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## Energy balance and health in SENECA participants

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In 1988 a European Community project, SENECA (Survey in Europe on Nutrition and the Elderly, a Concerted Action), started with nineteen research groups in twelve countries to work on the major nutritional issues affecting the growing number of elderly people. About 2600 subjects aged 70–75 years old were studied, according to a strictly standardized methodology. The study has a mixed longitudinal design with an intermediate contact carried out in 1991 and a follow-up study conducted in 1993 in nine centres.

An important indicator of the nutritional status is a change in the energy balance leading to either overweight or underweight. Overweight is associated with increased abdominal fat deposition (Shimokata, 1989; Den Tonkelaar *et al.* 1990) and has been implicated in the development of cardiovascular risk factors, including diabetes mellitus, hypertension, hypercholesterolaemia, and left ventricular hypertrophy in the young as well as older persons (Harris *et al.* 1993). Underweight is associated with decreased immune response and the development of decubitus ulcers, in addition to increased hip fractures and mortality (Morley & Kraenzle, 1994).

Results of the SENECA baseline study showed that obesity, defined as BMI ⩾30 $kg/m^2$, was prevalent in at least 20% of men in eight centres and women in twelve centres. Underweight, defined as a BMI lower than 20 $kg/m^2$, occurred less frequently, but in four centres the prevalence amongst men was higher than 10% (De Groot *et al.* 1991). In order to get a better insight into predictors of changes in the energy balance, the present paper describes the relationship between BMI ($kg/m^2$) and, more specifically, underweight on the one hand and health, nutrition and life-style factors on the other hand.

### METHODS

#### *Subjects*

Three centres had to be excluded because insufficient data were available. From the other centres 924 men and 836 women with complete sets of data are included. They live in towns which were chosen for having stable populations (i.e. not commuter towns) of 10 000–20 000 and socio-economic structures comparable with that of their region or country as a whole (Table 1).

Table 1. *Towns included in the present study*

| Country | Town | Code | Country | Town | Code |
|---|---|---|---|---|---|
| Belgium | Hamme | H/B | Italy | Fara Sabina, Magliano Sabina, Poggio Mirteto | FMP/I |
| Denmark | Roskilde | R/DK | The Netherlands | Culemborg | C/NL |
| France | Haguenau | H/F | Norway | Elverum | E/N |
| France | Romans | R/F | Portugal | Vila Franca de Xira | V/P |
| Greece | Markopoulo | M/GR | Spain | Betanzos | B/E |
| Greece | Anogia, Archanes (in Crete) | AA/GR | Switzerland | Yverdon | Y/CH |
| Hungary | Monor | M/H | Switzerland | Burgdorf | Bu/CH |
| Italy | Padua | P/I | Switzerland | Bellinzona | Be/CH |

The core protocol called for a random sample, stratified by sex and age, of elderly subjects born in 1913 and 1914. Nine of the research sites added an optional longitudinal component with a random sample of elderly subjects born in 1915–1918, also stratified by sex and age. The mean response rate was 51%, while 60% of the non-responders completed a non-responders' questionnaire. It was found that males, non-smokers, healthy and better educated subjects participated better in the SENECA study (Van 't Hof *et al.* 1991).

### *Anthropometric data*

Anthropometric data were collected by trained personnel. Standing height was measured to the nearest 1 mm using a microtoise fixed to the wall. Weight was measured to the nearest 0·5 kg, in the morning after breakfast and after emptying the bladder (De Groot *et al.* 1991). For the examination of the association between BMI and nutrition, health and life-style variables three classes of BMI (kg/m$^2$) were formed using Garrow's (1981) obesity classification: <20 fragile, 20–29 normal and ≥30 obese.

### *Laboratory analyses*

Biochemical variables selected as indicators of nutritional status were: serum lipids and plasma pyridoxal-5′-phosphate (PLP). The latter was selected because Haller *et al.* (1991) have shown that, in contrast to other vitamins, prevalence of inadequate PLP levels was high in the SENECA participants. The protocol required blood sampling by antecubital venipuncture after an overnight fast with the subject in the sitting position.

For measurement of serum total cholesterol an enzymic colorimetric method was applied using Boehringer-Mannheim reagents (Siedel *et al.* 1983). HDL-cholesterol was determined after apo-β-lipoprotein precipitation with dextran sulphate–$Mg^{2+}$ by the enzymic cholesterol oxidase (*EC* 1.1.3.6)–para-aminophenozon (CHOP–PAP) method (Warnick *et al.* 1982). Fasting serum triacylglycerols were measured by an enzymic colorimetric method using Boehringer-Mannheim reagents after elimination of free glycerol from the samples (Sullivan *et al.* 1985); for a more detailed description of these methods, see Kafatos *et al.* (1991). PLP in plasma was assayed using the enzyme assay method (Chabner & Livingstone, 1970).

### *Dietary data*

A modified validated dietary history was used. The method is characterized mainly by a 3 d estimated record and a frequency checklist of foods, based on the meal pattern of the country. Trained interviewers visited the participants twice: the first time to introduce the estimated record and the second time to complete the checklist of foods, which questioned the usual food intake of the previous month. Portion sizes were checked by weighing, or standardized household measures were used. Scales were not supplied centrally and, therefore, were not the same for all centres. Foods were coded and analysed for nutrient composition in each participating country using local food tables; for more details of the method, see De Groot & Van Staveren (1988).

### *Life-style and health data*

A general structured interview with the participants included questions on age, sex, living arrangements, smoking and functional status (activities of daily living; ADL). Each country translated the questionnaire into the appropriate language. Subsequently questionnaires were translated back into English by translators of Hoffmann-La Roche, ensuring that all the code numbers of questions in the original questionnaire corresponded to those in the translated questionnaire. Living arrangements were coded as living alone or living with others. The subjects were classified according to smoking habits as non-smokers, former smokers or current smokers. Subjects smoking one or more cigarettes per d fell into the latter category. ADL were assessed by sixteen questions and for each item the level of competence was measured on a four-point scale. A total ability score was calculated as a sum score over all items. The lower the rating the better the performance (Osler *et al.* 1991). For the present study subjects were grouped into three categories: good performers had a score of 16, intermediate from 17–33 and inability to perform was 34 and over. Comparative activity was assessed by asking the subjects if they consider themselves, compared with others of their age-group, less active, more active or average.

### *Statistical analysis*

Descriptive and sex-specific statistics were calculated from crude and weighted data (Van 't Hof *et al.* 1991). The weighted data were little different from the crude data. The present paper, therefore, will concentrate on the crude data. Effects of centre and age were calculated by ANOVA and by Scheffé's multiple-comparison test. Chi-square was used for nominal variables.

For the following analyses obese participants having a BMI $\geqslant 30$ were excluded, assuming that determinants of obesity would interfere with determinants of overweight. A linear-regression model with BMI as the continuous dependent variable was used for multivariate analyses to examine simultaneously the effect of demographic, life-style and health indicators. Odds ratios contrasting BMI $<20$ with those having a BMI between 20 and 30 were derived from a logistic-regression model including all main effects. To examine whether the correlation between health and BMI was due to a direct effect on low BMI or whether it was an indirect effect mediated by physical activity or by smoking, a path analysis was carried out using LISREL (Jöreskog & Sörbom, 1988–9). For this procedure errors in the assessments were assumed to be unrelated and the maximum-likelihood procedure was used for the estimation of the effect.

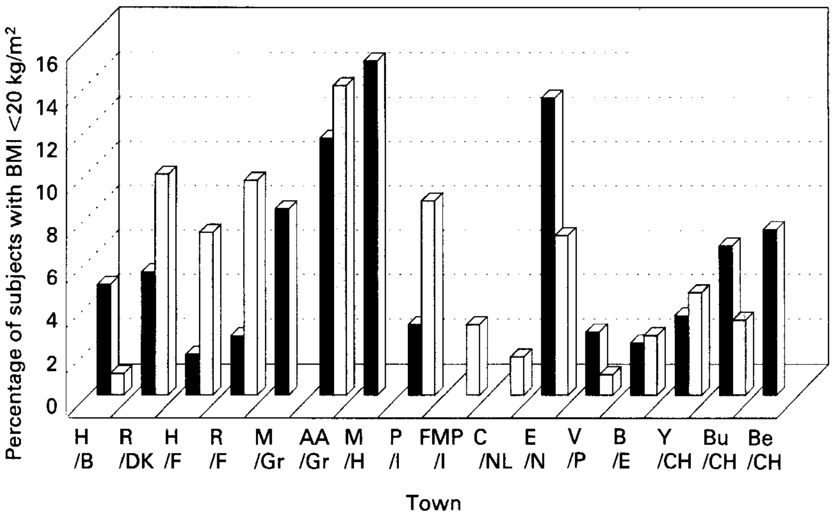


Fig. 1. SENECA study. The percentages of elderly men (■) and women (□) with low BMI (<20 kg/m$^2$) in the present study, classified by town (see Table 1). For details of subjects and procedures, see pp. 617–619.

## RESULTS

In Fig. 1 the percentage of subjects with a BMI <20 is shown. Two centres, C/NL and FMP/I, appeared not to include men with a BMI <20 and three other centres, M/Gr, M/H and Be/CH, did not include women with a BMI <20. In three centres more than 10% of men or women had a BMI lower than 20. Fig. 2 shows that a higher percentage of subjects had a BMI at the other end of the distribution (⩾30).

To examine the relationship between BMI and dietary intake, mean energy and selected nutrient intakes were calculated for men and women in the three classes of BMI. A significant difference has been found for energy and protein intake expressed per kg body weight. An inverse relationship between these variables and BMI is shown in Table 2. For intake of fat a significant difference has been found only between the intake of women with a BMI ⩾30 *v.* women in the other two classes. Micronutrient intake did not appear to be significantly different between the three classes, but clearly there is a tendency for subjects with a lower BMI to have lower intakes.

Table 3 shows the relationship between serum lipids and plasma pyridoxine levels on the one hand and BMI on the other hand. The relationship for serum total cholesterol and triacylglycerols was positive and for HDL-cholesterol negative. The relationship with plasma PLP was weak ($P \leq 0{\cdot}06$).

Of the life-style, health and performance variables, smoking, comparative activity, the lowest ADL score and subjective health were related to BMI in the subgroup with BMI <30. For men and women the relationships were not always in the same direction, as shown in Table 4.

In a logistic-regression analysis we examined the prevalence of low BMI for subjects with different life-style, health and nutritional variables. In Table 5 the relative odds and 95% confidence intervals were calculated with simultaneous adjustment for other

Table 2. *SENECA study*. Mean daily energy and selected nutrient intakes for elderly men and women classified in three categories of BMI*

(Mean values and standard deviations)

| | Men | | | | | | Women | | | | | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|
| BMI (kg/m²) . . . | <20 | | 20–29 | | ≥30 | | <20 | | 20–29 | | ≥30 | |
| | Mean | SD | Mean | SD | Mean | SD | Mean | SD | Mean | SD | Mean | SD |
| *n* | 43 | | 868 | | 187 | | 53 | | 771 | | 293 | |
| Energy: (MJ) | 9·8 | 3·0 | 9·7 | 2·6 | 9·7 | 3·3 | 7·4 | 1·7 | 7·6 | 2·2 | 7·9 | 2·9 |
| (kJ/kg body wt) | 184[a] | 54 | 135[b] | 39 | 111[c] | 41 | 168[a] | 42 | 126[b] | 40 | 102[c] | 40 |
| Protein: (g) | 77 | 26 | 81 | 23 | 85 | 28 | 63[a] | 17 | 67[a] | 22 | 72[b] | 26 |
| (g/kg body wt) | 1·4[a] | 0·5 | 1·1[b] | 0·4 | 1·0[c] | 0·4 | 1·4[a] | 0·4 | 1·1[b] | 0·4 | 0·9[c] | 0·4 |
| Total fat (g) | 98 | 38 | 93 | 35 | 91 | 44 | 74[ab] | 30 | 76[a] | 29 | 82[b] | 38 |
| Fe (mg) | 12·6 | 5·2 | 13·1 | 5·7 | 13·9 | 6·5 | 9·5 | 4·4 | 10·4 | 4·4 | 11·1 | 5·4 |
| Thiamin (mg) | 1·10 | 0·35 | 1·18 | 0·45 | 1·17 | 0·48 | 0·85 | 0·24 | 0·97 | 0·38 | 1·01 | 0·42 |
| Riboflavin (mg) | 1·58 | 0·60 | 1·67 | 0·68 | 1·82 | 1·06 | 1·38 | 0·46 | 1·50 | 0·78 | 1·60 | 0·91 |
| Pyridoxine (mg)† | 1·37 | 0·45 | 1·54 | 0·51 | 1·59 | 0·55 | 1·17 | 0·37 | 1·29 | 0·45 | 1·31 | 0·52 |

[a,b,c] Means within horizontal rows with different superscript letters were significantly different ($P \leq 0{\cdot}05$).

* For details of subjects and procedures, see Table 1 and pp. 617–619.

† No data available for 183 men and 277 women.

Table 3. *Serum lipid and plasma pyridoxal-5′-phosphate (PLP) values in elderly men and women classified in three categories of BMI*

(Mean values and standard deviations)

| | Men | | | | | | Women | | | | | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|
| BMI (kg/m$^2$) . . . | <20 | | 20–29 | | ≥30 | | <20 | | 20–29 | | ≥30 | |
| | Mean | SD | Mean | SD | Mean | SD | Mean | SD | Mean | SD | Mean | SD |
| *n* | 39 | | 810 | | 169 | | 40 | | 701 | | 268 | |
| Cholesterol (mmol/l) | 5·8 | 1·0 | 6·0 | 1·0 | 6·1 | 1·0 | 6·1$^{a}$ | 1·1 | 6·7$^{b}$ | 1·2 | 6·6$^{ab}$ | 1·3 |
| HDL (mmol/l) | 1·5$^{a}$ | 0·4 | 1·2$^{b}$ | 0·3 | 1·1$^{c}$ | 0·3 | 1·7$^{a}$ | 0·4 | 1·4$^{b}$ | 0·4 | 1·3$^{c}$ | 0·4 |
| Triacylglycerols (mmol/l) | 1·0$^{a}$ | 0·2 | 1·4$^{b}$ | 0·8 | 1·8$^{c}$ | 1·2 | 1·0$^{a}$ | 1·0 | 1·4$^{b}$ | 0·8 | 1·7$^{c}$ | 1·2 |
| *n* | 16 | | 304 | | 63 | | 14 | | 267 | | 100 | |
| PLP (nmol/l) | 26·9 | 9·0 | 38·0 | 4·0 | 31·5 | 10·0 | 35·4$^{ab}$ | 12·0 | 46·0$^{a}$ | 8·0 | 35·0$^{b}$ | 5·0 |

a,b,c Means within horizontal rows with different superscript letters were significantly different ($P \leq 0·05$).

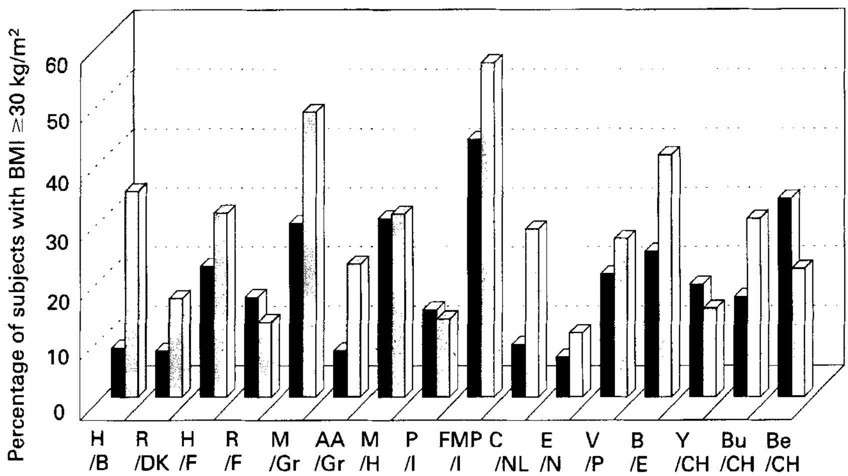


Fig. 2. SENECA study. The percentage of obese (BMI ≥30 kg/m²) elderly men (■) and women (□) in the present study, classified by town (see Table 1). For details of subjects and procedures, see pp. 617–619.

Table 4. *Relationships between BMI and variables of life-style, health and performance of elderly subjects in the SENECA population**†

| | Men | Women |
|---|---|---|
| Centre | Effect on distribution of BMI | Effect on distribution of BMI |
| Living alone | No association | No association |
| Smoking | Low BMI more prevalent in frequent smokers | Low BMI more prevalent in frequent smokers |
| Comparative activity | Low BMI more prevalent in less active men | High BMI more prevalent in less active women |
| Performance of activities of daily living | Low BMI more prevalent in poor performers | High BMI more prevalent in poor performers |
| Subjective health | Low BMI more prevalent in both extremes of the distribution: poor health and good health | High BMI more prevalent in women reporting poor health |

* Reported relationships were significant according to Chi-square test.
† For details of subjects and procedures, see Table 1 and pp. 617–619.

variables listed. The results show that a low BMI appears to be more prevalent in women, subjects living with others, in smokers, subjects with a high ADL score and with poor subjective health. Also a geographical effect appeared in this analysis (not shown). Energy intake and physical activity did not show up as a risk factor for low BMI after adjustment for the other factors.

Based on these results a model was developed for a path analysis as shown in Fig. 3(a). The results depicted in Fig. 3(b and c) did not show a one-way path from smoking to poor

Table 5. *SENECA study*. Prevalence (relative odds) of low BMI (<20 kg/m²) by selected characteristics in men and women 70–75 years old*

| | Relative odds* | Confidence limits |
|---|---|---|
| Sex | | |
| Men | (1·0) | |
| Women | 1·4 | 0·9, 2·1 |
| Living situation | | |
| With others | (1·0) | |
| Living alone | 0·6 | 0·4, 1·0 |
| Smoking | | |
| Non-smoker | (1·0) | |
| Former smoker | 0·8 | 0·5, 1·4 |
| Smoker | 2·2 | 1·4, 3·6 |
| ADL score (sixteen items) | | |
| 16 | (1·0) | |
| 17–32 | 1·2 | 0·8, 1·9 |
| 33–64 | 2·0 | 0·9, 4·4 |
| Subjective health | | |
| Good | (1·0) | |
| Fair | 1·0 | 0·8, 1·4 |
| Poor | 2·9 | 1·6, 5·0 |

ADL, activities of daily living.
* For details of subjects and procedures, see Table 1 and pp. 617–619.
† Odds ratios were derived from a logistic-regression model including all main effects listed.

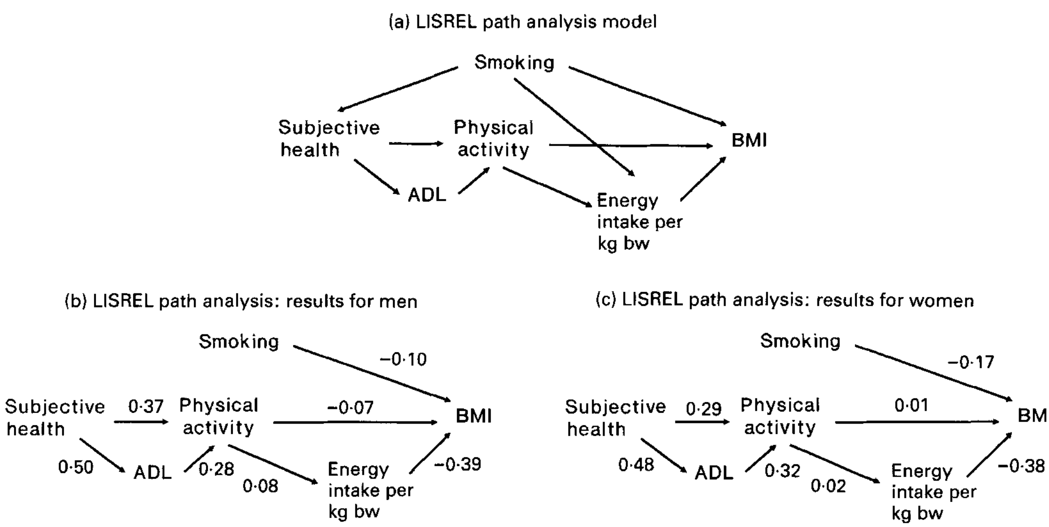


Fig. 3. SENECA study. LISREL path analysis model (a) and results for elderly men (b) and women (c) showing associations between the variables surveyed in the present study. ADL, activities of daily living; bw, body weight. For details of subjects and procedures, see Table 1 and pp. 617–619.

health, less activity and low BMI. Smoking was uncorrelated with subjective health. Energy intake per kg body weight and smoking appeared to be negatively related to BMI in men and women.

## DISCUSSION

The present study confirms the hypothesis of an association between low BMI (<20) and poor health and performance. The relationship with nutritional variables is less clear. In considering these data we have to realize that although the study methods were highly standardized between the centres, cultural differences in the interpretation of questionnaires still might have led to some bias in the answers and this is particularly true for the life-style, health and performance questionnaire. Furthermore, one should keep in mind that the average participation rate was about 50% with wide variations between towns. The present results, therefore, are not truly representative of all 70–75-year-old subjects living in these towns, despite the corrections for non-participation.

### *BMI as a predictor of functional status*

BMI values, derived from height and weight, are relatively simple estimates which give information on fat mass (FM) and fat-free mass (FFM) of the body. Studies in our institute and other institutes indicated that in apparently-healthy subjects between 60 and 80 years old FFM derived from body density and FFM derived from BMI were highly correlated and it was concluded that age-specific prediction equations based on BMI could be used to assess body composition in groups of elderly subjects as long as kyphosis and oedema are absent (World Health Organization Subcommittee on the Elderly, 1993; Visser *et al.* 1994). However, P. Deurenberg (unpublished results) showed that while BMI is a good predictor of body composition on an aggregate level, on an individual level large differences with the densitometry method may occur. This might have affected the associations examined in this study.

### *Relationships between BMI and variables of the nutritional situation*

These are summarized in Table 6. The observed inverse relationships between BMI, and protein and energy intakes each expressed per kg body weight may be inflated since body

Table 6. *Summary of apparent relationships between BMI and variables of the nutritional status in the SENECA population**†

| Relationship between BMI and: | Yes | No |
|---|---|---|
| Consumption of | Energy (/kg body wt)<br>Protein (/kg body wt) | Total energy<br>Total protein<br>Total fat |
| | Riboflavin (men) | Thiamin, pyridoxine |
| Biochemical status | Serum lipids<br>Pyridoxine (weak) | |

* Summary: analyses of variance and multiple-comparison test.
† For details of subjects and procedures, see Table 1 and pp. 617–619.

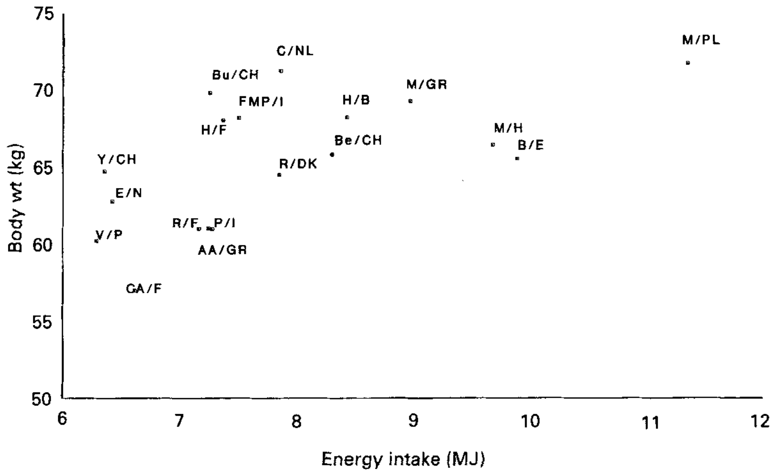


Fig. 4. SENECA study. The relationship between mean body weight and energy intake of elderly women in the towns (see Table 1) surveyed in the present study. For details of subjects and procedures, see pp. 617–619. *R* 0·59.

weight is implicit in the units for the dependent variable as well as the independent variables. Another explanation for the inverse relationship with energy intake per kg body weight and protein intake per kg body weight might be the lower resting metabolic rate for FM compared with FFM. Furthermore, some subjects in the category with a low BMI might be more physically active. In addition to a biological explanation, the potential of bias in the estimates of energy intake has to be considered. As also reported in other studies (Bandini *et al.* 1990; Schoeller *et al.* 1990) it is quite likely that subjects in the higher BMI category under-reported their energy intake more than subjects in the lower BMI category. The latter could partly contribute also to the observation that energy intake per kg body weight in women was negatively related to BMI. Although the validation study of our method did not indicate under-reporting on an aggregate level (Nes *et al.* 1991), and an ecological analysis showed a positive relationship between body weight and absolute energy intake (Fig. 4), bias in the association due to more under-reporting of energy intake in the higher BMI class cannot be excluded.

No significant relationship between intakes of other nutrients and BMI could be detected, although there was a tendency towards higher intakes in subjects with a higher BMI. Average intakes were adequate for all BMI categories according to European standards (Trichopoulou & Vassilakou, 1990; Amorim Cruz *et al.* 1991). The tendency towards lower intakes in lower BMI category could be detected also in plasma PLP levels. As in the vitamin intake estimates, the relationship with PLP levels appeared to be weak.

The relationships found between BMI and serum cholesterol levels were in the same directions as often found for younger adults (Kannel, 1988). Harris *et al.* (1992) indicated that lower levels of serum cholesterol are found in two groups of elderly subjects: those with a better-than-average health status might have stable low levels in contrast to those with a poor health status for whom the low level might be the result of a recent decline. Since in this study a low BMI was associated with poor health, the lower levels of serum cholesterol in that category might well be the result of a recent decline due to a disease. Both the trend in triacylglycerols and the inverse relationship with HDL-cholesterol were similar to findings in younger adults (Burton & Foster, 1985).

### *Relationships between BMI and smoking and living arrangements*

In the present study we found that the prevalence of low BMI in smokers was twice that of non-smokers and former-smokers. This is what we expected from earlier results in younger adults (Colditz *et al.* 1992; Seidell, 1992). Smoking increases resting metabolic rate and as suggested in the path analyses, smoking may have a direct effect on BMI. In agreement with the findings of Sem *et al.* (1988), living alone was not associated with a low BMI.

### *Relationships between BMI and health, performance and physical activities*

The relationships we found between health, performance and physical activity on the one hand and BMI on the other hand suggested that poor health causes reduced mobility and, thus, less physical activity, which consequently leads to lower BMI in men. However, BMI and energy intake also affect mobility. With a path analysis in a cross-sectional study we cannot prove either direction and the interpretation of the finding is hard due to other factors which have to be accounted for in evaluating health risks from anthropometric measures. In elderly subjects such factors are, for instance, selective mortality, and sex, age and ethnic variation in fixed cut-off points for over- and underweight (Andres, 1985; Harris *et al.* 1992). The results in our study show that the relationship between health and BMI in women is unlike the relationship found for men. The model suggests that, unlike for men, for women reduced mobility hardly affects energy intake (or, as a consequence, BMI).

In conclusion the analyses of the SENECA baseline data performed for the present study suggest that health and immobility are the main determinants of low BMI in men, meanwhile in women these variables are associated with high BMI. For both sexes changes in BMI will be easier to interpret. Changes in BMI in both directions might affect health (Deeg *et al.* 1990; World Health Organization Subcommittee on the Elderly, 1993) and we hope that the follow-up study will give us more insight into life style and other factors associated with these changes.

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