# Dietary Supplements and Physical Exercise Affecting Bone and Body Composition in Frail Elderly Persons

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ABSTRACT

*Objectives.* This study determined the effect of enriched foods and all-around physical exercise on bone and body composition in frail elderly persons.

*Methods.* A 17-week randomized, controlled intervention trial, following a 2×2 factorial design—(1) enriched foods, (2) exercise, (3) both, or (4) neither—was performed in 143 frail elderly persons (aged 78.6±5.6 years). Foods were enriched with multiple micronutrients; exercises focused on skill training, including strength, endurance, coordination, and flexibility. Main outcome parameters were bone and body composition.

*Results.* Exercise preserved lean mass (mean difference between exercisers and nonexercisers: 0.5 kg±1.2 kg; $P<.02$). Groups receiving enriched food had slightly increased bone mineral density (+0.4%), bone mass (+0.6%), and bone calcium (+0.6%) compared with groups receiving nonenriched foods, in whom small decreases of 0.1%, 0.2%, and 0.4%, respectively, were found. These groups differed in bone mineral density (0.006±0.020 g/cm$^2$; $P=.08$), total bone mass (19±g; $P=.04$), and bone calcium (8±21 g; $P=.03$).

*Conclusions.* Foods containing a physiologic dose of micronutrients slightly increased bone density, mass, and calcium, whereas moderately intense exercise preserved lean body mass in frail elderly persons. (*Am J Public Health*. 2000;90:947–954)

Physical frailty in elderly persons has been defined as a state of reduced physiologic reserve associated with increased susceptibility to disability.[1] The main causes of such frailty in an individual are an increasingly sedentary lifestyle and the resulting lower energy expenditure. A decline in appetite and in dietary intake concurrently increase the risk of developing (micro)nutrient deficiencies. Further deterioration of health and nutritional status may in turn hamper the physical activity level.

Both inactivity and inadequate dietary intake are important contributors to sarcopenia. This loss of skeletal muscle mass, together with advancing age, is associated with other changes in body composition, including a reduction in total lean body mass, total body water, and bone density and an increase in body fat.[2–5] These alterations affect health, physical functioning, and quality of life.[6,7] Moreover, decreased bone density may lead to fractures after minimal trauma.[8]

The potential reversibility of sarcopenia in particular, and of bone loss and osteoporosis in general, is therefore of great interest.[2,7,9] Until now, only 1 study had examined the effects of dietary supplements combined with physical exercise on body composition in frail elderly persons.[5] The study showed that low muscle mass was strongly related to impaired mobility. Resistance training increased muscle size, but the supplement did not affect muscle mass. Other trials either investigated nutritional (energy and nutrients) supplementation[10,11] or focused only on strength training.[9] Supplementation increased body weight (both lean and fat mass), and strength training protected bone mineral density and muscle mass. Interactive effects or effectiveness of supplements on bone loss were not studied thoroughly.

For our intervention, we specifically developed micronutrient-dense foods with a physiologic amount of only those vitamins (100% of the Dutch recommended daily allowance) and minerals (25%–100% of the recommended daily allowance) frequently characterized as deficient in elderly people. Furthermore, we developed a unique progressive all-around exercise program aiming at long-term feasibility. We investigated the effect of micronutrient-dense products, a physical exercise program, and a combination of both on bone parameters and body composition in frail elderly persons.

## Methods

### Subjects

The study population comprised 217 frail elderly persons living in their private houses in Wageningen, the Netherlands. Figure 1 gives an outline of the selection of the subjects. The main criterion was need for health care, which consisted of (1) medical home care, (2) use of meals-on-wheels service, (3) household assistance through home care, or (4) household assistance through a social network. Other selection criteria were age (70 years or older), lack of regular exercise, body mass index (BMI) below average (≤25 kg/m$^2$, based on self-reported weight and height) or recent weight loss, ability to

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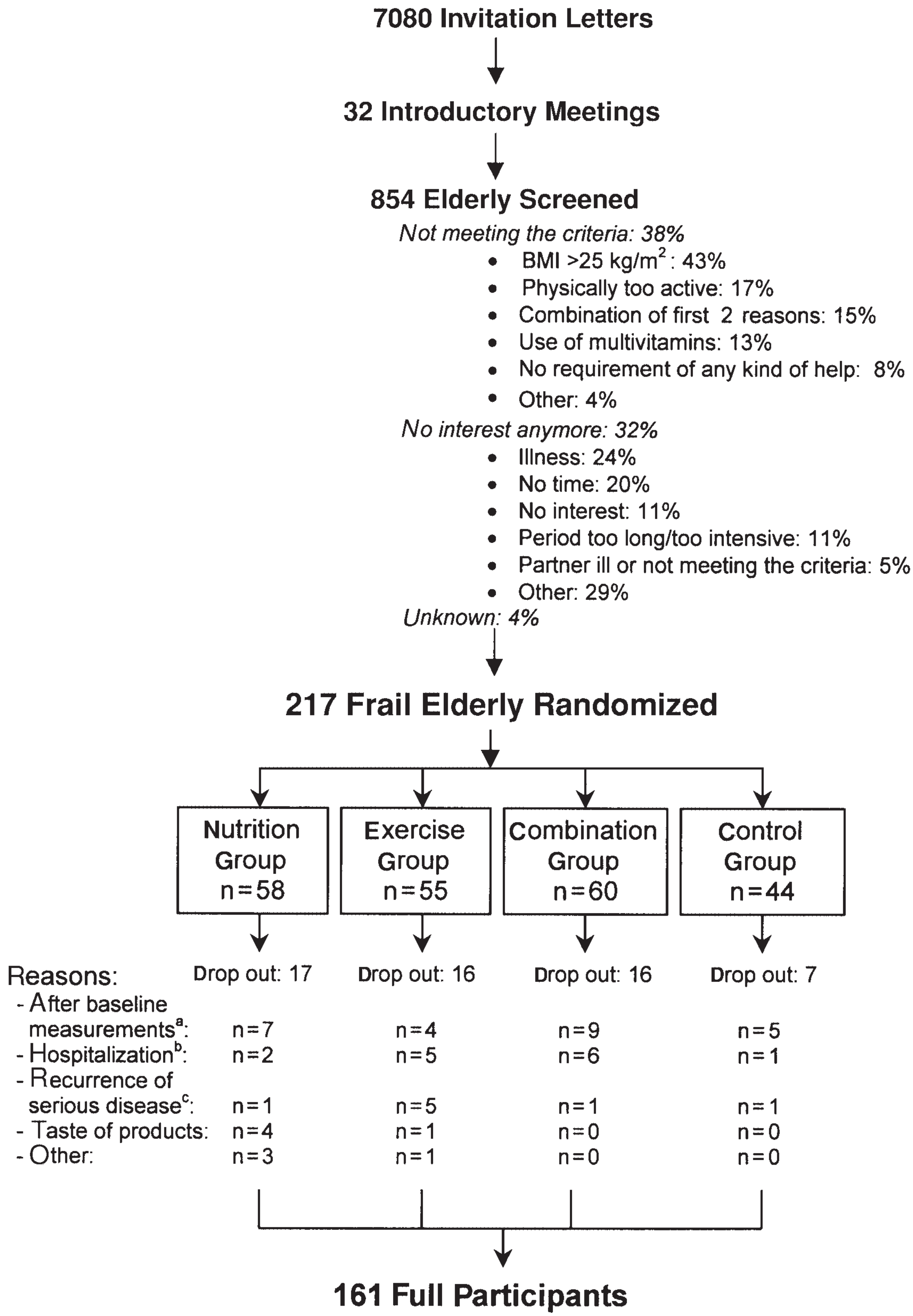


*Note.* BMI = body mass index. [a]Too much physical and mental distress as a result of the measurements. [b]Cardiac infarction, hip fracture or hip replacement surgery, kidney stones, umbilical hernia. [c]Cancer, rheumatoid arthritis.

**FIGURE 1—Outline of the selection and flow of subjects: Wageningen (and surrounding area), the Netherlands.**

understand the study procedures, and no use of multivitamin supplements.

All 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, Wageningen University

*Design, Randomization, and Follow-Up*

Enrollment took place between January and June 1997. After confirmation of eligibility, subjects were randomized to 1 of the following 4 intervention groups through selection of sealed envelopes: (1) *nutrition* (nutrient-dense products + social program); (2) *exercise* (regular products + exercise program); (3) *combination* (nutrient-dense products + exercise program); and (4) *control* (regular products + social program).

Because a higher dropout rate was expected in the intervention groups, more subjects were assigned to these groups. Couples were randomized together. After randomization, baseline measurements (week 0) were performed at our research center. The intervention period was 17 weeks, after which (week 18) data were collected again. Preintervention and postintervention measurements were available for 161 subjects.

A total of 56 (26%) subjects dropped out (Figure 1). Twenty-five subjects dropped out immediately after baseline measurement, mainly because of physical and mental distress as a result of the measurements. Other reasons for dropout (n = 27) were related to health problems, including (terminal) disease, hospitalization, and recent falls or fractures. In 4 subjects who withdrew between week 8 and week 17 of intervention, intermediate measurements were available, but they were not included in the data analysis. Valid dual-energy x-ray absorptiometry (DXA) measurements were available for 143 subjects.

*Nutrient-dense products.* Subjects had to consume 2 products per day: 1 from a series of fruit products and 1 from a series of dairy products. A variety of products were available to avoid monotony and to increase acceptability of the products. Every week, fresh 100-g servings of fruit-based products (2 types of both fruit juice and compote) and dairy products (vanilla custard, 2 types of fruit yogurt, and cheese curd with fruit [75 g]) were provided. Daily consumption of 2 enriched products delivered about 100% of the Dutch recommended daily allowance[12,13] of vitamins D, E, $B_1$, $B_2$, $B_6$, folic acid, $B_{12}$, and C and about 25% to 100% of the Dutch recommended daily allowance of the minerals calcium (25%), magnesium (25%), zinc (50%), iron (50%), and iodine (100%).

Subjects in the control and exercise groups received the natural amount present in identical regular products (concentration vitamins and minerals at the highest 15% of the concentration in enriched products). Total energy content of the enriched products was equal to that of the regular products (0.48 MJ/day).

Subjects were allowed to consume the intervention products either in addition to their habitual daily diet or as a replacement. Because change in spontaneous dietary intake was an additional outcome parameter, 3-day dietary records were obtained at baseline and follow-up.[14] Compliance was checked by measurement of the following serum vitamin levels: D, $B_1$, $B_2$, $B_6$, and $B_{12}$.

*Exercise program.* The main objective of the exercise program was maintenance and/or improvement of mobility and performance of daily activities essential for independent functioning. Skill training was emphasized: muscle strength, coordination, flexibility, speed, and endurance were trained with use of different materials, such as balls, ropes, weights, and elastic bands. Group sessions were held twice a week for 45 minutes and were of moderate, gradually increasing intensity. To guarantee uniformity, sessions were extensively rehearsed with all skilled teachers and the supervisor. Moreover, an instruction videotape and manual were developed. Participants and teachers were instructed to train at moderate to high intensity (value of 7) according to a 10-point rating of perceived exertion.[15]

A social program served as a control (for attention) for the exercise program. Sessions were held biweekly by a skilled creative therapist. This program focused on creative and social activities and lectures about topics of interest for elderly people. Transport to and from the sessions was arranged. Compliance was checked by recording attendance to the sessions.

*Questionnaires*

The general questionnaire recorded information about age, sex, marital status, education, living conditions, use of care, illness, use of medicine, and recent falling and fracturing. Physical activity was assessed with the validated Physical Activity Scale for the Elderly.[16,17]

*Anthropometry and Body Composition*

All anthropometric measurements were performed with subjects wearing underwear. Body weight was measured to the nearest 0.05 kg on a digital scale (ED-6-T; Berkel, Rotterdam, the Netherlands). Height was measured to the nearest 0.001 m with a wall-mounted stadiometer. BMI was calculated as weight in kilograms divided by height in meters squared. Waist and hip circumferences were measured for calculation of the waist-to-hip ratio as a measure of fat distribution.[18]

Body composition of the subjects was measured by DXA (Lunar DPX-L, whole body scanner, Radiation, Madison, Wis). The system uses a filtered x-ray source that provides peak energies at 40 and 70 keV. The software divides pixels into bone mineral and soft tissue compartments. The soft tissue is then further separated into fat and fat-free soft tissue. The fast-scan mode was used for all subjects.

*Statistical Analysis*

Data were analyzed with SAS (SAS Institute, Inc, Cary, NC). Means ± standard deviations (SDs), medians (10th–90th percentiles), or percentages of baseline values were calculated per intervention group for the primary outcome variables. Absolute changes ± SD per intervention group were calculated and compared with changes in the control group (unpaired *t* test). A multiple regression model was used to determine the effect of both interventions and a possible interaction on the change in body and bone composition variables. For all changes in these variables, confounding by baseline age, weight, BMI, frequency of fractures, change in energy intake, and interaction between sex and intervention program was examined. With respect to the models analyzing the change in bone parameters, change in body weight also was taken into account. Because no interaction between the interventions was evident, a comparison was made between the supplemented group and the nonsupplemented group and the exercising group and the nonexercising group, respectively.

A rank procedure was completed in which the population was divided in half: a relatively high-compliance group of exercisers (high attendance at the session) and a low-compliance group (low attendance at the session) next to a relatively high-compliance supplemented group (large increase in serum vitamin levels) and a low-compliance group (small increase in serum vitamin levels). Differences at a probability of $\leq .05$ were considered statistically significant.

## Results

*Baseline Characteristics*

Approximately 70% of the participants were women (Table 1). Mean age of the study

**TABLE 1—Baseline Characteristics of the Study Population**

| | Nutrition Group (n = 35) | Exercise Group (n = 36) | Combination Group (n = 39) | Control Group (n = 33) |
|---|---|---|---|---|
| Women, % | 69 | 69 | 74 | 67 |
| Age, y (mean ± SD) | 79.6 ± 5.0 | 76.5 ± 4.6 | 79.8 ± 5.8 | 78.8 ± 6.7 |
| Activity score[a] (median; 10th–90th percentiles) | 63 (34–103) | 63 (30–100) | 59 (30–111) | 59 (34–100) |
| Subjective health[b] (mean ± SD) | 7.1 ± 1.3 | 7.1 ± 1.2 | 6.9 ± 1.3 | 7.0 ± 1.4 |
| Chronic illness, % | 86 | 92 | 95 | 88 |
| Prescribed medicines, % | 88 | 75 | 83 | 80 |
| Living alone, % | 69 | 64 | 67 | 67 |
| Use of care for health reasons, % | | | | |
| Meals-on-wheels | 31 | 31 | 44 | 39 |
| Household assistance through | | | | |
| Home care | 49 | 36 | 41 | 52 |
| Assistance through social network | 20 | 31 | 26 | 12 |
| Medical home care | 20 | 14 | 15 | 15 |
| Physiotherapy | 43 | 50 | 46 | 55 |
| Recent falls, % | 43 | 50 | 44 | 36 |
| Recent fractures, % | 9 | 8 | 13 | 24 |
| Fear of falling, % | 71 | 64 | 49 | 70 |

[a]Range of Physical Activity Scale for the Elderly: 0–400.
[b]Range: 1–10.

population was 79 years, with the exercise group being slightly younger. At least 91% of the population had 1 or more diseases. Subjective health on a 10-point scale (with 1 = not healthy and 10 = very healthy) was on average rated as 7. Most lived alone and had a substantial fear of falling. In the control subjects, the prevalence of fractures was somewhat higher (24%) than in the other groups (8%–13%).

In 38 subjects who dropped out, additional information was available (not presented in a table). Their mean age (78.9 years) and mean body weight (64.9 kg) were comparable to those of the subjects who completed the trial. Their mean subjective health (6.6) was slightly lower, however.

*Changes in Anthropometric Variables*

Significant changes in anthropometric variables were not observed in either intervention group when compared with the control group (unpaired *t* test: $P > .21$) (Table 2). A tendency toward a decrease in body weight in the control and nutrition groups was observed compared with a preservation of body weight in the exercising and combination groups.

*Changes in Bone Parameters and Body Composition*

Table 3 presents mean baseline values and change (± SD) in the bone parameters and body composition based on DXA measurements. Significant differences in change in lean body mass were observed between the exercise group (0.2 kg) and the control group (–0.5 kg). With respect to change in bone mineral density, a significant difference between the nutrition group (0.006 g/cm$^2$) and the control group (–0.003 g/cm$^2$) was detected.

Because no interaction was evident between the 2 interventions, the effect of each intervention was analyzed separately (Table 4). Supplementation showed a slightly positive, borderline statistically significant effect on bone mineral density (unadjusted difference between supplemented and nonsupplemented groups: 0.006 g/cm$^2$, $P = .08$). Bone mass and bone calcium improved significantly in the supplemented group compared with the nonsupplemented group (unadjusted differences: 0.019 g, $P = .04$ and 0.008 g, $P = .03$, respectively). No interaction between the nutrition program and sex was observed for change in bone parameters. Addition of other relevant covariates to the models also did not markedly alter the results.

When bone parameters in a high-compliance supplemented group (n = 36) were compared with those in the control group (n = 33), bone mineral density appeared to increase by 0.006 g/cm$^2$ in the first group but to decline by 0.003 g/cm$^2$ in the latter group (unpaired *t* test: $P = .03$). The improvement in

**TABLE 2—Mean Anthropometric and Mean 17-Week Changes in the 4 Intervention Groups**

| | Nutrition Group (n = 35) | | Exercise Group (n = 36) | | Combination Group (n = 39) | | Control Group (n = 33) | |
|---|---|---|---|---|---|---|---|---|
| | Mean Baseline ± SD | Mean Change ± SD | Mean Baseline ± SD | Mean Change ± SD | Mean Baseline ± SD | Mean Change ± SD | Mean Baseline ± SD | Mean Change ± SD |
| Height, m | 1.65 ± 0.09 | . . . | 1.65 ± 0.10 | . . . | 1.65 ± 0.08 | . . . | 1.64 ± 0.08 | . . . |
| Weight, kg | 65.8 ± 9.1 | –0.2 ± 1.2 | 67.0 ± 12.1 | 0.1 ± 1.2 | 67.3 ± 7.8 | 0.2 ± 1.3 | 64.7 ± 10.9 | –0.3 ± 1.7 |
| Body mass index, kg/m$^2$ | 24.1 ± 2.4 | 0.0 ± 0.0 | 24.2 ± 3.0 | 0.0 ± 0.0 | 25.1 ± 2.5 | 0.0 ± 0.0 | 23.8 ± 3.1 | 0.0 ± 0.0 |
| Waist circumference, cm | 87.9 ± 8.7 | 4.3 ± 5.2 | 88.7 ± 10.8 | 3.2 ± 5.0 | 90.5 ± 9.6 | 1.9 ± 6.7 | 87.8 ± 9.7 | 2.4 ± 5.6 |
| Hip circumference, cm | 97.9 ± 5.3 | 1.0 ± 3.3 | 97.6 ± 8.0 | 1.8 ± 3.0 | 98.6 ± 4.7 | 1.8 ± 3.5 | 97.0 ± 7.4 | 1.8 ± 3.7 |
| Waist-to-hip ratio | 0.90 ± 0.08 | 0.03 ± 0.06 | 0.91 ± 0.07 | 0.01 ± 0.05 | 0.92 ± 0.09 | 0.00 ± 0.07 | 0.91 ± 0.08 | 0.01 ± 0.06 |

**TABLE 3—Mean Baseline Values and Mean Changes in the 4 Groups of Elderly Persons With Valid Pre-DXA and Post-DXA Measurements**

| | Nutrition Group (n=35) | | Exercise Group (n=36) | | Combination Group (n=39) | | Control Group (n=33) | |
|---|---|---|---|---|---|---|---|---|
| | Mean Baseline±SD | Mean Change±SD | Mean Baseline±SD | Mean Change±SD | Mean Baseline±SD | Mean Change±SD | Mean Baseline±SD | Mean Change±SD |
| Lean body mass, kg | 42.1±8.2 | –0.4±1.0 | 42.8±8.6 | 0.2±1.4* | 42.6±6.7 | –0.1±1.0 | 42.5±7.5 | –0.5±1.4 |
| Fat mass, kg | 21.5±6.6 | 0.1±1.2 | 21.9±7.4 | –0.1±1.2 | 22.6±5.8 | 0.2±1.1 | 20.1±8.2 | 0.1±1.4 |
| Bone mass, kg | 2.19±0.47 | 0.02±0.06 | 2.24±0.71 | –0.01±0.06 | 2.31±0.49 | 0.01±0.05 | 2.20±0.49 | 0.00±0.05 |
| Bone mineral density, $g/cm^2$ | 1.028±0.111 | 0.006±0.014* | 1.031±0.145 | 0.000±0.022 | 1.065±0.120 | 0.003±0.023 | 1.031±0.106 | –0.003±0.018 |
| Bone calcium, kg | 0.832±0.179 | 0.007±0.020 | 0.851±0.270 | –0.006±0.020 | 0.866±0.175 | 0.004±0.020 | 0.835±0.185 | 0.002±0.019 |

*Note.* DXA=dual-energy x-ray absorptiometry.
*$P<.05$, change compared with change in control group, unpaired *t* test.

bone mass (+.025 kg) and bone calcium (+.009 kg) was also notable in this high-compliance group compared with the control group (+.004 kg and +.002 kg, respectively; $P<.11$). Differences were of the same magnitude when the high-compliance group (n=36) was compared with the low-compliance group (n=36). The latter group showed increases of 0.002 $g/cm^2$ in bone mineral density ($P=.33$), .003 kg in bone mass ($P=.08$), and .001 kg in bone calcium ($P=.08$).

Exercise had a positive effect on lean body mass compared with no exercise (unadjusted difference: 0.5 kg, $P=.02$). Interaction between exercise and sex with respect to change in lean body mass was borderline significant ($P=.09$), whereas other covariates did not markedly contribute. Stratified analyses revealed a difference in men of 1.0 kg ($P=.04$) and in women of 0.3 kg ($P=.20$). The effect on lean body mass was attributed mainly to preservation in the exercise group compared with a decrease among the nonexercising subjects. Comparison of high-compliance exercisers (relatively high attendance rate, n=39) and control subjects (n=33) revealed that the lean body mass in the high-compliance group increased by 0.1 kg compared with a decrease of 0.5 kg in the control group (unpaired *t* test: $P=.04$). The difference was nonsignificant ($P=.73$) when the high-compliance group (+0.1 kg) was compared with the low-compliance group (+0.01 kg, n=36). Exercise had no effect on bone parameters.

**TABLE 4—Unadjusted Estimates of the Mean Difference in Change in Body Composition Measured by Dual-Energy X-Ray Absorptiometry Between Groups Receiving Nutrient-Dense vs Regular Products and Groups Receiving Exercise vs No Exercise (n=143)**

| | Nutrient-Dense Products (n=74) vs Regular Products (n=69) | | Exercise (n=75) vs No Exercise (n=68) | |
|---|---|---|---|---|
| | Difference | *P* | Difference | *P* |
| Lean body mass, kg | –0.1 | .60 | 0.5[a] | .02 |
| Fat mass, kg | 0.1 | .48 | 0.0 | .95 |
| Bone calcium, kg | 0.008 | .03 | –0.005 | .15 |
| Bone mass, kg | 0.019 | .04 | –0.012 | .19 |
| Bone mineral density, $g/cm^2$ | 0.006 | .08 | 0.000 | .99 |

[a]Stratified analyses revealed the following: men (n=43): 1.0 kg, $P=.04$; women (n=100): 0.3 kg, $P=.20$.

## Discussion

As far as we know, this is the first trial to investigate the effects of a progressive, moderately intense all-around exercise program combined with specially developed foods containing a physiologic dose of micronutrients in frail elderly persons. After a 17-week intervention with nutrient-dense foods, bone mineral density, total bone mass, and bone calcium increased slightly. The exercise program showed a protective effect on the age-related decline in lean body mass. No evidence of interaction between the two intervention programs was found.

### *Population*

Because uniform criteria to select frail elderly persons are still lacking, we defined our own and thereby emphasized the need for care, physical inactivity, and BMI below average or involuntary weight loss. For practical reasons, we had to rely on subjects' self-reports. Because many elderly have senile kyphosis and often overestimate height and underestimate weight, the distribution of actual BMI shifted to the right compared with the initial calculated BMI. We did, however, succeed in recruiting a population with a health profile worse than that of healthy Dutch elderly people. Their mean BMI was lower than that in the Dutch elderly men and women in the European Seneca study (24 $kg/m^2$ vs 26 $kg/m^2$ in men and 28 $kg/m^2$ in women).[19] Furthermore, self-rated health (7.0 vs 7.7) and activity level (Physical Activity Scale for the Elderly score: 59 vs 85) were lower than those of healthy Dutch elderly people.[17] Mean energy intake and scores on physical fitness tests also were below average[20] (M. J. M. Chin A Paw, PhD, MSc, et al., unpublished data, 2000).

Half of the dropouts withdrew before, during, or immediately after baseline measurements. Thus, dropping out seemed unrelated to the type of intervention. With respect to the health-related reasons (e.g., hospitalization and recurrence of serious illnesses), slightly more subjects dropped out in both the exercise and the combination groups. Combined with a moderately lower rating of subjective health of dropouts compared with the actual study population, this might point to a slight selective withdrawal. However, if selective withdrawal did occur (with dropouts having a worse health profile), it would have caused only an underestimation of the effect of exercise, because effects in a "healthier" group are assumed to be smaller.

### *Type of Intervention*

The specific aim of developing our all-around progressive exercise program was to investigate the effects of exercises that are feasible and acceptable for frail individuals in the long term rather than the effects of monotonous resistance and endurance training programs with unfamiliar equipment.

We added only vitamins and minerals frequently characterized as deficient in elderly people. No extra energy or macronutrients were added, because we expected that low levels of activity would result in relatively low energy requirements. The need for sufficient micronutrients often is not altered in less active elderly persons[13,21,22]; however, debate is ongoing.[23,24] Nutrient-dense foods instead of vitamin and mineral pills are attractive and preferred because foods generally also contain other important nutrients. In addition, elderly people often already take many medications. Vitamin and mineral pills may be regarded as another "medicine" and, as a consequence, may be taken together and confused with the regular medications.

### *Measurements*

DXA is a noninvasive, relatively fast, and therefore appealing method of assessing bone mass in elderly people. Because the device also can precisely assess soft tissue mass, it is clearly a promising method of choice.[25] There are, however, indications that DXA yields less valid measurements.[26–28] Moreover, DXA, like other methods, still assumes constancy in the composition of fat-free mass.

Our main objective was investigating changes; therefore, the absolute validity of our data toward a reference was of less importance. With respect to repeatability, DXA should allow accurate measurements of small changes in body composition.[29–31] Additional data obtained with the $D_2O$ dilution technique showed a small increase in lean body mass in the exercising group vs a small decrease in the nonexercising group, although this difference did not reach statistical significance. When this method was used to calculate the ratio between extracellular water and total body water, changes were not found in any of the intervention groups. This means that effects cannot be attributed to change in hydration state (N. de Jong, PhD, MSc, unpublished data). These $D_2O$ dilution data, when combined with our data on body weight, point in the same direction as our DXA data.

### *Effect on Lean Body Mass*

To date, most studies have focused only on the effects of high-intensity resistance training in frail elderly persons. Progressive resistance training proved to be effective in the prevention of sarcopenia.[32,33] Several trials[5,9,34] clearly showed beneficial effects of resistance training on muscle size, muscle mass, and strength. Meredith et al.[11] concluded that strength training in elderly men combined with a nutritional supplement affected body composition (both lean and adipose tissue), but their findings should be confirmed in a larger trial with sedentary control subjects.

We found that exercise preserved lean body mass. The response to exercise differed between men and women. Men apparently benefited more from exercise and also lost more mass with no exercise. Men simply have more lean mass to train or to lose and also may be more responsive to exercise; a higher "trainability" may have been accompanied by more enthusiastic participation.

The comparison of a high-compliance exercising group with the control group as well as a low-compliance exercising group indicated that the preserving effect on lean body mass was indeed attributable to the exercise program. In the control subjects, lean body mass declined; in the low-compliance group, no change occurred; and in the high-compliance group, a small increase was found. The decrease in the nonexercising groups may be attributed to the ongoing process of sarcopenia in frail elderly persons. The positive result of our exercise program is a valuable addition to all earlier findings, because we expect the long-term feasibility of our program to be higher compared with high-intensity strength training with monotonous exercises.

Our nutrient-dense products had no effect on lean or fat mass in frail elderly persons. We hypothesized that extra micronutrients would correct existing deficiencies, and subjects with a better nutritional status might develop a higher activity level, a better appetite, and in turn a higher energy intake. Because of these changes, sarcopenia might be reversed. The lack of an effect on lean or fat mass with the nutrition intervention may have been caused by several factors. First, the intervention may not have been long enough to establish a considerable effect on the mechanism described. Second, at baseline, the process of age-related sarcopenia may not have been severe enough to establish an improvement with nutrient-dense products. In earlier reports,[5,10] an increase in body weight due to (energy-dense) supplements was described. No significant changes in muscle mass were found; therefore, fat mass must have increased. This effect may be attributed to the energy-dense supplement used, which is not comparable to the nutrient-dense foods used in our study.

### *Effect on Bone*

The small but significant changes in bone parameters after 17 weeks of consumption of the nutrient-dense products are important in the debate over whether bone loss and osteoporosis are reversible and whether changes found within 1 year can be ascribed to transient effects.[35] Several public health approaches to osteoporosis are currently recommended: (1) maximization of the peak bone mass in the younger age groups, (2) use of estrogen replacement therapy in postmenopausal women, and (3) intake of sufficient or extra calcium and vitamin D at older age. Optimal supplies of both nutrients are essential for restoring bone and should be effective even at old age.[36,37] Exercise also is often recommended.

Given that we found a larger increase in bone mass, bone calcium, and bone density in the group with the largest increase in their serum vitamin levels, the enriched products did seem to contribute to the observed changes in bone parameters in elderly persons. The response to the nutrient-dense foods with respect to bone density, bone mass, and bone calcium appeared not to be markedly different between men and women.

Our results certainly should be interpreted with caution. The effects observed could be attributed to the variability of the DXA machine, although the magnitude of our effects is in agreement with those from a 1-year walking program.[9] In addition, several studies reporting effects on bone mass and density after 1 or 2 years of supplementation observed these effects within the first (half) year,[38–40] after which they leveled off. Chapuy et al.[41] reported effects of supplementation on fracture rates even after 2 months, accompanied by a modest increase in bone density. Studies of the precision and stability of DXA measurements reported coefficients of variation of total body parameters between 0.6% and 1.0%[31,42]; it is possible that we were able to detect statistically significant changes only because we recruited enough subjects to observe an effect and the standard deviation appeared to be smaller than expected. Nevertheless, the change in control and experimental groups is in the direction expected. A longer intervention period, as well as biochemical markers of bone turnover, might have given more convincing and more relevant results. This should be confirmed in future studies.

The exercise program did not have an (additional) effect on bone parameters. Again, a possible explanation may be the duration of the program. Longer controlled trials showed that exercise can positively influence bone density by a few percentage points.[43] Nelson et al.[9,44] identified effects on bone density and bone mass after 1 year of resistance or endurance training. Because they did not report an earlier measurement, the time span required before exercise affects bone parameters remains unclear. Furthermore, the mechanical load of our exercise program may not have been large enough to establish an effect on bone. An even more important effect of exercise may be the decline in risk of falling, as a result of improved balance and coordination. This may have a greater effect on prevention of fractures than the modest effects of exercise on bone density.

In summary, loss of bone, a decline in bone mineral density, and the process of sarcopenia are a serious threat to independently functioning, community-dwelling frail elderly persons. Investigating potential reversibility of not only sarcopenia but also bone loss and osteoporosis is important, because a slight improvement in these factors may improve physical functioning and the quality of life and may subsequently reduce the need for support services. This trial confirmed that supplementing and training frail elderly persons is beneficial even beyond 70 years of age because of positive effects on both lean body mass and bone parameters. However, because our interventions were unique and changes after 17 weeks of intervention were small, these results should be confirmed in future studies. □

## Contributors

N. de Jong and M. J. M. Chin A Paw, the principal investigators, finalized the study protocol, analyzed the data, interpreted the results, and wrote the paper. L. C. P. G. M. de Groot directly assisted in performing the fieldwork, in interpreting the results, and in the writing of the paper. G. J. Hiddink significantly contributed to the conception of the trial, participated in the interpretation of the results, and commented on the paper. W. A. van Staveren initiated the study, handled the fundraising, and actively assisted in the writing of the paper. All authors contributed to earlier drafts of the paper, provided revisions, and approved the final version. All authors take public responsibility for the content of the paper.

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## References

1. Buchner DM, Wagner EH. Preventing frail health. *Clin Geriatr Med.* 1992;8:1–17.
2. Evans WJ, Cyr-Campbell D. Nutrition, exercise, and healthy aging. *J Am Diet Assoc.* 1997;97:632–638.
3. Evans WJ. What is sarcopenia? *J Gerontol A Biol Sci Med Sci.* 1995;50(special no.):5–8.
4. Evans WJ. Exercise, nutrition and aging. *J Nutr.* 1992;122:796–801.
5. Fiatarone MA, O'Neill EF, Ryan ND, et al. Exercise training and nutritional supplementation for physical frailty in very elderly people. *N Engl J Med.* 1994;330:1769–1775.
6. Chumlea WC, Guo SS, Glaser RM, Vellas BJ. Sarcopenia, function and health. *Nutr Health Aging.* 1997;1:7–12.
7. Payette H, Hanusaik N, Boutier V, Morais JA, Gray-Donald K. Muscle strength and functional mobility in relation to lean body mass in free-living frail elderly women. *Eur J Clin Nutr.* 1998;52:45–53.
8. Sowers M. Epidemiology of calcium and vitamin D in bone loss. *J Nutr.* 1993;123:413–417.
9. Nelson ME, Fiatarone MA, Morganti CM, Trice I, Greenberg RA, Evans WJ. Effects of high-intensity strength training on multiple risk factors for osteoporotic fractures: a randomized controlled trial. *JAMA.* 1994;272:1909–1914.
10. Gray-Donald K, Payette H, Boutier V. Randomized clinical trial of nutritional supplementation shows little effect on functional status among free-living frail elderly. *J Nutr.* 1995;125:2965–2971.
11. Meredith CN, Frontera WR, O'Reilly KP, Evans WJ. Body composition in elderly men: effect of dietary modification during strength training. *J Am Geriatr Soc.* 1992;40:155–162.
12. Commissie Voedingsnormen Voedingsraad. *Nederlandse Voedingsnormen 1989 [Dutch Nutrition Guidelines].* The Hague, the Netherlands: Voedingsraad; 1989.
13. Commissie Voeding van de Oudere Mens Voedingsraad. *Voeding van de Oudere Mens [Nutrition of Elderly People].* The Hague, the Netherlands: Voedingsraad; 1995.
14. de Jong N, Chin A Paw JMM, de Groot LCPGM, de Graaf C, Kok FJ, van Staveren WA. Functional biochemical and nutrient indices in frail elderly people are partly affected by dietary supplements but not by exercise. *J Nutr.* 1999;129:2028–2036.
15. Feriche B, Chicharro JL, Vaquero AF, Perez M, Lucia A. The use of a fixed value of RPE during a ramp protocol: comparison with the ventilatory threshold. *J Sports Med Phys Fitness.* 1998;38:35–38.
16. Washburn RA, Smith KW, Jette AM, Janney CA. The Physical Activity Scale for the Elderly (PASE): development and evaluation. *J Clin Epidemiol.* 1993;46:153–162.
17. Schuit AJ, Schouten EG, Westerterp KR, Saris WH. Validity of the Physical Activity Scale for the Elderly (PASE): according to energy expenditure assessed by the doubly labeled water method. *J Clin Epidemiol.* 1997;50:541–546.
18. Fidanza F. *Nutritional Status Assessment: A Manual for Population Studies.* New York, NY: Chapman & Hall; 1991.
19. de Groot CPGM, Perdigao AL, Deurenberg P. Longitudinal changes in anthropometric characteristics of elderly Europeans: SENECA Investigators. *Eur J Clin Nutr.* 1996;50(suppl 2):S9–S15.
20. de Jong N, de Groot CPGM, de Graaf C, Chin A Paw JMM, van Staveren WA. Assessment of dietary intake and appetite in frail elderly [abstract]. *Eur J Clin Nutr.* 1998;52(suppl 2):S37.
21. van der Wielen RPJ. *Vitamin Intake and Status in Elderly Europeans.* Wageningen, the Netherlands: Department of Human Nutrition, Wageningen Agricultural University; 1995.
22. Heseker H, Kubler W. Vitamin requirements of the elderly. In: Munro H, Schlierf G, eds. *Nutrition of the Elderly.* New York, NY: Nestec Ltd, Vervey; Raven Press; 1992:129–143.
23. Wood RJ, Suter PM, Russell RM. Mineral requirements of elderly people. *Am J Clin Nutr.* 1995;62:493–505.
24. Russell RM. New views on the RDAs for older adults. *J Am Diet Assoc.* 1997;97:515–518.
25. Kohrt WM. Body composition by DXA: tried and true? *Med Sci Sports Exerc.* 1995;27:1349–1353.
26. Bergsma-Kadijk JA, Baumeister B, Deurenberg P. Measurement of body fat in young and elderly women: comparison between a four-compartment model and widely used reference methods. *Br J Nutr.* 1996;75:649–657.
27. Nelson ME, Fiatarone MA, Layne JE, et al. Analysis of body-composition techniques and models for detecting change in soft tissue with strength training. *Am J Clin Nutr.* 1996;63:678–686.
28. Jebb SA, Goldberg GR, Jennings G, Elia M. Dual-energy X-ray absorptiometry measurements of body composition: effects of depth and tissue thickness, including comparisons with direct analysis. *Clin Sci (Colch).* 1995;88:319–324.
29. Mazess RB, Barden HS, Bisek JP, Hanson J. Dual-energy x-ray absorptiometry for total-body and regional bone-mineral and soft-tissue composition. *Am J Clin Nutr.* 1990;51:1106–1112.
30. Going SB, Massett MP, Hall MC, et al. Detection of small changes in body composition by dual-energy x-ray absorptiometry. *Am J Clin Nutr.* 1993;57:845–850.
31. Jebb SA. Measurement of soft tissue composition by dual energy X-ray absorptiometry. *Br J Nutr.* 1997;77:151–163.
32. Fielding RA. The role of progressive resistance training and nutrition in the preservation of lean body mass in the elderly. *J Am Coll Nutr.* 1995;14:587–594.
33. Campbell WW, Crim MC, Young VR, Evans WJ. Increased energy requirements and changes in body composition with resistance training in older adults. *Am J Clin Nutr.* 1994;60:167–175.

34. Fiatarone MA, Marks EC, Ryan ND, Meredith CN, Lipsitz LA, Evans WJ. High-intensity strength training in nonagenarians: effects on skeletal muscle. *JAMA.* 1990;263:3029–3034.
35. O'Brien KO. Combined calcium and vitamin D supplementation reduces bone loss and fracture incidence in older men and women. *Nutr Rev.* 1998;56:148–150.
36. Masi L, Bilezikian JP. Osteoporosis: new hope for the future. *Int J Fertil Womens Med.* 1997; 42:245–254.
37. Chapuy MC, Meunier PJ. Physiopathology and prevention of fractures of the proximal end of the femur. *Rev Prat.* 1995;45:1120–1123.
38. Dawson-Hughes B, Harris SS, Krall EA, Dallal GE, Falconer G, Green CL. Rates of bone loss in postmenopausal women randomly assigned to one of two dosages of vitamin D. *Am J Clin Nutr.* 1995;61:1140–1145.
39. Dawson-Hughes B, Harris SS, Krall EA, Dallal GE. Effect of calcium and vitamin D supplementation on bone density in men and women 65 years of age or older. *N Engl J Med.* 1997; 337:670–676.
40. Ooms ME, Roos JC, Bezemer PD, van-der VW, Bouter LM, Lips P. Prevention of bone loss by vitamin D supplementation in elderly women: a randomized double-blind trial. *J Clin Endocrinol Metab.* 1995;80:1052–1058.
41. Chapuy MC, Arlot ME, Duboeuf F, et al. Vitamin D3 and calcium to prevent hip fractures in the elderly women. *N Engl J Med.* 1992;327: 1637–1642.
42. Johnson J, Dawson-Hughes B. Precision and stability of dual-energy X-ray absorptiometry measurements. *Calcif Tissue Int.* 1991;49:174–178.
43. Reid IR. Therapy of osteoporosis: calcium, vitamin D, and exercise. *Am J Med Sci.* 1996; 312:278–286.
44. Nelson ME, Fisher EC, Dilmanian FA, Dallal GE, Evans WJ. A 1-y walking program and increased dietary calcium in postmenopausal women: effects on bone. *Am J Clin Nutr.* 1991;53:1304–1311.