symptoms were consistent with the relationships between reported dietary intake and the objective measure of lung function. Sequential increase in quintile of “Western” diet intake was associated with lower percent predicted FEV₁ ($\beta = -0.74$; 95% CI, -1.00 to -0.48), percent predicted FVC ($\beta = -0.55$; 95% CI, -0.78 to -0.31), and FEV₁/FVC ($\beta = -0.20$; 95% CI, -0.32 to -0.08). “Prudent” diet was associated with higher percent predicted FEV₁ ($\beta = 0.38$; 95% CI,

Table 3. Associations between quintile of dietary intake pattern and pulmonary function

	Quintile of Dietary Intake Pattern					<i>P</i> _{trend} Value
	Q1	Q2	Q3	Q4	Q5	
FEV ₁ , % of predicted						
Western diet	95.1 (0.33)	93.9 (0.30)	93.3 (0.28)	92.9 (0.29)	91.8 (0.38)	<0.001
Prudent diet	92.7 (0.30)	93.0 (0.28)	93.5 (0.28)	93.6 (0.28)	94.3 (0.30)	<0.001
FVC, % of predicted						
Western diet	101.8 (0.30)	100.9 (0.28)	100.7 (0.26)	100.3 (0.26)	99.3 (0.34)	<0.001
Prudent diet	100.3 (0.27)	100.4 (0.26)	100.7 (0.26)	100.7 (0.26)	100.9 (0.28)	0.116
FEV ₁ /FVC						
Western diet	74.88 (0.15)	74.54 (0.14)	74.28 (0.13)	74.32 (0.13)	74.01 (0.17)	0.001
Prudent diet	74.00 (0.14)	74.21 (0.13)	74.39 (0.13)	74.51 (0.13)	74.94 (0.14)	<0.001

Definition of abbreviations: FEV₁ = forced expiratory volume in 1 second; FVC = forced vital capacity; SE = standard error.

Adjusted mean (SE) data are presented. Results were derived from linear regression analyses accounting for age, sex, race, education, center, smoking (status and pack-years), physical activity, total energy intake, and body mass index ($n = 14,829$). *P* values are in bold typeface when statistically significant.

Figure 2. Dietary intake is associated with respiratory symptoms. Poisson regression with robust variance estimation was used to model the associations between increasing quintile of each dietary score (“Western” diet pattern in red; “Prudent” diet pattern in green; reference = quintile 1) and prevalent cough, wheeze, and phlegm. Prevalence ratios and 95% confidence intervals are presented. Analyses are adjusted for age, sex, race, education, center, smoking (status and pack-years), physical activity, total energy intake, and body mass index ($n = 14,938$). * $P_{\text{trend}} < 0.05$.

0.19 to 0.58) and FEV_1/FVC ($\beta = 0.22$; 95% CI, 0.13 to 0.31). Adjusted means within each quintile of dietary intake are presented in Table 3. Adjustment for secondhand smoke exposure and occupation did not alter effect estimates, and there was no effect modification by smoking status on the relationship between dietary patterns and lung function (Table E3). The relationship of each dietary pattern to FEV_1/FVC ratio was of greater magnitude in nonobese than in obese individuals (Table E4), and the relationship of “Western” diet to percent predicted FEV_1 and FVC was of greater magnitude in males than in females (Table E5).

Discussion

In this large, U.S.-based population cohort, dietary pattern was associated with COPD prevalence, respiratory symptoms, and lung function. Consumption of a “Western” diet, characterized by high intake of refined grains, red and processed meats, french fries, eggs, and soda, was associated with higher prevalence of COPD; more frequent reports of wheeze, cough, and phlegm; and lower lung function. Conversely, a “Prudent” dietary pattern, which is high in vegetables, fruit, fish, poultry, and whole grains, was associated with lower COPD prevalence, less frequently reported cough, and higher lung function. The effects were independent of energy intake and were not consistently modified by smoking history, BMI, or sex. These findings in a population-based cohort of men and women residing in the United States demonstrate consistency and extend the current evidence supporting the effect of dietary intake on respiratory morbidity in the United States.

Several studies done outside the United States demonstrate associations between dietary patterns and COPD. A U.K. study of 2,942 adults demonstrated lower prevalence of COPD and higher FEV_1 , FVC, and FEV_1/FVC with higher reported intake of a “Prudent” diet; symptoms were not examined (30). Conflicting results were seen in a second, smaller U.K. study in which investigators identified five dietary patterns (including “Prudent,” “Western,” and “Traditional”) where a higher prevalence of chronic bronchitis was associated with higher “Prudent” diet intake; lung function and respiratory symptoms were not examined (31). In a large cohort of older adults of Chinese ethnicity, researchers in Singapore identified beneficial effects of a pattern analogous to the “Prudent” pattern identified in the present study (rich in fruit, vegetables, and soy protein) on development of chronic bronchitis symptoms. Conversely, the unhealthy pattern rich in meats and noodles was related to increased risk (32).

Because diet represents a complex exposure variable that varies by region, analogous dietary patterns may demonstrate variation precluding comparison across country and continent. As such, unique evaluations, ideally encompassing respiratory diagnoses, morbidity, and lung function, are necessary within each region. The majority of the literature evaluating the effects of dietary patterns is based on populations outside the United States; evaluation of dietary patterns in U.S. populations is a necessary step to inform regional interventions. Although two large cohort studies support the positive effects of a “Prudent” diet and negative effects of a “Western” diet on incident COPD in the

United States, neither of these was population based (11, 12). Investigation within the population-based ARIC cohort provides a unique opportunity to examine the consistency of relationships in a setting that facilitates generalization to the population as a whole. By analyzing the prevalence of respiratory disease, respiratory symptoms, and objective lung function data within one population, we are able to demonstrate consistent, strong associations with dietary patterns.

Also consistent with our results, prior studies have failed to demonstrate consistent associations between dietary patterns and prevalent or incident adult asthma (8). It is possible that diet does not play a role in adult asthma prevalence. However, the importance of the timing of dietary exposure in relation to adult asthma is unknown, and it may be that the time of dietary assessment does not capture the critical time of exposure relevant to asthma development, resulting in exposure misclassification. Furthermore, our present investigations may be underpowered to detect associations between dietary patterns and asthma prevalence, given a 3.2% population prevalence of asthma. Dietary intake has previously been associated with adult asthma morbidity (8), consistent with our findings that dietary patterns are associated with respiratory symptoms.

A proposed mechanism for the influence of diet on respiratory outcomes centers on the summation of pro- and antiinflammatory effects contributed by diet (33). Oxidative stress in the lungs is generated in response to exposures such as air pollution, tobacco smoke, infection, and potentially even systemic exposures such as obesity and proinflammatory dietary

components (i.e., n-6 polyunsaturated fatty acids, preservatives). Early studies of diet were focused on micronutrients, such as antioxidant vitamins and minerals, on the basis of the rationale that these components could provide respiratory protection against oxidative stress by increasing levels of antioxidants in the body. Yet, randomized controlled trials of dietary supplementation with individual dietary components demonstrated inconsistent or negative effects (7). Therefore, emphasis and interest have shifted to whole foods and dietary patterns, with recognition that the combination and interaction of nutrients may be important.

In addition to systemic pro- or antiinflammatory effects of foods (34, 35), accumulation or loss of adipose tissue (36, 37) and/or unfavorable or favorable alterations in the gut microbiome (38–40) have been proposed as additional potential mechanisms. Indeed, fiber, found in multiple food sources and increased in a typical healthy diet through intake of cereals, fruit, and vegetables, has been found to impact the gut microbiome, and alterations in the gut microbiome can influence systemic inflammation and weight changes or have other effects relevant to pulmonary disease (38–41). Higher intake of fiber was related to better lung function and reduced prevalence of COPD in an earlier cross-sectional analysis in the ARIC cohort (42) and has been linked to lower respiratory mortality (41) and lower incidence of respiratory symptoms (43). Alternatively, aspects of a diet high in vegetables and fruits, other than fiber, may be equally as important as or more important than fiber itself, and they bear independent exploration in the context of dietary pattern analyses.

Limited trials intended to favorably shift the balance of antioxidants in diet demonstrate modest improvements in asthma symptoms and improvement in lung function compared to alternate or control diet in patients with asthma (44–46).

Although evidence suggests that a “Western” dietary pattern confers increased risk of COPD and a “Prudent” diet confers a protective benefit (11, 12), diet trials among participants with COPD have been aimed largely at increasing energy balance and protein intake, targeting those with cachexia (47, 48). A pilot trial was effective at increasing fruit and vegetable intake in COPD, but it did not alter other dietary components and was not powered to detect clinical outcomes (49). Another trial aimed at increasing antioxidant intake demonstrated improved FEV₁ compared with the control group (50). Given epidemiologic evidence for a positive effect of a “Prudent” diet and a negative effect of a “Western” diet in COPD, in addition to the findings in trials that associate higher fruit intake with decreased COPD mortality (50) and intake of cured meat with higher risk of morbidity (readmissions) (51), there is a rationale supporting additional diet trials aimed at dietary pattern change in individuals with COPD.

There are several limitations of the present analyses. Dietary intake may be confounded in observational studies because nutritional behaviors tend to cluster with other important factors, including other health behaviors and socioeconomic status. We adjusted our statistical models for these factors, completed sensitivity analyses, and performed interaction analyses; however, residual confounding may remain. FFQs contain a limited number of items and are thus limited in characterization of unusual dietary components, and they carry the potential for reporting bias (52). However, the Willett FFQ has been validated previously (18), and prior studies demonstrated the reliability of dietary patterns obtained from FFQs (53). The level of variation explained by the two dietary patterns is limited and may not capture the full complexity of dietary intake within the population. However, the percentage of

variation explained is comparable to that in other published works in the diet and pulmonary literature (14, 30–32) and thus is reasonable for this approach. Because this is a cross-sectional analysis, we cannot determine the time course of these associations, nor can we investigate incidence. However, the investigation benefits from a comprehensive suite of self-reported diagnoses, symptoms, and objective measures of lung function within the same population.

The present study adds to the evidence base demonstrating that dietary intake is associated with COPD prevalence, respiratory symptoms, and lung function. The dietary patterns in the 1980s do not fully represent dietary intake in the United States today, and over the last several decades, dietary patterns may be more extreme than those that emerged in the present analysis. As the understanding of the complex interplay between diet and respiratory disease advances, the presence of the relationships demonstrated in this large cohort of adults in the United States at a critical juncture provides quantifiable evidence that can serve as an anchor when exploring the impact of dietary change on the trajectory of chronic respiratory disease in the United States. ■

Author disclosures are available with the text of this article at www.atsjournals.org.

Acknowledgment: The Atherosclerosis Risk in Communities Study is carried out as a collaborative study supported by National Heart, Lung, and Blood Institute contracts (HHSN268201100005C, HHSN268201100006C, HHSN268201100007C, HHSN268201100008C, HHSN268201100009C, HHSN268201100010C, HHSN268201100011C, and HHSN268201100012C). The authors thank the staff and participants of the ARIC study for their important contributions. The authors also thank the Johns Hopkins Institute for Clinical and Translational Research and Dr. Nae-Yuh Wang for support in statistical revisions.

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