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Effect of dietary supplements and physical exercise on sensory perception, appetite, dietary intake and body weight in frail elderly subjects

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This present study investigated the effect of a 17-week intervention programme with nutrient-dense foods (enriched with vitamins and minerals at 25–100 % of the Dutch recommended dietary allowance) and/or physical exercise in 159 frail elderly subjects (forty-six men, 113 women, mean age 78·7 (SD 5·6) years). Subjects were randomized into four groups: (1) control, (2) nutrition intervention, (3) exercise or (4) both nutrition intervention and exercise. Main outcome variables were sensory perception (smell test and questionnaire), appetite (questionnaire), energy intake (3 d food record) and body weight (on a weighing scale and with dual energy X-ray absorptiometry measurements). At baseline, moderate but significant correlations were found between appetite and energy intake (r 0·30, $P < 0·0001$), between smell test and smell perception assessed by questionnaire (r 0·40, $P < 0·0001$) and between lean body weight and energy intake (r 0·50, $P < 0·0001$). Results after 17-weeks intervention revealed neither change in smell test scores ($P = 0·19$) nor in appetite ($P = 0·17$). A slight positive effect of exercise compared with non-exercising groups on energy intake (difference 0·5 MJ, $P = 0·05$) was shown next to a preserving effect of exercise on lean body mass (+0·08 kg) compared with a decrease (–0·4 kg) in non-exercisers ($P < 0·02$). The correlation between the change in lean body mass and change in energy intake was 0·18 ($P = 0·05$). In conclusion, an interesting preserving effect on lean body mass in frail elderly subjects due to 17 weeks of exercise was shown. Since a decline in lean body mass was observed in the non-exercisers, effects may be attributable to change in activity pattern. Changes in lean mass were also slightly, but significantly, correlated with changes in energy intake. In turn, energy intake was not related to a change in reported appetite or sensory perception. Nutrient-dense foods were not able to improve any of the outcome variables in this study.

Frail elderly: Appetite: Exercise: Nutrient-dense foods

Ageing is often associated with an impairment of health and nutritional status. The onset and intensity of this process is determined not only by chronological age but also by biological factors. These factors differ for each individual and therefore they lead to heterogeneity in the elderly population (Feldman, 1993). Researchers have made a distinction between successful normal, and accelerated ageing (Rowe & Kahn, 1987; Harris & Feldman, 1991). Within all these categories the process of frailty may commence. Buchner & Wagner (1992) define frailty as a state of reduced physiological reserve associated with increased susceptibility to disability. However, other more extensive or more confined definitions have also been used (Strawbridge *et al*. 1998). Frailty is in most cases related to a diminished physical, cognitive, emotional, sensory and/or social functioning (Guralnik & Simonsick, 1993).

An impairment in sensory functioning, such as reduced taste and smell perception, may have a negative impact on appetite and feelings of hunger and thereby cause a decrease in energy intake. Clear evidence, however, for the relationship between an impaired taste and smell perception and a decreased appetite and food and energy intake has not been found so far. A few studies confirmed this relationship, especially in sick (Schiffman, 1983*a*,*b*; Schiffman & Warwick, 1993), but also in healthy elderly subjects (Griep *et al*. 1996). Others failed to detect an association between taste and smell perception, food acceptability and a substantial reduced energy or nutrient intake in apparently healthy elderly (Ferris & Duffy, 1989; Mattes *et al*. 1990; Mattes & Cowart, 1994).

A good appetite is generally regarded as a sign of good health and a decreasing willingness or acceptance of food could be an early sign of the process of worsening health (Frisoni *et al*. 1995). Since this process might be one of the indicators of frailty, attendance to this problem is of major importance. To improve or maintain the quality of ‘the frail

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elderly life' it is important to maintain a sufficient appetite and nutritional and health status, or if necessary improve them. Adopting physical exercise, thereby increasing energy expenditure and hence appetite and total dietary intake, and particularly assuring a high nutritional quality of the diet of the elderly in order to combat any potential deficiencies, are believed to be key factors in slowing the process of frailty (Fiatarone *et al*. 1994; Gray-Donald, 1995; Gray-Donald *et al*. 1995). Changes in the taste and smell system with age may be related to nutrient intake (Chauhan *et al*. 1987). Only a few studies in frail (or 'at risk') elderly people have been performed to investigate the effects of either physical exercise and/or nutritional supplements on several indicators of nutritional and health status (Lipschitz *et al*. 1985; Meredith *et al*. 1992; Fiatarone *et al*. 1994; Nelson *et al*. 1994; Gray-Donald *et al*. 1995). However, none of these studies has focused on the effects of these interventions on sensory factors in relation to appetite, energy intake and (lean) body weight.

We hypothesized that frailty is at least partially mediated by an impaired sensory functioning, decreased appetite and hunger feelings and therefore a marginal nutritional intake. This in the end may result in a decreasing body weight. The present study is part of a large scale intervention trial in frail elderly and was designed to investigate the effect of the consumption of micronutrient-dense products, a physical exercise programme or a combination of both on the variables mentioned. Emphasis is placed on the measurement of appetite and taste and smell perception as predictors for energy intake.

Subjects and methods

Subjects

A total of 7080 letters were sent to elderly people living in the neighbourhood of Wageningen, The Netherlands, resulting in a study population of 217 free-living frail elderly, who were interested in the study and met the selection criteria. Fig. 1 summarizes the process of subject selection for the trial. To fulfil the criteria 'frail', subjects must have required some kind of health care, such as home

7080 Invitation letters
(through home-care institutions, meals-on-wheels services, elderly community centres, senior homes)

↓

Thirty-two introductory meetings

↓

854 Elderly people screened

Not meeting the criteria 38 %
- BMI > 25 kg/m^2 43 %
- Physically too active 17 %
- Combination of first two reasons 15 %
- Use of multivitamins 13 %
- No requirement of any kind of help 8 %
- Other 4 %

No interest anymore 32 %
- Illness 24 %
- No time 20 %
- No interest 11 %
- Period too long or too intensive 11 %
- Partner ill or not meeting the criteria 5 %
- Other 29 %

Unknown 4 %

↓

217 Frail elderly subjects randomized

↓

Control group (*n* 44)	Exercise group (*n* 55)	Nutrition group (*n* 58)	Combination group (*n* 60)
Drop out *n* 6	Drop out *n* 15	Drop out *n* 16	Drop out *n* 15

↓

165 Elderly subjects with pre- and post-intervention measurement(s)

Fig. 1. Outline of the selection of the subjects.

care or meals-on-wheels. The other main selection criteria that were applied were: (1) age (70 years or older); (2) inactivity (no regular participation in physical activities of moderate to high intensity); (3) BMI $\leqslant 25\,kg/m^2$ (based on self-reported weight and height) or recent involuntary weight loss; (4) no use of multivitamin supplements; (5) ability to understand the study procedures.

Before the start of the baseline measurements, subjects gave their written informed consent. The study protocol was approved by the external Medical Ethical Committee of the Division of Human Nutrition and Epidemiology of the Wageningen Agricultural University. Pre- and post-intervention measurement(s) were available for 165 subjects. Reasons for drop out (*n* 52, 24 %) were mainly health problems, including (terminal) disease, hospital stay, recent falling and/or fracturing. Another four subjects were excluded because time between pre- and post-intervention measurement was less than 17 weeks due to hospitalization. Two subjects were hospitalized in the week of post-intervention measurements (sudden heart attack) and were excluded as well. This resulted in a population of 159 subjects.

Design

Enrolment took place between January (first starting group) and June 1997 (sixth starting group), depending on the area of residence. Within each starting group subjects were randomly assigned to one of the four intervention groups: (1) nutrition (nutrient-dense products + social programme); (2) exercise (regular products + exercise programme); (3) combination (nutrient-dense products + exercise programme); (4) control (regular products + social programme). The intervention period was 17 weeks. The data were collected at baseline (week 0) and after 17 weeks (week 18).

Nutrient-dense products

The micronutrient-dense products as well as the regular products were comprised of two categories: a fruit-based category and a dairy category. All subjects were asked to consume one product daily out of each category (one dairy product and one fruit-based product per d). Within the two categories several products were developed. Availability of a variety of products was intended to help to prevent boredom and to increase acceptability of the enriched products. Since these foods had a limited shelf-life each participant was given a cooled container with fresh stock each week, containing the following: fruit-based category, four portions of apple/berry/grape juice (portion size 100 g), four portions of orange/peach juice (portion size 100 g), two portions of apple compote (portion size 100 g), two portions of apple/peach compote (portion size 100 g); dairy category, four portions of vanilla custard (portion size 100 g), four portions of strawberry yoghurt (portion size 100 g), four portions of vanilla/apple yoghurt (portion size 100 g), four portions of vanilla/mixed fruit quark (portion size 75 g due to the ‘satieting’ effect of quark). Due to daily consumption of two nutrient-dense products, subjects in the nutrition group and combination group got about 100 % of the Dutch recommended dietary allowance (Commissie Voedingsnormen Voedingsraad, 1989; Commissie Voeding van de Oudere Mens Voedingsraad, 1995) of vitamins D, E, B_1, B_2, B_6, folic acid, B_{12}, C and about 25–100 % of the Dutch recommended dietary allowance of the following minerals: Ca (25 %), Mg (25 %), Zn (50 %), Fe (50 %), I (100 %) in addition to their normal intake. Subjects in the control group and the exercise group got the natural amount of the regular products in addition to their normal intake (the amount of vitamins and minerals in the regular products was negligible compared with the nutrient-dense products). The energy content of the nutrient-dense products was the same as the regular products. Consumption of two products per d delivered a mean energy intake of 0·48 MJ/d. Compliance was checked by counting the left-over products weekly and by measuring several blood vitamin concentrations afterwards (de Jong *et al.* 1999*a*).

Exercise programme

The main objective of the exercise programme was maintenance or improvement of mobility and performance of daily activities essential for independent functioning by maintenance of versatility in movement. Emphasis was placed on skill training; muscle strength, coordination, flexibility, speed and endurance were trained by exercises such as walking, stooping and chair stands, thereby improving performance of daily activities. Different equipment was used, for example, balls, ropes, weights and dynabands. Group sessions were organized twice per week for 45 min and were of moderate, gradually increasing intensity. The sessions were coordinated by skilled teachers and supervised by one of the project leaders (M.CAP). In order to guarantee uniformity all sessions were extensively rehearsed with all teachers together, and an instruction video and manual was made in advance. A social programme was organized as a control for the exercise programme, in order to check for possible effects of attention. Sessions of 90 min were organized once every 2 weeks by a skilled creative therapist. This programme focused on creative activities, social activities and lectures about topics of interest for elderly people. Transport to and from all the sessions was arranged.

General and activity questionnaires

Questions in the general questionnaire revealed information about age, sex, marital status, education, social activities, living conditions, illness, medicine use, dental state, chewing and swallowing problems and former and present smoking habits. Physical activity was assessed using a validated questionnaire based on the physical activity scale for elderly (PASE) (Washburn *et al.* 1993; Schuit *et al.* 1997).

Dietary intake

At baseline and in the last week of intervention, a 3 d (two weekdays and one weekend day; non-consecutive) estimated dietary record was collected by three trained dietitians. Subjects having difficulties with writing could make use of a voice tape recorder. Face-to-face interviews at home were organized before the dietary record was made in order to explain the procedure, and afterwards to revise and correct the diaries. Portion sizes were recorded in household measures, and frequently used household measures were weighed afterwards. Food consumption data were coded (with a frequent cross-checking by all three dietitians) after which energy and nutrients were calculated with the computerized Dutch food composition tables (Stichting Nederlands Voedingsstoffenbestand, 1997). The energy and macronutrient content of the intervention food products were included in the food consumption data.

Appetite, hunger, subjective taste and smell questionnaire

Subjects were asked to respond to a total of twenty-nine questions about their feelings of appetite and hunger and about their taste and smell perception (de Jong *et al*. 1999*b*). After reading the question, subjects had to score on a five-point Likert scale with verbally labelled answering categories. An example of a 'question' is the following statement: 'In former days my appetite was: 1. much better than nowadays, 2. better than nowadays, 3. the same as nowadays, 4. worse than nowadays, 5. much worse than nowadays'. A higher score corresponded to a more positive feeling about their taste and smell perception, a better appetite and more feelings of hunger. Initially five variables were calculated: present taste perception (eight items, range 8–40), present smell perception (three items, range 3–15), appetite (six items, range 6–30), daily feelings of hunger (nine items, range 9–45), present smell perception compared with the past (three items, range 3–15).

Smell identification test

The smell identification test was based on the validated Connecticut Chemosensory Clinical Research Centre (CCCRC) test (Cain *et al*. 1988; Cain & Rabin, 1989). The test involved ten 40 ml plastic jars with holes (2 mm diameter) in their lids, containing the following stimuli: baby powder, chocolate, cinnamon, coffee, mothballs, peanut butter, soap, ammonia, onion (included instead of the original item wintergreen, which is not familiar in the Netherlands), Vicks Vapo-Steam. To reduce cognitive bias, subjects selected the answer from a list, which consisted of the ten test items and ten distracters. The items were presented in random order. Scores were calculated as the number of correct answers (minimal 0, maximal 10) with answers like 'do not know' or 'smells nothing' coded as incorrect.

Body weight and height

All anthropometric measurements were performed in the morning with subjects wearing underwear. Body weight was measured to the nearest 0·01 kg using a digital scale (ED-6-T; Berkel, Rotterdam, The Netherlands). Height was measured to the nearest 0·001 m using a wall-mounted stadiometer. Lean body mass data were obtained with dual energy X-ray absorptiometry measurements (detailed data and method described by de Jong *et al*. 2000). BMI was calculated as weight (kg) divided by height^2 (m^2) (Fidanza, 1991).

Data treatment

Data were analysed using the statistical programme SAS (Statistical Analysis Program, version 6, 1990, SAS Institute Inc., Cary, NC, USA). Means and standard deviations of baseline values were calculated for each intervention group for the primary outcome variables. Absolute changes and standard deviations per intervention group were calculated and compared with each other by ANOVA. Differences were tested with Tukey's procedure. A multiple regression model was used to determine the effect of both interventions and a possible interaction on the change in outcome variables. Since no interaction was observed between nutrition and exercise only these two independent variables were included in the model. Pearson correlation coefficients were used to calculate relationships in the baseline data between scores on the smell test, energy intake, body weight and outcomes of the questionnaire on appetite, hunger and sensory perception. The internal validity of this latter questionnaire was tested by calculating Cronbach's α. Two-tailed P values were considered statistically significant at $P < 0{\cdot}05$.

Results

Baseline characteristics

In Table 1, baseline characteristics of the four intervention groups are presented. About 70 % of the participants were women. Mean age of the study population was 79 years and mean BMI was 24·5 kg/m^2. One or more chronic diseases were present in at least 91 % of the subjects. The majority was living alone. Only 25 % of the subjects reported chewing problems, while at least 75 % complained of a dry mouth. Complete or partial dentures were found in 85 % of the subjects.

Smell test and appetite, hunger, taste and smell perception questionnaire

In Table 2, the mean scores (and standard deviations) and absolute changes (and standard deviations) on the smell identification test are shown. In general, no difference in the magnitude of change was observed relative to controls. On an individual level improvement was found in forty-one subjects, a decrease in seventy-seven people and the remainder (n 37) scored equally. The distribution of increasing and decreasing subjects was equal over the four intervention groups. With respect to the five variables of the questionnaire on appetite, hunger feelings and taste and smell perception, there was also no difference in change compared with the control group after 17 weeks of intervention (Table 2).

In Table 3, the baseline score of the smell identification test is compared with the outcomes of the appetite, hunger and smell questionnaire at baseline. The smell test score correlated ($P < 0{\cdot}0001$) with the answers on our smell perception variables. Furthermore, the answers on appetite and daily feelings of hunger were positively correlated ($P < 0{\cdot}0002$) with reported energy intake. No correlation appeared between smell test score and energy intake (r 0·03, $P = 0{\cdot}65$).

At baseline, appetite was negatively correlated with a dry mouth feeling (r −0·35, $P < 0{\cdot}0001$) and problems with

Table 1. Baseline characteristics of the study population according to intervention group
(Mean values and standard deviations)

Intervention group …	Nutrition group (*n* 41)		Exercise group (*n* 39)		Combination group (*n* 42)		Control group (*n* 37)	
Variable	Mean	SD	Mean	SD	Mean	SD	Mean	SD
Women (%)	73		73		72		68	
Age (years)	79·6	4·8	76·7	4·4	79·2	6·1	79·3	6·6
BMI (kg/m^2)	24·4	2·5	24·5	3·0	25·0	2·5	24·1	3·2
Activity score*	59 (27–117)		63 (27–100)		59 (30–111)		59 (34–97)	
Subjective health (range 0–10)	6·9	1·6	7·0	1·2	6·9	1·3	7·0†	1·4
Current smokers (%)	12		10		7		16	
Illness (%)	88		93		95		87	
Prescribed medicines (%)	89		75		83		75	
Living alone (%)	71		68		67		70	
Problems with swallowing (%)	12		17		9		16	
Problems with chewing (%)	24		25		28		27	
Dry mouth feeling (%)	68		70		60		76	
Dental state (%)								
Complete dentures	54		48		52		68	
Partial dentures	29		34		29		27	
No dentures	17		18		19		5	

* Assessed using a validated questionnaire based on the physical activity scale (0–400) for the elderly (PASE) (Washburn *et al*. 1993; Schmit *et al*. 1997). The values shown are the median score and P_{10}–P_{90} values shown in parentheses.
† *n* 36.

swallowing (*r* –0·19, *P* = 0·007). Problems with chewing were not directly related to appetite (*r* 0·07, *P* = 0·36), however correlation of appetite with number of teeth bordered on significance (*r* 0·25, *P* = 0·06).

Dietary intake

In Table 4, the mean baseline energy and macronutrient intakes (and standard deviations) and their changes (and standard deviations) are presented for each intervention group. No statistically significant differences in baseline values or in changes between the intervention groups compared with the control group were found. At baseline, 66 % (*n* 104) of the subjects had an energy intake below the Dutch recommended dietary intakes (Commissie Voedingsnormen Voedingsraad, 1989; Commissie Voeding van de Oudere Mens Voedingsraad, 1995). As regards micronutrients, on average 58 % of subjects had intakes below these recommendations. Approximately 30 % of the subjects had energy intakes below 6·3 MJ (two-thirds of the recommended intake). With respect to macro- and micronutrients, the percentage of subjects consuming below two-thirds of the recommended intake varied from 3 % for protein to 93 % for vitamin D (de Jong *et al*. 1999*a*).

Since we observed no evidence of an interaction between the two types of interventions, we could analyse the effect of

Table 2. Baseline appetite, hunger, sensory perception and smell test scores and changes after 17 weeks of intervention in Dutch frail elderly subjects†
(Mean values and standard deviations)

Intervention group‡ …	Nutrition group (*n* 40)				Exercise group (*n* 39)				Combination group (*n* 40)				Control group (*n* 36)			
	Baseline		Change		Baseline		Change		Baseline		Change		Baseline		Change	
Variable	Mean	SD	Mean	SD	Mean	SD	Mean	SD	Mean	SD	Mean	SD	Mean	SD	Mean	SD
Smell test score (range 0–10)	5·2	2·7	–0·5	0·3	5·6	2·6	–0·03	0·3	5·1	2·7	–0·7	0·3	4·7	3·2	–0·4	0·3
Appetite score (range 6–30)	20·9	3·7	–0·5	0·4	21·0	3·9	–0·08	0·4	20·5	4·5	–1·0	0·6	21·0	4·3	0·0	0·6
Present taste perception (range 8–40)	25·6	4·3	0·2	0·6	27·4	4·0	–0·3	0·4	26·0	4·8	–0·9	0·7	26·3	4·8	–0·2	0·6
Present smell perception (range 3–15)	11·2	2·3	–0·8	0·3	11·9	2·3	–1·9*	0·3	11·4	2·2	–1·3	0·4	11·1	2·8	–0·6	0·4
Present smell perception compared with the past (range 3–15)	8·1	2·0	–0·4	0·3	8·5	2·1	–0·3	0·3	7·8	2·4	–0·2	0·3	8·5	2·3	–0·7	0·3
Daily feelings of hunger (range 9–45)	33·3	4·3	–1·5	0·7	36·1	5·8	–0·8	0·6	34·3	5·4	–0·6	0·8	35·5	5·1	–0·3	0·8

Mean value was significantly different from that of the control group: **P* < 0·05.
† For details of subjects see Table 1, of interventions see p. 607, and of scoring systems p. 608.
‡ Numbers of subjects for each variable vary slightly due to an incomplete smell test or a partially incomplete questionnaire.

Table 3. Pearson correlation coefficients of baseline scores on appetite, hunger and sensory perception *v.* energy intake and smell test in Dutch frail elderly subjects*

	Energy intake			Smell score		
Variable	*n*	*r*	Statistical significance; *P*	*n*	*r*	Statistical significance; *P*
Appetite	158	0·30	0·0001	155	0·06	0·44
Perception of present taste	158	0·13	0·07	155	0·11	0·15
Perception of present smell	154	0·08	0·27	151	0·40	0·0000
Present smell perception compared with the past	156	0·09	0·23	154	0·32	0·0001
Daily feelings of hunger	156	0·27	0·0002	153	0·08	0·26

* For details of subjects see Table 1 and for details of scoring systems see p. 608.

Table 4. Baseline energy and macronutrient intake and changes after 17 weeks of intervention in Dutch frail elderly subjects*
(Mean values and standard deviations)

Intervention group† …	Nutrition group (*n* 41)				Exercise group (*n* 38)				Combination group (*n* 42)				Control group (*n* 37)			
	Baseline		Change		Baseline		Change		Baseline		Change		Baseline		Change	
Nutrient intake	Mean	SD	Mean	SD	Mean	SD	Mean	SD	Mean	SD	Mean	SD	Mean	SD	Mean	SD
Energy (MJ)	7·8	1·8	–0·3	0·2	7·4	1·7	0·3	0·2	7·2	1·5	0·02	0·2	7·8	2·3	–0·4	0·4
Total protein (g)	66	15	–0·6	2·2	67	19	4·5	2·6	67	16	–1·3	2·1	69	21	0·3	2·4
Total fat (g)	72	22	–1·5	3·2	70	17	2·3	2·8	68	18	–0·4	2·8	70	27	–4·3	3·9
Total carbohydrate (g)	222	57	–14·7	5·9	212	56	3·5	5·7	200	43	5·3	5·9	221	63	–4·4	10·7

* For details of subjects see Table 1.
† For details of interventions see p. 607.

each intervention separately: exercise *v.* no-exercise and nutrient-dense foods *v.* regular foods. In Table 5, the crude regression coefficients are presented with their *P* values. Exercise increased energy intake and carbohydrate intake (borderline significant, $P = 0{\cdot}05$) compared with the non-exercisers, although no clear effect is shown on the intake of the other macronutrients. When we corrected for baseline energy intake and age the regression coefficient for energy declined slightly to 0·4 MJ. The group receiving nutrient-dense products compared with the group receiving regular products did not reveal significant differences on the intake variables. Furthermore, no clear effect of the nutrition intervention or of the exercise intervention was found on the changes in smell test score or items from the appetite, hunger and sensory perception questionnaire.

Body weight

At baseline, the correlation between body weight and energy intake (*n* 156) was rather low (*r* 0·26, $P = 0{\cdot}0008$), but this correlation coefficient was increased when only lean body weight as a measure of metabolic tissue was taken into account (*r* 0·50, $P = 0{\cdot}0001$, *n* 141). With respect to change in total body weight (measured by weighing scale) due to

Table 5. Estimates of the mean difference in change between a group of frail elderly subjects receiving nutrient-dense products *v.* regular products, and a group receiving exercise *v.* no exercise for 17 weeks*

	Nutrient-dense foods *v.* regular products		Exercise *v.* no exercise	
Variable	Difference	Statistical significance; *P*	Difference	Statistical significance; *P*
Change in energy intake (MJ)	–0·09	0·72	0·48	0·05
Change in protein intake (g)	–3·40	0·15	1·61	0·49
Change in carbohydrate intake (g)	–4·17	0·56	14·2	0·05
Change in fat intake (g)	0·00	0·99	3·73	0·24
Change in score on smell test (0–10)	–0·39	0·19	0·06	0·84
Change in score for hunger feelings (9–45)	–0·48	0·51	0·24	0·75
Change in score for appetite (6–30)	–0·72	0·17	–0·27	0·61
Change in score for present taste perception (8–40)	–0·13	0·83	–0·63	0·27
Change in score for present smell perception (3–15)	0·20	0·52	–0·83	0·009

* For details of subjects see Table 1, for details of dietary products and the exercise programme see p. 607, and for details of scoring systems see p. 608.

the interventions, a mean decline was found in the non-exercising group of −0·3 kg, whereas a small increase of 0·2 kg was found in the exercising groups (estimate of the difference between exercisers and non-exercisers: 0·5 kg, $P=0·041$). Lean body mass (measured by dual energy X-ray absorptiometry) declined even more in the non-exercising group (−0·4 kg) compared with a preserving effect of +0·08 kg in the exercisers (estimate of the difference between the two groups 0·5 kg, $P=0·014$), leaving room for perhaps a shift in lean body mass towards fat mass in the non-exercisers. Correlation between change in energy intake and change in both total body weight and lean body weight was moderate (r 0·18, $P=0·021$; r 0·16, $P=0·052$ respectively).

Discussion

This present study revealed no effect of the nutrition and exercise interventions on appetite and sensory perception, but a small effect of exercise was found on energy intake and lean body weight. A moderate, significant correlation between change in energy intake and change in (lean) body weight indicated that effects of interventions on these variables may be related to each other. The small benefits observed from exercise on energy intake and body weight could not be attributed to an increase in reported appetite. The micronutrient-dense foods did not result in an increment in energy and macronutrient intake or body weight.

Effect of interventions on energy and/or food intake

In order to improve compliance, the products were designed in small portions, and so that they could easily be included in the daily meals and be acceptable throughout the day. Consumption of two products provided 0·48 MJ/d, but we observed that total energy intake did not increase due to the nutritional intervention. The participants probably replaced their normal dessert or soft drink for a dairy product or a fruit juice supplied during the study, despite the intention of consumption of the products on top of their normal intake. This indicates that our supplements fitted well in the daily eating pattern of elderly and that they maintained their dietary pattern and regulated their food intake in this way.

With respect to subjects participating in the exercise programme they might have been in need of extra energy or nutrients to maintain energy balance. We found a small, borderline significant increase in energy intake of the exercising group towards a small decrease in the non-exercising group. Furthermore, a preserving effect in (lean) body mass in the exercisers compared with a decline in the non-exercisers, and in addition, a correlation between change in body mass and change in energy intake was observed. In a supplementation study of Gray-Donald *et al.* (1995) in which free-living frail elderly increased their total energy intake, although not statistically significant the observed weight gain was also compatible with the extra energy consumed.

The effect of adopting an exercise programme on dietary intake was only investigated in a few studies which have given inconsistent results (for reviews see Titchenal, 1988; Kris-Etherton *et al.* 1991). Data on components of energy balance due to exercise in (frail) elderly subjects have also not been extensively detailed in the literature. Campbell *et al.* (1994) studied the effect of a relatively intense progressive resistance-training programme in healthy older adults and concluded that their programme was effective in increasing energy requirements by 15 %. Pollock *et al.* (1998) recently classified endurance-type physical activity intensity for different age groups. For the very old (80+ years), light to moderate intensity was classified between 1·1–2·9 metabolic equivalent of the task (MET), whereas hard intensity was classified between 3·0–4·25 MET. Our moderate intense exercise programme might therefore perhaps achieve an increase in the energy requirement of half of that observed by Campbell *et al.* (1994), e.g. 7·5 % = 0·5 MJ giving a mean total of 7·4 MJ. Calculations of the sample size with a power of 80 % and a two-sided significance level of 0·05 revealed that for detecting a mean change of 0·5 (SD 0·6) MJ, twenty-three subjects per group were needed. In our exercising group, the increase in energy intake was, however, smaller (0·2 MJ) but interesting, taking into account that our subjects could not tolerate a vigorous exercise stimulus. Butterworth *et al.* (1993) confirms the small effect of moderate amounts of exercise on enhanced dietary intake in elderly women. In accordance with this, Blundell *et al.* (1997) hypothesizes that the human body may try as long as possible to deal with the higher physical activity levels with the same amount of nutrients.

In the frail study population of Fiatarone *et al.* (1994), total energy intake even declined after the trial in the exercise and control group. In both the supplementation and combination group total energy intake increased, but this was fully attributed to the energy-dense supplement supplied. The same results have been found by Meredith *et al.* (1992). Their study clearly showed that the unsupplemented group tended to reduce their energy and macronutrient intake after training, whilst the supplemented group increased their intake mainly due to the supplement itself.

Appetite, hunger feelings and sensory perception

With respect to the appetite, hunger and smell questionnaire, the internal validity was satisfactory (range 0·69–0·89), and a poor appetite based on the questionnaire predicted a lower energy intake. The questionnaire is a relatively newly developed instrument and was initially tested in a population of institutionalized and free-living elderly with acceptable results (de Jong *et al.* 1999*b*). Up until now, a reliable extensive questionnaire with respect to appetite variables is lacking and therefore still a challenging topic of study.

An interesting theory of de Castro (1993) may apply to the lack of effect on outcomes of this questionnaire: while ageing the ability of ingested nutrients to affect the subjective state of hunger in the individual is decreasing. In other words, the internal state becomes less able to influence the subjective state as ageing progresses.

The prognosis for recovery of smell and taste sensations is poor, since mainly degenerative age-related factors and smoking may be involved (Kaplan *et al.* 1965; Doty *et al.* 1984; Ship & Weiffenbach, 1993; Schiffman, 1997). On the other hand, it has been postulated that several micronutrient deficiencies might influence taste and smell perception as well (Chauhan *et al*. 1987). Zn is mentioned particularly in this respect, but also vitamins A, B_1, B_6, B_{12} and folic acid. Whether our subjects did have a relatively low dietary intake when compared with healthy Dutch elderly and Dutch recommendations (Commissie Voedingsnormen Voedingsraad, 1989; Commissie Voeding van de Oudere Mens Voedingsraad, 1995), but not low enough to establish an effect (de Jong *et al*. 1999*a*) or whether subtle micronutrient deficiency is of minor importance compared with the (possibly irreversible) degenerative process in taste buds and nerves while ageing (Schiffman, 1993) remains an interesting question.

Type and duration of intervention

The advantages of our interventions compared with other supplementation and/or exercise studies (Lipschitz *et al*. 1985; Meredith *et al*. 1992; Butterworth *et al*. 1993; Fiatarone *et al*. 1994; Gray-Donald *et al*. 1995) are, amongst others, the type of the exercise programme (a more realistic all-round programme instead of only resistance training) and the type of supplement used. We strictly added only micronutrients, known to be frequently reduced in elderly people, and no extra energy or macronutrients to the product since we had special interest in spontaneous changes in appetite and energy and macronutrient intake. Our time frame of 17 weeks is comparable with others, however longer-term studies may be needed to establish effects on for example reported appetite.

Appetite should be viewed as a sign of good health, so it is important to focus on this topic, and not only through the difficult and intensive to measure 'gold standard' energy intake. Moreover, energy intake does not always reflect appetite since elderly may eat because they are used to eating although they do not feel like it. We were not able to improve either appetite, hunger feelings and sensory perception. Due to exercise small, but interesting, effects on energy and nutrient intake were observed. Changes in energy intake were weakly correlated with effects on body weight but not with reported appetite. This once more confirms the complexity of the whole system and the extremely difficult task of improving nutritional and health status of (frail) elderly subjects through increasing appetite by providing nutrient-dense foods and/or exercise.

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