Patterns of dietary intake and relation to respiratory disease, forced expiratory volume in 1 s, and decline in 5-y forced expiratory volume

Tricia M McKeever, Sarah A Lewis, Patricia A Cassano, Marga Ocke, Peter Burney, John Britton, and Henriette A Smit

ABSTRACT

Background: The independent effect of individual foods on the risk of respiratory disease is difficult to establish because intakes of specific foods are generally strongly correlated. To date, few studies have examined the relation between dietary food patterns and forced expiratory volume in 1 s (FEV1) or respiratory symptoms.

Objective: The objective was to investigate the relation between dietary patterns and FEV1, FEV1 decline, and respiratory health in a general population sample.

Design: Data were collected from the cross-sectional study in 12,648 adults from the Netherlands [MORGEN-EPIC (Monitoring Project on Risk Factors and Chronic Diseases in the Netherlands–European Prospective Investigation into Cancer and Nutrition)]. Principal components analysis was used to derive dietary patterns, and multivariate regression analyses were conducted to investigate these patterns with FEV1 or respiratory health. We also investigated these dietary patterns in relation to lung function decline over 5 y in a subpopulation.

Results: A more traditional diet (high intake of meat and potatoes and lower intake of soy and cereal) was associated with a lower risk of wheeze and asthma. However, none of the dietary patterns appear to be related to lung function decline.

Conclusions: The results suggest that a traditional diet has adverse effects on lung function and chronic obstructive pulmonary disease and that a more cosmopolitan diet was associated with increased risk of wheeze and asthma. However, none of the dietary patterns appear to be related to lung function decline.

INTRODUCTION

Asthma and chronic obstructive pulmonary disease (COPD) have a multifactorial etiology, but diet has been shown to be an important risk factor for both (1–5). To date, most of the evidence relates to effects of single nutrients or food items. However, nutrients and foods are not eaten in isolation but rather in combination. Moreover, there is a high correlation between the nutrient and food intakes in individual diets, so it can be difficult to determine their independent effects. It may therefore be more appropriate to characterize dietary patterns within a population and investigate how different dietary patterns relate to respiratory disease. This may also provide a clearer public health message, shifting the focus away from individual nutrients or food items to the promotion of healthy eating patterns. Although dietary patterns have been widely investigated in terms of heart disease and cancer (6, 7), the evidence for respiratory disease is more limited, and there is little data on the association of dietary patterns with lung function, either cross-sectionally or longitudinally (8–14).

The aim of this study was to use principal components analysis to determine dietary patterns and assess their relation to forced expiratory volume in one second (FEV1), and symptoms of COPD, asthma, wheeze, and longitudinal change in FEV1 in a large population based in the Netherlands. Principal components analysis combines food items into “dietary pattern(s),” which best explain the variation between individual diets (15, 16), which can then be explored in relation to disease. These results were previous published in abstract form (17).

SUBJECTS AND METHODS

Study population

The Monitoring Project on Risk Factors and Chronic Diseases in the Netherlands–European Prospective Investigation into Cancer and Nutrition (MORGEN-EPIC) study comprises a cross-sectional data set of >17,000 individuals aged 20–59 y, who were randomly sampled from 3 towns in the Netherlands (Amsterdam, Doetinchem, and Maastricht) between 1994 and 1997 (18, 19). The data set was initiated to study the epidemiology of chronic disease, and the data collected include demographic characteristics, physical measurements (height, weight, and FEV1), dietary habits, and respiratory symptoms. Lung function in the MORGEN-EPIC Study was measured in just >15,400 individuals; however, 1986 subjects were excluded from the analyses because they had a technically unacceptable

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2 Supported by the Wellcome Trust, Ministry of Public Health, Welfare and Sport of the Netherlands and by the Institute of Public Health and the Environment.

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or nonreproducible FEV<sub>1</sub> measurement, 87 individuals because of missing data on other outcomes, 98 individuals because of pregnancy, and 314 because of missing data on important confounding factors [smoking, body mass index (BMI; in kg/m<sup>2</sup>), and educational level]. Finally, we excluded 1246 individuals who were currently following a diet for medical or nonmedical reasons because this would affect their pattern of food intake. This research was approved by the Dutch Medical Ethical Committee (Utrecht, Netherlands).

### Longitudinal population

In one of the study areas, Doetinchem, the population was followed up 5 y later between 1999 and 2002 (20), with a repeat of all the measurements made at baseline. The total follow-up population in Doetinchem comprised 4662 individuals. However, 1349 subjects were excluded because they had missing or invalid lung function measurements in the initial study and/or the follow-up study. A further 347 subjects were excluded because they had missing data on other variables, including diet, or were pregnant, which left a study population of 2911.

### Data collection

Participants completed 2 self-administered questionnaires. One was a 178-item food-frequency questionnaire developed and validated for this research project as part of the EPIC Study (21, 22). The other collected information on demographic variables, smoking history, physical activity, socioeconomic status, environmental factors, and self-reported respiratory symptoms and diagnosed disease (derived from the Dutch component of the European Community Respiratory Health Survey; 23, 24).

Lung function was measured by trained paramedics using a heated pneumotachometer (E Jaeger, Wurzburg, Germany) in a seated upright position. The best of ≥3 technically acceptable measurements, of which 2 were reproducible according to the criteria of the European Respiratory Society (25), was accepted for inclusion in the analysis. Both FEV<sub>1</sub> and forced vital capacity (FVC) were recorded. Height (to within 0.5 cm) and weight (to within 1 kg) were measured and used to calculate BMI, which was then recoded in 4 categories (<20, 20–25, 25–30, and ≥30).

### Outcomes

FEV<sub>1</sub> was modeled on age, age squared, height, and age × height interaction, for each sex separately, in individuals who were never smokers, nonwheezerers, and nonasthmatics. This model was then used to predict FEV<sub>1</sub> for the complete data set, and the residuals—calculated as the difference of each observed FEV<sub>1</sub> from the predicted value—were used in the analyses. This process was repeated for the longitudinal population at their second visit, and the change in FEV<sub>1</sub> residuals was used to estimate the decline in lung function over 5 y (26, 27). Wheeze was defined as self-reported in the past year, asthma as physician-diagnosed, and COPD as FEV<sub>1</sub> at Global Initiative for Chronic Obstructive Lung Disease (GOLD) criteria stage 2 and above, although measures of FEV<sub>1</sub> were not made post-bronchodilator.

### Data analysis

Food items on the food-frequency questionnaire were grouped by nutrient content, and culinary use was grouped into 46 different food groups, similar to a previous report in this study (28). Two changes were made to previous food groupings because of knowledge of their potential associations with respiratory disease: 1) fish was further subdivided into oily and nonoily fish, and 2) red meat is presented as one group rather than being further subdivided by the amount of fat. Each of the food groups was adjusted for total energy intake by using the residual method (29). Factors were similar within subgroups according to sex and location of the study population.

In the principal components analysis, varimax rotation was used to obtain uncorrelated factors, which are more easily interpreted. To determine the number of factors to retain, we used a Scree plot, eigenvalues (factors with eigenvalues >2 were considered for further investigation in relation to outcomes), interpretability, and previous analyses on dietary patterns within

### Table 1

Characteristics of the cross-sectional and longitudinal study populations in the MORGEN-EPIC (Monitoring Project on Risk Factors and Chronic Diseases in the Netherlands–European Prospective Investigation into Cancer and Nutrition) study.

<table>
<thead>
<tr>
<th>Characteristics</th>
<th>Cross-sectional population&lt;sup&gt;1&lt;/sup&gt; (n = 12,648)</th>
<th>Longitudinal population&lt;sup&gt;2&lt;/sup&gt; (n = 2911)</th>
</tr>
</thead>
<tbody>
<tr>
<td>Sex [n (%)]</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Males</td>
<td>6080 (48)</td>
<td>1451 (50)</td>
</tr>
<tr>
<td>Females</td>
<td>6568 (52)</td>
<td>1460 (50)</td>
</tr>
<tr>
<td>Age (y)</td>
<td>41.5 ± 11.2&lt;sup&gt;3&lt;/sup&gt;</td>
<td>45.0 ± 9.5</td>
</tr>
<tr>
<td>Smoking [n (%)]</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Never</td>
<td>4294 (34)</td>
<td>991 (34)</td>
</tr>
<tr>
<td>Ex</td>
<td>3626 (29)</td>
<td>1031 (35)</td>
</tr>
<tr>
<td>Current</td>
<td>4728 (37)</td>
<td>889 (30)</td>
</tr>
<tr>
<td>Educational level [n (%)]</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Low</td>
<td>5576 (44)</td>
<td>1446 (50)</td>
</tr>
<tr>
<td>Medium</td>
<td>3768 (30)</td>
<td>837 (29)</td>
</tr>
<tr>
<td>High</td>
<td>3304 (26)</td>
<td>628 (22)</td>
</tr>
<tr>
<td>BMI (kg/m&lt;sup&gt;2&lt;/sup&gt;)</td>
<td>24.7 ± 4</td>
<td>25.1 ± 3.5</td>
</tr>
<tr>
<td>Energy (kJ)</td>
<td>9642 ± 2878</td>
<td>9622 ± 2610</td>
</tr>
<tr>
<td>FEV&lt;sub&gt;1&lt;/sub&gt; (L)</td>
<td>3.6 ± 0.9</td>
<td>3.6 ± 0.8</td>
</tr>
<tr>
<td>FEV&lt;sub&gt;1&lt;/sub&gt; decline (mL/y)</td>
<td>—</td>
<td>−30.3 ± 45.2</td>
</tr>
<tr>
<td>Wheeze [n (%)]&lt;sup&gt;4&lt;/sup&gt;</td>
<td></td>
<td></td>
</tr>
<tr>
<td>No</td>
<td>10,971 (87)</td>
<td>2611 (81)</td>
</tr>
<tr>
<td>Yes</td>
<td>1677 (13)</td>
<td>300 (10)</td>
</tr>
<tr>
<td>Asthma [n (%)]&lt;sup&gt;4&lt;/sup&gt;</td>
<td></td>
<td></td>
</tr>
<tr>
<td>No</td>
<td>12,264 (97)</td>
<td>2832 (97)</td>
</tr>
<tr>
<td>Yes</td>
<td>384 (3)</td>
<td>79 (3)</td>
</tr>
<tr>
<td>COPD [n (%)]&lt;sup&gt;4&lt;/sup&gt;</td>
<td></td>
<td></td>
</tr>
<tr>
<td>No</td>
<td>11,579 (96)</td>
<td>2797 (96)</td>
</tr>
<tr>
<td>Yes</td>
<td>497 (4)</td>
<td>114 (4)</td>
</tr>
</tbody>
</table>

<sup>1</sup> Cross-sectional (Amsterdam, Maastricht, and Doetinchem) and longitudinal (Doetinchem only) studies. FEV<sub>1</sub>, forced expiratory volume in 1 s; COPD, chronic obstructive pulmonary disease.

<sup>2</sup> Population demographics from the baseline study (from 1994 to 1997) in the population followed up between 1999 and 2002.

<sup>3</sup> Mean ± SD (all such values).

<sup>4</sup> Wheeze was defined as wheeze in the past 12 mo, asthma as self-reported physician diagnosis, and COPD as GOLD (Global Initiative for Chronic Obstructive Lung Disease) stage 2 or higher but not postbronchodilator.
the data set (28). This resulted in 3 dietary factors, as described in this article. We applied the principal components procedure for factor analysis to produce “factors” (linear combinations of food items), which best explained the variation in diet. Three factors (dietary patterns) were retained for further analyses.

A score was created for each individual for each dietary pattern, which represented the degree to which they conform to that dietary pattern, and these dietary pattern variables were then divided into quintiles and investigated in relation to FEV$_1$ residuals, wheeze, asthma, COPD, and decline in FEV$_1$. For wheeze, asthma, and COPD, a priori confounders include age, sex, smoking status, pack-years of smoking, BMI, and educational level: low (intermediate secondary education or less), intermediate (intermediate vocational or higher secondary education), and high (higher vocational or university education), and town of examination. With the use of the FEV$_1$ residuals for

### TABLE 2

Factor loading matrix for defining food-consumption patterns by principal components analysis: diet pattern score for the 46 foods included in the analyses—MORGEN-EPIC (Monitoring Project on Risk Factors and Chronic Diseases in the Netherlands–European Prospective Investigation into Cancer and Nutrition) study ($n = 12,648$)

<table>
<thead>
<tr>
<th>Mean intake</th>
<th>Factor 1: cosmopolitan diet</th>
<th>Factor 2: traditional diet</th>
<th>Factor 3: refined-foods diet</th>
</tr>
</thead>
<tbody>
<tr>
<td>g/d</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Salad vegetables</td>
<td>33.6 0.52</td>
<td>-0.18</td>
<td>-</td>
</tr>
<tr>
<td>Fried vegetables</td>
<td>10.8 0.52</td>
<td>-0.17</td>
<td>-0.18</td>
</tr>
<tr>
<td>Legumes</td>
<td>9.5</td>
<td>-</td>
<td>-0.21</td>
</tr>
<tr>
<td>Boiled vegetables</td>
<td>75.6</td>
<td>0.21</td>
<td>-0.35</td>
</tr>
<tr>
<td>Garlic</td>
<td>0.2</td>
<td>0.67</td>
<td>-</td>
</tr>
<tr>
<td>Juice</td>
<td>84.8 0.15</td>
<td>-0.26</td>
<td>-</td>
</tr>
<tr>
<td>Soy products</td>
<td>2.5 0.17</td>
<td>-0.46</td>
<td>-</td>
</tr>
<tr>
<td>Nuts</td>
<td>10.8</td>
<td>-0.21</td>
<td>-</td>
</tr>
<tr>
<td>Fruit</td>
<td>166.3</td>
<td>-0.27</td>
<td>-0.28</td>
</tr>
<tr>
<td>Eggs</td>
<td>16.9 0.17</td>
<td>0.28</td>
<td>-</td>
</tr>
<tr>
<td>Red meat</td>
<td>64.9</td>
<td>0.58</td>
<td>-</td>
</tr>
<tr>
<td>Organ meat</td>
<td>1.1 0.24</td>
<td>0.19</td>
<td>-</td>
</tr>
<tr>
<td>Processed meat</td>
<td>40.9</td>
<td>0.50</td>
<td>0.21</td>
</tr>
<tr>
<td>Chicken</td>
<td>13.1 0.32</td>
<td>-</td>
<td>0.17</td>
</tr>
<tr>
<td>Oily fish</td>
<td>2.5 0.43</td>
<td>-</td>
<td>-</td>
</tr>
<tr>
<td>Nonoily fish</td>
<td>7.3 0.45</td>
<td>-</td>
<td>-0.17</td>
</tr>
<tr>
<td>Cheese</td>
<td>35.5</td>
<td>-</td>
<td>-0.26</td>
</tr>
<tr>
<td>Dairy products, &gt;0.02 g fat/g</td>
<td>129.1  -0.22</td>
<td>-0.22</td>
<td>-0.24</td>
</tr>
<tr>
<td>Dairy products, ≤2 g fat/g</td>
<td>262.9  -0.37</td>
<td>-0.37</td>
<td>-0.21</td>
</tr>
<tr>
<td>Vegetable oil</td>
<td>3.8</td>
<td>0.65</td>
<td>-</td>
</tr>
<tr>
<td>Added fat, &lt;0.35 g SFA/g fat</td>
<td>11.5  -0.33</td>
<td>-0.33</td>
<td>-0.15</td>
</tr>
<tr>
<td>Added fat, ≥0.35 g SFA/g fat</td>
<td>12.0</td>
<td>0.39</td>
<td>-</td>
</tr>
<tr>
<td>Warm sauces</td>
<td>18.3 0.28</td>
<td>-0.20</td>
<td>0.26</td>
</tr>
<tr>
<td>Mayonnaises</td>
<td>6.4</td>
<td>-</td>
<td>0.43</td>
</tr>
<tr>
<td>Salty snacks</td>
<td>13.5</td>
<td>-</td>
<td>0.41</td>
</tr>
<tr>
<td>Added sugar</td>
<td>30.5 0.31</td>
<td>-</td>
<td>-</td>
</tr>
<tr>
<td>Candy</td>
<td>14.5</td>
<td>-0.24</td>
<td>0.28</td>
</tr>
<tr>
<td>Pastries</td>
<td>26.5 0.15</td>
<td>-0.32</td>
<td>-</td>
</tr>
<tr>
<td>Coffee</td>
<td>564.1</td>
<td>0.37</td>
<td>-0.16</td>
</tr>
<tr>
<td>Tea</td>
<td>252.8</td>
<td>-0.36</td>
<td>-</td>
</tr>
<tr>
<td>High-sugar beverages</td>
<td>121.1</td>
<td>-</td>
<td>0.50</td>
</tr>
<tr>
<td>Low-sugar beverages</td>
<td>37.1</td>
<td>-</td>
<td>0.29</td>
</tr>
<tr>
<td>Beer</td>
<td>157.3</td>
<td>0.34</td>
<td>-</td>
</tr>
<tr>
<td>Wine</td>
<td>47.4 0.39</td>
<td>-</td>
<td>-0.16</td>
</tr>
<tr>
<td>Spirits</td>
<td>8.1</td>
<td>-0.21</td>
<td>-</td>
</tr>
<tr>
<td>Water</td>
<td>351.5</td>
<td>0.23</td>
<td>-</td>
</tr>
<tr>
<td>Pasta</td>
<td>36.5 0.26</td>
<td>-0.21</td>
<td>0.16</td>
</tr>
<tr>
<td>White rice</td>
<td>19.7 0.41</td>
<td>-0.41</td>
<td>0.16</td>
</tr>
<tr>
<td>Brown rice</td>
<td>6.6 0.32</td>
<td>-0.28</td>
<td>-</td>
</tr>
<tr>
<td>Potatoes</td>
<td>90.8 -0.32</td>
<td>0.44</td>
<td>-0.20</td>
</tr>
<tr>
<td>French fries</td>
<td>29.0</td>
<td>-0.40</td>
<td>-</td>
</tr>
<tr>
<td>Breakfast cereals</td>
<td>4.5</td>
<td>-0.20</td>
<td>0.57</td>
</tr>
<tr>
<td>White bread</td>
<td>43.0</td>
<td>0.19</td>
<td>0.40</td>
</tr>
<tr>
<td>Whole-grain bread</td>
<td>112.6</td>
<td>-0.50</td>
<td>-</td>
</tr>
<tr>
<td>Soup</td>
<td>72.6</td>
<td>0.15</td>
<td>-</td>
</tr>
<tr>
<td>Pizza</td>
<td>13.3 0.19</td>
<td>-0.27</td>
<td>0.26</td>
</tr>
</tbody>
</table>

1 Factor loadings between -0.15 and 0.15 are not shown for simplicity. SFA, saturated fatty acid.
modeling, a priori confounders included smoking status, packyears of smoking, BMI, and educational level. Physical activity and year of examination were also investigated for potential confounding effects and were only left in the model if they changed the measure of effect by >10%. Interactions were tested for smoking and BMI, and only data showing a significant interaction are presented.

Study power

Although the longitudinal population involved smaller numbers, it was still adequate to provide 90% power to detect a difference in FEV₁ decline between the fifth and first quintiles of 45 mL, if we assume an estimate of 350 mL for the within-subject SD (as in our previous study in Nottingham; 27). Dietary factors from principal components analysis were derived in SAS (SAS Institute Inc, Cary, NC), and the remaining analyses were done in STATA (version 10.0; Stata Corp, College Station, TX).

RESULTS

Study population

A description of the final study populations used in the analyses is presented in Table 1. The overall response rate for the cross-sectional population was 33% in Amsterdam, 45% in Maastricht, and 68% in Doetinchem; 70% of the responders had complete data for the analyses. Of those living in Doetinchem, data were collected at follow-up for 75% of the original study population (20) with complete data for this analysis in 70% of those subjects in the higher quintiles of the cosmopolitan diet trended to be slightly more women, with a higher intake of ex-smokers and a lower proportion of current smokers with longitudinal data.

Dietary pattern

The factor loadings of food items in the 3 identified dietary patterns are shown in Table 2 and are similar to previous dietary patterns determined within this population (28). Individual factor loading scores can be regarded as correlation coefficients between the original food items and the dietary patterns extracted, such that the items with the more positive values contribute the most to the factor score, and those with the more negative values contribute least to the factor score. Those subjects in the higher quintiles of the cosmopolitan diet (factor 1) were characterized by higher intakes of vegetables, fish, chicken, wine, rice and lower intakes of high-fat dairy products, added fat, added sugar, and potato. Those subjects in the higher intakes of the second dietary pattern, the traditional pattern (factor 2), were characterized by higher intakes of red meat, processed meat, potato, boiled vegetables, added fat, coffee, and beer and lower intakes of soy products, low-fat dairy products, tea, breakfast cereal, brown rice, pizza, juice, and fruit. Finally, subjects in the higher quintiles of the refined food dietary pattern (factor 3) were characterized by higher intakes of mayonnaise, salty snacks, candy, high-sugar beverages, French fries, white bread, and pizza and lower intake of boiled vegetables, whole-grain bread, fruit, and cheese.

When the 3 different diets were examined in relation to nutrients, it was shown that the cosmopolitan diet had a strong positive correlation with alcohol, vitamin C, and β-carotene (Table 3). The traditional diet had a positive correlation with alcohol and total fat intake and a negative correlation with carbohydrate intake. Finally, the refined-food diet had strong negative correlation with magnesium, fiber, and vitamin C intake.

There were different demographic characteristics associated with the identified dietary patterns (Table 4). Those with a more cosmopolitan diet tended to be slightly more women, with a higher educational level, and to be never smokers. Those with a higher intake of the traditional diet tended to be men, to be older, and to be current smokers. Those with a higher intake of

<table>
<thead>
<tr>
<th>TABLE 3</th>
<th>Pearson’s correlation coefficients (r) for dietary pattern scores and nutrient intakes among participants in the MORGEN-EPIC (Monitoring Project on Risk Factors and Chronic Diseases in the Netherlands–European Prospective Investigation into Cancer and Nutrition) study (n = 12,648)</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>Cosmopolitan diet</td>
</tr>
<tr>
<td>Total fat (% of energy intake)</td>
<td>-0.03</td>
</tr>
<tr>
<td>Polyunsaturated fat (% of energy intake)</td>
<td>0.17</td>
</tr>
<tr>
<td>Protein (% of energy intake)</td>
<td>0.07</td>
</tr>
<tr>
<td>Carbohydrates (% of energy intake)</td>
<td>-0.25</td>
</tr>
<tr>
<td>Alcohol (g/d)</td>
<td>0.31</td>
</tr>
<tr>
<td>Cholesterol (g/d)</td>
<td>0.12</td>
</tr>
<tr>
<td>Fiber (g/d)</td>
<td>-0.02</td>
</tr>
<tr>
<td>Magnesium (mg/d)</td>
<td>0.07</td>
</tr>
<tr>
<td>Vitamin C (mg/d)</td>
<td>0.26</td>
</tr>
<tr>
<td>Vitamin E (mg/d)</td>
<td>0.15</td>
</tr>
<tr>
<td>β-Carotene (µg/d)</td>
<td>0.34</td>
</tr>
</tbody>
</table>

Footnotes:

1 Food-consumption patterns were derived from energy-adjusted food intakes, and the dietary pattern scores were uncorrelated with total energy intake in the MORGEN-EPIC study. All correlations were significant (P < 0.05), except where otherwise indicated.

² P > 0.05.
the refined food pattern tended to be younger, current smokers, and have an equal proportion of men and women.

Dietary pattern and FEV<sub>1</sub> or respiratory health

After adjustment for confounders, a high intake of the cosmopolitan diet pattern was associated with a small increased prevalence of wheeze (fifth compared with first quintile odds ratio (OR): 1.3; 95% CI: 1.0, 1.5; P for < 0.001) and asthma (fifth compared with first quintile OR: 1.4; 95% CI: 1.0, 2.0; P for trend = 0.047 Table 5). A higher intake of a traditional diet was associated with lower lung function (fifth compared with first quintile: −94.4 mL (95% CI: −123.4, −65.5) and an increased prevalence of COPD (fifth compared with first quintile OR: 1.6; 95% CI: 1.1, 2.3). A diet higher in the refined-food dietary pattern was associated with a small increase in wheeze (P for trend = 0.07). Additional variables, such as physical activity or year of examination, did not demonstrate any confounding effect and were therefore not included in the final model. There was no interaction with smoking or BMI (all P > 0.05).

There were no overall associations between the dietary patterns and decline in lung function within the Doetinchem cohort population, although those with the highest quintile of intake of refined food had a significantly greater decline in lung function (−48.5 mL; 95% CI: −80.7, −16.3; P for trend = 0.11) or equivalent to an extra 10-mL decline per year as compared with the lowest quintile of refined food intake. None of the other dietary patterns were associated with lung function decline. In addition, no other potential confounders showed any confounding effect and were therefore not included in the final model. There was no interaction with smoking or BMI (all P > 0.05).

DISCUSSION

In this study, we assessed the relation between dietary patterns and respiratory outcomes. A traditional dietary pattern (characterized by higher intakes of red meat, processed meat, boiled vegetables, added fat, coffee, beer, and potato and lower intakes of soy products, low-fat dairy products, tea, breakfast cereal, brown rice, pizza, pasta, and fruit) was associated with a lower FEV<sub>1</sub> and an increased prevalence of COPD. In addition, an increased intake of a cosmopolitan diet (characterized by higher intakes of vegetables, fish, chicken, and wine and lower intakes of added fat, added sugar, and potato) was associated with a small increase in wheeze. A high intake of refined foods was associated with an accelerated longitudinal decline in FEV<sub>1</sub> over 5 y.

The strengths of the study include its use of a large representative sample with information on potential confounding lifestyle factors. However, we recognize that dietary patterns are also potentially associated with different lifestyle choices, such as smoking behavior and physical activity, and these same lifestyle choices could also affect FEV<sub>1</sub>. We adjusted for confounding by these factors, where they were available and measurable, and demonstrated no confounding effect (changed the exposure-outcome association >10%), although there may have been other factors that we were not able to control for in these analyses.

### Table 4

Demographic and lifestyle characteristics by quintile (Q) of dietary pattern score in a cross-sectional population: MORGEN-EPIC (Monitoring Project on Risk Factors and Chronic Diseases in the Netherlands–European Prospective Investigation into Cancer and Nutrition) study (n = 12,648)

<table>
<thead>
<tr>
<th>Factor 1: cosmopolitan diet</th>
<th>Factor 2: traditional diet</th>
<th>Factor 3: refined food pattern</th>
</tr>
</thead>
<tbody>
<tr>
<td>Male sex (%)</td>
<td>55</td>
<td>41.6</td>
</tr>
<tr>
<td>Age (y)</td>
<td>42.0</td>
<td>39.4</td>
</tr>
<tr>
<td>Educational level (%)</td>
<td>52</td>
<td>44</td>
</tr>
<tr>
<td>Low</td>
<td>60</td>
<td>27</td>
</tr>
<tr>
<td>Intermediate</td>
<td>37</td>
<td>30</td>
</tr>
<tr>
<td>High</td>
<td>13</td>
<td>35</td>
</tr>
<tr>
<td>Never</td>
<td>27</td>
<td>29</td>
</tr>
<tr>
<td>Ex</td>
<td>27</td>
<td>29</td>
</tr>
<tr>
<td>Current</td>
<td>27</td>
<td>29</td>
</tr>
<tr>
<td>BMI (kg/m&lt;sup&gt;2&lt;/sup&gt;)</td>
<td>24.8</td>
<td>24.8</td>
</tr>
<tr>
<td>Mean ± SD</td>
<td>24.8 ± 5.7 ± 3.7</td>
<td>24.8 ± 5.8 ± 3.8</td>
</tr>
<tr>
<td>95% CI</td>
<td>24.2–25.4 ± 3.3–4.3</td>
<td>24.6–25.6 ± 3.5–4.5</td>
</tr>
<tr>
<td><strong>P for trend</strong></td>
<td>0.047</td>
<td>0.07</td>
</tr>
<tr>
<td>n</td>
<td>944</td>
<td>944</td>
</tr>
</tbody>
</table>

1 Q1–Q5 correspond to the lowest through the highest intakes, respectively. Chi-square test or ANOVA was used, as appropriate, to test for statistical significance.
2 Mean ± SD (all such values).
3 P < 0.005.
4 Q1–Q5 correspond to the lowest through the highest intakes, respectively.
The association between dietary patterns and respiratory disease provides an additional dimension in studies on diet and respiratory disease. Intakes of certain nutrients are highly correlated when they occur in the same food or when they are part of the same metabolic route. It is also known that the intake of certain foods is correlated with aspects of lifestyle. Knowledge of the effects of foods can be used in preventive measures directed to avoid or stimulate the intake of individual foods or nutrients. However, knowledge of the beneficial or harmful effects of dietary patterns can be used in public health campaigns on healthy lifestyle. However, we need to address some potential limitations of these analyses. First, there were many decisions made in the analysis of dietary patterns that may have driven the results; for example, in the determination of food groups to be included in the analysis, food items with a similar nutrient profile or culinary use were grouped together, and previous knowledge of the effect of individual food items on respiratory disease was used to make these choices. However, the dietary patterns appear robust in this population, because dietary patterns were similar between sexes and were similar to the dietary patterns previously produced within this population (28), despite different inclusion/exclusion criteria for the study population. In addition, the labeling of the dietary patterns is subjective; however, these labels can be assessed by the reader by using the factor loading table (Table 2).

### TABLE 5

<table>
<thead>
<tr>
<th>Factor 1: cosmopolitan diet</th>
<th>Factor 2: traditional diet</th>
<th>Factor 3: refined-foods diet</th>
</tr>
</thead>
<tbody>
<tr>
<td>Cross-sectional (n = 12,648)</td>
<td></td>
<td></td>
</tr>
<tr>
<td>FEV₁ (mL)</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Q1 (low intake)</td>
<td>β 0.97</td>
<td>β 0.97</td>
</tr>
<tr>
<td>Q2</td>
<td>β 0.97</td>
<td>β 0.97</td>
</tr>
<tr>
<td>Q3</td>
<td>β 0.97</td>
<td>β 0.97</td>
</tr>
<tr>
<td>Q4</td>
<td>β 0.97</td>
<td>β 0.97</td>
</tr>
<tr>
<td>Q5 (high intake)</td>
<td>β 0.97</td>
<td>β 0.97</td>
</tr>
<tr>
<td>P for trend</td>
<td>0.97</td>
<td>0.97</td>
</tr>
<tr>
<td>Asthma²</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Q1 (low intake)</td>
<td>1.0</td>
<td>1.0</td>
</tr>
<tr>
<td>Q2</td>
<td>0.9</td>
<td>0.9</td>
</tr>
<tr>
<td>Q3</td>
<td>1.1</td>
<td>1.1</td>
</tr>
<tr>
<td>Q4</td>
<td>1.3</td>
<td>1.3</td>
</tr>
<tr>
<td>Q5 (high intake)</td>
<td>1.3</td>
<td>1.3</td>
</tr>
<tr>
<td>P for trend</td>
<td>0.047</td>
<td>0.047</td>
</tr>
<tr>
<td>Wheeze²</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Q1 (low intake)</td>
<td>1.0</td>
<td>1.0</td>
</tr>
<tr>
<td>Q2</td>
<td>0.9</td>
<td>0.9</td>
</tr>
<tr>
<td>Q3</td>
<td>1.1</td>
<td>1.1</td>
</tr>
<tr>
<td>Q4</td>
<td>1.3</td>
<td>1.3</td>
</tr>
<tr>
<td>Q5 (high intake)</td>
<td>1.3</td>
<td>1.3</td>
</tr>
<tr>
<td>P for trend</td>
<td>0.047</td>
<td>0.047</td>
</tr>
<tr>
<td>COPD²</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Q1 (low intake)</td>
<td>1.0</td>
<td>1.0</td>
</tr>
<tr>
<td>Q2</td>
<td>0.9</td>
<td>0.9</td>
</tr>
<tr>
<td>Q3</td>
<td>1.0</td>
<td>1.0</td>
</tr>
<tr>
<td>Q4</td>
<td>1.1</td>
<td>1.1</td>
</tr>
<tr>
<td>Q5 (high intake)</td>
<td>0.9</td>
<td>0.9</td>
</tr>
<tr>
<td>P for trend</td>
<td>0.047</td>
<td>0.047</td>
</tr>
<tr>
<td>Longitudinal (n = 2911)</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Change in FEV₁ residuals (mL)³</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Q1 (low intake)</td>
<td>0.0</td>
<td>0.0</td>
</tr>
<tr>
<td>Q2</td>
<td>8.5</td>
<td>16.2</td>
</tr>
<tr>
<td>Q3</td>
<td>11.4</td>
<td>19.1</td>
</tr>
<tr>
<td>Q4</td>
<td>1.9</td>
<td>19.1</td>
</tr>
<tr>
<td>Q5 (high intake)</td>
<td>3.7</td>
<td>17.0</td>
</tr>
<tr>
<td>P for trend</td>
<td>0.82</td>
<td>0.33</td>
</tr>
</tbody>
</table>

---

1. Adjusted for age, sex, age squared, height, age × height, smoking status, pack-years of smoking, BMI, educational level, and location by using linear regression.
2. Wheeze was defined as wheeze in the past 12 mo, asthma as a self-reported physician diagnosis, and COPD as GOLD (Global Initiative for Chronic Obstructive Lung Disease) stage 2 or higher but not postbronchodilator. The analyses were made by using logistic regression adjusted for age, sex, smoking status, pack-years of smoking, educational level, and location.
3. Adjusted for age, sex, age squared, height, age × height, smoking status, pack-years of smoking, BMI, and educational level by using linear regression.
There is potential measurement error in the ascertainment of diet (30, 31), despite the use of a validated food-frequency questionnaire (21, 22). Also, for these analyses, diet was only measured at one point in time; however, evidence indicates that diet does track throughout a lifetime (32). Despite these limitations, dietary epidemiology is still an important area of investigation because diet is a modifiable risk factor.

The results of analysis of food and food group effects are also possibly more practically relevant to public health, because the public can be informed to increase a certain food or food groups, which is easier than increasing the intake of a particular nutrient. To date, 7 papers on the relation between dietary patterns and respiratory outcomes have been published. One cross-sectional study based in Japan found that a diet higher in fast food and quick sugar was associated with an increased prevalence of wheeze (OR: 1.19; 95% CI: 1.04, 1.37) (11). Two studies have examined the effect of diet in pregnancy on the risk of disease in the child. The first of these found that children at age 6.5 y were less likely to have wheeze, atopic wheeze, and atopy if their mothers had a high compliance with a Mediterranean diet (12). The second study found no association between dietary patterns in mothers and wheeze or allergy in the children (13). The remaining 4 studies examined the incidence or prevalence of disease in large cohorts. Two of them found that an increased intake of a prudent dietary pattern (higher intakes of fruit, vegetables, fish, and whole-grain products) decreased the risk of COPD and that an increased intake of a Western dietary pattern (higher intakes of refined grains, cured and red meats, desserts, and French fries) increased the risk of COPD, but there was no association with incidence of asthma in either study (9, 10). Another study in females found no association between any of the dietary patterns (prudent, Western, or nuts and wine) and current or adult-onset asthma; however, they did find that an increased intake of a Western pattern was associated with a significantly increased risk in the frequency of asthma attacks among asthmatics (at least one attack per week) and an increased intake of the nuts and wine pattern was associated with a significantly reduced risk of frequent asthma attacks (14). Finally, a cohort study in Singapore Chinese found that an increased intake of the meat dim-sum dietary pattern (pork and chicken dim-sum foods and noodle dishes) was associated with an increased incidence of cough with phlegm, but no association was found with asthma or chronic productive cough (8). The current study found a small and weak association with cosmopolitan diet and prevalence of wheeze. Given the small effect size, no clear trend through the quintiles, and that none of the other respiratory outcomes were associated with the cosmopolitan diet, it is possible that this was just a chance finding. The finding that the more traditional diet was associated with a lower FEV₁ and an increase in COPD fits in with current and previous research, because one of the characteristics of this diet is a lower intake of fruit. Finally, in this study, the top quintile of the refined diet was associated with a greater decrease in lung function and also agrees with current literature, because this diet is characterized by a lower intake of fruit and vegetables, which both have protective effects on respiratory health.

To date, only 3 studies have investigated the effect of nutrients or foods on the decline in lung function. One found that a higher intake of vitamin C was associated with a lower rate of decline in FEV₁ over 7 y (33). The third study found that higher apple consumption was associated with a lower rate of decline; however, they found no significant association between intakes of individual nutrients and change in FEV₁ (34).

Although certain dietary patterns were associated cross-sectionally with FEV₁ in our study, none of the dietary patterns were associated with a decline in lung function over 5 y, although there was some evidence that a diet high in refined foods is associated with an increased decline in lung function. The overall lack of association with a decline in lung function may indicate that the association of dietary patterns with lung function in adulthood reflects the importance of diet in childhood and the strong tracking of diet since childhood. In addition, it must be recognized that the measurement of change in lung function over only 5 y is subject to noise and it may be possible that the follow-up was not long enough to observe a change in lung function or possibly that the sample size was not big enough. However, the previous studies that found an association between lung function decline and diet were smaller in size, the smallest of which found a significant effect in 1346 individuals followed-up for 7 y (27). Previous studies with similar follow-up times (ie, 5 y) also showed an effect (n = 2512) (34). The current study had a follow-up time of only 5 y and had the largest sample size to date (n = 3126 individuals).

Overall, our results provide evidence that a traditional diet, including a relatively high intake of red meat and processed meat and a lower intake of low-fat dairy products, appears to have adverse effects on lung function and COPD. However, this study did not show a consistent association between one particular dietary pattern and respiratory health; therefore, diet may not be as important a modifiable risk factor for respiratory health as the current evidence suggests.

The authors’ responsibilities were as follows—TMM: design, statistical analyses, and preparation of the manuscript; and SAL, PAC, MO, PB, JB, and HAS: design and preparation of the manuscript. None of the authors had any conflicts of interests.

REFERENCES