The Impact of Nutritional Supplementation and Resistance Training on the Health Functioning of Free-Living Chilean Elders: Results of 18 Months of Follow-up[1,2]

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ABSTRACT Body composition changes and loss of functionality in the elderly are related to substandard diets and progressive sedentariness. The aim of this study was to assess the impact of an 18-mo nutritional supplementation and resistance training program on health functioning of elders. Healthy elders aged ≥70 y were studied. Half of the subjects received a nutritional supplement. Half of the supplemented and nonsupplemented subjects were randomly assigned to a resistance exercise training program. Every 6 mo, a full assessment was performed. A total of 149 subjects were considered eligible for the study and 98 (31 supplemented and trained, 26 supplemented, 16 trained and 25 without supplementation or training) completed 18 mo of follow-up. Compliance with the supplement was 48%, and trained subjects attended 56% of programmed sessions. Activities of daily living remained constant in the supplemented subjects and decreased in the other groups. Body weight and fat-free mass did not change. Fat mass increased from 22.2 ± 7.6 to 24.1 ± 7.7 kg in all groups. Bone mineral density decreased less in both supplemented groups than in the nonsupplemented groups (ANOVA, $P < 0.01$). Serum cholesterol remained constant in both supplemented groups and in the trained groups, but it increased in the control group (ANOVA, $P < 0.05$). Upper and lower limb strength, walking capacity and maximal inspiratory pressure increased in trained subjects. In conclusion, patients who were receiving nutritional supplementation and resistance training maintained functionality, bone mineral density and serum cholesterol levels and improved their muscle strength. J. Nutr. 131: 2441S–2446S, 2001.

KEY WORDS: • *nutritional supplementation* • *resistance training* • *muscle strength* • *bone mineral density*

Extensive research has shown how resistance training can improve healthy functioning. However, little is known about the overall impact of nutrition supplementation when provided separately or in combination with training in older individuals. Moreover, there is little information on the usefulness of these interventions when provided for prolonged periods to free-living elders.

Elders may be more prone to nutritional deficiencies, which in turn cause significant adverse consequences in terms of functionality. The main reasons for their deficiencies are an increased prevalence of gastrointestinal diseases, changes in metabolic and synthetic function, changes in nutrient requirements, alterations in taste sensation, social isolation and poverty. A Chilean survey showed that mean protein intake was 54 g/d in poor male elders and 57 g/d in female elders. This intake is below the recommendation for healthy young adults. Likewise, intake of most micronutrients was below recommended daily allowances (1).

Nutritional supplementation programs for the elderly have been successfully developed in different countries. The "meals on wheels" program, designed to provide food to North American homebound elders with extremely limited financial resources, increased caloric intake of these subjects by 40–50% and proved to be effective in improving weight and serum albumin levels (2). Another study, performed in the Netherlands, showed that dietary intakes were below the recommendation in a high proportion of free-living frail elders and that a supplementation program during 17 wk with nutrient-dense foods improved a series of nutritional indicators, in particular blood vitamin levels (3).

Among lifestyle changes, the lack of physical exercise is one of the most important predictors of disability in elders. Therefore, an important adjunct to a good provision of proteins to improve muscle mass and function should be muscle training. Strength training of lower limbs in frail elders improves muscle function, size and mobility and reduces gait instability (4,5). However, the long-term beneficial effects of a physical activity program for the elderly can be hampered by a lack of compli-

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ance with exercise protocols. An 18-mo exercise intervention in community-dwelling older subjects showed an attrition rate of 36% (6). The lack of compliance can also limit the possible beneficial effects of a long-term nutritional supplementation program in this age group.

Thus, it is important to assess the combined effects of nutritional supplementation and resistance training on the long term. The present study reports the results of an 18-mo controlled trial of nutritional supplementation and resistance exercise training in a group of healthy free-living Chilean elders.

MATERIALS AND METHODS

We considered eligible subjects aged 70 y or older who were assigned to three public outpatient clinics, two of which were providing a nutritional product (prepared as a soup or porridge and given as two daily snacks; the composition is shown in **Table 1**) delivered by the government and one that was not delivering the supplement. Supplemented and nonsupplemented individuals were randomly assigned to a resistance exercise training program or to a not trained group. Thus, four groups of subjects were generated: supplemented and trained (SE), supplemented and not trained (SN), not supplemented and trained (NE) and not supplemented and not trained (NN). We excluded subjects with chronic debilitating diseases such as cancer, chronic infections, severe organ failure and diabetes. We also excluded subjects who were not able to go to the clinic by their own means and individuals with a mini-mental state examination score < 20 (7).

Subjects assigned to resistance exercise training were invited to attend sessions of 1 h each, twice a week. Training consisted of a period of warming up, three levels of chair stands, three levels of modified squats, three levels of step-ups in a stair and arm pull-ups using rubber bands that are color coded to confer progressive resistance. Respiratory muscle training was done using threshold valves (Threshold Inspiratory Muscle Trainer; HealthScan Products, Cedar Grove, NJ) calibrated at 30% of maximal inspiratory pressure of each individual. Subjects were also engaged in 15-min walking periods, before and after resistance training. Exercise intensity was graded by a specialized coach according to the progression of each subject and based on the Borg scale (8). Attendance to each training session was recorded to assess compliance with the exercise program. The percentage of programmed sessions that the subject attended was calculated.

All individuals were subjected to full assessments at the baseline period and 6, 12 and 18 mo of follow up that included Kats activities of daily living (maximum score 6), mini-mental state examination (maximum score 30) and the abbreviated geriatric depression score (maximum score 11) (9). A fasting blood sample was drawn for routine blood chemistry assessment. Body composition was assessed by dual-energy X-ray absorptiometry using a Lunar DPX-L densitometer (System 7660, Software 1.3z; Lunar, Madison, WI). Limb muscle strength was measured using a Nicholas Manual Muscle Tester (Model 01160, Lafayette Instrument, Lafayette, IN) according to the instructions provided by the manufacturer (10). Respiratory muscle strength was measured using a Collins Digital Pulmonary Manometer (Warren E. Collins, Braintree, MA). Endurance was measured calculating the distance that could be walked in 12 min at a normal pace (12-min test).

Every month, a research assistant contacted each study subject by telephone. Individuals receiving the nutritional supplement were asked about the number of days in the week and the number of times in the day that they were eating the product. A 100% compliance with the supplement was considered when the subject consumed 14 servings per week.

Analytical procedures and statistical analysis. Blood chemistry was measured using standard automated laboratory methods with Abbott commercial kits. Statistical analysis was done using Statistica for Windows, version 4.5 (StatSoft, 1993, Tulsa, OK). Comparisons of basal data between study groups was performed using one-way ANOVA. Comparisons of the evolution of parameters during the follow up, within and between groups, was done using ANOVA for repeated measures. Sex was entered as a covariate in all statistical analyses, and results are expressed as adjusted means. Post hoc comparisons between groups, when the two-way interaction yielded significant changes, was done using the Newman-Keuls test.

This study complied with the Helsinski Declaration, as revised in 1983, and was approved by the ethics committee at the Institute of Nutrition and Food Technology at the University of Chile; all subjects signed an informed consent before entry into the study.

TABLE 1

Nutritional composition of the product delivered to the elderly

	Per 100 g	Per Serving
Energy, *Kj*	1,674	873
Protein, *g*	13	6.5
Saturated fat, *g*	1.6	0.8
Monounsaturated fat, *g*	5.4	2.7
Polyunsaturated fat, *g*	4	2
Cholesterol, *g*	0	0
Carbohydrates, *g*	62.3	31.2
Total fiber, *g*	6.2	3.1
Vitamins/minerals		
Vitamin A, *μg RE*	240	120
Vitamin C, *mg*	30	15
Vitamin D, *μg*	1.5	0.75
Vitamin E, *mg TE*	4	2
Thiamin, *mg*	0.4	0.2
Riboflavin, *mg*	0.4	0.2
Niacin, *mg NE*	4.5	2.25
Pyridoxine, *mg*	1	0.5
Folate, *μg*	100	50
Vitamin B_{12}, *μg*	0.5	0.25
Sodium, *mg*	280	140
Calcium, *mg*	400	200
Iron, *mg*	2.8	1.4
Phosphorus, *mg*	400	200
Magnesium, *mg*	150	75
Zinc, *mg*	3	1.5

RESULTS

Participant flow is shown in **Figure 1**. Compared with subjects who completed the study period, those lost from follow up were older (76.3 ± 5.7 and 74.1 ± 3.4 y, respectively, $P = 0.004$) and had lower mini-mental scores (25.8 ± 3.1 and 24.0 ± 3.4, respectively, $P = 0.002$). The four study groups had similar age, weight, mini-mental and activities of daily living scores, body composition and bone mineral density (**Table 2**).

Compliance with the nutritional product was 49% (95% CI 45–52%) during the first semester of follow up and 44% (40–48%) during the third semester. Likewise, during the first 6 mo of follow up, trained subjects attended 63% of programmed training sessions (59–69%) and during the third semester of follow up, the attendance was 43% (33–43%).

Among geriatric assessment scores, activities of daily living scores remained constant in the supplemented groups and decreased in the nonsupplemented individuals. No effect of exercise was noted (**Fig. 2**). Mini-mental scores increased significantly in all groups from 25.9 ± 3.1 to 26.7 ± 2.8 ($P = 0.016$). No differences among groups were observed for this change.

Body weight remained constant during the observation period. Dual-energy X-ray absorptiometry showed no change in fat-free mass, but an overall increment in fat mass from 22.2 ± 7.6 to 24.1 ± 7.7 kg was observed ($P < 0.001$). Bone mineral

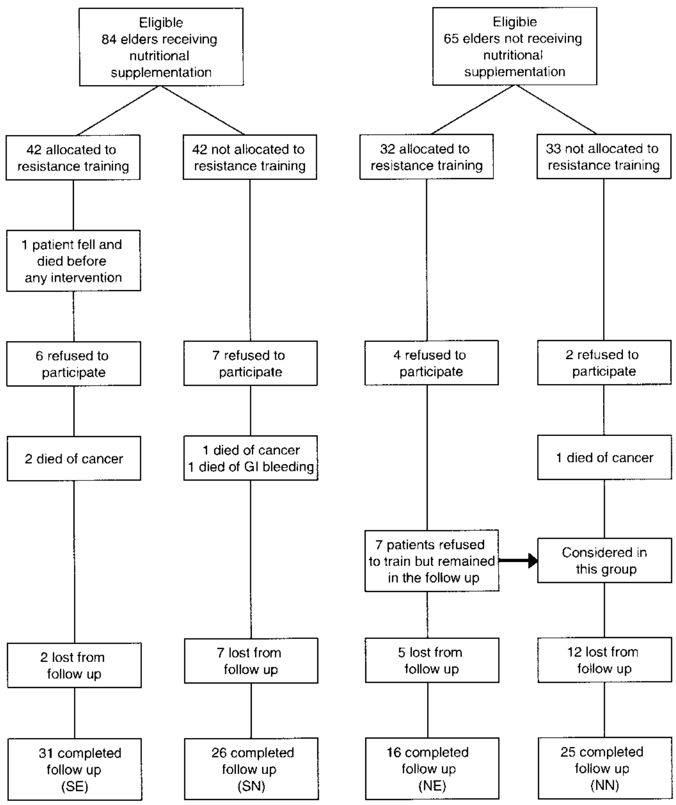

FIGURE 1 Participant flow.

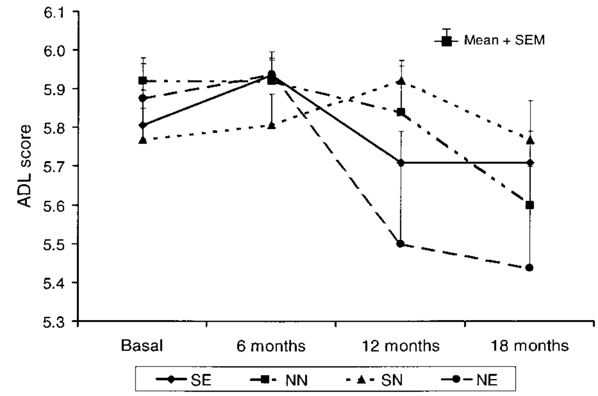

FIGURE 2 Changes in activities of daily living in the 18 mo of follow up. Results are expressed as means ± SEM. Repeated-series ANOVA showed a significant two-way interaction (P = 0.048). Post hoc Newman-Keuls analysis showed significant differences between supplemented and nonsupplemented groups. Groups are indicated by the following: SE = supplemented plus exercise; SN = supplemented without exercise; NE = exercise alone; NN = control subjects.

density declined in all groups, but the decline was less marked in the SE group compared with the other groups (**Fig. 3**).

Walking capacity, remained constant in trained subjects, whereas it declined significantly in nontrained groups, regardless of supplementation. Right quadriceps strength, right biceps strength and maximal inspiratory pressure improved more in trained than in nontrained subjects. Again, no effect of nutritional supplementation was observed in regard to these parameters (**Table 3**).

Total cholesterol increased in the control group and remained constant in both supplemented and trained subjects. Serum triacylglycerol and HDL cholesterol increased in all groups from 1.55 ± 0.85 to 1.88 ± 2.12 mmol/L and from 1.14 ± 0.25 to 1.27 ± 0.32 mmol/L, respectively, but there were no differences between groups (**Table 4**).

DISCUSSION

The results of this follow-up study show that, in free-living poor elders, a nutritional supplementation can avoid detrimental changes in activities of daily living, bone mineral density and blood lipid levels. A resistance exercise program can improve muscle strength and walking capacity.

The nutritional supplement provided in this study was specifically devised for the elderly to provide ~25% of daily requirements for macro- and micronutrients. The compliance with the supplement during the follow-up period was the expected one, considering that the product was supplied to free-living subjects. Therefore, individuals will probably skip servings and share the product with other individuals. A 12-wk nutritional supplementation program for free-living elders reported a 68% compliance (11).

Resistance training was designed using simple and inexpensive means, considering that such a program should be carried out in a setting of public primary care clinics. The advantage of such a type of training is that it can be massively applied; the drawback is that an accurate planning of the progression in workload is difficult. Training of respiratory muscles in previous studies showed that such training reduces the incidence of respiratory complications in hospitalized, malnourished pa-

TABLE 2

Baseline features of study subjects[1]

	Supplemented + exercise	Control subjects	Supplemented	Exercise	*P* (ANOVA)
M/F	9/22	13/12	10/16	4/12	NS
Age, *y*	73.7 ± 3.0	74.0 ± 3.7	74.7 ± 3.7	74.4 ± 3.3	NS
Weight, *kg*	66.7 ± 12.3	65.9 ± 12.6	61.2 ± 11.2	62.2 ± 10.1	NS
Height, *cm*	155.1 ± 8.4	154.8 ± 11.5	153.6 ± 9.4	151.5 ± 8.8	NS
Mini-mental score	26.2 ± 3.0	25.0 ± 3.0	26.5 ± 2.9	25.6 ± 3.4	NS
Activities of daily living score	5.8 ± 0.5	5.9 ± 0.3	5.8 ± 0.4	5.9 ± 0.3	NS
Fat mass, *g*	24,115.5 ± 8,366.4	22,213.0 ± 8,515.5	20,649.9 ± 6,827.4	21,430.9 ± 6,239.4	NS
Fat free mass, *g*	40,318.7 ± 9,258.7	41,153.9 ± 8,305.8	38,795.5 ± 8,149.3	38,173.9 ± 7,431.7	NS
Bone mineral content, *g*	2,087.0 ± 515.5	2,174.0 ± 511.7	2,023.0 ± 531.9	2,018.1 ± 557.2	NS
Bone mineral density, *g/cm*^{2}	1.1 ± 0.1	1.1 ± 0.1	1.0 ± 0.1	1.1 ± 0.1	NS

[1] Values are means ± SD.

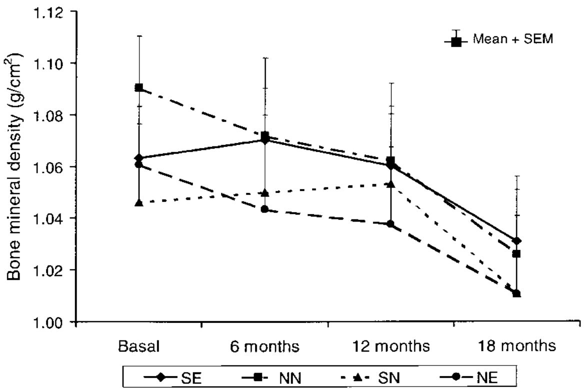

FIGURE 3 Changes in bone mineral density in the 18 mo of follow up. Results are expressed as means ± SEM. Repeated-series ANOVA showed a significant two-way interaction (P = 0.006). Post hoc Newman-Keuls analysis showed significant differences between the supplemented and trained group and the other groups. Groups are indicated by the following: SE = supplemented plus exercise; SN = supplemented without exercise; NE = exercise alone; NN = control subjects.

tients (12,13). The compliance with exercise sessions was ~50%. This figure is comparable with the attrition rates in long-term exercise programs reported elsewhere (6). Moreover, apparently there is not a threshold in the amount of weekly sessions to obtain beneficial results from exercise, and subjects exercising once a week can also obtain positive results (14). The safety of resistance training and subsequent increase in muscle strength in the elderly has been previously reported by several authors (4,15).

The lesser detriment in the activities of daily living score in supplemented subjects is noteworthy. This score assesses bathing, dressing, toilet use, motility, sphincter continence and feeding capacity. The loss of one point means the deprivation of an important function for independent living. Therefore, the small though significant differences between supplemented and nonsupplemented subjects can have important functional consequences. There are previous reports showing a relationship between activities of daily living and nutritional status (16,17). Also, a study performed on hospitalized elders showed an improvement in functional status that lasted even after hospital discharge, when a 500-kcal supplement was provided (18). However, this work was done in a setting of institutionalized subjects with a very poor baseline functional status; in such subjects, an improvement in functionality is more feasible.

The rise in the mini-mental score that we observed is not surprising, since the repeated application of this test, as in our patients, has a learning effect. Other authors have reported a 0.6–0.8 score-point increase when the test is applied for the second time (19,20).

Exercise increased muscle strength without changes in lean mass; this observation indicates that training probably improves the metabolic efficiency of muscles and muscle quality per mass unit, as reported previously in experimental animals and humans (21,22). Muscle strength is clearly related to functional capacity in the elderly and, as long as strength is

TABLE 3

Evolution of walking capacity, muscle strength and maximal inspiratory pressure during the 18 mo of follow up[1,2]

	Supplemented + exercise (n = 31)	Control subjects (n = 25)	Supplemented (n = 26)	Exercise (n = 16)	P (two-way ANOVA)
Walking capacity (m)					
Basal	865.8 ± 190.4	943.2 ± 201.4	848.4 ± 161.1	865.1 ± 201.0	<0.01
6 mo	948.1 ± 183.6	810.3 ± 167.7	814.1 ± 156.3	959.3 ± 160.4	
12 mo	979.6 ± 166.9	729.5 ± 246.2	785.1 ± 178.7	939.8 ± 251.1	
18 mo	859.7 ± 259.9	688.0 ± 241.0	738.6 ± 249.9	908.0 ± 220.1	
Right quadriceps strength (kg)					
Basal	14.9 ± 7.8	17.3 ± 4.4	14.7 ± 8.4	13.8 ± 6.0	<0.01
6 mo	22.2 ± 5.6	18.5 ± 5.9	18.7 ± 15.0	22.2 ± 6.7	
12 mo	24.2 ± 6.6	18.8 ± 4.8	17.8 ± 5.9	22.9 ± 7.4	
18 mo	23.1 ± 8.4	18.8 ± 4.8	18.7 ± 6.6	22.7 ± 8.7	
Right biceps strength (kg)					
Basal	9.8 ± 4.9	11.1 ± 5.5	9.8 ± 6.6	9.8 ± 6.3	<0.01
6 mo	19.5 ± 6.5	16.5 ± 6.2	14.0 ± 6.0	20.0 ± 8.3	
12 mo	20.8 ± 8.7	17.1 ± 5.7	15.8 ± 5.7	20.1 ± 7.9	
18 mo	19.2 ± 7.7	16.4 ± 5.2	15.7 ± 6.1	18.4 ± 6.9	
Maximal inspiratory pressure (cm H_2O)					
Basal	53.7 ± 17.6	51.8 ± 18.8	51.7 ± 24.6	52.9 ± 20.5	0.03
6 mo	61.2 ± 20.4	49.8 ± 14.9	47.4 ± 22.8	60.1 ± 29.5	
12 mo	58.9 ± 22.4	50.5 ± 17.8	52.6 ± 23.8	54.0 ± 23.4	
18 mo	64.1 ± 20.8	53.2 ± 17.3	50.5 ± 20.9	63.8 ± 37.9	

1 Values are means ± SD.
2 The lines join the groups that are significantly different in the post hoc analysis.

TABLE 4

Evolution of serum lipid levels in 18 mo of follow up[1,2]

	Supplemented + exercise (n = 31)	Control subjects (n = 25)	Supplemented (n = 26)	Exercise (n = 16)	P (ANOVA)
Total cholesterol (mmol/L)					
Basal	5.34 ± 1.05	4.67 ± 0.81	5.51 ± 1.30	6.00 ± 1.43	<0.001
6 mo	5.16 ± 0.89	5.46 ± 1.08	5.52 ± 1.16	6.01 ± 1.35	
12 mo	5.37 ± 1.18	5.56 ± 1.08	5.60 ± 0.85	6.06 ± 1.28	
18 mo	5.10 ± 0.82	5.15 ± 0.88	5.36 ± 0.92	5.58 ± 0.88	
Triacylglycerol (mmol/L)*					
Basal	1.52 ± 0.55	1.39 ± 0.62	1.74 ± 1.24	1.60 ± 1.00	0.29
6 mo	2.12 ± 0.90	1.58 ± 0.54	1.82 ± 0.79	2.06 ± 0.96	
12 mo	1.73 ± 0.73	1.58 ± 0.78	1.66 ± 0.98	1.62 ± 0.76	
18 mo	1.70 ± 0.69	1.61 ± 0.83	2.43 ± 3.84	1.81 ± 1.17	
HDL cholesterol (mmol/L)*					
Basal	1.12 ± 0.26	1.15 ± 0.23	1.14 ± 0.31	1.19 ± 0.18	0.63
6 mo	1.19 ± 0.27	1.27 ± 0.28	1.34 ± 0.36	1.22 ± 0.30	
12 mo	1.36 ± 0.33	1.43 ± 0.44	1.54 ± 0.46	1.42 ± 0.29	
18 mo	1.23 ± 0.29	1.27 ± 0.33	1.31 ± 0.39	1.28 ± 0.31	

1 Values are means ± SD.
2 The lines join the groups that differ significantly.
* Serum triacylglycerol and HDL cholesterol increased significantly in all groups throughout the 18 months, but there was no differences between groups.

increased, we can expect better walking capacity and better lower extremity performance (23–25). We did not observe an additive effect of nutritional supplementation on muscle strength. Short term (10-wk) studies of resistance training and nutritional supplement have also reported a lack of effect of nutrition on the gain in muscle strength achieved with exercise (5).

In our study, unlike others, nutritional supplementation did not induce changes in body weight or composition. Most nutritional supplementation studies have reported increases in body weight. However, these studies have been targeted to frail elders who had worse baseline conditions than our study subjects (2,3). All elders in the study gained ~1.9 kg fat during the 18 mo of follow up. Other reports have shown that elders lose lean body mass, despite maintenance of a stable body weight. An 0.18–0.65 kg/y reduction in lean body mass and a similar gain of fat mass has been reported. Longitudinal studies show greater changes in body composition than cross-sectional observations (26,27).

During the follow up, the reduction in bone mineral density in the nonsupplemented groups was higher than that in the supplemented and trained elders. The positive effect of the nutritional product on bone mineralization can be attributed to the extra provision of protein and calories or to the provision of micronutrients. The latter possibility is unlikely, because the product provided 400 mg calcium/d for subjects with a 100% compliance. This amount is lower than the amounts reported to promote changes in bone mineral density (28,29). Other micronutrients with a potential benefit in bone mineralization, such as vitamin K or vitamin D, were only supplemented to cover 24% of daily needs. Therefore, the most likely explanation for the preservation of bone calcium in supplemented subjects was the extra amount of proteins provided. Schurch et al. (30) reported a lower loss of hip-bone mineral density in a 6-mo follow-up study of patients recovering from a hip fracture and receiving a nutritional supplement that provided 250 kcal and 20 g of proteins per day during 6 mo. The positive effects of exercise on bone mineralization are well known (31).

Serum cholesterol increased in the control group and remained constant in the intervened subjects. The cholesterol increase in the control group was 16%, equivalent to the increase seen in 5 y in young populations (32). The explanation for this greater increase can be the concomitant increase in fat mass, the main determinant of age-related serum cholesterol modifications (33). The beneficial effects of the nutritional supplementation on serum cholesterol levels are probably related to its content in soluble fiber. This product is manufactured with vegetable products, and it also has an adequate amount of polyunsaturated fats. The other possibility is that supplemented subjects reduced their intake of other animal-derived foods and therefore avoided their detrimental effects on serum cholesterol. Soluble fiber and food of vegetable origin have a clear-cut cholesterol-reducing effect (34–36). Exercise also has a cholesterol-reducing effect; however, in this study we did not observe an additive effect of exercise in serum lipid changes. Probably the lack of effect is due to the absence of changes in body composition in intervened subjects, because in most trials in which exercise has shown a positive effect on serum lipids, there has also been a concomitant weight reduction (37,38). The increase in serum triacylglycerol is probably related to the concomitant accretion of fat mass that occurred in all of the groups (39). However, we do not have an explanation for the rise in HDL cholesterol observed in all of the subjects.

In summary, an 18-mo nutritional supplementation program with a vegetable-based product and resistance training decreased bone mineral loss, avoided deterioration of activities of daily living and serum cholesterol levels and increased respiratory and limb muscle strength. These benefits justify the design and implementation of nutritional supplementation and exercise programs for the elderly.

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