Dietary Quality and Lifestyle Factors in Relation to 10-Year Mortality in Older Europeans

The SENECA Study

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The single and combined effects of three healthy lifestyle behaviors—nonsmoking, being physically active, and having a high-quality diet—on survival were investigated among older people in the SENECA Study. This European longitudinal study started with baseline measurements in 1988–1989 and lasted until April 30, 1999. The study population consisted of 631 men and 650 women aged 70–75 years from Belgium, Denmark, Italy, The Netherlands, Portugal, Spain, and Switzerland. A lifestyle score was calculated by adding the scores of the lifestyle factors physical activity, dietary quality, and smoking habits. The single lifestyle factors and the lifestyle score were related to mortality. Even at ages 70–75 years, the unhealthy lifestyle behaviors smoking, having a low-quality diet, and being physically inactive were singly related to an increased mortality risk (hazard ratios ranged from 1.2 to 2.1). The risk of death was further increased for all combinations of two unhealthy lifestyle behaviors. Finally, men and women with all three unhealthy lifestyle behaviors had a three- to fourfold increase in mortality risk. These results underscore the importance of a healthy lifestyle, including multiple lifestyle factors, and the maintenance of it with advancing age.

aged; diet; exercise; life style; mortality; smoking; survival analysis

Abbreviations: CI, confidence interval; SENECA, Survey in Europe on Nutrition and the Elderly: a Concerted Action.

Major causes of mortality in old age are diseases in which lifestyle plays an important role. The main behavioral factors of concern, namely nutrition, physical activity, and smoking, are modifiable and are a major focus of national health improvement strategies. Changing these factors in the direction of a healthier lifestyle pattern could postpone the age of onset of permanent morbidity and disability and could have a major effect on quality of life (1, 2).

So far, many studies have focused on the relation between one lifestyle factor and survival throughout life. These studies point to the importance of healthy lifestyle behaviors—adhering to a high-quality diet, not smoking, and being physically active—for achieving long-term health gains (3–9). Several studies indicate that healthy lifestyle behaviors are mutually related (10, 11). However, only a few studies have investigated the relation between lifestyle patterns, including multiple lifestyle factors, and survival (12, 13). This article investigates the relation between three modifiable lifestyle factors—diet, smoking, and physical activity—and their effects, separately and combined, on 10-year survival among people aged 70–75 years in a Europe-wide longitudinal study, the SENECA [Survey in Europe on Nutrition and the Elderly: a Concerted Action] Study.

MATERIALS AND METHODS

Study population and follow-up

Data in the SENECA Study were collected from a random age- and sex-stratified sample of inhabitants of several small...
European towns. At baseline, participation rates varied from 37 percent to 62 percent (14). All inhabitants born between 1913 and 1918 were eligible for enrollment in the study. The only exclusion criteria were living in a psychogeriatric nursing home, not being fluent in the country’s language, and being unable to answer questions independently (15). For this study, data were available on 631 men and 650 women from the following towns: Hamme, Belgium; Roskilde, Denmark; Padua, Italy; Culemborg, the Netherlands; Vila Franca de Xira, Portugal; Betanzos, Spain; and Yverdon, Burgdorf, and Bellinzona, Switzerland. The follow-up period lasted from the baseline examination in 1988–1989 until April 30, 1999.

Information on the vital status of participants was obtained by means of a standardized procedure. First, municipal registers were consulted for individual death certificates. If the municipal registers could not supply this information, the physician and the family were contacted. In our study population, vital status was known for 1,251 (98 percent) subjects. Approximately half of the male population and three quarters of the female population (307 men and 472 women) survived throughout the study period. Mean follow-up time was 7.5 years in men and 8.9 years in women.

Dietary assessment

Food intake data were collected by trained personnel using the modified dietary history method. This method is characterized by a 3-day estimated food record and a frequency checklist of foods, based on the meal pattern of each particular country. Portion sizes were based on standard portion sizes and/or were checked by weighing (15). Foods were coded and analyzed for nutrient composition at each participating center separately, using country-specific food composition tables (14). Food intake data were arranged into food groups according to the EUROCODE classification system (16). To express dietary quality in one variable, we calculated the Mediterranean diet score, a measure of how well dietary intake approximates the typical Mediterranean diet. Trichopoulou et al. (9) considered a Mediterranean diet score composed of the following food items: the ratio of monounsaturated fat to saturated fat; alcohol; legumes; cereals; fruits and nuts; vegetables; meat and meat products; and dairy products. Intake values were adjusted to daily intakes of 10.5 MJ (2,500 kcal) for men and 8.4 MJ (2,000 kcal) for women. The sex-specific median intake values of the food items were used as cutoff points. If the subject’s intake was comparable to the Mediterranean diet, the food item was coded 1, and if not it was coded 0. We made minor adjustments to the original Mediterranean diet score. We replaced the group “legumes” with the group “legumes/nuts/seeds” and we placed the two groups “vegetables” and “fruits and nuts” together into one group, “vegetables and fruits.” On the basis of the literature, we defined intake of dairy products between the 25th and 75th percentile values as the optimal intake instead of an intake below the median value. In women, we increased the upper limit of alcohol intake from the median value (0 g/day) to the 75th percentile value (8 g/day) and the upper limit of intake of meat and meat products to 130 g/day (17–19). This diet score ranged from 0 (a low-quality diet) to 7 (a high-quality diet). The adjusted Mediterranean diet score is described in detail by van Staveren et al. (20).

Health status and lifestyle factors

Information on lifestyle factors and health status was collected through a general interview, examination of blood, and anthropometric measurements (15). In the general interview, questions were asked about subjective health status (classified as poor, fair, or good), chronic diseases, smoking habits, and physical activity. The number of chronic diseases a subject had was determined by calculating the prevalence of the following: ischemic heart disease; stroke; respiratory problems; malignancy; arthritis; and diabetes mellitus. In a review paper, LaCroix and Omenn (21) stated that the overall risk of death among former smokers approaches that of persons who have never smoked after 15–20 years of abstinence. In addition, other studies have indicated that mortality among former smokers approaches the level of never smokers after a smoking cessation time of 10–20 years (6, 22–24). Therefore, former smokers were split into two groups with smoking cessation times of ≤15 years and >15 years. The following two smoking groups were composed: 1) current smokers and persons who had stopped smoking ≤15 years previously, designated “smokers”; and 2) never smokers and persons who had stopped smoking more than 15 years previously, designated “nonsmokers.” Physical activity was measured with a physical activity score including household, sport, and leisure-time components. For classification of physical activity, sex-specific tertiles (low, intermediate, and high physical activity) were composed (25). Standing height was measured to the nearest 0.1 cm with the person standing erect and wearing no shoes. Weight was recorded to the nearest 0.5 kg. Subjects clothed in light undergarments were measured in the morning after breakfast and after voiding. Blood samples were collected after an overnight fast, and serum albumin level was analyzed following standardized procedures at the Nestlé Research Centre in Lausanne, Switzerland (26). For an extensive description of the measurement procedures, see the SENECA manual of operations (15).

A lifestyle score ranging from 0 (poor) to 3 (good) was calculated by adding the scores of three lifestyle factors: 1) physical activity (lowest tertile of activity (coded 0) versus the intermediate and highest tertiles (coded 1)); 2) diet (low-quality diet group with a diet score of 4 or less (coded 0) versus the high-quality diet group with a diet score greater than 4 (coded 1)); and 3) smoking (current smokers and past smokers for ≤15 years (coded 0) versus never smokers and past smokers for more than 15 years (coded 1)).

Statistical analyses

For statistical analyses, data on all participants with complete sets of information on dietary intake, lifestyle habits, health status, and mortality follow-up were used. Statistical analyses were carried out with SAS, version 6.12 (SAS Institute, Inc., Cary, North Carolina).
Kaplan-Meier survival curves, unadjusted for confounders, were plotted for the different categories of the lifestyle score. Cox proportional hazards survival analysis was used to investigate associations between single and combined lifestyle factors and all-cause mortality (27). First, the proportional hazards assumption was tested for all lifestyle factors and confounding factors. All variables met the proportional hazards assumption and could be considered to have a constant hazard ratio over time. Region (Northern Europe and Southern Europe) and health status (number of chronic diseases, self-perceived health, and albumin level) turned out to be related to lifestyle factors as well as mortality and were therefore included in the model as confounding factors. Two other potentially confounding factors, body mass index (weight \( \text{kg}/\text{height (m)}^2 \)) and socioeconomic status (type of education), were examined but hardly affected the results. Interactions between lifestyle factors were tested, but none were found significant. Main lifestyle effects were estimated using a Cox regression model that included groups for physical activity, smoking, and dietary quality. Combined lifestyle effects were predicted assuming an additive model for the log hazard ratio, that is, multiplicative effects on the hazard ratio itself. Allowance was made for region, health status, and age at baseline.

RESULTS

Table 1 presents the baseline health and lifestyle characteristics of the SENECA participants. Overall, men had a better subjective health status and body mass index than did women. In the male population, the percentage of subjects with a body mass index exceeding 30 was higher in the southern centers than in the northern centers. In the female population, no geographic pattern appeared. Although the percentage of men who had ever smoked was very high (81 percent), the percentage of current smokers was only 32 percent. With the exception of Danish women (48 percent had never smoked), the percentage of women who had never smoked was very high (ranging from 75 percent for Bellinzona, Switzerland to 99 percent for Vila Franca de Xira, Portugal and Betanzos, Spain). In all centers, men had a higher leisure-time activity score and a lower household score than women. For both men and women, the mean Mediterranean diet score was highest for participants from the southern centers.

In figure 1, Kaplan-Meier curves are presented for the four categories (scores 0–3) of the lifestyle score. For both men and women, an increasing number of unhealthy lifestyle behaviors appeared to be related to a higher mortality rate (log rank test: \( p < 0.001 \)). More women than men (23 percent vs. 12 percent) had a healthy lifestyle, including nonsmoking, a moderate/high activity level, and a high-quality diet. Because of the low number of smokers in the female group, only 22 women (3 percent) had three unhealthy lifestyle behaviors. Approximately 75 percent of men and women had one or two unhealthy lifestyle behaviors.

The effect of single lifestyle factors was estimated from a proportional hazards model with three main effects and three confounders. Age at baseline, number of chronic diseases, and region were accounted for in this analysis. In both men and women, unhealthy lifestyle behaviors were related to an increased risk of death. For men, the mortality risk for a low-quality diet was 1.25 (95 percent confidence interval (CI): 0.93, 1.68); the risk for inactivity was 1.36 (95 percent CI: 1.08, 1.73); and the risk for smoking was 2.06 (95 percent CI: 1.63, 2.60). For women, the mortality risks for smoking (1.76; 95 percent CI: 1.14, 2.70) and inactivity (1.75; 95 percent CI: 1.29, 2.39) were much higher than the risk associated with a low-quality diet (1.26; 95 percent CI: 0.88, 1.81). The predicted hazard ratios for combined lifestyle factors are presented in table 2. Assuming no interaction, men and women with three unhealthy lifestyle behaviors had a three- to fourfold increase in mortality risk.

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**TABLE 1. Baseline health and lifestyle characteristics of European men and women born between 1913 and 1918, The SENECA Study, 1988–1999**

<table>
<thead>
<tr>
<th></th>
<th>Men (n = 631)</th>
<th>Women (n = 650)</th>
</tr>
</thead>
<tbody>
<tr>
<td>Mean age (years)</td>
<td><em>73.1 (1.8)</em></td>
<td><em>73.0 (1.7)</em></td>
</tr>
<tr>
<td>No. of chronic diseases† (%)</td>
<td>0</td>
<td>53</td>
</tr>
<tr>
<td></td>
<td>1</td>
<td>34</td>
</tr>
<tr>
<td></td>
<td>≥2</td>
<td>13</td>
</tr>
<tr>
<td>Prevalence of low serum albumin‡ (%)</td>
<td>2</td>
<td>2</td>
</tr>
<tr>
<td>Self-perceived health (%)</td>
<td>Poor</td>
<td>7</td>
</tr>
<tr>
<td></td>
<td>Fair</td>
<td>26</td>
</tr>
<tr>
<td></td>
<td>Good</td>
<td>68</td>
</tr>
<tr>
<td>Body mass index§ (%)</td>
<td>&lt;20</td>
<td>3</td>
</tr>
<tr>
<td></td>
<td>20–25</td>
<td>33</td>
</tr>
<tr>
<td></td>
<td>25–30</td>
<td>49</td>
</tr>
<tr>
<td></td>
<td>≥30</td>
<td>14</td>
</tr>
<tr>
<td>Smoking (%)</td>
<td>Never smoker</td>
<td>19</td>
</tr>
<tr>
<td></td>
<td>Past smoker for &gt;15 years</td>
<td>32</td>
</tr>
<tr>
<td></td>
<td>Past smoker for ≤15 years</td>
<td>32</td>
</tr>
<tr>
<td></td>
<td>Current smoker</td>
<td>32</td>
</tr>
<tr>
<td>Mean physical activity score</td>
<td>Household score</td>
<td>0.9 (0.7)</td>
</tr>
<tr>
<td></td>
<td>Sport score</td>
<td>0.5 (1.4)</td>
</tr>
<tr>
<td></td>
<td>Leisure-time score</td>
<td>17.8 (12.9)</td>
</tr>
<tr>
<td>Mean Mediterranean diet score¶</td>
<td>3.5 (1.5)</td>
<td>3.9 (1.4)</td>
</tr>
</tbody>
</table>

* Numbers in parentheses, standard deviation.
† Includes ischemic heart disease, stroke, respiratory problems, malignancy, arthritis, and diabetes mellitus.
‡ The cutoff value for a low serum albumin level was less than 35 g/liter for both men and women.
§ Weight (kg)/height (m)^2.
¶ A measure of how well dietary intake approximates the typical Mediterranean diet (see Trichopoulou et al. (9)).
DISCUSSION

Even at ages 70–75 years, a high-quality diet, nonsmoking, and physical activity were positively related to survival in a European population. The combination of healthy lifestyle behaviors was even more strongly related to survival.

One of the strengths of this Europe-wide study was its great diversity in food and lifestyle factors assessed with validated measures (25, 28). Furthermore, many potential confounders were measured in the SENECA Study, and their relation to lifestyle factors and mortality was determined. Adjustments were made for variables that appeared to be confounding factors. Health status at baseline is an important determinant of mortality and is associated with baseline lifestyle factors. Therefore, health status at baseline was taken into account in the Cox proportional hazards regression model investigating the relation between lifestyle factors and mortality. Health is a multidimensional concept; therefore, adjustment was made by means of different variables such as the presence of chronic diseases, self-perceived health, or albumin level (29), a more objective indicator of health status. Adjustment for different health indicators did not change the relation between the three lifestyle factors and survival; neither did the exclusion of persons who died within 1, 2, or 3 years after the first baseline measurement.

A multiplicative model was used to assess the effect of combinations of lifestyle factors on mortality (table 2). Consequently, the seven hazard ratios shown in each section of table 2 (men and women) are not seven independent estimates of relative risk, since the relative risks for combined lifestyle factors were derived from the relative risks of single factors.
lifestyle factors. Nevertheless, they fit remarkably well with the empirical results of figure 1, despite the fact that the latter were not adjusted for covariates such as age, region, and number of chronic diseases at baseline.

In line with our results, it has been found in previous studies that single healthy lifestyle behaviors are related to survival. A sedentary lifestyle was found to be significantly associated with increased mortality risk in comparison with being moderately physically active (3, 7). Davis et al. (7) reported that nonrecreational physical activity was an even better predictor of survival time in older subjects (65–74 years) than in middle-aged subjects (45–54 years). Overall, unhealthy dietary patterns, assessed by various methods, were associated with increased risk of disease or mortality (5, 9–11). For analysis of smoking, most studies categorized subjects into three groups: nonsmokers, past smokers, and current smokers. It is evident from these studies that smokers had a higher risk of mortality than never smokers, though the mortality risk was higher among middle-aged subjects than among older subjects. For those who had quit smoking, the mortality risk varied from an intermediate risk to a non-elevated risk in comparison with never smokers (3, 7, 30).

Lifestyle habits are assumed to be characteristic of a person’s way of living, though these habits may change over time. Changes in lifestyle habits probably influence relations with mortality; at worst, it is possible that the greatest part of a mortality risk is determined not by baseline lifestyle habits but by former lifestyle habits. The stability of lifestyle behaviors over a 4-year period was studied by Mulder et al. (31) in specific age groups ranging from 30 years to 70 years, using very sensitive scales for lifestyle measures. Smoking behavior remained mostly the same in all age groups, but physical activity behavior was more subject to change (31). In the SENECA Study, where lifestyle measures were categorized into only two groups (healthy and unhealthy), we studied changes in lifestyle factors over a 5-year period. In our research population, only a few persons changed their smoking habits (15 percent of men and 3 percent of women), and only 28–36 percent of the subjects changed their dietary and activity patterns. In several other studies, changes of the same magnitude were found for smoking habits and activity patterns in middle-aged and older men (32, 33).

Although most people seem to have rather stable lifestyle habits, changes in habits appear and may influence relations with mortality. For the three lifestyle factors in our study, we evaluated the impact of having totally different former habits on assessments of mortality risk. In the SENECA Study, former smoking habits prior to the age of 70 years were related to mortality. Past smokers who had stopped smoking more than 15 years previously had a survival curve comparable to that of never smokers. This information on former smoking habits had already been incorporated into the smoking variable used in this study. On the contrary, having a different former activity or dietary pattern could not be related to mortality in the SENECA Study, because no information on physical activity and dietary patterns before the age of 70 years was available in the data set. However, in the longitudinal Seven Countries Study, it was found that the variation in dietary patterns between different cultures in Europe has become smaller over a period of 20 years (34). Although this may have resulted in attenuation of the association between diet and mortality, cultural differences in dietary patterns still exist in the SENECA baseline study (35). For physical activity, the latest activity patterns are more strongly related to mortality than are former activity patterns (32, 36).

In summary, most SENECA participants have stable lifestyle habits, and as a result the assessed mortality risks are the risks of long-lasting lifestyle habits. For persons who changed their lifestyle habits, the assessed mortality risks might be underestimated by baseline measures of dietary quality, while baseline measures of activity patterns are probably relevant measures in the assessment of mortality risks.

Selective survival might have influenced the associations between the lifestyle factors and survival. Progressive elimination of less healthy subjects from a group with an unhealthy lifestyle makes this group more and more like the group with a healthy lifestyle with respect to health status. This selective survival results in a weakening of the association between a lifestyle factor and survival with increasing

### TABLE 2. Hazard ratios* for single and combined effects of the lifestyle factors diet, smoking, and physical activity in European men and women born between 1913 and 1918, The SENECA Study, 1988–1999

<table>
<thead>
<tr>
<th></th>
<th>Low physical activity plus smoking</th>
<th>High physical activity plus smoking</th>
<th>Low physical activity plus nonsmoking</th>
<th>High physical activity plus nonsmoking</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>No.</td>
<td>HR†</td>
<td>No.</td>
<td>HR</td>
</tr>
<tr>
<td><strong>Men</strong></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Low-quality diet</td>
<td>94</td>
<td>3.5</td>
<td>162</td>
<td>2.6</td>
</tr>
<tr>
<td>High-quality diet</td>
<td>20</td>
<td>2.8</td>
<td>35</td>
<td>2.1</td>
</tr>
<tr>
<td><strong>Women</strong></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Low-quality diet</td>
<td>22</td>
<td>3.9</td>
<td>36</td>
<td>2.2</td>
</tr>
<tr>
<td>High-quality diet</td>
<td>4</td>
<td>3.1</td>
<td>5</td>
<td>1.8</td>
</tr>
</tbody>
</table>

* Adjustments were made for age at baseline, region, and number of chronic diseases.
† HR, hazard ratio.
‡ Reference category.
age. The relation between the lifestyle factor and survival is age-related and is not fully generalizable to other age groups.

Although lifestyle habits are intercorrelated (3, 10, 11, 35), the joint influence of lifestyle factors on mortality has hardly been investigated. To our knowledge, only two studies have investigated the relation between multiple lifestyle factors and mortality (12, 13). Breslow and Enstrom (13) performed a study on health practices and adult mortality that included seven lifestyle factors: smoking, physical activity, alcohol use, nightly hours of sleep, maintenance of proper weight, breakfast-eating, and eating between meals. Age-adjusted mortality rates decreased with an increasing health practice score (13). Recently, a 6-year follow-up study of older men and women aged >65 years demonstrated a positive joint influence of the two healthy lifestyle behaviors nonsmoking and physical activity on longevity (12). Our 10-year follow-up study of older men and women aged 70–75 years stresses the importance of a high-quality diet in addition to nonsmoking and physical activity for survival. A lifestyle pattern including these three healthy lifestyle behaviors was related to the highest survival rate.

The next step is to investigate whether the lifestyle factors that are related to a higher survival rate are also related to a better health status at older ages. A longer life in combination with more years spent in good health contributes to healthy aging. Identifying determinants of healthy aging requires longitudinal studies with many healthy persons at baseline who are followed for a long period and frequently measured. Furthermore, appropriate measurements of health status in elderly people are necessary to monitor health status over time.

In conclusion, in this analysis the positive effect of the single healthy lifestyle behaviors nonsmoking, being physically active, and having a high-quality diet on survival still existed in an older European population aged 70–75 years, and the combination of these healthy lifestyle behaviors was even more strongly related to survival than the individual factors. Our results emphasize the importance of a healthy lifestyle, including multiple lifestyle factors, for survival probability and the importance of maintaining a healthy lifestyle with advancing age.

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