Adherence to French Nutritional Guidelines Is Associated with Lower Risk of Metabolic Syndrome\textsuperscript{1,2}

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Abstract

A decrease in metabolic syndrome (MetS) prevalence may lower the cardiovascular disease (CVD) burden. The predictive value of nutritional recommendations for the incidence of MetS has not yet been evaluated. We assessed, in a population-based study, the association between the French National Nutrition and Health Program Guideline Score (PNNS-GS) and 6-y risk of MetS. Participants in the Supplémentation en Vitamines et Minéraux Antioxydants study were followed-up from 1994–1996 to 2001–2002. MetS was defined according to International Diabetes Federation criteria. We also defined “mild” and “severe” MetS as waist criteria plus 2, or more than 2, other criteria. Prospective associations between the PNNS-GS at baseline (either as a continuous variable or in quartiles) and incident MetS were assessed using binary or multinomial logistic regression to provide OR and 95% CI in participants free of MetS at baseline (n = 2763). In multivariate models, each unit increase in the PNNS-GS score was associated with a 9% lower risk of MetS (OR = 0.91; 95% CI = 0.83–1.00). This association was even stronger with the risk of severe MetS (OR = 0.76; 95% CI = 0.63–0.91). After adjustment for baseline and change in BMI, this association remained significant for severe MetS but did not reach significance for overall MetS. These findings support a potential beneficial impact of nutritional guidelines upon primary prevention of MetS. Improvement in compliance with nutritional recommendations may help to reduce the burden of CVD disease in the general population. J. Nutr. 141: 1134–1139, 2011.

Introduction

The current heavy burden of cardiovascular disease (CVD),\textsuperscript{6} the leading cause of death worldwide, is likely to worsen in the near future because of population ageing, obesity, and type 2 diabetes (1). Metabolic syndrome (MetS) depicts a cluster of abnormalities that include central obesity, hyperglycemia, high blood pressure (BP), and TG levels and low HDL cholesterol concentrations (1). Although the definition of MetS remains controversial and metabolic pathways are not entirely understood, MetS is considered to be a combination of cardiovascular risk factors resulting from insulin resistance and abdominal obesity. Because MetS has been associated with an ~2-fold higher risk of CVD and an up to 5 times higher risk of type 2 diabetes (1), prevention strategies for reducing MetS prevalence, in particular through diet and physical activity, may help to reduce the burden related to the aforementioned chronic diseases.

A holistic approach to dietary intake is useful for evaluating the pooled effect of foods, generally consumed in combination (2). A “healthy” dietary pattern has been extensively related to significantly lower risk of CVD and death (3,4), with an effect ranging from 15 to 30% depending on the study (4). In terms of public health, one major issue lies in determining whether the overall quality of the diet, in particular adherence to nutritional guidelines, may be involved in prevention of MetS prior to CVD development. However, few longitudinal studies have investigated the association between a healthy pattern and the incidence of MetS (5–7).

Several national nutritional policies have been developed in various countries to provide dietary recommendations for preventing chronic diseases (8). In 2001 in France, the National Nutrition and Health Program (Program National Nutrition Santé, PNNS) was implemented to improve the health status of the population through nutritional measures (9). The purpose of our study was to evaluate the effect of baseline compliance with nutritional recommendations on the risk of MetS over a 6-y follow-up period. Secondary analyses were carried out to study

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2 Supplemental Tables 1 and 2 and Figure 1 are available from the “Online Supporting Material” link in the online posting of the article and from the same link in the online table of contents at jn.nutrition.org.
3 Abbreviations used: BP, blood pressure; CVD, cardiovascular disease; MetS, metabolic syndrome; PNNS-GS, Plan National Nutrition Santé-Guidelines Score; SU.VI.MAX, Supplémentation en Vitamines et Minéraux Antioxydant.
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the predictive value of the PNNS-GS for severity of MetS at 6 y according to the number of criteria met, because this has been related to cardiovascular risk (10).

**Participants and Methods**

**Participants**
The Supplementation en Vitamines et Minéraux Antioxydants (SU.VI.MAX) study (1994–2002) was a prevention trial designed to test the efficacy of antioxidant supplementation on ischemic heart disease and cancer (11). Eligible participants, 7713 women aged 35–60 y and 5028 men aged 45–60 y at baseline, were included in 1994–1995 and followed-up for 7.5 y. During follow-up, all participants underwent a yearly visit, alternating blood sampling (at baseline) and clinical examination (1995–1996) every other year. They also provided information on health, diet, and various lifestyle indicators. The SU.VI.MAX study was approved by the Ethical Committee for Studies with Human Subjects of the Paris-Cochin Hospital (CCPPRB no. 706) and the Commission Nationale Informatique et Liberte (CNIL no. 334641), which ensures that medical information is kept confidential and anonymous.

Participants with MetS or diabetes mellitus (glycemia ≥ 7 mmol/L and/or antidiabetic medication) at baseline were excluded, as were those who developed a stroke or a coronary event during the follow-up.

Among the 6892 eligible participants free of MetS and diabetes at baseline and with no history of CVD during follow-up, 4129 were excluded because of missing information on MetS status at the end of follow-up on PNNS-GS or on covariates (Supplemental Fig. 1). The final sample size was 2763 participants, 1091 men and 1672 women.

Compared to those included, excluded participants were more often women (67.5 vs. 60.5%; \( P < 0.0001 \)) and smokers (14.6 vs. 12.0%; \( P = 0.01 \)). They were also younger (49.3 ± 6.4 vs. 50.0 ± 6.2 y; \( P < 0.0001 \)) and had higher BMI levels (23.3 ± 3.2 vs. 23.0 ± 2.8 kg/m²; \( P = 0.0004 \)). Education level as well as mean PNNS-GS were similar between groups.

**Data assessment**

**Covariates.** Sociodemographic data and lifestyle, including gender, date of birth, education, smoking status, and hormonal replacement therapy for menopausal women were collected using a self-administered questionnaire at baseline. Antidiabetic (oral agents or insulin), antihypertensive, and lipid-lowering medications were self-reported via a questionnaire at baseline and at the end of follow-up.

**Health examination.** Blood samples were collected in 1994–1995 and 2001–2002 after a 12-h fast; all biochemical measurements were centralized at a single laboratory. Fasting blood glucose, serum TG, baseline total serum cholesterol (Advia 1650, Bayer Diagnostic), baseline serum apolipoprotein B (nephelometric assay, BNA Behring), and serum HDL-cholesterol (Advia 1650, Bayer Diagnostic) were measured. At baseline, HDL-cholesterol was not measured. Thus, Planella’s equation and the Friedewald formula were used to calculate HDL-cholesterol from total cholesterol and apolipoprotein B (12,13).

BP and anthropometric measurements were performed in 1995–1996 and 2001–2002. Weight was measured using an electronic scale (Seca) with participants wearing indoor clothes and no shoes. Height was measured to the nearest 0.5 cm by using a wall-mounted stadiometer. BP was measured during a clinical visit by a trained investigator using a standard mercury sphygmomanometer.

Waist was measured as the circumference midway between the lower ribs and iliac crests, with participants in a standing position and wearing underwear. Waist was measured to the nearest 0.5 cm using an elastic tape measure.

**Definition of MetS.** MetS status was defined according to International Diabetes Federation criteria (14), which include abdominal obesity (waist circumference ≥ 94 cm for men and ≥ 80 cm for women) and 2 or more of the following: high BP (systolic BP/diastolic BP ≥ 130/85 mmHg or antihypertensive medication), hypertriglyceridemia (≥1.7 mmol/L or fibrate medication), low HDL-cholesterol (<1.03 mmol/L for men or <1.29 mmol/L for women), and hyperglycemia (glycemia ≥5.6mmol/L or under antidiabetic medication).

**Physical activity and sedentary behavior.** A French validated self-administered version of the modifiable activity questionnaire was used in 1998 to assess physical activity (15). Type, frequency, and duration of activity, each performed at least 10 times for 10 min each session during leisure time over the past 12 mo, were collected. Using published compendiums (16,17), metabolic equivalent task were assigned to each activity time activity reported and summary scores were computed, including average metabolic equivalent task h/wk of physical activity. For participants with missing data for the modifiable activity questionnaire, we used data from other sources and imputations as previously reported (18).

Time spent watching television daily was reported and was considered a proxy for sedentary behavior.

**Dietary data and PNNS-GS computation.** Participants were asked to provide a 24-h record every 2 mo for a maximum of 6 records/day covering all days of the week and all seasons. To facilitate coding food portions, participants were assisted by an instruction manual that included validated photographs of ≥250 typical foods represented in 3 different portion sizes. Participants could also choose from 2 intermediates or 2 extreme portions for a total of 7 possible portion sizes (19). Dietary nutrient intakes were calculated using a food composition table that included >900 foods (20). Additionally, at baseline, information on weekly consumption of seafood was collected by a self-administered questionnaire and alcohol intake (g/d) was estimated using a short, validated, semiquantitative dietary questionnaire (21).

Individual means of food and nutrient intake were calculated from at least three 24-h dietary records during the first 2 y of follow-up. PNNS-GS computation, including food grouping, serving sizes, scoring, cutoff, and penalties, was previously described in detail (18). Briefly, the score is based on French national guidelines and includes 13 components for a total of 15 points maximum. Eight components refer to food groups, including recommended servings, and 4 components are related to overall limitation. Thresholds were established according to the French RDA (22) or PNNS public health objectives (9). Most serving sizes were defined using national food recommendations (9). Portion sizes varied for dairy products and starchy foods. For example, the portion size of cheese was 30 g, whereas that of yoghurt was 125 g. When serving size was not available, we used portion sizes commonly described in the literature, such as 80 g for fruit and vegetables (23). The final component deals with adherence to the physical activity recommendation. Scoring and cutoff values are presented in Supplemental Table 1.

A penalty for overconsumption was assigned to individuals with energy intakes higher than needs. Schofield’s basal metabolic rate was estimated using age, height, and weight (24). Physical activity values were scored as 1.55 (sedentary), 1.78 (moderate), and 2.10 (vigorous) in men and 1.56, 1.64, and 1.82 in women, respectively (25). Individual energy expenditures (basal metabolic rate × physical activity level) were then compared with energy intakes. If energy intake was >5% compared with calculated energy needs, an identical fraction was deducted from the score (18). For example, considering a participant with a score of 7 points and an energy intake:energy expenditure ratio of 1.10 (i.e. overconsumption of 10%), the penalized score was 6.3 (7 – 7 × 0.10).

**Statistical analyses**

About 18.5% of data was missing for sedentary behavior proxy; thus, a missing category was created to avoid drastically reducing the number of excluded participants.

Among the 6892 eligible participants, participants who were included and those who were excluded for missing MetS status at the end of follow-up, for PNNS-GS or for covariates, were compared using the chi-square test or Wilcoxon’s rank test.

Values in the text are means ± SD or percent across quartiles of PNNS-GS. Reported \( P \)-values referred to the linear contrast test or trend chi-square test as appropriate. We used logistic regression to study the relationship between the PNNS-GS (as a continuous variable and quartiles) and the MetS incidence over a 6-y follow-up period among...
participants free of MetS at baseline. The linear trend was estimated through the P-value corresponding to the PNNS-GS treated as a continuous variable. Values in the text are OR (95% CI).

Models were adjusted for age (y), gender, total daily energy intake from diet (kJ/d), and number of 24-h dietary records. A further adjusted model took into account smoking status (never, former, current), education level (primary school, secondary school, high school or equivalent), sedentary behavior (time spent watching TV: <1, 1 to <2, 2 to <3, and ≥3 h/d or missing data), hormonal replacement therapy (yes/no), and oral contraceptive use (yes/no) for women only. Finally, 2 supplementary models were also adjusted for baseline BMI and then BMI changes (kg/m²).

We did not adjust for daily supplementation (placebo or intervention group), because no effect (P = 0.36) on MetS incidence has been reported (26). We also estimated associations by alternately removing an individual specific component of the score and the same MetS risk.

Finally, to assess the association between the PNNS-GS and the severity grade of MetS based on the number of criteria met in addition to the waist criterion, we used the polytomous logistic regression model (SAS Proc Logistic, model option link = glogit), considering participants who remained free of MetS throughout the study as the reference group. OR were compared using Wald chi-square tests.

Interactions between PNNS-GS and age, gender, and BMI at baseline were tested and were revealed to be nonsignificant in terms of MetS (all P > 0.05). Statistical tests were 2-sided, with a type I error set at <0.05. All analyses were performed using SAS software (release 9.1, SAS Institute).

Results

Participant characteristics. At baseline, men and women were aged 52.8 ± 4.7 and 48.1 ± 6.5 y, respectively. The PNNS-GS mean was 7.5 ± 1.9 and 7.7 ± 1.9 among men and women, respectively. Characteristics of the population across PNNS-GS quartiles are presented (Table 1). Participants were more often women, older, better educated, and nonsmokers, and tended to have higher BMI with increasing PNNS-GS quartiles. In addition, they had lower sodium intake, lower cholesterol intake, lower energy intake, lower energy from total lipids and SFA, and higher fiber intake and energy from proteins and carbohydrates with increasing PNNS-GS quartile.

Association between PNNS-GS and the incidence of MetS. A significant 9% reduction in MetS incidence was observed for a 1-point increase in the PNNS-GS (Table 2).

### Table 1 Baseline characteristics of participants by PNNS-GS quartile (SU.VI.MAX study, 1994–1996)1

<table>
<thead>
<tr>
<th>Variable</th>
<th>Q1 (&lt;6.4)</th>
<th>Q2 (6.4–7.6)</th>
<th>Q3 (7.6–9.0)</th>
<th>Q4 (≥9.0)</th>
<th>P-trend1</th>
</tr>
</thead>
<tbody>
<tr>
<td>n</td>
<td>691</td>
<td>693</td>
<td>689</td>
<td>690</td>
<td></td>
</tr>
<tr>
<td>PNNS-GS</td>
<td>5.1 ± 1.1</td>
<td>7.1 ± 0.4</td>
<td>8.2 ± 0.4</td>
<td>10.0 ± 0.9</td>
<td>&lt;0.0001</td>
</tr>
<tr>
<td>Male, %</td>
<td>42.3</td>
<td>42.1</td>
<td>38.8</td>
<td>34.6</td>
<td>0.002</td>
</tr>
<tr>
<td>Age, y</td>
<td>48.9 ± 6.3</td>
<td>49.8 ± 6.0</td>
<td>50.5 ± 6.1</td>
<td>50.7 ± 6.3</td>
<td>&lt;0.0001</td>
</tr>
<tr>
<td>BMI, kg/m²</td>
<td>22.8 ± 2.9</td>
<td>23.1 ± 2.8</td>
<td>23.0 ± 2.8</td>
<td>23.1 ± 2.6</td>
<td>0.06</td>
</tr>
<tr>
<td>Education, %</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Primary</td>
<td>21.9</td>
<td>20.2</td>
<td>19.3</td>
<td>17.1</td>
<td>0.02</td>
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<tr>
<td>Secondary</td>
<td>37.8</td>
<td>37.8</td>
<td>37.9</td>
<td>38.1</td>
<td></td>
</tr>
<tr>
<td>High</td>
<td>40.4</td>
<td>42.0</td>
<td>42.8</td>
<td>44.8</td>
<td></td>
</tr>
<tr>
<td>Smoking status, %</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Nonsmoker</td>
<td>47.3</td>
<td>50.2</td>
<td>54.0</td>
<td>54.5</td>
<td>&lt;0.0001</td>
</tr>
<tr>
<td>Former smoker</td>
<td>37.5</td>
<td>35.9</td>
<td>33.4</td>
<td>39.3</td>
<td></td>
</tr>
<tr>
<td>Smoker</td>
<td>15.2</td>
<td>13.9</td>
<td>12.6</td>
<td>6.2</td>
<td></td>
</tr>
<tr>
<td>Sedentary lifestyle, %</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>≤1 h/d</td>
<td>12.6</td>
<td>13.3</td>
<td>11.6</td>
<td>13.7</td>
<td>0.66</td>
</tr>
<tr>
<td>1 to &lt;2 h/d</td>
<td>29.4</td>
<td>28.2</td>
<td>30.2</td>
<td>27.6</td>
<td></td>
</tr>
<tr>
<td>2 to &lt;3 h/d</td>
<td>35.4</td>
<td>36.1</td>
<td>37.8</td>
<td>38.0</td>
<td></td>
</tr>
<tr>
<td>≥3 h/d</td>
<td>22.7</td>
<td>22.5</td>
<td>20.4</td>
<td>20.7</td>
<td></td>
</tr>
<tr>
<td>Intervention group, %</td>
<td>50.1</td>
<td>53.7</td>
<td>50.9</td>
<td>52.8</td>
<td>0.53</td>
</tr>
<tr>
<td>Hormonal replacement therapy, %</td>
<td>8.3</td>
<td>13.7</td>
<td>14.2</td>
<td>18.9</td>
<td>&lt;0.0001</td>
</tr>
<tr>
<td>Oral contraceptive, %</td>
<td>17.5</td>
<td>13.5</td>
<td>14.2</td>
<td>11.8</td>
<td>0.03</td>
</tr>
<tr>
<td>Energy intake, kJ/d</td>
<td>9.7 ± 2.6</td>
<td>8.4 ± 2.2</td>
<td>8.1 ± 2.3</td>
<td>7.8 ± 2.0</td>
<td>&lt;0.0001</td>
</tr>
<tr>
<td>Alcohol, g/d</td>
<td>17.7 ± 17.8</td>
<td>14.4 ± 15.6</td>
<td>12.3 ± 13.7</td>
<td>10.3 ± 13.0</td>
<td>&lt;0.0001</td>
</tr>
<tr>
<td>Daily nutrient intakes, %</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Proteins</td>
<td>17.3 ± 2.9</td>
<td>17.6 ± 3.0</td>
<td>17.7 ± 2.9</td>
<td>18.0 ± 3.1</td>
<td>&lt;0.0001</td>
</tr>
<tr>
<td>Carbohydrates</td>
<td>41.8 ± 6.8</td>
<td>41.8 ± 6.4</td>
<td>42.0 ± 6.5</td>
<td>43.2 ± 6.5</td>
<td>&lt;0.0001</td>
</tr>
<tr>
<td>Lipids</td>
<td>41.0 ± 5.5</td>
<td>40.5 ± 5.6</td>
<td>40.2 ± 5.5</td>
<td>38.8 ± 6.0</td>
<td>&lt;0.0001</td>
</tr>
<tr>
<td>SFA</td>
<td>17.5 ± 2.8</td>
<td>16.8 ± 2.9</td>
<td>16.5 ± 2.9</td>
<td>15.3 ± 2.8</td>
<td>&lt;0.0001</td>
</tr>
<tr>
<td>MUFA</td>
<td>15.2 ± 2.5</td>
<td>15.3 ± 2.6</td>
<td>15.1 ± 2.9</td>
<td>14.8 ± 2.8</td>
<td>0.003</td>
</tr>
<tr>
<td>PUFA</td>
<td>5.8 ± 1.6</td>
<td>6.0 ± 1.6</td>
<td>6.2 ± 1.7</td>
<td>6.2 ± 1.8</td>
<td>&lt;0.0001</td>
</tr>
<tr>
<td>Cholesterol, mg/d</td>
<td>463.1 ± 154.4</td>
<td>386.0 ± 150.9</td>
<td>380.7 ± 145.6</td>
<td>351.4 ± 137.4</td>
<td>&lt;0.0001</td>
</tr>
<tr>
<td>Fiber, g/d</td>
<td>19.6 ± 7.4</td>
<td>18.6 ± 7.2</td>
<td>19.5 ± 7.1</td>
<td>21.2 ± 7.3</td>
<td>&lt;0.0001</td>
</tr>
<tr>
<td>Sodium, g/d</td>
<td>4.04 ± 1.33</td>
<td>3.53 ± 1.29</td>
<td>3.30 ± 1.28</td>
<td>3.03 ± 1.14</td>
<td>&lt;0.0001</td>
</tr>
</tbody>
</table>

1 Values are means ± SD or percent as appropriate, n = 2763.
2 P-values based on linear contrast test or trend chi-squared test.
3 Time spent watching TV. S14 were missing.
4 Excluding energy from alcoholic beverages.
Similarly, the OR for developing MetS among participants in the 4th quartile of PNNS-GS compared with those in the first was 0.63 (95% CI = 0.39–1.03). Additional adjustment for BMI at baseline and for changes in BMI provided nonsignificant findings ($P > 0.05$). For the modified PNNS-GS (Table 3), i.e., without accounting for each individual component, estimated OR were similar, but the associations did not remain significant after subtracting physical activity and intake of fruits and vegetables, added fat, whole grain, salt, and dairy products. In these models, each individual component of the PNNS-GS was not independently associated with the development of the MetS (Supplemental Table 2). However, a borderline association was observed between whole grain component and risk of MetS ($P = 0.06$).

**Association between PNNS-GS and severity of MetS.**
Analyses focusing on the severity of MetS showed that the PNNS-GS was significantly associated with lower risk among participants meeting the waist criterion and at least 3 other criteria only (Table 4). This association remained significant even after accounting for BMI and change in BMI.

**Discussion**
Among middle-aged adults, strengthening of compliance with nutritional guidelines was significantly associated with lower probability of developing MetS over a 6-y follow-up. When assessing severity of MetS, PNNS-GS was associated only with high-grade MetS, i.e., that corresponding to waist circumference criteria and at least 3 other components. After adjustment for BMI change, the overall association was no longer significant, whereas the probability of developing high-grade MetS after a 6-y follow-up period was significantly lower with increasing compliance with the PNNS-GS. Focusing on modified PNNS-GS by alternately removing each individual component suggested that several components may be responsible for the observed association. Removing fruits and vegetables, salt, physical activity, dairy products, whole grain, or the added fat component led to nonsignificant findings, indicating that each of these factors may be implicated.

Inclusion of physical activity in the PNNS-GS, although not customary (3), goes hand in hand with developing an adherence score based on French nutritional guidelines. Indeed, the com-

| TABLE 2 | PNNS-GS (in quartiles and continuous) related to 6-y incidence of MetS (SU.VI.MAX study, 1994–2002)$^1$
| Quartile of PNNS-GS | Continuous PNNS-GS (≤ 6.4) | Q2 (6.4–7.6) | Q3 (7.6–9.0) | Q4 (9.0) | $P^2$
|---|---|---|---|---|---|
| $n$ | 691 | 693 | 689 | 690 | OR (95% CI)
| Model 1$^3$ | 0.90 (0.82–0.99) | 1 (ref) | 0.76 (0.48–1.20) | 0.71 (0.44–1.12) | 0.60 (0.37–0.98) | 0.03
| Model 2$^4$ | 0.91 (0.83–1.00) | 1 (ref) | 0.78 (0.49–1.23) | 0.74 (0.46–1.18) | 0.63 (0.39–1.03) | 0.05
| Model 3$^5$ | 0.91 (0.83–1.01) | 1 (ref) | 0.75 (0.45–1.22) | 0.72 (0.43–1.20) | 0.63 (0.37–1.07) | 0.10
| Model 4$^6$ | 0.94 (0.84–1.04) | 1 (ref) | 0.79 (0.48–1.32) | 0.79 (0.46–1.33) | 0.72 (0.42–1.23) | 0.21

$^1$ $n = 2763$.
$^2$ $P$ for the PNNS-GS as a continuous variable.
$^3$ Adjusted for age, energy intake, gender, and number of 24-h dietary records.
$^4$ Adjusted for all variables in model 1 and education level, sedentary behavior, tobacco smoking status, hormonal replacement therapy, and oral contraceptive use (for women only).
$^5$ Adjusted for all variables in model 2 and BMI.
$^6$ Adjusted for all variables in model 3 and change in BMI.

| TABLE 3 | Modified PNNS-GS in relation to 6-y incidence of MetS (SU.VI.MAX study, 1994–2002)$^1$
| Modified PNNS-GS | OR$^3$ (95% CI) for 1-point increment | $P$
|---|---|---|
| PNNS-GS without physical activity (maximum = 13.5 points) | 0.93 (0.84–1.04) | 0.22
| PNNS-GS without fruits and vegetables (maximum = 13 points) | 0.92 (0.83–1.03) | 0.14
| PNNS-GS without salt (maximum = 13.5 points) | 0.92 (0.83–1.01) | 0.07
| PNNS-GS without vegetable added fat (maximum = 14 points) | 0.90 (0.82–1.00) | 0.04
| PNNS-GS without added fat (maximum = 14 points) | 0.91 (0.83–1.01) | 0.07
| PNNS-GS without alcohol (maximum = 14 points) | 0.90 (0.82–0.99) | 0.04
| PNNS-GS without whole grain (maximum = 14 points) | 0.93 (0.84–1.03) | 0.15
| PNNS-GS without sweetened product (maximum = 14 points) | 0.90 (0.82–0.99) | 0.03
| PNNS-GS without dairy products (maximum = 14 points) | 0.92 (0.84–1.01) | 0.10
| PNNS-GS without bread, cereals, potatoes and legumes (maximum = 14 points) | 0.91 (0.82–1.00) | 0.04
| PNNS-GS without meat, seafood, eggs (maximum = 14 points) | 0.90 (0.82–0.99) | 0.04
| PNNS-GS without beverages (maximum = 14 points) | 0.91 (0.82–1.00) | 0.05
| PNNS-GS without seafood (maximum = 14 points) | 0.89 (0.80–0.98) | 0.02

$^1$ $n = 2763$.
$^3$ Adjusted for age, energy intake, gender, number of 24-h dietary records, education level, sedentary behavior, tobacco smoking status, hormonal replacement therapy, oral contraceptive use (for women only), and the removed component.
TABLE 4  PNNS-GS in relation to 6-y number of MetS components met (SU.VI.MAX study, 1994--2002)\(^1\)

<table>
<thead>
<tr>
<th>Model</th>
<th>OR (95% CI)</th>
</tr>
</thead>
<tbody>
<tr>
<td>Model 1(^1)</td>
<td>0.95 (0.85--1.06)</td>
</tr>
<tr>
<td>Model 2(^2)</td>
<td>0.96 (0.86--1.07)</td>
</tr>
<tr>
<td>Model 3(^3)</td>
<td>0.97 (0.86--1.09)</td>
</tr>
<tr>
<td>Model 4(^4)</td>
<td>0.98 (0.87--1.10)</td>
</tr>
</tbody>
</table>

\(^1\) Values are OR (95% CI), \(n = 2763.\) OR in row with superscripts without a common letter differ, \(P < 0.05.\)

\(^2\) Corresponding to waist circumference criteria not met or waist circumference criteria met, but fewer than 2 other components met

\(^3\) Adjusted for age, energy intake, gender, and number of 24-h dietary records

\(^4\) Adjusted for all variables in model 1 and education level, sedentary behavior, tobacco smoking status, hormonal replacement therapy (for menopausal women only).

\(^5\) Adjusted for all variables in model 2 and baseline BMI.

\(^6\) Adjusted for all variables in model 3 and change in BMI.

bination of a healthy diet and physical activity may act synergistically to enhance chronic disease prevention. In our study, levels of adherence to physical activity and dietary recommendations, when reciprocally adjusted, were not significantly associated with risk of MetS. This finding argues for a synergistic effect on MetS of adherence to nutritional factors and physical activity recommendations rather than the sum of independent effects.

Several limitations to our study should be stated. First, HDL-cholesterol was not measured at baseline but was calculated through validated equations (12,13). Second, a selection bias may have arisen due to inclusion of participants with required data for PNNS-GS computation and MetS status definition, in addition to bias related to long-term participation in the trial. Such participants may have been particularly compliant and health conscious, leading to homogeneity in our population; thus, caution must be used when generalizing the present findings. Finally, although nutritional guideline-based scores are useful for evaluating recommendations for chronic disease prevention, a priori indices present limitations (3). In particular, the scoring system, cutoff criteria, and definition of included components may have been subjective. However, several indices have proven to be predictive of disease incidence and later mortality (3).

The strengths of the present study include its prospective design, enabling estimation of the predictive value of compliance with nutritional guidelines upon the risk of MetS. Moreover, the PNNS-GS has been proven to adequately discriminate between participants according to the overall quality of the diet (18). The PNNS-GS accounted for excess energy intakes with respect to needs, because it has been reported that several dietary indexes were positively correlated with energy intake (3). Indeed, the greater the overall consumption, the greater the likelihood of meeting recommendations. Finally, residual confounding arising from the potentially healthier lifestyle of participants strongly compliant with nutritional guidelines was limited by adjustment for relevant covariates available in this large database.

Some prospective studies have reported an association between the dietary quality score and risk of hypertension, obesity, and changes in BP or anthropometric measurements (27–32). However, the clustering of all these risk factors must be taken into account, because they are not interdependent and reflect lifestyle modifications (33). Literature focusing on adherence to nutritional guidelines in association with MetS is scarce and most study designs are cross-sectional. However, our findings are in line with those from cross-sectional studies reporting a lower prevalence of MetS among participants who more closely adhered to American nutritional recommendations assessed through the Dietary Guidelines for Americans Index (34,35). Moreover, in a French transversal study, the PNNS-GS was associated with a lower prevalence of MetS only among young adults (36). The Dietary Guidelines for Americans Index and PNNS-GS share a number of concepts, although their computation and the recommendations from which they are derived are different. Although no study, to our knowledge, except ours has yet reported an association between compliance with nutritional recommendations per se and MetS incidence, the beneficial effect of adherence to a Mediterranean diet has been observed in some studies (5,7).

Recent studies carried out among Framingham Heart Study Offspring (7,34) used the revised National Cholesterol Education Program Adult Treatment Panel III definition (33). We performed primary analysis among the 3561 participants with adequate data for determining longitudinal MetS status according to the National Cholesterol Education Program Adult Treatment Panel III definition (data not shown). Findings were similar with, for the basic model, an OR of 0.9 for an increase of 1 point in the PNNS-GS (95% CI = 0.81–1.00), arguing for the robustness of our results. These findings, when added to ours, support the hypothesis of an effect of overall diet on MetS incidence, whatever the method used to evaluate dietary quality and the definition used to characterize MetS. However, further studies are needed to confirm the effect of dietary guidelines on MetS risk in a longitudinal design.

Additional adjustment for baseline BMI and changes in BMI was performed to assess the mediation effect of total adiposity. In our study, accounting for these factors attenuated the association between compliance with nutritional guidelines and the incidence of MetS as a whole, which is not surprising, because adiposity, through waist circumference, is directly included in the MetS definition. We hypothesize that an increase in BMI is, in most cases, a necessary condition for developing MetS. However, high-grade MetS remained significantly associated with, for the basic model, an OR of 0.9 for an increase of 1 point in the PNNS-GS (95% CI = 0.81–1.00), arguing for the robustness of our results. These findings, when added to ours, support the hypothesis of an effect of overall diet on MetS incidence, whatever the method used to evaluate dietary quality and the definition used to characterize MetS. However, further studies are needed to confirm the effect of dietary guidelines on MetS risk in a longitudinal design.

In conclusion, our findings suggest that better compliance with nutritional guidelines is a successful strategy for decreasing the prevalence of MetS through weight management but also through other pathways. Such an effect on the prevalence of MetS could lead to a reduction in the incidence of CVD and type 2 diabetes.

This study provides additional arguments for evaluating nutritional guidelines. However, complementary investigations are needed to validate the effects of nutritional recommendations on intermediate factors in chronic disease progression.

Acknowledgments

E.K. carried out data verification and analyses and was responsible for writing the manuscript; K.C. was involved in data analyses and interpretation of findings; L.E., P.G., S.H., S.C., and K.C. were involved in data checking and critical revision of the manuscript for important intellectual content; and S.H. and P.G. were responsible for design and protocol development of the study and collection of data. All authors read and approved the final paper.

Literature Cited

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