Dietary Patterns Predict Changes in Two-Hour Post-Oral Glucose Tolerance Test Plasma Glucose Concentrations in Middle-Aged Adults\textsuperscript{1,2}

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Abstract

We examined whether the adherence to major dietary patterns at baseline of 5824 nondiabetic Danes (30–60 y) enrolled in the nonpharmacological Inter99 intervention predicted changes in fasting plasma glucose (FPG) and postchallenge 2-h plasma glucose (2h-PG) concentrations during a 5 y period and whether a potential association was dependent on baseline glucose tolerance status. Through principal component analysis, a score for a traditional dietary pattern (characterized by higher intakes of high-fat sandwich spreads, red meat, potatoes, butter and lard, low-fat fish, sandwich meat, and sauces) and a score for a modern dietary pattern (characterized by higher intakes of vegetables, fruit, vegetable oil/vinegar dressing, poultry, pasta, rice, and cereals) were estimated for each person at baseline. Random effect models adjusting for relevant confounders were used to estimate changes in repetitive measures of FPG and 2h-PG. A higher modern score (of 1 SD) predicted an annual decrease in 2h-PG of 0.015 mmol/L (\(P\), 0.01) regardless of glucose tolerance status. For individuals with isolated impaired glucose tolerance, a higher traditional score (of 1 SD) predicted an annual increase in 2h-PG of 0.083 mmol/L (\(P\), 0.0001). In conclusion, glucose tolerance status did not, in general, affect the predictive effect of the dietary patterns. The study suggests that the risk of worsening 2h-PG concentrations may be smaller for individuals with a high modern dietary pattern score characterized by high intakes of vegetables, fruit, vegetable oil/vinegar dressing, poultry, pasta, rice, and cereals. J. Nutr. 139: 588–593, 2009.

Introduction

The analysis of dietary patterns emerged >25 y ago and is now an important tool for examining diet-disease relations (1). One advantage to using dietary patterns is the potential to detect the combined effect of foods, especially if the individual components of a pattern contribute to only a small amount of risk (2) or benefit. Therefore, dietary patterns can be used as good predictive variables in analyses of diet-disease associations where the synergistic dietary effects are of interest.

Some cohort studies have examined whether dietary patterns identified by principal component analysis are predictive of diabetes risk in a prospective setting (2–5). One advantage to using dietary patterns is the potential to detect the combined effect of foods, especially if the individual components of a pattern contribute to only a small amount of risk (2) or benefit. Therefore, dietary patterns can be used as good predictive variables in analyses of diet-disease associations where the synergistic dietary effects are of interest.

Some cohort studies have examined whether dietary patterns identified by principal component analysis are predictive of diabetes risk in a prospective setting (2–5). None of these have analyzed the relation between dietary patterns at baseline and changes over time in continuous plasma glucose (PG) concentrations, which gives a sensitive and specific picture of the potential dietary pattern score effect. Dietary patterns associated with a lower risk of diabetes have been characterized by a relatively high intake of these food groups: vegetables, fruit, and poultry (3,4). Dietary patterns associated with a higher risk of diabetes have been characterized by a relatively high intake of one or more of the following food groups: red meat, potatoes, refined grains, butter, high-fat dairy products, rye and grains other than wheat, and confectionaries (2–5). In a previous article, we showed that 2 dietary patterns (traditional and modern) could be identified in the nonpharmacological Danish intervention study Inter99 using principal component analysis and that the patterns were robust as markers of food intake pattern at a group level (6). The relation

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  \item \textsuperscript{*} To whom correspondence should be addressed. E-mail: cala@steno.dk.
  \item \textsuperscript{8} Abbreviations used: FPG, fasting plasma glucose; i-IFG, isolated impaired fasting glycemia; IFG/IGT, a combined group of IFG and IGT; i-IGT, isolated impaired glucose tolerance; NGT, normal glucose tolerance; PG, plasma glucose; 2h-PG, 2-h plasma glucose.
\end{itemize}
between the dietary pattern scores and diabetes in the Inter99 study has not, to our knowledge, previously been examined.

Based on the above-mentioned studies, we hypothesized that the dietary pattern scores at baseline in Inter99 can predict changes in fasting PG (FPG) and 2-h PG (2h-PG). We assumed that a higher modern pattern score (primarily characterized by higher intakes of vegetables, fruit, vegetable oil/vinegar dressing, poultry, pasta, rice, and cereals) predicts lower PG concentrations, whereas a higher traditional pattern score (primarily characterized by higher intakes of high-fat sandwich spreads, red meat, potatoes, butter and lard, low-fat fish, sandwich meat, and sauces) predicts higher PG concentrations. Further, we hypothesized that the relative effect of the dietary pattern scores differs between groups of glucose intolerance at baseline because of differences in risk profile. We therefore examined whether dietary pattern scores identified at baseline in the Inter99 study were predictive of changes in FPG and 2h-PG during a 5-year period and whether the predictive effect of the dietary pattern scores differed between different glucose tolerance groups at baseline.

### Subjects, Materials, and Methods

The Danish population-based Inter99 study is an intervention study on diet, physical activity, smoking, and alcohol. The primary aim was to evaluate the effect of the intervention on incidence of ischemic heart disease. Data collection methods and nondietary and dietary baseline results have been reported elsewhere (7–9).

An age- and sex-stratified random sample of 13,016 individuals born in 1939–40, 1944–45, 1949–50, 1954–55, 1959–1960, 1964–65, and 1969–70 and living in Copenhagen County in 1999–2000 was drawn from the Civil Registration and prerandomized into 2 groups (group A, n = 11,708; group B, n = 1308) with different intervention strategies. Of these individuals, 6784 (52.5%) participated in the study at baseline (7). Written informed consent was obtained from all the participants. The Inter99 study was approved by the local Ethics Committee (KA 98 135) and is registered with ClinicalTrials.gov (registration no. NCT00289237).

### Study population

We excluded individuals who had not completed the FFQ, who had left 5 or more pages of 14 blank, or who had clearly misunderstood the FFQ (including questionnaires where 2 or more answers per question line recurrently were ticked or questionnaires where only the highest response frequency was ticked repeatedly). Individuals with missing PG measures at baseline or diabetes at baseline were also excluded. Consequently, 5824 (85.8%) individuals qualified for the analyses.

### Dietary assessment

In the self-administered, validated, 198-item FFQ, the participants were asked to report their dietary intake during the previous month (9). Validation of the FFQ has shown that the FFQ provides a reasonable classification of individuals and a valid quantitative measurement of the dietary intake (10). For the present analyses, consumption of each food item in the FFQ (including alcohol) was estimated in g/d and total energy intake in MJ/d.

We have previously identified, named, and reproduced 2 dietary patterns in a subsample of the Inter99 population at baseline using principal component analysis (6). Principal component analysis reduces dietary data into factors (patterns) based on correlations between food groups. Individuals receive a factor score for each derived dietary pattern. The traditional pattern was characterized by high loadings (≥0.40) on pâté or high-fat sandwich meat, mayonnaise salads, red meat, potatoes, butter and lard, low-fat fish, low-fat sandwich meat, and sauces. The modern pattern was characterized by high loadings on vegetables, fruit, mixed vegetable dishes, vegetable oil and vinegar dressing, poultry, pasta, rice, and cereals. The larger the loading of a given food group to the pattern, the greater the contribution of that food group to the pattern. The loadings ranged from −0.34 to 0.62. The dietary patterns are continuous variables of scores on which a person can have any combination of scores from each of the dietary patterns. A high score for a given pattern indicates that the individual consumed foods from food groups with high loadings on the respective dietary pattern more frequently than a person with a low score. The dietary patterns were reproducible, and reproducibility was better for women than men (6).

In this article, the factor loadings from the dietary patterns previously identified in the subsample were used to calculate a modern factor score and a traditional factor score for each of all participants at baseline. Each person therefore has a score for each of the dietary patterns and those scores were used as predictors of change in PG concentrations.

### Risk assessment

Blood samples for analysis of venous PG were taken after an overnight fast and after a standard 75-g oral glucose tolerance test in individuals without previous diagnosis of diabetes. The blood samples were taken in heparin-sodium fluoride glasses, put on ice immediately, and centrifuged (1500 × g for 10 min) within 60 min in a cool centrifuge. The PG was analyzed using the hexokinase/glucose-6-phosphate dehydrogenase technique (Boehringer Mannheim). The participants were classified into normal glucose tolerance (NGT), isolated impaired fasting glycaemia (i-IFG), isolated impaired glucose tolerance (i-IGT), and a combined group of IFG and IGT (IFG/IGT) at baseline (11).

Body weight was measured to the nearest 0.1 kg and height was measured to the nearest 0.5 cm. Information on age, gender, physical activity, smoking, known hypertension, family history of diabetes, and known diabetes was obtained from a self-administered general questionnaire completed before the first visit. Based on answers about time spent on physical activity in transportation to and from work and time spent on leisure-time physical activity (but not including occupational physical activity), the variable voluntary physical activity (min/wk) was constructed by summing responses from these questions (12). Family history of diabetes included parents and siblings.

The population was divided into a low and a high risk group at baseline based on a risk estimate of ischemic heart disease (13) or the presence of risk factors (smoking, hypertension, hypercholesterolemia, obesity, or having impaired glucose tolerance). A more specific definition of individuals with high or low risk has been described elsewhere (7).

### Intervention

All individuals were invited to a health screening program and an individual lifestyle consultation focused on diet, physical activity, smoking, and alcohol at baseline. Individuals at high risk in group A were further offered group counseling on diet and physical activity or smoking cessation/reduction, depending on lifestyle and motivation to change the lifestyle. Low risk participants in group A and B were treated identically and followed only by questionnaire. All high risk individuals in group A and B were invited after 1 and 3 y for a health examination (including oral glucose tolerance test), completion of a questionnaire, a risk assessment, and lifestyle counseling. After 5-y of follow-up, all participants were invited for a health examination and a short lifestyle counseling (14).

In summary, we had a 3-level intervention intensity categorization from baseline to 5 y of follow-up: low risk in either group A or B (n = 2500, 42.9%), high risk in group B (n = 344, 5.9%), or high risk in group A (n = 2980, 51.2%).

### Statistical methods

Baseline characteristics of the participants were computed in quintiles of the 2 dietary pattern scores for illustration. Linear regression was used to test for association between each of the dietary patterns as continuous explanatory variables (scores) and the following continuous independent variables: age, BMI, voluntary physical activity, and natural log-transformed intake of energy. For categorical variables, logistic regression was applied to test whether the probability of being male, a daily smoker, at high risk, or having known hypertension or family history of diabetes increased or decreased across the factor score range. The analyses were also conducted with adjustment for energy intake at baseline.

We modeled the predictive effects of the dietary pattern scores at baseline (difference of 1 SD) on repeated measurements of PG concentrations during the 5-year period. There were up to 4 occasions (baseline, y 1, 3, and 5) where FPG and/or 2h-PG measures were available. The outcome variables FPG and 2h-PG were modeled separately. Each individual contributed with information to the analyses only as long as diabetes or treatment for diabetes was not reported. Persons who participated at
baseline and from whom we collected a PG measure in at least 1 of the follow-up investigations were included in the analyses. We checked that the residuals of FPG and 2h-PG were normally distributed. For these analyses, the dietary pattern scores were standardized to mean = 0 and SD = 1, which made comparison of the predictive effect of the 2 dietary patterns possible.

Different random effect models were used (proc mixed in SAS); all included random effects of person and time (year) and fixed effects of time and dietary pattern score. The simple model included only the 2 dietary pattern scores as variables. In the fully adjusted models, the confounders included were as follows: level of intervention intensity (3 levels), gender, age (continuous), known hypertension (yes/do not know/no), family history of diabetes (yes/no), physical activity (continuous), smoking (daily smoker/occasional smoker/ex-smoker/never-smoker), intake of energy (continuous), and BMI (continuous). To deal with potential qualitative dietary changes throughout the follow-up period, we also adjusted for intake of total fat, saturated fat, fish, fruit, vegetables, and dietary fiber (continuous). We included both dietary pattern scores in all models, because it made it possible to estimate the effect of a higher score in one dietary pattern, assuming no difference in the other dietary pattern score. Change in FPG and 2h-PG over time differed among the 3 intervention categories (P < 0.01); hence, we adjusted for level of intervention intensity in the fully adjusted models, assuming that the effect of a given dietary pattern score was the same at all 3 levels of intervention intensity. Gender was included in the fully adjusted models, because we previously had identified differences in the dietary patterns and their reproducibility between men and women (6). Known hypertension (15), family history of diabetes (16,17), physical activity, and smoking (18–20) as well as BMI (21) have previously been shown to be predictive of increased risk of abnormal glucose tolerance or diabetes and were therefore included as confounders. The quality and not the quantity of the diet was important in this study. Total energy intake was therefore included in the fully adjusted models. The confounders included in the fully adjusted models were first included as baseline values. Second, follow-up values were included for those variables where these were available: age, physical activity, smoking, energy intake, and BMI. In extra analyses, intake of total fat, saturated fat, fish, fruit, vegetables, and dietary fiber were included instead of energy intake. Finally, we further tested for interaction between each dietary pattern and glucose tolerance status at baseline (NGT, i-IFG, i-IGT, or IFG/IGT) and time. When the interaction was significant, we estimated the change in PG per year for each glucose tolerance status group. For all analyses, P < 0.05 was considered significant. All analyses were conducted using SAS version 9.1 (SAS Institute).

**Results**

The standardized traditional pattern scores ranged from −2.86 to 7.35 and the standardized modern pattern scores ranged from −2.68 to 6.66. These ranges were comparable to the standardized range of the scores observed in the subsample (data not shown).

At baseline, mean age and the probability of having known hypertension decreased across the traditional pattern score range (Table 1). The probability of having known hypertension increased with a higher modern pattern score. The probability of being male, a daily smoker, or at high risk increased with an increasing traditional pattern score and decreased with an increasing modern pattern score. Voluntary physical activity and intake of energy both increased with higher traditional and modern pattern scores. After adjustment for energy intake at baseline, a few relationships changed; the traditional pattern was no longer associated with lower age but was associated with higher BMI and less time spent on physical activity (data not shown).

Individuals excluded from the descriptive baseline analyses due to useless information on diet, missing PG measures, or self-reported diabetes (n = 960) were older, less active, more likely to be women, obese, and at higher risk than those included (P < 0.05).

Of the 5824 individuals with PG measures at baseline, 66.6% also had PG measures at y 5 of follow-up. At y 1 and 3 of follow-up, blood samples were taken only for individuals at high risk (n = 3324). Of those, 58.8% had PG measures at y 1 of follow-up and 59.0% at y 3 of follow-up. The time between the first and the last examination of FPG or 2h-PG was 5.0 ± 1.0 y (mean ± SD). The annual decrease in FPG was 0.006 ± 0.001 mmol/L (P = 0.0001) and the annual increase in 2h-PG was 0.025 ± 0.005 mmol/L (P = 0.0001).

In Table 2 and Figure 1, a higher score for any of the dietary patterns refers to a difference of 1 SD. For the modern pattern, estimates from the simple model and the fully adjusted models show that a higher score predicted an annual decrease in 2h-PG between 0.008 and 0.015 mmol/L, but no change in FPG (Table 2). Glucose tolerance status did not affect the predictive effect of the modern pattern score in relation to FPG or 2h-PG. For a higher traditional pattern score, no significant general changes were observed for either the simple model or the fully adjusted models without an interaction term for glucose tolerance status in relation to both FPG and 2h-PG. However, there were significantly different effects of the traditional pattern score on 2h-PG in the 4 different glucose tolerance groups.

Results from the fully adjusted model, including the confounders with baseline values only, did not differ from the results

### Table 1

Baseline characteristics of the study sample according to quintiles of dietary pattern scores

<table>
<thead>
<tr>
<th>Variable²</th>
<th>Quintile 1</th>
<th>Quintile 3</th>
<th>Quintile 5</th>
<th>P-value³</th>
</tr>
</thead>
<tbody>
<tr>
<td>Age, y</td>
<td>46.2 ± 8.0</td>
<td>45.8 ± 7.9</td>
<td>45.4 ± 7.6</td>
<td>&lt;0.001</td>
</tr>
<tr>
<td>Men, %</td>
<td>16.9</td>
<td>50.6</td>
<td>79.7</td>
<td>&lt;0.0001</td>
</tr>
<tr>
<td>Known hypertension, %</td>
<td>21.3</td>
<td>17.3</td>
<td>13.4</td>
<td>&lt;0.0001</td>
</tr>
<tr>
<td>Daily smokers, %</td>
<td>31.0</td>
<td>32.5</td>
<td>44.3</td>
<td>&lt;0.0001</td>
</tr>
<tr>
<td>At high risk, %</td>
<td>55.8</td>
<td>55.3</td>
<td>61.3</td>
<td>&lt;0.0001</td>
</tr>
<tr>
<td>Family history of diabetes, %</td>
<td>17.4</td>
<td>18.8</td>
<td>15.8</td>
<td>0.757</td>
</tr>
<tr>
<td>BMI, kg/m²</td>
<td>26.2 ± 4.6</td>
<td>26.0 ± 4.3</td>
<td>25.9 ± 4.3</td>
<td>0.131</td>
</tr>
<tr>
<td>Physical activity, min/wk</td>
<td>283 ± 162</td>
<td>293 ± 162</td>
<td>311 ± 163</td>
<td>&lt;0.0001</td>
</tr>
<tr>
<td>Energy intake, 4 MD/d</td>
<td>6.5 ± 1.8</td>
<td>9.5 ± 1.8</td>
<td>14.1 ± 3.6</td>
<td>&lt;0.0001</td>
</tr>
</tbody>
</table>

1 Values are means ± SD or %.
2 Individuals included n = 5824. Missing information for n = 43 on smoking, n = 523 on hypertension and n = 14 on family history of diabetes, n = 1 on BMI and n = 366 on physical activity.
3 P-values refer to a model with the continuous dietary pattern scores as explanatory variables without adjustment for total energy intake at baseline.
4 Log-transformed scale.

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of the fully adjusted model, where follow-up values for age, physical activity, smoking, energy intake, and BMI were included.

For individuals with i-IGT, a higher traditional pattern score was associated with an annual increase in 2h-PG of 0.087 mmol/L (from the fully adjusted model with interaction term for glucose tolerance status). For individuals with i-IGT, the predicted difference in the 2h-PG between persons one standardized modern score apart at baseline was estimated to be 0.415 ± 0.087 mmol/L. (Fig. 1). For the other glucose tolerance groups, no change was observed. In general, the predicted mean difference in the 5-y change in 2h-PG between persons one standardized modern score apart at baseline was estimated to be 0.073 ± 0.028 mmol/L (from the fully adjusted model). For individuals with i-IGT, the predicted difference in the 5-y change in 2h-PG between persons one standardized traditional score apart at baseline was estimated to be 0.15 ± 0.087 mmol/L (from the fully adjusted model with the interaction term for glucose tolerance status).

Our results indicate that complying with a pattern of consuming vegetables, fruit, oil, and poultry can reduce the increment in 2h-PG. The estimated change in 2h-PG for a higher modern score indicated that the modern pattern in general predicted a lower 2h-PG concentration, whereas the estimated change in 2h-PG for a higher traditional score predicted higher PG concentrations for individuals with i-IGT. However, glucose tolerance status did not in general affect the predictive effect of the dietary pattern scores.

The strengths of this study are the large number of individuals and the novelty of prospective examination of the predictive effect of dietary pattern scores on changes in continuous PG concentrations. No other study, to our knowledge, has examined this in particular. The continuous outcome variables FPG and 2h-PG were chosen instead of fixed glucose tolerance categories, because modeling of continuous outcome variables uses data in full and enables a more sensitive and specific picture of the dietary pattern score effect. Additionally, estimated changes on scales of FPG and 2h-PG can be useful in determining the risk of progressing from one glucose tolerance category to the next for a specific dietary pattern score combination. A clear description and comparison of models adjusted for baseline vs. follow-up values is another strength in this study, compared with other studies where the confounders included rarely are described in detail (2) or where only baseline values have been included (3,4). Generally, adjustment for the respective confounders only marginally affected the estimated change in PG. No remarkable differences between the fully adjusted models including confounders with baseline compared with follow-up values were observed, indicating that the confounders from baseline tracked strongly. So even though the participants in this study were likely to have changed their diet and other lifestyle factors as they all underwent some kind of lifestyle intervention (including coun-

### TABLE 2

<table>
<thead>
<tr>
<th>Effect of difference of 1 SD score</th>
<th>Change in FPG (95% CI)</th>
<th>P</th>
<th>Change in 2h-PG (95% CI)</th>
<th>P</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>mmol · L⁻¹ · y⁻¹</td>
<td></td>
<td>mmol · L⁻¹ · y⁻¹</td>
<td></td>
</tr>
<tr>
<td><strong>Modern pattern</strong></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Simple model</td>
<td>0.002(−0.004, 0.001)</td>
<td>0.242</td>
<td>0.008(−0.018, 0.001)</td>
<td>0.092</td>
</tr>
<tr>
<td>Fully adjusted model (baseline)</td>
<td>0.001(−0.002, 0.004)</td>
<td>0.764</td>
<td>0.013(−0.024, −0.002)</td>
<td>0.019</td>
</tr>
<tr>
<td>Fully adjusted model (follow-up)</td>
<td>0.000(−0.004, 0.003)</td>
<td>0.950</td>
<td>0.015(−0.025, −0.004)</td>
<td>0.009</td>
</tr>
<tr>
<td>Fully adjusted + interaction with GTS</td>
<td>0.280*</td>
<td></td>
<td>0.219*</td>
<td></td>
</tr>
<tr>
<td><strong>Traditional pattern</strong></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Simple model</td>
<td>0.001(−0.002, 0.004)</td>
<td>0.686</td>
<td>0.004(−0.006, 0.014)</td>
<td>0.418</td>
</tr>
<tr>
<td>Fully adjusted model (baseline)</td>
<td>0.001(−0.002, 0.004)</td>
<td>0.527</td>
<td>0.005(−0.006, 0.018)</td>
<td>0.351</td>
</tr>
<tr>
<td>Fully adjusted model (follow-up)</td>
<td>0.001(−0.003, 0.004)</td>
<td>0.632</td>
<td>0.002(−0.009, 0.013)</td>
<td>0.677</td>
</tr>
<tr>
<td>Fully adjusted + interaction with GTS</td>
<td>0.140*</td>
<td>&lt;0.0001*</td>
<td></td>
<td></td>
</tr>
</tbody>
</table>

1 Values are mean annual changes and 95% CI in FPG and 2h-PG during the follow-up period for a difference of 1 SD score of each dietary pattern.
2 \( n = 4521 \) with baseline and \( ≥1 \) follow-up value on FPG.
3 \( n = 4498 \) with baseline and \( ≥1 \) follow-up value on 2h-PG.
4 \( 2h-PG = \text{time} + \text{traditional score} + (\text{time} \times \text{traditional score}) + \text{modern score} + (\text{time} \times \text{modern score}) + \text{random (person + time)}. \)
5 As simple model and adjusted for level of intervention intensity, gender, known hypertension, family history of diabetes, age, physical activity, smoking, energy intake, and BMI at baseline.
6 As simple model and adjusted for level of intervention intensity, gender, known hypertension, family history of diabetes at baseline, and follow-up values for age, physical activity, smoking, energy intake, and BMI.
7 Adjusted as the fully adjusted follow-up model with additional inclusion of interaction term between GTS (glucose tolerance status) at baseline, time, and each of the dietary pattern scores. *P-value for interaction term (dietary pattern score \( \times \) time \( \times \) glucose tolerance status at baseline).
selying on dietary changes), it was not noteworthy in these analyses. A limitation of the study is that the response rate was only 52.5% at baseline. The low response rate may have affected the range of the CI for change in PG.

Most other studies examining the effect of dietary patterns in a prospective setting have found that dietary patterns that resemble our traditional pattern were significantly associated with higher risk of diabetes independent of energy intake. In most (2,4,5), but not all (3), of these studies, this association was also independent of BMI. In our study, food groups with high loadings on the traditional dietary pattern did not include high-fat dairy products, French fries, or sugar-rich condiments as in the other studies (2,4,5), which may partly explain the lack of significant general effects in the present study. For dietary patterns that resembled our modern pattern, some prospective studies have found a protective effect (4), whereas others found no effect in relation to diabetes independent of BMI (2,3,5). Our study conforms to this picture, because we found a protective or no effect of a high modern pattern score on PG. The estimated 5-y change in 2h-PG by 0.073 mmol/L between persons one standardized modern score apart is in itself not clinically relevant. However, in the long term, persons with higher modern scores may be able to delay the increase in 2h-PG, especially if the diet is combined with other beneficial lifestyle parameters.

Within the model adjusted for follow-up values, we examined the effect of adjusting for energy intake or intake of total fat, saturated fat, fish, fruit, vegetables, and dietary fiber, because these dietary variables especially affect the risk of developing diabetes (17,21–23) and were affected over the study period. We have previously shown that especially intake of vegetables increased and intake of saturated fats decreased during the follow-up period (24). However, adjustment for energy intake gave roughly the same estimates as adjustment for the other dietary variables (data not shown), indicating that the effects observed are explained by other food items than fat, fish, fruit, vegetables and fiber, and/or interactions between food items.

For the purpose of preventing diabetes, it is of interest that, from this study, we found that dietary patterns potentially affect 2h-PG values. A high score on the traditional pattern reflected a dietary intake high in high-fat sandwich spreads, red meat, butter and lard, and sauces dominated by nutrients (e.g. saturated fat) associated with increased risk of diabetes (23). On the other hand, a high score on the modern pattern reflected a dietary intake high in vegetables, fruit, and vegetable oil dominated by nutrients (e.g. fiber and monounsaturated fat) associated with lower risk of diabetes (23). The principal component analysis identified existing dietary patterns in the Inter99 study (6) and not dietary patterns designed to predict PG changes or risk of developing diabetes. Therefore, a high score on the traditional pattern in our study does not necessarily represent food choices that would pose the highest diabetes risk, nor does a high score on the modern pattern necessarily represent the lowest risk. Nevertheless, after 5 y, we observed a difference in estimated change in 2h-PG by 0.415 mmol/L for individuals with i-IGT one standardized traditional score apart at baseline. This potential change is of most concern for those with the highest 2h-PG values (>10.7 mmol/L) at baseline, because if these individuals have a high traditional score, they are likely to be classified as having diabetes (2h-PG ≥ 11.1 mmol/L) after a 5-y period.

No studies, to our knowledge, have previously examined the effect of glucose tolerance status on the predictive effect of dietary pattern scores on diabetes risk. We assumed that individuals with impaired glucose metabolism in terms of their insulin resistance would have a different effect of the dietary pattern scores than individuals with NGT. The change observed for individuals with i-IGT and a higher traditional dietary pattern score in relation to 2h-PG was more than 5 times greater than the general effect observed for the modern pattern score in relation to 2h-PG. The degree of insulin resistance is highly affected by environmental factors, including the diet (17,25). In a subsample of Inter99, it was previously observed that individuals with i-IGT were more peripherally insulin resistant than individuals with NGT or i-IGF (26), which leaves a greater potential for dietary effects on changes in PG. Because 2h-PG is used to classify individuals with i-IGT, our findings of effects on these individuals and the respective outcome was to be expected. However, only 1 of 4 tested interactions between groups of glucose tolerance and dietary pattern score was significant, so the findings should be taken with some caution.

In summary, a higher modern dietary pattern score at baseline predicted a decrease in 2h-PG over 3 y of follow-up regardless of glucose tolerance status at baseline. Glucose tolerance status affected the predictive effect of a higher traditional dietary pattern score in relation to 2h-PG (for individuals with i-IGT, a higher traditional pattern score was associated with increased 2h-PG), but glucose tolerance status did not in general affect the predictive effect of the dietary pattern scores. Our findings, therefore, do not support the hypothesis that dietary patterns may generally be more likely to affect PG concentrations in individuals with impaired glucose metabolism than in individuals with NGT. Further studies are needed to explore this area.

In the future, it may be of relevance to analyze lifestyle scores (combining the effect of dietary patterns, physical activity, smoking, BMI, and other relevant lifestyle parameters) or clusters of a "healthy" lifestyle compared with an "unhealthy" lifestyle in relation to PG changes to reveal a greater impact on PG than identified in this study focusing on dietary patterns and to indicate cluster areas for future prevention strategies.

**Literature Cited**


