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Review Article

Lifestyle, Nutritional Status, Health, and Mortality in Elderly People Across Europe: A Review of the Longitudinal Results of the SENECA Study

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This article provides an overview of the longitudinal Survey in Europe on Nutrition and the Elderly: a Concerted Action (SENECA) study, which was designed to assess differences in dietary and lifestyle factors among elderly Europeans, and to identify the factors that contribute to healthy aging. Elderly people from Belgium, Denmark, France, Italy, Portugal, Spain, Switzerland, and The Netherlands participated in the SENECA study. Standardized measurements were conducted at baseline in 1988–1989 and were repeated in 1993 and 1999. Diet, physical activity, and smoking, as well as maintenance of health and survival, were assessed. At baseline, considerable differences in lifestyle factors existed among elderly people. Mealtime patterns as well as dietary intake varied across Europe, and geographical patterns were apparent. Similar results were found for engagement in sport or professional activities. The smoking prevalence among women was generally low. Distinct geographical differences were also observed in percentages of deaths during the SENECA study and in overall survival time. A healthy lifestyle was related to stable self-perceived health, a delay in functional dependence, and mortality. Inactivity and smoking, and to a lesser extent a low-quality diet, increased mortality risk. A combined effect of multiple unhealthy lifestyle factors was also observed. The SENECA study showed that a healthy lifestyle at older ages is related to a delay in the deterioration of health status and a reduced mortality risk. Improving and maintaining a healthy lifestyle in elderly people across Europe is a great challenge for the European Community.

DURING the last century, life expectancy increased rapidly in Europe as well as in other parts of the world. Chronic diseases have now superseded acute diseases as major causes of mortality, and this change is largely due to improvements in living standards and medical care. Combined with the decline in birth rates, Europe faces an increasingly aging population (1). Various authors have distinguished two stages in aging. The first stage is characterized by a gradual functional decline as a result of the normal aging process. The second stage, by contrast, is caused by progressive illness or catastrophic events. Ideally, people would reach an advanced age while they are in the first stage, with a short second stage of functional and cognitive impairment (2–4). Because aging is associated with an increasing risk for chronic diseases such as cardiovascular diseases and cancer, a sharp rise in the need for social and medical services is to be expected. In line with the hypothesis of Fries (5), this need can possibly be reduced if the onset of chronic diseases and the related disability can be postponed. To achieve this, modification of a number of unhealthy lifestyle factors has received substantial attention in research and public health practice. Nutrition, physical activity, and smoking are among the major modifiable lifestyle factors that are related to cardiovascular disease and cancer. Evidence suggests that improvements in these factors can prevent the functional limitations that are strongly associated with advanced age, and can thus lead to a healthier, more active, and more independent way of aging (2,6,7).

Nutritional deficiency is more common at older ages than at other periods in life, yet many elderly people eat well. Furthermore, the dietary variation between individuals is large in comparison with the variations within individuals (8). Because of differences in social, cultural, and societal factors, diversity in lifestyle factors and thus in health are to be expected among European countries (9). In order to address this diversity in diet and other lifestyle factors, the Survey in Europe on Nutrition and the Elderly: a Concerted Action (SENECA) began in 1988. The study was designed to assess regional or cross-cultural differences in nutrition, lifestyle, health, and performance of elderly Europeans (10). Selected survey towns were revisited 5 and 10 years after baseline to address the role of the apparent variability in diet and lifestyle in the aging process and, in particular, to health maintenance and mortality. This article gives an overview of the SENECA study and its findings.

Figure 1. The longitudinal research towns in the Survey in Europe on Nutrition and the Elderly: a Concerted Action (SENECA) study.

Design and Methods of Seneca

Approximately 2600 elderly people born between 1913 and 1918 living in 19 "traditional" towns in 12 countries were included. Site characteristics of the 19 towns differ from mainly rural to urban and from lowland to mountains with a range of temperature climates. The towns were to have a stable population of 10,000 to 20,000 inhabitants, and their population and economical structures were comparable to the average country structures. Participants were selected from an age- and sex-stratified sample of the inhabitants. Only people who were living in psychogeriatric nursing homes, who were not fluent in the country's language, or who were not able to answer questions independently were excluded. In some towns, people born 1915–1918 were included in the sample, and the initial data collection in 1988–1989 was repeated with a follow-up in 1993 and a finale in 1999. These towns are referred to as the longitudinal research towns (11). Full baseline and follow-up data were collected in the following nine towns: Hamme (Belgium, H/B), Roskilde (Denmark, R/DK), Haguenau and Romans (France, H/F and R/F), Padua (Italy, P/I), Culemborg (The Netherlands, C/NL), Vila Franca de Xira (Portugal, V/P), Betanzos (Spain, B/E), and Yverdon (Switzerland, Y/CH). Figure 1 shows the nine longitudinal research towns. The northern (H/B, R/DK, C/NL) and southern (H/F, R/F, P/I, V/P, B/E, Y/CH) survey towns were grouped to explore the possible effect of geographical variability on the nutritional status and SENECA's outcome measures.

Data collection on lifestyle, morbidity, and mortality during the 10-year study period was conducted using a standardized methodology across Europe and over time. For each town, equal numbers of men and women were selected. A nonresponder's questionnaire at baseline revealed that healthier and more health-concerned elderly people were more likely to participate in the study (10). Although not confirmed by differences in the prevalence of chronic diseases, these findings were replicated at follow-up. Furthermore, the participants at follow-up were on average 0.2 years younger than nonparticipants, partially due to a higher mortality in older people, which is inevitable in longitudinal studies of older populations (12).

Considerations and Implications of a Longitudinal Design Including Different Cohorts

The SENECA study was conducted using a mixed-longitudinal design, which is a mixture of longitudinal and cross-sectional studies. It included several birth cohorts, several occasions of screening, and consequently several ages. Therefore, three time parameters with a time dimension should be considered in the analysis: age (life time), cohort (time/year of birth), and period (time of measurement). The effect of interest in SENECA was the age effect. Period effects are defined as temporal influences that affect all cohorts and age groups similarly, such as: socioeconomic changes affecting the food market and consumption patterns, and changes in chemical laboratory protocols. Cohort effects are caused by differences in the history of the cohorts, in the SENECA population, for example, as a result of changes in health care or the First World War. The three time parameters each have their own effects, which can be assessed using a so-called APC analysis (Age Period Cohort). This analysis revealed hardly any period or cohort effects; as a result, the differences in longitudinal observations may be considered to reflect changes due to aging (10,12).

Lifestyle Assessment

A general structured interview questionnaire was used to obtain data on participant and family demographics, housing, exposure to sunlight, social involvement, general health, and the lifestyle variables of interest. The study protocol was developed in close collaboration with all participating centers. Pilot studies were carried out, and all procedures were described in detail in a manual of operations (11). Questionnaires in local languages were back-translated into English to validate their semantic validity.

Diet.—Food intake was assessed in detail using a modified dietary history consisting of a 3-day record and a meal-based list of foods to check the usual consumption of the previous month (11). Food consumption data were converted into nutrient data by using country-specific food composition tables. A validation study in which a 3-day weighed record was used to assess the validity of the SENECA measurement method, showed acceptable agreement (13). Based on the knowledge on circadian rhythms, it was hypothesized that different mealtime patterns across Europe might lead to different metabolic responses and can thus influence the onset and development of disease (14). The relations between the energy contribution of the midday meal and other factors that can influence health, such as the

total intake of energy and the consumption of certain foods (15), might also play a role (16). Therefore, information on meal patterns of elderly people in the different towns was obtained from the respective project leaders.

A diet score based on the Mediterranean Diet Score (MDS) developed by Trichopoulou and colleagues was applied. For each component of the MDS, it was assessed if the participant's intake was more or less in accordance with the Mediterranean diet. The sex-specific median intake values of the food items were used to determine cut-off points. If intake levels were in agreement with the Mediterranean diet, the component was coded as 1, otherwise, it was coded as 0 (17). Haveman-Nies and colleagues (18) later adapted the MDS with respect to legumes, nuts, and seeds, and van Staveren and colleagues (8) with respect to milk and milk products, meat, and poultry (only for women) and alcohol (only for women). Data presented in this article were obtained from the work of Haveman-Nies and colleagues (18). Component scores were added to form the MDS (range 0–8; a higher score reflected a better resemblance with a Mediterranean-like diet). People in the low-quality diet group had MDS scores of 4 or less. MDS scores in the high-quality diet group were greater than 4.

Physical activity and activities of daily living.—The general structured interview consisted partly of a validated questionnaire developed by Voorrips and colleagues (19,20) about physical activity (work activity, housework activity, sport activity, leisure activity, and rest activity). Sex-specific tertiles were constructed from the baseline SENECA survey to compose two physical activity groups. The inactive group consisted of people in the lowest tertile, whereas the active group consisted of the highest two tertiles.

Data on physical activity in H/F and R/F were only available after the longitudinal analyses by Haveman-Nies and colleagues were conducted. These towns were therefore excluded from the longitudinal data presented in this article.

Smoking.—Smoking was assessed with several questions addressing past and current smoking behavior. The numbers of cigarettes, cigars, and pipes were recorded (11). Former smokers were split into two groups, with smoking cessation times of 15 years or less and over 15 years. Based on this categorization, two groups were defined. Current smokers and people who had stopped smoking 15 years or less were categorized as smokers. Never-smokers and people who had stopped smoking over 15 years were combined in a non-smokers group (21). Ostbye and colleagues (22) provided justification for this categorization by showing that persons who quit smoking over 15 years prior to the survey were no more likely than never-smokers to experience ill health.

Combined lifestyle score.—As described by Haveman-Nies and colleagues (21), a lifestyle score was calculated by combining the scores of three lifestyle factors. The combined score ranged from 0 (poor) to 3 (good). Smoking prevalence in women across Europe was low. Therefore, the number of women having three unhealthy lifestyle behaviors was limited.

Nutritional Status

Trained investigators collected anthropometrical data using standardized methodologies. Weight was recorded to the nearest 0.5 kg. Calibrated scales fitted onto a wooden board were used, and participants dressed in undergarments only were weighed in the morning after breakfast and after voiding. If it was not possible to measure a participant while wearing undergarments, weight was adjusted by an estimate of the weight of the clothes (11,23). Body mass index (BMI) was calculated by dividing an individual's weight in kilograms by the square of his or her stature in meters.

Health and Vital Status

The SENECA study was focused on three health outcomes: vital status, functional status, and self-rated health. Information on vital status was obtained using standardized procedures. Small differences due to local laws and traditions were inevitable. Municipal authorities were requested to provide the present address of each participant, or to provide the date of death if the participant had passed away. Cause of death was determined using standard death certificates when available, or by contacting the medical doctor who had completed the death certificate or relatives of the deceased. One researcher did the coding of vital status for all participating centers using the World Health Organization's (WHO's) International Classification of Diseases (24).

Functional ability was assessed by measuring the capacity to perform activities of daily living (ADL). Competence was measured with 16 questions, using a 4-point scale. From these questions, a total score, a mobility score, and a self-care ability score were calculated. The lower the score, the better the performance (19).

Self-rated health is a subjective integration of individual health aspects weighted by personal values and preferences. It was assessed with the question: ''How would you judge your present health in general?'' using a 5-point scale ranging from very poor to very good (19).

Results

Diversity in Lifestyle Factors

In the baseline study, a considerable variability between centers was observed in dietary intake (quantity and composition), indicators of nutritional status, lifestyle factors, health, and performance. In 1993, changes in indicators of nutritional status and health were all in an unfavorable direction, as discussed below.

Diet.—Differences in dietary intake as well as in mealtime patterns were found across Europe. Energy intake varied from 7.2 MJ (Y/CH) to 10.3 MJ (B/E) per day (Table 1). The relative contributions of protein, fat, carbohydrate, and alcohol also showed considerable differences. With the exception of V/P, low carbohydrate intake levels coincided with low alcohol intakes. The relative contribution of alcohol to energy intake in the survey town with the lowest intake (C/NL; 2.2% of energy) was almost four times lower than in the survey town with the highest intake (P/I; 8.6% of energy).

Table 1. Baseline Lifestyle Parameters and Health Status in Elderly European Men and Women in the SENECA Study

	Town								
	H/B	R/DK	H/F	R/F	P/I	C/NL	V/P	B/E	Y/CH
Diet									
Energy intake (MJ)	9.5	8.9	8.2	8.5	8.3	9.0	7.6	10.3	7.2
% of energy from protein	13.7	12.9	16.6	15.7	13.6	14.9	17	15.9	14.7
% of energy from fat	41.2	41.3	36.3	37.2	31.1	40.8	25.7	35.4	41.9
% of energy from carbohydrates	41.8	42.7	43.6	44.4	50.6	43.4	55	48.4	41.4
% of energy from alcohol	3.3	3.4	4.5	4.2	8.6	2.2	3.7	4.6	3.4
Distribution of energy intake (%)									
Morning	—	17	—	—	14	19	—	—	22
Midday	—	24	—	—	41	31	—	—	43
Evening	—	37*	—	—	45	50	—	—	35
Mediterranean Diet Score	3.3	2.7	—	—	4.4	3.1	4.3	4.2	3.5**
Alcoholic drink on most days (%)	30	32	52	37	78	19	33	22	45
Smoking (%)	24	41	15	10	23	21	7	14	18
Physical activity									
% playing sports	6	29	7	26	23	30	4	14	32
Leisure time activities (h/w)	1.8	1.9	—	—	1.8	1.6	2.4	1.7	1.9
Health status									
People who manage all ADL activities (%)	26	45	46	64	44	39	2	30	64
Self-perceived health (% good)	59	67	52	57	61	73	20	50	82
% suffering from chronic diseases	77	73	80	84	77	69	92	79	59

Notes: Values are means unless otherwise specified.

*22% of energy was derived from snacks.

**Mean is also based on two other Swiss towns.

H/B = Hamme, Belgium; R/DK = Roskilde, Denmark; H/F = Haguenau, France; R/F = Romans, France; P/I = Padua, Italy; C/NL = Culemborg, the Netherlands; V/P = Vila Franca de Xira, Portugal; B/E = Betanzos, Spain; Y/CH = Yverdon, Switzerland; MJ = megajoules; ADL = activities of daily living; SENECA = Survey in Europe on Nutrition and the Elderly: a Concerted Action.

Schlettwein-Gsell and colleagues described the large diversity in dietary habits in the baseline survey of the SENECA study in detail (25). In total, 86%–99% of the participants ate a cooked meal every day. For four of the longitudinal survey towns, data on energy intake for the different meals were available. The relative contribution of the meals to the energy intake differed. The contrasts were particularly pronounced in survey towns in which a cooked meal was consumed for lunch as opposed to survey towns where a cooked meal was eaten for dinner.

Breakfast and lunch were consumed at roughly the same time across Europe. Dinner in Portugal and Spain was consumed later in the evening than in the northern European countries. Participants in C/NL and Y/CH consumed foods on more occasions per day than participants in more southern geographic regions (V/P and P/I). Differences in distribution of energy intake across the day were also observed at baseline (25). These findings were replicated for a larger number of survey towns when data on energy intake from snacks were also collected (14,26). MDS scores in seven of the longitudinal survey towns are presented in Table 1. The mean Mediterranean diet score was highest for participants from the southern centers.

Physical activity and activities of daily living.—In general, most of the elderly people were engaged in physical activity of some sort. In some centers, a high percentage of particularly elderly men were still undertaking work activity (Table 1). Percentages of elderly people working full-time or part-time varied between 1% in C/NL and 12% in B/E. The mean number of hours doing housework per day varied between 2.4 (R/F) and 3.3 (B/E). The mean numbers of hours performing leisure-time activities varied between 1.6 (C/NL) and 2.4 (V/P), respectively. Self-perceived physical activity varied considerably among the survey towns. Thirty-five percent (H/F and V/P) to 60% (Y/CH) of elderly people believed they were more active than other people of the same age.

The percentages of people engaged in sports were highest in northern and central European towns. On the other hand, high employment rates still occurred in some southern towns where professional activities continued to be a natural part of daily life.

Smoking.—In all survey towns, with the exception of R/DK (35%) and P/I (17%), current smoking prevalence in women was low. For both sexes combined, smoking prevalence varied to a large extent from 7% (V/P) to 41% (R/DK). The high smoking prevalence in R/DK was largely due to the relatively high percentages of cigar smokers in both men and women, and pipe smokers in men (27) (Table 1).

Diversity in Nutritional Status

Baseline body weight and BMI of the SENECA participants are presented in Table 2. Considerable differences in BMI and prevalences of obesity and underweight were found across Europe. BMI was highest in H/F and B/E. Strikingly, the BMI of men in H/B was lower than in any of

Table 2. Baseline Body Weight and Body Mass Index of Elderly European Men and Women in the SENECA Study

	Men				Women			
	Weight (kg)		BMI (kg/m^2)		Weight (kg)		BMI (kg/m^2)	
Town	Mean	*SD*	Mean	*SD*	Mean	*SD*	Mean	*SD*
H/B	71.4	10.5	25.2	3.3	68.2	10.3	28.3	4.1
R/DK	75.0	10.4	25.5	3.2	64.5	12.4	25.2	4.7
H/F	77.9	12.7	27.1	3.6	68.1	14.4	27.6	5.7
R/F	73.6	10.2	26.5	3.5	60.8	11.0	25.4	4.6
P/I	73.6	10.0	26.1	3.5	61.0	10.9	24.9	4.2
C/NL	78.2	10.7	26.1	3.0	71.4	11.4	27.6	4.2
V/P	70.6	11.2	27.0	3.6	60.2	11.0	27.5	4.5
B/E	74.2	10.6	27.7	3.6	65.5	11.2	28.6	4.4
Y/CH	75.0	11.5	26.8	3.9	64.8	11.8	26.3	4.2

Note: H/B = Hamme, Belgium; R/DK = Roskilde, Denmark; H/F = Haguenau, France; R/F = Romans, France; P/I = Padua, Italy; C/NL = Culemborg, the Netherlands; V/P = Vila Franca de Xira, Portugal; B/E = Betanzos, Spain; Y/CH = Yverdon, Switzerland; *SD* = standard deviation; BMI = body mass index; SENECA = Survey in Europe on Nutrition and the Elderly: a Concerted Action.

the other survey towns, while the BMI of women in H/B was the second highest. A geographic pattern in BMI was previously reported in men, but not in women (21). BMI was above 30 kg/m^2 in 8%–24% of the men and 12%–41% of the women. The prevalence of a BMI below 20 kg/m^2 was much less common; it was highest (10%) in women in R/DK and R/F. None of the participating men in C/NL had a BMI below 20 kg/m^2 (28).

As is to be expected in a longitudinal study on aging, stature decreased over the course of the study. In Hamme/B and Romans/F, where people lost 4 cm over a decade, the stature decrease was largest. The use of changes in BMI over time may hence be questionable. In men, weight change varied between a reduction of 4.2 kg in B/E and an increase of 0.5 kg in C/NL. In women, weight decreased in all survey towns. The average decrease varied between 0.2 kg in H/B and 4.0 in B/E (23).

Diversity in Health Status

There were large variations in all three measures of health. Generally, health was better in northern industrial towns than in southern rural towns.

The percentage of people who had deceased by 1999 varied between centers. Geographical differences in 10-year mortality, survival time, and hazard ratio were discussed in more detail by Amorim Cruz and colleagues (29). A summary of their findings is presented in Table 3. Percentages of death ranged e.g., in women, from 36% in B/E and Y/CH to 45% in C/NL and R/DK, and distinct differences between the northern survey towns (H/B, R/DK, C/NL) and the southern towns were observed. A similar pattern was found for the average hazard ratio. With the exception of P/I, survival time in the southern towns was higher than in the northern. Geographical patterns were more apparent in men than in women.

The percentages of people capable of performing all ADL activities ranged from as little as 2% in V/P to 64% in Y/CH and R/F. The total ADL score as well as the mobility and self-care scores were lowest in V/P, B/E, H/B, and C/NL (19). Self-perceived health also varied considerably across the survey towns (30). The weighted percentages of people rating their health as ''good'' varied between 20% (V/P) and 82% (Y/CH). Because self-perceived health in V/P was much lower than in the other European survey towns without being supported by data on the prevalence of

Table 3. Mortality, Average Hazard Ratio and Mean Survival Time of Elderly European Men and Women in the SENECA Study

	Men				Women			
Town	*N*	% Deceased	Mean Survival Time (y)	Average Hazard Ratio (*N* Died/1000 Person-Years)	*N*	% Deceased	Mean Survival Time (y)	Average Hazard Ratio (*N* Died/1000 Person-Years)
H/B	126	56	7.2	77	105	43	8.89	32
R/DK	101	54	7.83	68	101	45	8.47	42
H/F	109	53	7.94	67	110	39	9.21	26
R/F	135	54	7.97	67	134	39	9.19	24
P/I	95	48	6.36	63	87	35	7.61	26
C/NL	114	59	6.95	85	124	45	8.87	36
V/P	111	46	7.86	58	111	40	8.91	37
B/E	75	48	7.93	52	98	36	9.08	22
Y/CH	123	48	8.23	57	126	36	9.19	27

Note: H/B = Hamme, Belgium; R/DK = Roskilde, Denmark; H/F = Haguenau, France; R/F = Romans, France; PI = Padua, Italy; C/NL = Culemborg, the Netherlands; V/P = Vila Franca de Xira, Portugal; B/E = Betanzos, Spain; Y/CH = Yverdon, Switzerland; SENECA = Survey in Europe on Nutrition and the Elderly: a Concerted Action.

Table 4. Mortality Risks and Risks of Deterioration of Health Status Resulting From Three Unhealthy Lifestyle Behaviors of Elderly Men and Women Across Europe (29)

	Vital Status HR (95% CI)[§]	Decreased vs Stable Self-Rated Health OR (90% CI)[‖]	Becoming Dependent vs Remaining Independent OR (90% CI)[‖]
Men			
Physical activity*	1.4 (1.1–1.7)	2.8 (1.3–6.2)	1.9 (0.9–3.9)
Dietary quality[†]	1.2 (0.9–1.7)	1.1 (0.5–2.3)	1.0 (0.5–2.2)
Smoking habits[‡]	2.1 (1.6–2.6)	2.0 (1.0–4.1)	2.2 (1.1–4.5)
Women			
Physical activity*	1.8 (1.3–2.4)	0.8 (0.3–1.7)	2.6 (1.4–4.9)
Dietary quality[†]	1.3 (0.9–1.8)	1.4 (0.7–2.8)	0.9 (0.5–1.8)
Smoking habits[‡]	1.8 (1.1–2.7)	—	—

Notes: *Lowest physical activity tertile versus intermediate and highest physical activity tertiles combined.
[†]Mediterranean diet score below 4 versus Mediterranean diet score above 4.
[‡]Current smokers and people who have quit smoking 15 years or less versus never smokers and people who have quit smoking over 15 years.
[§]Hazard Ratio and 95% confidence interval.
[‖]Odds Ratio and 90% confidence interval.
HR = hazard ratio; CI = confidence interval; OR = odds ratio.

chronic diseases, V/P was excluded from the longitudinal analyses on self-perceived health.

Lifestyle, Nutritional Status, Health Status, and Mortality

The effects of diet, smoking, and physical activity and the overall lifestyle score on the three parameters of health status have been studied extensively. Inactivity and smoking and, to a lesser extent, a low-quality diet increased mortality risk in both elderly men and women in Europe (8,21). An increasing number of unhealthy lifestyles was also related to a higher mortality rate. After 10 years, the survival fraction in participants with three healthy lifestyle factors was twice as high as in participants with no healthy lifestyle factors (21). This is particularly relevant, as unhealthy lifestyles often co-occur (3). The absence of weight loss during the first 5 years of the SENECA study was also predictive of subsequent survival (RR = 2.2, $p < .0001$ for men; RR = 1.3, $p = .35$ for women) (23). Table 4 shows the mortality risks and risks of deterioration of health status. A healthy lifestyle was not only related to reduced mortality, but also to stable self-perceived health and a delay in functional dependence. Inactive and smoking men, for example, had a two- to three-fold increased risk of a decline in self-rated health or in losing functional independence (3,31).

Discussion

The baseline SENECA study has contributed substantially to the knowledge of differences in distribution of lifestyle factors across groups of elderly people in Europe. Longitudinal results from the SENECA study stress the importance of lifestyle for healthy aging. The delayed onset of deterioration of health combined with increased survival in people with a healthy lifestyle are likely to coincide with the much sought-after compression of morbidity (3).

One of the problems in surveying older people is the high proportion of nonresponders, but also of drop-outs largely due to deaths (8). Both conditions were present in the SENECA study. Baseline participation rates in the longitudinal survey towns ranged from 34% (H/F) to 62% (V/P), with healthier people being more likely to participate. Drop-outs were also considerable; in 1993, 41% (B/E) to 74% (V/P) of the baseline study population was included (10,12). The participants who passed away during the study had a less favorable health status and less healthy lifestyle behaviors than the remainder of the participants. This progressive drop-out of people with unhealthy lifestyle behaviors reduced the contrasts in lifestyle behavior between the group with healthy behavior at baseline and the group with unhealthy behavior at baseline. As a result, the likelihood of finding effects of lifestyle factors on health status and mortality might be reduced (31). However, there are also advantages of a relatively healthy population at baseline in studies relating lifestyle parameters to health status and subsequent morbidity (3). In less healthy elderly people, the relative rapid decline in functional status as a result of progressive illness or catastrophic events that was discussed in the introduction is likely to have started already. Lifestyle factors that may have changed as a result of these sudden influential changes can potentially mask the lifelong health behavior people had before becoming ill. In the SENECA study, self-reported measures were used to assess the variability in lifestyles, and also the prevalence of chronic diseases. The lack of confirmation of the chronic diseases by a doctor may have affected the prevalences. As discussed by van Staveren and colleagues (32), up to the age of 72 years, most people are in good physical and mental health, after which a decline in both parameters can be observed. This has consequences for the lifestyle assessment methods that can be used. Fading memory at older age in the SENECA population could have reduced the validity of the recall assessment methods. Yet, studies in the SENECA population have shown sufficient validity for both dietary intake and physical activity assessment methods (13,20).

In general, dietary intake of the elderly people in the SENECA study was sufficient, but tended to decline over time (33,34). This was reflected in data on nutritional status (28). Nevertheless, potential concerns were identified in relation to vitamin D and vitamin B_{12}, where dietary intake levels may not suffice. This is caused partially by a reduced synthesis capacity (vitamin D) and reduced absorption of vitamin B_{12}. In both cases, supplements can help overcome

deficiencies and thus prevent potential health problems. Vitamin D supplementation is recommended to prevent deficiencies in elderly people, particularly in the winter (35). For vitamin B_{12}, current dose-finding studies will help to give shape to future supplementation strategies (36).

Data from the SENECA study as well as from other studies have shown the impact that lifestyle can have on morbidity and mortality. Ongoing research on lifestyle and cause-specific mortality in the SENECA study (37) will continue to add to our knowledge about the importance of health behavior change. The suggested combined effect of changes in multiple lifestyles (38) increases the possible impact of health behavior change even further. The implementation of such health behavior in elderly people living in different European regions is a great challenge for the European Community.

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REFERENCES

1. Kinsella KG. Changes in life expectancy 1900–1990. *Am J Clin Nutr*. 1992;55:1196S–1202S.
2. Campion EW. Aging better. *N Engl J Med*. 1998;228:1064–1066.
3. Haveman-Nies A, de Groot LCPGM, van Staveren WA. Dietary quality, lifestyle factors and healthy ageing in Europe: the SENECA study. *Age Ageing*. 2003;32:427–434.
4. Vellas BJ, Albarede J-L, Garry PJ. Diseases and aging, patterns of morbidity with age: relationship between aging and age-associated diseases. *Am J Clin Nutr*. 1992;55:125S–130S.
5. Fries JF. Aging, natural death, and the compression of morbidity. *N Engl J Med*. 1980;303:130–135.
6. Robinson F. *Nutrition for Healthy Ageing*. British Nutrition Foundation; March 2003.
7. World Health Organization. *World Atlas of Aging*. WHO Technical Series 98. Geneva: World Health Organization, Center for Health Development. Kobe, Japan, 1998.
8. van Staveren WA, de Groot LCPMG, Haveman-Nies A. The SENECA study: potentials and problems in relating diet to survival over 10 years. *Publ Health Nutr*. 2002;5:901–905.
9. de Groot LCPGM, van Staveren WA. SENECA's accomplishments and challenges. *Nutrition*. 2000;16:541–543.
10. Van't Hof MA, Hautvast JGAJ, Schroll K, Vlachonikolis IG. Design, methods and participation. *Eur J Clin Nutr*. 1991;45(Suppl 3):5–22.
11. de Groot L, van Staveren W. *Nutrition and the Elderly: Manual of Operations*. Wageningen, The Netherlands: Euronut, Report 11 (1988).
12. Van't Hof MA, Burema J. Assessment of bias in the SENECA study. *Eur J Clin Nutr*. 1996;50(Suppl 2):S4–S8.
13. Nes M, van Staveren WA, Zajkás G, Inelmen EM, Moreiras-Varela O. Validity of the dietary history method in elderly subjects. *Eur J Clin Nutr*. 1991;45(Suppl 3):97–104.
14. Schlettwein-Gsell D, Barclay D. Longitudinal changes in dietary habits and attitudes of elderly Europeans. *Eur J Clin Nutr*. 1996;50(Suppl 2): S56–S66.
15. Schlettwein-Gsell D, Decarli B, de Groot L. Meal patterns in the SENECA study of nutrition and the elderly in Europe: assessment method and preliminary results on the role of the midday meal. *Appetite*. 1999;32:15–22.
16. Schlettwein-Gsell D. Impact of socio-cultural food patterns. *Int J Vit Nutr Res*. 1995;65:73–74.
17. Trichopoulou A, Kouris-Blazos A, Wahlqvist ML, et al. Diet and overall survival in elderly people. *Br Med J*. 1995;11:1457–1460.
18. Haveman-Nies A, Tucker KL, de Groot LCPGM, Wilson PWF, Van Staveren WA. Evaluation of dietary quality in relationship to nutritional and lifestyle factors in elderly people of the US Framingham Heart Study and the European SENECA study. *Eur J Clin Nutr*. 2001;55: 870–880.
19. Osler M, de Groot LCPGM, Enzi G. Life-style: physical activities and activities of daly living. *Eur J Clin Nutr*. 1991;45(Suppl 3):139–151.
20. Voorrips LE, Ravelli ACJ, Dongelmans PCA, Deurenberg P, van Staveren WA. A physical activity questionnaire for the elderly. *Med Sci Sports Exerc*. 1991;23:974–979.
21. Haveman-Nies A, de Groot LCPGM, Burema J, Amorim-Cruz JA, Osler M, van Staveren WA. Dietary quality and lifestyle factors in relation to 10-year mortality in older Europeans. *Am J Epidemiol*. 2002; 156:962–968.
22. Ostbye T, Taylor DH, Jung SH. A longitudinal study of the effects of tobacco smoking and other modifiable risk factors on ill health in middle-aged and old Americans: results from the health and retirement study and asset and health dynamics among the oldest survey. *Prev Med*. 2002;34:334–345.
23. de Groot CPGM, Enzi G, Matthys C, Moreiras O, Roszkowski W, Schroll M. Ten-year changes in anthropometric characteristics of elderly Europeans. *J Nutr Health Age*. 2002;6:4–8.
24. WHO. *International Classification of Diseases, Ninth Revision*. Geneva, Switzerland: World Health Organization; 1987.
25. Schlettwein-Gsell D, Barclay D, Osler M, Trichopoulou A. Dietary habits and attitudes. *Eur J Clin Nutr*. 1991;45(Suppl 3):83–95.
26. de Groot CPGM, Schlettwein-Gsell D, Schroll-Bjornsbo K, van Staveren WA. Meal patterns and food selection of elderly people from six European towns. *Food Qual Pref*. 1998;9:479–486.
27. Schlettwein-Gsell D, Prins L, Ferry M. Life-style: marital status, education, living situation, social contacts, personal habits (smoking, drinking). *Eur J Clin Nutr*. 1991;45(Suppl 3):153–168.
28. de Groot LCPGM, Sette S, Zajkás G, Carbajal A, Amorim Cruz. Nutritional status: anthropometry. *Eur J Clin Nutr*. 1991;45(Suppl 3):31–42.
29. Amorim Cruz JA, Haveman-Nies A, Schlettewein-Gsell D, De Henauw S. Gender, cohort and geographical differences in 10-year mortality in elderly people living in 12 European towns. *J Nutr Health Aging*. 2002; 6:269–274.
30. Schroll M, Ferry M, Lund-Larsen K, Enzi G. Assessment of health: self-perceived health, chronic diseases, use of medicine. *Eur J Clin Nutr*. 1991;45(Suppl 3):169–182.
31. Haveman-Nies A, de Groot LCPGM, van Staveren WA. Relation of dietary quality, physical activity, and smoking habits to 10-year changes in health status in older Europeans in the SENECA study. *Am J Publ Health*. 2003;93:318–323.
32. van Staveren WA, de Groot LCPGM, Blauw YH, Van der Wielen RPJ. Assessing diets of elderly people: problems and approaches. *Am J Clin Nutr*. 1994;59(Suppl):221S–223S.
33. Moreiras O, van Staveren WA, Amorim-Cruz JA, Nes M, Lund-Larsen K. Intake of energy and nutrients. *Eur J Clin Nutr*. 1991;45(Suppl 3): 105–119.
34. Amorim-Cruz JA, Moreiras-Varela O, van Staveren WA, Trichopoulou A, Roszkowski W. Intake of vitamins and minerals. *Eur J Clin Nutr*. 1991;45(Suppl 3):121–138.
35. Van der Wielen RPJ, Löwik MRH, Van den Berg H, de Groot CPGM, Haller J, Moreiras O, van Staveren WA. Serum vitamin D concentrations among elderly people in Europe. *Lancet*. 1995;346:207–210.
36. Eussen SJPM, de Groot LCPGM, Clarke R, Scneede J, van Staveren WA. Minimum effective dose of oral vitamin B12 to treat elderly people with mild vitamin B12 deficiency [Abstract]. *J Nutr Health Aging*. 2003;7:210–221.
37. Knoops KTB, de Groot CPGM, van Staveren WA. Lifestyle factors and cause-specific mortality [Abstract]. *Int J Behav Med*. 2002;9(Suppl 1): 149–150.
38. Tuomilehto J, Lindstrom J, Eriksson JG, et al. Prevention of type 2 diabetes mellitus by changes in lifestyle among subjects with impaired glucose tolerance. *N Engl J Med*. 2001;344:1343–1350.
39. de Groot CPGM, Van den Broek T, van Staveren W. Energy intake and micronutrient intake in elderly Europeans: seeking the minimum requirement in the SENECA study. *Age Ageing*. 1999;28:469–474.
40. van Staveren WA, de Groot LCPMG. Vitamin D, nutritional significance. In: Roginski H, Fuquay JW, Fox PF, eds. *Encyclopedia of Dairy Sciences*. London: Academic Press; 2002.
41. Van Asselt DZB, de Groot LCPGM, van Staveren WA, Blom HJ, Biemond I, Hoefnagels WHL. Role of cobalamin intake and atrophic

gastritis in mild cobalamin deficiency in older Dutch subjects. *Am J Clin Nutr*. 1998;68:328–334.
42. Haller J, Löwik MRH, Ferry M, Ferro-Luzzi A. Nutritional status: blood vitamins A, E, B_6, B_{12}, folic acid and carotene. *Eur J Clin Nutr*. 1991;45:63–82.
43. Russell RM. Mild cobalamin deficiency in older Dutch subjects. *Am J Clin Nutr*. 1998;68:222–223.
44. Eussen SJPM, Ferry M, Hininger I, Haller J, Mathys C, Dirren H. Five year changes in mental health and associations with vitamin B12/folate status of elderly Europeans. *J Nutr Health Aging*. 2002;6:43–50.

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APPENDIX

Vitamin B_{12} and Vitamin D

Data from the Survey in Europe on Nutrition and the Elderly: a Concerted Action (SENECA) study as well as from other studies showed that dietary intake levels of many vitamins and minerals are sufficient in elderly people (39). Vitamin B_{12} and vitamin D—of which low levels are often related to causes other than insufficient dietary intake levels—are the exceptions.

Approximately one third of vitamin D requirements can be obtained from diet. The rest is synthesized in the skin under the influence of sunlight (ultraviolet light). As a result of limited sunlight exposure and a four-fold reduced capacity of the skin to produce vitamin D, deficiencies may occur in homebound elderly people (40). Surprisingly, Van der Wielen and colleagues (35) showed that serum 25-hydroxyvitamin D concentrations were lowest in southern European countries (no data available on P/I); winter concentrations were lowest in B/E (25 nmol/L) and highest in Y/CH (52 nmol/l). The low concentrations in southern survey towns could be explained by reduced sunlight exposure (avoidance of sunlight, clothing habits, going outdoors for leisure-time activities) and by problems performing activities of daily living (an indicator of physical health status). Using sunlamps and/or vitamin D supplements was particularly prevalent in the northern SENECA towns, and use was associated with a higher serum 25-hydroxyvitamin D concentration. Yet, regardless of geographical location, elderly people are at risk of having an inadequate vitamin D status in winter and supplementation strategies should be considered.

Van Asselt and colleagues (41) studied vitamin B_{12} status in Dutch participants in the 1993 follow-up of the SENECA study. People with impaired renal function were excluded. Vitamin B_{12} deficiency is an important cause for elevated methyl-malonic acid (MMA) concentrations. Because people with the only other important cause for MMA concentrations (i.e., impaired renal function) were excluded from the study, MMA concentrations were also studied as an indicator of vitamin B_{12} status. Twenty-four percent of the apparently healthy participants were defined as mildly vitamin B_{12} deficient, and 51% as possibly vitamin B_{12} deficient. Dietary intake of vitamin B_{12} did not differ between groups with mild, possible, or no vitamin B_{12} deficiency, but supplement intake was higher in the nondeficient group (41). A reduced absorption capacity and also gastric atrophy, which is particularly prevalent in older people, rather than low dietary intake levels, are thus believed to be the cause of a deficiency (42). Yet, these causes cannot explain all cases of deficiency, and research into other factors is necessary (41,43). Ongoing research will also help address the question of how vitamin B_{12} deficiencies can best be explained and treated, in particular for the prevention and treatment of cognitive decline (44).