Thanks to Body Exercise, Getting Mobile and Being Less Dependent

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Key Words

Endurance training • Nutritional intervention • Antioxidants • Lipid peroxidation • Physical fitness

Abstract

The study was aimed at determining the influence of aerobic endurance exercise and the intake of a multivitamin beverage (MV) on institutionalized people in their 8th and 9th decades of life. The study comprised 4 groups: exercise + MV (n = 16 complete, age: 83 ± 8 years), exercise (n = 8, age: 82 ± 8 years), MV (n = 8, age: 83 ± 5 years), control (n = 7, age: 83 ± 5 years). The period of exercise, 'aqua training', lasted 17 weeks, two times a week for 25 min. During this period, 250 ml/day of a commercially available multivitamin drink was administered in two of the four groups. At the outset and after the intervention, status of lipophilic antioxidants, vitamin C, malondialdehyde (MDA), cholesterol (total, LDL, HDL), triglycerides and uric acid was assessed. The influence on physical activity was evaluated via spiroergometry. The initial status of nutritive antioxidants was very satisfactory for this population group, only plasma β -carotene was borderline. Plasma levels of total-cholesterol (243 ± 42 mg/dl), LDL-cholesterol (161 ± 35 mg/dl) and uric acid (5.8 ± 1.4 mg/dl) were slightly above the reference value. Endurance exercise neither increased MDA nor decreased plasma antioxidants or changed plasma lipids. Moreover, plasma levels of β -carotene (all MV intervention) and cryptoxanthin (group: exercise + MV) increased after intervention ($p < 0.05$). Physical performance did not enhance, only in the group exercise + MV the respiratory ratio ($p < 0.05$) and lactate ($p = 0.072$) increased.

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Introduction

Referring to the total population, the number of elderly people is increasing continuously in Central Europe. For the city of Vienna, it has been projected that especially the group of seniors which are older than 80 years of age will increase by 38% by 2030 as compared to 1996, which will then be one tenth of the total population in Vienna, Austria [1]. For this group, the advanced years of life are often filled with chronic illness and a reduced enthusiasm to perform activities. As a consequence, the quality of life is reduced. Aging is also associated with a high risk of micronutrient deficiency based on a lower energy intake, which is largely a physiologic effect of aging and may reinforce the harmful anorectic effects of physiological, social and physical problems of the elderly. In this population group, borderline antioxidant and trace element deficiencies have been found [2–4]. Poor nutritional status has been implicated in the development and progression of chronic diseases commonly affecting the elderly, including diabetes mellitus, osteoporosis, cardiovascular disease and cancer [5, 6]. Beside nutritional status, a further main cause of frailty is an increased sedentary lifestyle and the resulting lower energy expenditure. Both inactivity and low micronutrient status are important contributors to the loss of skeletal muscle mass, which is associated with a reduction in lean body mass, total body water, bone density, an increase in body fat [7] and a decline in immune function [8]. The risk of coronary heart disease is associated with inactivity [9].

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Until now only a few studies have investigated the influence of nutrition optimization and/or endurance training on the antioxidative status and parameters of lipid oxidation in elderly people aged 80 years or older.

Subjects and Methods

The study population comprised 55 elderly people living in three senior homes in Vienna. The people lived together in the homes and therefore they had similar lifestyle and exercise patterns and all received their meals three times a day offered by the institution.

Screening and Exclusion Criteria

During a period of 8 weeks subjects were tested for inclusion. Exclusion criteria were: acute or chronic cardiovascular diseases, heart rhythm disturbance, heart insufficiency, serious arterial hypertension, malign diseases and serious impediment to their mobility.

After a preliminary medical screening, each subject was examined by a physician specialized in sports medicine. Furthermore, a complete medical history, and hematological parameters were obtained prior to participation.

General Intervention Design

55 subjects (44 women, 11 men) who were cleared for participation had to complete a 7-day food record to estimate total energy intake and macronutrient intake. The fourfold number of women is due to the higher life expectancy of women and near the population ratio women to men in these decades of life.

Before interventions, baseline measurements of nutritional antioxidants and lipid parameters were performed. The maximal aerobic capacity test was ascertained with a spirometric test procedure. Participants were randomized into one of the three groups: (1) nutrition + endurance training, $n = 16$; (2) endurance training, $n = 16$; (3) nutrition, $n = 16$; 7 persons served as control without nutrition or endurance training (4). The total study period was 17 weeks. The controls were asked to maintain their normal nutrition habits and normal activity level for this period.

After the intervention, the status of nutritional antioxidants and plasma lipid parameters were analyzed again, and a spirometric test was performed. 39 subjects completed the study.

Spirometric Test Procedure

The subjects started with a strain of 15 W and performed several successive 2-min steps of increasing power output (by 15-watt steps) until exhaustion. The pedaling frequency was maintained between 70 and 75 rpm and the heart rate was recorded continuously (Sensormedics, Ergometrics 900). Oxygen and CO₂ fractions in expired air were measured continuously by the system Sensormedics 2900 Metabolic measurement cart.

Endurance Training and Nutrition Intervention Program

Endurance training such as 'aqua exercise' was performed twice a week in the senior homes' own swimming pools (depth: 110 cm). One training session lasted 25 min. The pulse frequency of each person during the sessions was monitored with polar pulse watches. The heart frequency (HF) during the training ses-

Table 1. Daily vitamin intake via the multivitamin beverage (total amount and % of the population reference intake (PRI))

	Daily intake	% of the PRI	
		men	women
A	300 µg	33	38
B ₁	525 µg	53	53
B ₆	750 µg	54	63
B ₁₂	0.38 µg	13	13
C	22.5 mg	23	23
E	3.8 mg	32	35
Biotin	56.3 µg	100	100
Folic acid	75.0 µg	19	19
Niacin	6.8 mg	52	52
Pantothenic acid	2.3 mg	38	38
Pro-vitamin A	no declaration		
Energy value	450 kJ		
Protein	0.25 g		
Carbohydrates	25 g		
Fat	0.25 g		

sions (HFTr) was defined individually on a 60% level of the first ergometric test according to the formula:

$$\text{HFTr} = \text{HFresting} + (\text{HFmaximal} - \text{HFresting}) \cdot 0.6 \pm 5 \text{ beats/min.}$$

To guarantee uniformity, exercises were demonstrated by skilled teachers, and every 5 min participants were requested to control their pulse rate. Additionally, supervisors were in the pool during the entire session for technical support, e.g. if a pulse watch had malfunctioned and for exercise support.

Nutritional intervention was performed by the additional intake of 250 ml/day of a commercially available multivitamin beverage to the normal daily food consumption. The micronutrient composition of the used beverage is presented in table 1. The additional daily vitamin consumption via beverage intake was between 13 and 100% of the personal daily intake. Additional total energy intake of the beverage was 0.45 MJ/day.

Biochemical Parameters

Blood samples were obtained from overnight-fasted volunteers by venipuncture into heparin-containing vacuum tubes (Vacuette; Greiner, Vienna, Austria). Plasma concentrations of retinol, α -, γ -tocopherol, α -, β -carotene, cryptoxanthin and lycopene were determined by reverse-phase HPLC according to the method of Jakob and Elmadfa [10]. Ascorbic acid was detected photometrically by the method of Denson and Bowers [11]. MDA was determined by HPLC using the method of Wong et al. [12]. Total cholesterol, LDL cholesterol, HDL cholesterol, triglycerides and uric acid plasma levels were measured colorimetrically with test kits from Boehringer-Mannheim GmbH (Vienna, Austria).

Statistical Analysis

Repeated measure ANOVA was used to test the treatment effects, and the t test to compare between groups for statistics with

Table 2. Mean values and significant changes (* $p < 0.05$; ** $p < 0.01$; *** $p < 0.001$) of anthropometric, antioxidant, lipid oxidation and fat parameters after the 17-week endurance training and/or nutrition intervention (T1) compared to the baseline values (T0)

	Exercise + nutrition group (1)		Exercise group (2)		Nutrition group (3)		Control group (4)	
	T0	T1	T0	T1	T0	T1	T0	T1
Age, years	83 ± 8		82 ± 8		83 ± 5		83 ± 5	
BMI	25.9 ± 3.1	26.1 ± 3.2	23.7 ± 2.8	24.2 ± 2.5	28.3 ± 2.1	27.5 ± 3.1	27.0 ± 2.4	27.6 ± 2.5
α-Tocopherol, mg/dl	1.4 ± 0.4	1.5 ± 0.5	1.4 ± 0.4	1.4 ± 0.6	1.5 ± 0.4	1.4 ± 0.4	1.3 ± 0.3	1.4 ± 0.3
γ-Tocopherol, μg/dl	69 ± 14	65 ± 31	66 ± 27	70 ± 322	79 ± 30	78 ± 18	76 ± 30	68 ± 17
TE/total lipids, mg/g	2.0 ± 0.5	2.2 ± 0.6	1.9 ± 0.5	2.0 ± 0.5	2.1 ± 0.8	2.1 ± 0.4	1.8 ± 0.4	2.2 ± 0.4
Retinol, μg/dl	60.1 ± 17.4	61.2 ± 18.0	52.3 ± 12.5	50.0 ± 14.0	63.2 ± 16.9	54.9 ± 16.3	60.3 ± 12.9	58.9 ± 12.5
α-Carotene, μg/dl	5.0 ± 2.4	4.3 ± 2.3	4.1 ± 1.4	4.2 ± 3.0	4.0 ± 2.3	2.8 ± 1.1	3.8 ± 2.6	4.1 ± 2.4
β-Carotene, μg/dl	20.6 ± 13.8	90.5 ± 45.1***	16.7 ± 6.4	23.3 ± 7.3	16.1 ± 4.8	74.3 ± 56.1**	16.1 ± 4.5	17.1 ± 7.1
Cryptoxanthin, μg/dl	13.3 ± 8.2	24.0 ± 14.1*	13.3 ± 5.4	18.5 ± 10.7	16.8 ± 12.2	15.3 ± 7.2	11.6 ± 9.6	20 ± 7.2
Lycopene, μg/dl	11.8 ± 5.2	9.3 ± 6.1	10.3 ± 5.4	9.4 ± 5.3	7.5 ± 5.2	5.7 ± 3.6	8.3 ± 4.2	11.1 ± 3.5
Vitamin C, mg/dl	1.2 ± 0.3	1.4 ± 0.6	1.2 ± 0.3	1.2 ± 0.4	1.0 ± 0.3	1.2 ± 0.5	0.9 ± 0.2	1.2 ± 0.2
MDA, μmol/l	1.4 ± 0.5	1.6 ± 0.3	1.4 ± 0.5	1.6 ± 0.5	1.6 ± 0.3	1.5 ± 0.4	1.5 ± 0.3	1.4 ± 0.5
Cholesterol, mg/dl	242 ± 44	235 ± 50	248 ± 39	233 ± 39	247 ± 44	240 ± 43	259 ± 34	232 ± 49
Cholesterol/HDL ratio	3.78 ± 0.13	3.67 ± 0.14	3.76 ± 0.11	4.01 ± 0.11	5.0 ± 0.18	4.8 ± 0.25	4.5 ± 0.14	4.5 ± 0.13
Triglycerides, mg/dl	113 ± 55	100 ± 47	117 ± 60	109 ± 39	133 ± 59	141 ± 65	139 ± 78	138 ± 74
Uric acid, mg/dl	6.1 ± 2.1	5.7 ± 1.7	5.5 ± 0.7	5.5 ± 0.8	6.2 ± 1.0	5.9 ± 0.5	5.5 ± 0.7	5.3 ± 0.8

TE: Tocopherol equivalents = α-tocopherol + 0.5 × β-tocopherol + 0.25 × γ-tocopherol + 0.01 × δ-tocopherol; MDA: malondialdehyde.

normal distribution. Mann-Whitney's U test was used for comparing groups that were not normally distributed. Pearson's correlation coefficients and multiple regression analysis were conducted using SPSS 14.0 for Windows. Values were expressed as mean ± SE, differences were considered to be significant at $p < 0.05$.

Results

Except β-carotene, which was borderline, the mean serum levels of the other plasma antioxidants were within the reference values. Data of the daily nutrient intake support the plasma levels except β-carotene, which indicate appropriate intake but borderline plasma status. MDA serum levels were slightly higher when compared with the reference values for adults [12]; however, so far there are no reference values available for this age class. Mean values and significant changes of the parameters analyzed are shown in table 2.

Plasma levels of total cholesterol (243 ± 42 mg/dl), LDL-cholesterol (161 ± 35 mg/dl) and uric acid (5.8 ± 1.4 mg/dl) were above the reference values. In contrast, HDL-cholesterol was surprisingly high, resulting in acceptable total cholesterol/HDL-cholesterol ratio. Elevated plasma LDL-cholesterol and total cholesterol and low

HDL-cholesterol are associated with an increased risk for CVD [13].

Especially plasma β-carotene levels of both MV obtaining groups increased significantly compared to their baseline values before the intervention. The slight, non-significant increases of β-carotene plasma levels in the exercise and the control group, both of which received no multivitamin beverage, can be explained by seasonal variations of β-carotene intake. While this study lasted from October to January, a higher intake of β-carotene-rich food in autumn is the explanation for the nonsignificant increase in the groups without nutrition intervention. The mean plasma level of cryptoxanthin increased significantly only in the exercise and nutrition group, as compared to baseline values from 13.3 ± 8.2 to 24.0 ± 14.1 μg/dl. In this group, a nonsignificant ($p < 0.08$) increase of vitamin C plasma level was determined. No other significant changes were observed in plasma antioxidants after intervention. There was also no change in lipid oxidation, either in the exercises or in the other groups. MDA levels slightly, but not significantly increased in the exercise groups.

Plasma lipid parameters could be maintained throughout the study, a slight but nonsignificant decrease of triglycerides and uric acid was observed in the exercise +

Table 3. Fitness parameter after the 17-week intervention (T1) compared to the baseline values (T0)

	Exercise + nutrition group (1)		Exercise group (2)		Nutrition group (3)		Control group (4)	
	T0	T1	T0	T1	T0	T1	T0	T1
% of the expected W ¹	65 ± 21	71 ± 24	42 ± 22	46 ± 26	54 ± 35	52 ± 3	40 ± 32	44 ± 35
% of the expected VO ₂ ¹	86 ± 19	86 ± 17	59 ± 25	65 ± 25	83 ± 33	81 ± 33	57 ± 26	62 ± 21
Maximum W	65 ± 24	72 ± 25	50 ± 24	54 ± 28	67 ± 42	65 ± 43	46 ± 31	50 ± 34
Maximum W/kg BW	1.0 ± 0.4	1.1 ± 0.4	0.6 ± 0.3	0.7 ± 0.3	0.8 ± 0.5	0.8 ± 0.5	0.6 ± 0.5	0.7 ± 0.6
VO ₂	1,081 ± 274	1,107 ± 244	719 ± 414	824 ± 334	1,137 ± 532	1,106 ± 507	795 ± 355	806 ± 324
VO ₂ /kg BW	16.7 ± 4.5	16.8 ± 3.8	10.3 ± 4.9	12.2 ± 4.1	14.8 ± 6.2	14.6 ± 5.8	11.0 ± 5.2	12.0 ± 4.4
Breath minute-volume	43.3 ± 13.7	45.5 ± 13.5	26.9 ± 11.3	29.3 ± 9.6	44 ± 19	45 ± 19	30 ± 18	31 ± 18
Breath volume	1.3 ± 0.4	1.4 ± 0.4	1.0 ± 0.5	1.1 ± 0.4	1.3 ± 0.4	1.3 ± 0.4	1.1 ± 0.3	1.2 ± 0.4
Lactate, mmol/l	4.8 ± 2.3	6.1 ± 2.5	3.2 ± 1.6	4.1 ± 2.7	3.7 ± 2.9	4.1 ± 2.7	3.4 ± 2.4	4.5 ± 2.9
RQ	0.9 ± 0.1	1.1 ± 0.1*	0.8 ± 0.1	0.9 ± 0.1	0.9 ± 0.1	1.0 ± 0.1	0.9 ± 0.08	1.0 ± 0.09

VO₂ = Oxygen inhalation; RQ = respiratory ratio.

¹ Reference value for this age group of the Austrian Cardiology Society. * p < 0.05

nutrition group, and a slight reduction of triglycerides in the exercise group.

Except for the increase of the respiratory ratio (RQ; $p < 0.05$) in the group that had endurance training together with nutrition intervention, no significant change could be determined after the spiroergometric test procedure (table 3). No group was able to increase their fitness during the study. All groups exhibited increases in blood lactate and the respiratory ratio, even though statistical significance was only shown in the exercise + nutrition group for the RQ ($p < 0.05$) and a tendency for the lactate concentration ($p = 0.072$).

Discussion

Less information is available on the group of seniors of 80 years or older and no information on the influence of exercise and nutritional intervention on quality of life.

After the 17-week intervention, the group which received both intervention exercise and the multivitamin beverage was influenced most. β -Carotene and cryptoxanthin increased significantly, which must be due to the additional intake via the beverage. But also vitamin C, with an additional daily amount via the beverage was 22.5 mg, could be increased in this group insignificantly ($p = 0.08$), while in the nutrition group only plasma β -carotene increased. Maybe this rise in vitamin C can be explained by an induced antioxidant pathway between plasma and cells due to mobilization by the exercise.

The papers published on this topic focused either on nutritional intervention/supplementation or exercise. Pike and Chandra [14] could show that a 1-year supplementation with micronutrients can play a crucial role in the maintenance of normal immune function in the elderly. Vitamin C levels were found to be significantly lower in institutionalized people than in healthy home-living people who were restored by a 15-day supplementation with a daily dose of 150 g vitamin C [9]. Even though some studies found some borderline antioxidant vitamin levels and trace element deficiencies, especially in institutionalized elderly people [4, 15], the seniors included in our study had surprisingly high plasma antioxidant levels, which can be explained by the regular food intake in the senior homes and their optimized food composition. The only nutrient with borderline initial plasma levels was β -carotene. This finding was similar to a study conducted by Monget et al. [16], who assessed low serum β -carotene levels in the elderly. In addition, factors other than dietary intake were shown to affect plasma carotenoid levels like gender, smoking, alcohol intake, BMI and more.

While it is generally agreed upon that imbalances of the antioxidative system together with increasing rates of oxidative stress fosters the development of age-related disorders, we could demonstrate that only a slight nutritional intervention via daily intake of 250 ml of a commercially available multivitamin beverage could maintain a high antioxidative level also during a period of increased physical activity.

Since it is shown that aging is associated with an increased generation of free radicals in the skeletal muscle that can cause oxidative modification of protein, lipid, and DNA [17], the question arises whether exercise would be advisable to an aged population. In contrast, we could only find moderate initial levels of the primary oxidation product MDA. Even though slight increases in MDA plasma levels were determined in both exercise groups after the intervention, no significance was found. An explanation for these findings might be the high plasma levels of vitamin C and vitamin E, which were both shown to be responsible for reduced generation of the lipid peroxidation parameter after exercise [18, 19].

However, the respiratory ratio ($p < 0.05$) and the lactate concentration ($p = 0.072$) are hints for slight improvements in physical fitness. The change in both parameters demonstrates that the volunteers achieved compliance within their physical capacity.

Interestingly, endurance training did not influence the BMI, which was maintained throughout the study period. This might also be due to the regular food intake of the people and the high food quality. The elevated lipid parameters were slightly decreased especially in the exer-

cise groups. Even though the reduction in plasma lipid levels was not the basic hypothesis when planning this study, these hints in the exercise groups might be used for detailed studies especially on this topic. It is probable that endurance exercise may be included as one main pillar in the reduction of plasma lipids.

In summary, the results of this intervention study allow the following two main conclusions. Firstly, the applied multivitamin beverage, which is commercially available, did not affect total energy intake, but was able to correct borderline plasma nutrient status and therefore can be easily used for corrections of existing deficiencies. Secondly, the trial confirmed that moderate stamina exercise for 17 weeks was not able to improve physical fitness of the elderly but also did not affect lipid oxidation and plasma antioxidants.

Disclosure Statement

The authors declare that no financial or other conflict of interest exists in relation to the content of the article.

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