Original Communication

Q10 Coenzyme Supplementation can Improve Oxidative Stress Response to Exercise in Metabolic Syndrome in Rats

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Abstract: *Background:* The metabolic syndrome leads to high morbidity and mortality. Almost all pathological states are associated with oxidative stress (OS) disorders. This study evaluates the effects of Coenzyme Q10 (CoQ10) supplementation on different lifestyles, in relation to serum and tissue OS parameters. *Materials and methods:* Twelve Wistar rat groups (10 rats/group) were equally divided in three types of diets: standard (St), high fat (HF), high sugar (HS); within each diet group there was one sedentary group with CoQ10 supplementation (100 mg/kg body weight), one sedentary without CoQ10, one trained group with CoQ10 and one trained group without CoQ10 supplementation. After 28 days blood samples were collected as follows: after 12 hours of fasting (T0), 1 hour postprandial (T1) and after 1 hour of exercise (T2) or sedentary postprandial time (T3). Thiol groups (SH) and malondialdehyde (MDA) were determined from serum and liver homogenate. *Results:* Significant changes were observed in fasting MDA for HF ($p = 0.024$ for training, 0.028 for CoQ10). Postprandial, OS status altered, with highest MDA in HF sedentary non-CoQ10 group (3.92 ± 0.37 vs 2.67 ± 0.41 nmol/ml in St trained CoQ10). At T2 the untrained and non-CoQ10 groups had the highest MDA levels (up to 22.3% vs T1, $p < 0.001$ in HF) as SH dropped (34.4% decrease vs T1, $p < 0.001$ in HF). At T3 high MDA levels were observed, correlated with low SH (Pearson $r = -0.423$ overall), irrespective of the CoQ10 supplementation. CoQ10 improved the liver OS status (MDA and SH decreased), but not the exercise, in all diets. *Conclusions:* CoQ10 supplementation accompanied by chronic exercise improved the OS serum profile, irrespective of the daily diet. CoQ10 lowered liver MDA and SH concentrations.

Keywords: Metabolic syndrome, Q10 coenzyme, malondialdehyde, thiol groups, chronic exercise

Introduction

Oxidative stress (OS), which has been an important research domain over the past years, has a proven involvement in all pathological states, from neurologic disorders (degenerative as Alzheimer's and Parkinson's diseases [1] or diabetes mellitus-related diseases [2]) to metabolic changes [3] and cardio-vascular diseases [4, 5]. Natural antioxidants can be found in all foods, but they are not always well balanced or sufficient. Oxygen reactive species are involved in physiological reactions, contributing to antimicrobial fight, phagocytosis and ageing [6]. Antioxidant (AO) supplementation is controversial, as no significant role has been proven so far. Although some pharmaceutical companies encourage the use of AO even in acute states [7], other meta-analysis showed different effects, a synergism with other micronutrients supplementation being concluded. Anticariogenic effects have been questioned, as high doses of beta- cryptoxanthin (a synthetic beta-carotene) supplementation increases lung-cancer prevalence in smokers [8].

Metabolic syndrome (MetS) became a serious problem of this century, with a prevalence of 10% to 84%, at its highest in developed countries, where a sedentary lifestyle is an important cause of obesity [9]. Eating habits have also changed in the last decades, with diets becoming rich in calories and low in nutritional components. This fact led the World Health Organization to consider overfeeding malnutrition as well, especially when a minimum standard of quality is not reached. Postprandial dysmetabolism, as a major component of MetS, is linked to a big number of cardiovascular diseases and comorbidities [10], as both postprandial hyperglycemia and hyperlipidemia are associated with OS increase [11]. A meta-analysis on 5 studies regarding diet

and cardiovascular risk showed an advantage to low-carbohydrate diets compared to low-fat ones, even if the latter lead to weight loss [12].

Exercise can contribute to reactive oxygen species (ROS) production, as it involves high oxygen consumption (oxygen debt at the beginning of the exercise, which is "paid" soon after the exercise), muscle fatigue (in high intensity exercising, with calcium ions being released through type I ryanodine receptors) [13], dehydration and increased heart rate. Exercise-related oxidative stress effects are less important in trained people, along with joint and muscle direct effect [14]. The energy required in muscle contraction can be produced either by aerobic or anaerobic pathways; the latter is the fastest but the least efficient and leads to high reactive oxidative species production rate [15].

Q10 coenzyme (CoQ10) is one of the most powerful natural antioxidants. Even if OS markers found in MetS patients were high and associated with waist circumference and blood pressure, CoQ10 levels failed to show any correlation [16]. However, other studies found that small doses of CoQ10 can improve insulin resistance and pancreatic β-cells function, but not the fasting glucose and the lipids profile [17]. Only low doses of CoQ10 were used on humans, up to 400 mg/day. On animals, doses up to 2400 mg/kg of body weight were used and no behavioral, biochemistry or histological alterations were observed. The latest studies show a moderate effect of CoQ10 supplementation on heart failure [18] and maybe higher doses would be necessary for serum efficient concentrations [19].

Several diets were studied, such as Mediterranean, fish-based – with proven beneficial effect on OS status – but there was no consensus on the necessary amount of antioxidants, as any antioxidant can act as an oxidant in high amounts. However, the effects of antioxidant supplementation are not well known when lifestyle changes are also involved; therefore the aim of our study was to evaluate the role of AO supplementation with high doses of CoQ10 in combination with different lifestyles in rats. Our study included rats with sedentary or active lifestyles, normal or high-calories diets, with or without CoQ10 supplementation. To our knowledge, this is the first study conducted on animals which analyzes several lifestyles with metabolic syndrome as a potential outcome.

Methods

Ethics

The study has been approved by the Ethics Comity of "Iuliu Hatieganu" University of Medicine and Pharmacy in Cluj Napoca (no 401/October 5th 2011). The animals were treated in accordance with the International Harmonization of Nomenclature and Diagnostic Criteria of Global Open Registry Nomenclature Information System (goRENI-INHAND) standards and they were sacrificed accordingly [20].

Study design

The experiment was conducted on 120 Wistar male rats (*Rattus norvegicus, Rodentia: Muridae*) divided into 12 groups (10 rats/group), weight of 200 ± 20 grams, aged 10 ± 1 weeks. Animals were housed in plastic cages with a constant room temperature of 21 ± 1 °C, 12 hours of light/dark cycle, and water was provided *ad-libitum*.

Each of the 12 groups were divided into 3 types of diet – standard, high sugar and high fat – with two subgroups for each diet type – one subgroup was sedentary (E−), while the other one performed exercise (E+) (as shown in Fig. 1). The same criteria were used for the CoQ10 supplemented groups. Each animal was supplemented with 100 mg/kg of body weight of CoQ10 daily. CoQ10 had a concentration of over 98% and was delivered from Cosphatec Hamburg, Germany.

High sugar and high fat diets were obtained through oral gavage of 2 ml of glucose 75% syrup (1.5 grams of pure glucose) and 2 ml of pig lard, respectively. The animals were fed at the same hour each day – 8:00 AM. Exercise involved swimming for 1 hour each morning (in wide and deep, slightly turbulent water containers to avoid escaping, bobbing or floating) at the same time, after eating [21]. The animals were harvested 1 ml of blood from the retro-orbital sinus after 12 hours of fasting (T0), 60 minutes after eating (T1) and 60 minutes after postprandial exercise (T2). In order to evaluate the postprandial sedentary time, a supplementary determination was made (T3), 2 hours postprandial, with no exercise, in all groups.

At the end of the experiments, the animals were euthanized by cervical dislocation. The liver was harvested in the first minutes after death and homogenized. The thiol groups (SH) and malondialdehyde (MDA) from the blood samples were extracted from liver homogenate as well.

Metabolic syndrome was considered if weight gain, elevated plasma glucose (G), triglycerides (TG) and low HDL-Cholesterol (HDL) levels were obtained [22].

Biochemical determinations

MDA was extracted from the supernatant with thiobarbituric acid in equal quantities trough spectrophotometry on double beam UV-VIS V-530 from JASCO Hachioji, Tokyo, Japan [23]. SH were determined through Ellman reagent (5 5'-dithiobis(2-nitrobenzoic acid)) from Merck KgaA

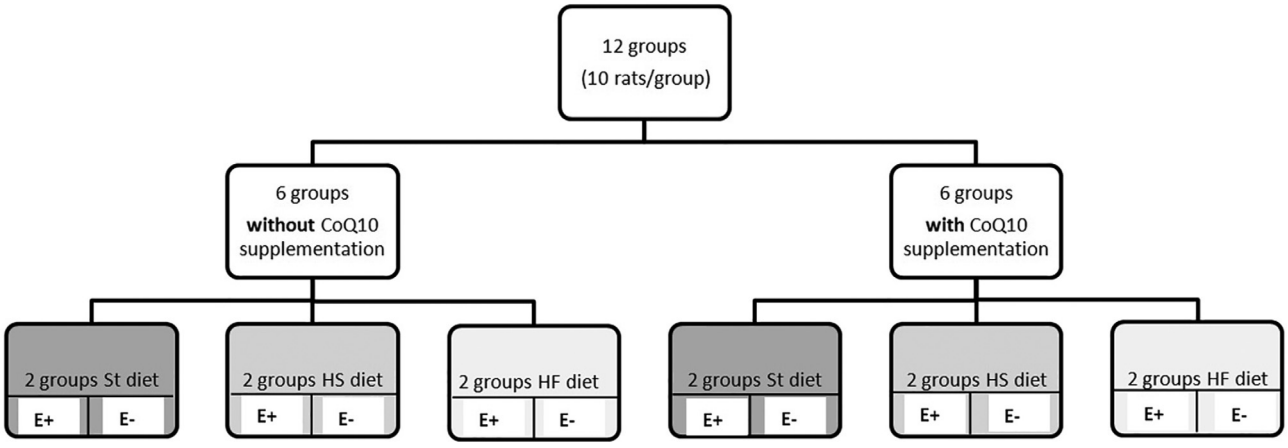

Figure 1. Animal groups distribution. E+ exercise daily, E- sedentary; St – standard diet, HS – high sugar diet, HF – high fat diet.

Gernsheim, Germany [24]. The same methods were used for liver homogenate.

Statistical analysis

Group size was determined using Mead's resource equation and Cohen's *d* table for a power of the study of 0.8. All the groups were considered independent groups and average, median, standard deviation and standard error were computed at each moment. For 2 normal distribution groups comparison we used the student t test, whereas for more than 3 groups Wilkoxon or Friedman tests were run. If normal distribution criteria were not met, Mann-Whitney and Krushal-Wallis tests were used instead. Pearson's correlation r was also computed and ANOVA general linear model test for repeated measurements (GLM-RM) was run for moments' comparison. Bonferoni post hoc test was applied. Statistical significant p was considered at 0.05. F-statistic value for univariate ANOVA was also computed for each group as high significance is correlated with high F. Statistical analysis was performed using SPSS 17 and Microsoft Excel 2010 software.

Results

Metabolic syndrome

In high-fat, high-calorie diets, sedentary groups and the groups without CoQ10 supplementation had higher body weight at the end of the experiment compared to trained and CoQ10 supplemented groups, with statistical significance for training (Table 1). Also, fasting glucose was significantly higher in high-sugar and high-fat diets ($p < 0.001$), while HDL-C levels were lower and TG serum concentrations higher. Between the same diet groups, fasting glucose was influenced only by chronic exercise, while CoQ10 supplementation and training significantly reduced fasting HDL-C and TG, especially in high-calorie diets ($p < 0.05$).

Standard diet

Serum MDA had increased levels in all moments, with the highest values in T2 and the lowest in T3 (Table 2). Univariate analysis for T0 showed no statistical significance for exercise ($F = 1.802$, $p = 0.188$) or CoQ10 supplementation ($F = 1.201$, $p = 0.280$). ANOVA GLM-RM showed that both chronic exercise and CoQ10 supplementation changed the oxidant profile ($F = 17.124$, $p < 0.001$ and $F = 13.820$, $p = 0.001$, respectively). SH increased in T1, but decreased in T2 and T3. CoQ10 supplementation changed the T0 values ($F = 88.668$, $p < 0.001$) but not for chronic exercise ($F = 3.033$, $p = 0.090$). Both physical training and CoQ10 supplementation changed the SH profile ($F = 41.102.823$, $p < 0.001$ and $F = 546.913$, $p < 0.001$, respectively in ANOVA GLM-RM). Liver MDA was slightly higher in trained groups ($F = 2.538$, $p = 0.120$) and lower in the CoQ10 supplemented groups ($F = 22.457$, $p < 0.001$). SH decreased in trained groups ($F = 0.808$, $p = 0.375$) but were significantly lower in CoQ10 supplemented groups ($F = 64.308$, $p < 0.001$). Liver MDA and SH were moderately correlated ($r = 0.465$, $p = 0.003$).

High sugar diet

MDA values in T0 were lower in trained and CoQ10 supplemented groups (Table 2) but with no statistical significance ($p = 0.064$ and $p = 0.119$ respectively). In T1 and T2 there was an increase of MDA values, which decreased in T3.

Table 1. Metabolic syndrome parameters

Group			Final Weight	Univariate analysis		G	Univariate analysis		HDL-C	Univariate analysis		TG	Univariate analysis	
				Training	CoQ10 supplementation		Training	CoQ10 supplementation		Training	CoQ10 supplementation		Training	CoQ10 supplementation
Standard diet	No CoQ10	Sedentary	234.3±12.1	***p=0.035***	*p=0.467*	112.5±5.6	***p=0.028***	*p=0.184*	42.1±7.4	*p=0.135*	*p=0.159*	93.5±15.5	***p<0.001***	***F=3.464,***
		Trained	218.9±20.8	***F=4.788***	*F=0.541*	107.8±11.5	***F=5.265***	*F=1.836*	44.3±12.2	*F=2.342*	*F=2069*	76.2±12.1	***F=16.428***	***p=0.071***
	CoQ10 supplementation	Sedentary	225.8±9.2			110.4±7.8			44.1±4.1			84.7±11.3		
		Trained	220.4±15.6			102.4±8.9			50.4±9.6			70.6±9		
High sugar diet	No CoQ10	Sedentary	239.1±14.6	***p<0.001***	*p=0.349*	117.6±8.8	***p=0.030***	*p=0.255*	30.1±5.2	***p<0.001***	***p=0.027***	104.9±13.8	***p<0.001***	***p<0.001***
		Trained	207.6±16	***F=19.901***	*F=0.899*	108.5±5.4	***F=5.115***	*F= 1.336*	37.5±6.9	***F=15.697***	***F=5.348***	85.3±12.7	***F=125.341***	***F=56.142***
	CoQ10 supplementation	Sedentary	232.7±13.1			111.8±10.4			34.4±5.6			95.8±13.5		
		Trained	222.8±14.8			107.4±11.9			41.7±5.6			72.63±13.9		
High fat diet	No CoQ10	Sedentary	258.1±35.6	***p=0.017***	*p=0.391*	122.7±11.2	***F=7.275,***	*p=0.11*	26.6±4.6	***p<0.003***	***p=0.024***	123.9±13.2	***p<0.001***	***p=0.004***
		Trained	224.4±10.2	***F=6.210***	*F=0.753*	113.9±9.09	***p=0.011***	*F=2.680*	32.4±8.5	***F=10.153***	***F=5.570***	101.2±16.5	***F=15.035***	***F=9.397***
	CoQ10 supplementation	Sedentary	234.6±11.9			117.3±11.4			30.9±3.8			105.1±14.8		
		Trained	237±8.2			108.8±0.6			36.6±4.8			91.3±14.7		

Note: Final weight in grams, serum Glucose- G in mg/dL, serum HDL-Cholesterol– HDL-C in mg/dL, serum triglycerides- TG in mg/dL. Data expressed as average±standard deviation.

GLM-RM showed increase significance for exercise (F = 26.056, p < 0.001) and CoQ10 supplementation (F = 25.266, p = 0.001). SH were lower in trained (F = 8.448, p = 0.006) and CoQ10 groups (F = 118.721, p < 0.001), higher in T1 but decreased in T2 and T3 as well (F = 38.207, p < 0.001 and F = 392.633, p < 0.001 in GLM-RM respectively). Liver MDA was lower in CoQ10 groups (F = 35.151, p < 0.001) and slightly higher in trained groups (F = 1.229, p = 0.275). Liver SH decreased strongly in CoQ10 supplemented groups (F = 67.741, p < 0.001) and less in trained ones (F = 4.397, p = 0.043). Tissue MDA and SH were moderately correlated (r = 0.436, p = 0.006).

High fat diet

Serum MDA in T0 was lower in trained (F = 5.594, p = 0.024) and CoQ10 supplemented groups (F = 5.222, p = 0.028), and increased in T1 and T2 (Table 3) but decreased in T3 for all the groups, especially in trained (F = 37.914, p < 0.001) and CoQ10 supplemented ones (F = 48.446, p < 0.001). T0 also had higher SH levels in trained (F = 6.741, p = 0.014) and CoQ10 groups (F = 110.335, p < 0.001), which increased in T1 and decreased in T2 and T3 (F = 280.763, p < 0.001 and F = 28.613, p < 0.001 in ANOVA GLM-RM test, respectively). Liver MDA was lower in CoQ10 groups (F = 36.812, p < 0.001), chronic exercise could not significantly change the tissue concentrations (F = 0.894, p = 0.351). Tissue SH were notably lower in CoQ10 groups (F = 36.410, p < 0.001). No correlation was found between MDA and SH liver concentrations when comparing the 2 groups with HF diet.

Rostprandial sedentary time

At 2 hours postprandial (T3), with no prior exercise, a divergent trend was observed in serum OS parameters (high MDA and low SH), with negative correlation between these parameters (Pearson r = −0.423 overall, with lowest correlation in standard diet group and higher in high-calorie diet), irrespective of the CoQ10 supplementation (Fig. 2).

Discussion

Metabolic syndrome was obtained through high-calorie diets in sedentary groups. Chronic exercise managed to reduce the significance of these changes, while CoQ10 supplementation had a rather cumulative effect, better observed in high fat and high sugar diets. No significant changes were found in fasting MDA serum concentrations in standard diet. CoQ10 supplementation managed to

Table 2. Serum and liver oxidative stress parameters

	Group			T0	Univariate analysis		T1	T2	ANOVA GLM-RM		Liver	Univariate analysis	
					Training	CoQ10 supplementation			Training	CoQ10 supplementation		Training	CoQ10 supplementation
MDA	Stan dard diet	No CoQ10	Sedentary	2.90±0.54	*p=0.188*	*p=0.280*	3.17±0.34	3.88±0.7	***p<0.001***	***p=0.001***	8.43±2.3	*p=0.120*	***p<0.001***
			Trained	2.68±0.35	*F=1.802*	*F=1.201*	2.87±0.57	3.51±0.54	***F=17.124***	***F=13.820***	9.34±1.82	*F=2.538*	***F=22.457***
		CoQ10 supplementation	Sedentary	2.72±0.57			2.92±0.43	3.48±0.46			6.12±0.94		
			Trained	2.51±0.51			2.67±0.41	3.12±0.48			6.83±0.93		
	High sugar diet	No CoQ10	Sedentary	3.03±0.41	***p=0.064***	*p=0.119*	2.41±0.68	4.18±0.55	***p<0.001***	***p=0.001***	9.57±2.06	*p=0.275*	***p<0.001***
			Trained	2.75±0.28	***F=3.643,***	*F=2.548*	3.04±0.33	3.70±0.58	***F=26.056***	***F=25.266***	10.55±2.49	*F=1.229*	***F=35.151***
		CoQ10 supplementation	Sedentary	2.80±0.54			3.11±0.65	3.67±0.39			6.66±0.86		
			Trained	2.56±0.41			2.76±0.32	3.20±0.38			6.90±0.97		
	High fat diet	No CoQ10	Sedentary	3.47±0.67	***p=0.024***	***p=0.028***	3.92±0.37	4.88±0.21	***p<0.001***	***p<0.001***	10.24±2.55	*p=0.351*	***p<0.001***
			Trained	3.10±0.41	***F=5.594***	***F=5.222***	3.47±0.41	4.19±0.62	***F=37.914***	***F=48.446***	11.14±2.37	*F=0.894*	***F=36.812***
		CoQ10 supplementation	Sedentary	3.18±0.41			3.43±0.55	4.03±0.31			6.81±1.16		
			Trained	2.77±0.34			3.06±0.46	3.61±0.43			7.08±1.30		
SH	Stan dard diet	No CoQ10	Sedentary	1.09±0.25	*p=0.090*	***p<0.001***	1.57±0.17	1.03±0.14	***p<0.001***	***p<0.001***	8.50±1.44	*p=0.375*	***p<0.001***
			Trained	1.23±0.32	*F=3.033*	***F=88.668***	1.76±0.36	1.38±0.35	***F=41.102.823***	***F=546.913***	7.93±1.96	*F=0.808*	***F=64.308***
		CoQ10 supplementation	Sedentary	1.86±0.18			2.41±0.29	2.03±0.29			4.63±1.26		
			Trained	2.01±0.25			2.54±0.29	2.29±0.36			4.36±1.04		
	High sugar diet	No CoQ10	Sedentary	0.87±0.23	***p=0.006***	***p<0.001***	1.75±0.31	0.90±0.25	***p<0.001***	***p<0.001***	7.54±1.26	*p=0.043*	***p<0.001***
			Trained	1.05±0.27	***F=8.448***	***F=118.721***	1.98±0.21	1.34±0.39	***F=38.207***	***F=392.633***	6.70±1.10	*F=4.397*	***F=67.741***
		CoQ10 supplementation	Sedentary	1.62±0.17			2.57±0.26	1.86±0.28			4.61±1.04		
			Trained	1.85±0.21			2.89±0.33	2.01±0.30			4.03±0.81		
	High fat diet	No CoQ10	Sedentary	0.77±0.19	***p=0.014***	***p<0.001***	1.75±0.11	0.77±0.17	***p<0.001***	***p<0.001***	6.41±0.93	*p=0.153*	***p<0.001***
			Trained	0.97±0.20	***F=6.741***	***F=110.335***	1.99±0.27	1.22±0.24	***F=28.613***	***F=280.763***	5.81±1.45	*F=2.128*	***F=36.410***
		CoQ10 supplementation	Sedentary	1.54±0.29			2.59±0.51	1.62±0.24			4.46±0.36		
			Trained	1.72±0.22			2.88±0.37	1.80±0.22			4.19±0.62		

Note: Serum malondialdehyde- MDA in nmol/ml, serum thiol groups- SH in μmol/ml, liver MDA in nmol/10 mg of protein, liver SH in μmol/100 mg of protein, T0- fasting, T1- postprandial, T2- after exercise. Data are expressed as average±standard deviation.

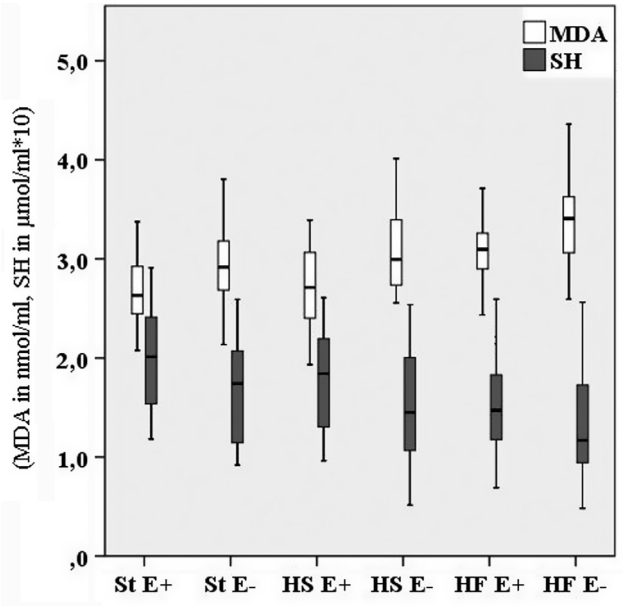

Figure 2. Serum parameters of oxidative stress without postprandial exercise (CoQ10 status not considered). n = 20, St – standard diet, HS – high sugar diet, HF – high fat diet, E- for chronic sedentary and E+ for trained groups. Malondialdehyde (MDA) in nmol/ml, thiol groups (SH) in µmol/ml × 10; box plots ± standard deviation.

induce a significant OS status drop during high-calorie diets, while training had a similar effect only in high-fat ones. It has been observed that the more calories, the higher the number of factors that can change the OS status and the stronger their effects, showing multiple ways of interfering with diet induced metabolic changes. The best antioxidant status was observed in the trained and CoQ10 supplemented group, for standard diet. The analysis of postmenopausal women without diabetes, made by by Kitabchi et al., showed that there is a difference between the high-protein diet and the high-carbohydrate diet regarding OS and inflammation, most probably due to β-cell function stimulation, insulin sensitivity increase, with consecutive protection against oxidative stress, cardio-vascular risk factors, and also improvement in adiponectin levels [25]. Several other studies showed that CoQ10 supplementation reduced MDA and total antioxidant capacity in diabetes mellitus patients, including the ones with onset coronary heart disease [17, 26], but with no other proof of adiponectin involvement. Our study did not include rats with diabetes, but the first components of metabolic syndrome (overweight and dysmetabolism) were reached.

60 minutes after eating, before exercising, all groups had higher serum MDA levels, in response to postprandial lipid peroxidation and protein glycation, which led to oxidative stress and its subsequent complications [27]. The lowest OS response was found in the trained group with standard diet and CoQ10 supplementation. As the postprandial MDA serum values were the highest in high fat diet groups, postprandial OS seems to be associated with the calorie intake, as the energy needed for digestion, lipid peroxidation and protein glycation is also higher. After eating, there was an increase in serum SH concentrations, along with higher MDA, as a result to OS production while eating. This antioxidant response was higher for CoQ10 supplemented groups and proportional to the calorie intake. Fisher et al. found that high-dextrose diet as a post-exercise energy rebalance did not change the fasting OS in young healthy males, as the glucose metabolism is considered adequate, with no insulin secretion impairment or peripheral resistance [28]. Our study reached the same conclusion for the group with standard diet and postprandial exercise, but in chronic high-calorie diets, especially in high-fat diets, the changes of OS were significant, possibly because of high amount of sugar/fat per serving.

After 60 minutes of swimming, serum MDA has the highest increase in untrained and non-CoQ10 groups, as a consequence of acute exercise-induced OS. The slowest antioxidant response was observed in high-calorie diets. After acute exercise, SH dropped trough antioxidants consumption as a response to MDA higher levels. This decrease is also more significant in untrained and non-CoQ10 groups, as there is a lower antioxidants reserve. Studying OS along with exercise is widely spread in the literature. MDA, as an OS marker, is highly sensitive between TBARS (thiobarbituric acid reactive species), as they are all involved in the carbohydrate oxidation. It's been shown that physical training can help muscle fibers adapt to OS [29]. Although harvesting blood itself can generate OS, there is evidence that lipid peroxidation can be produced by exercise as well [30]. These processes are held mainly in mitochondria involving NFkappaB (nuclear factor kappa B) and protein activated mitogen kinase [31]. Although other studies found no significant changes in MDA levels during standard exercise (along with other respiratory hydrocarbons) [32], our study involves chronic lifestyle changes – such as the diets – with consequent different antioxidant response. We also considered antioxidant supplementation. Cooke et al. found a significant effect of CoQ10 supplementation on lowering OS during and after exercise, when physical chronic training was considered [33]. Along MDA, another lipid oxidation marker could be the isoprostane F2 (with its 4 classes), which doesn't need cyclooxygenase for oxidation, but it is only applicable in high intensity acute exercise [34]. Our study involves chronic exercise, the only bout of acute unique exercise being used for sedentary groups, where high OS response has been observed.

In the case of groups with sedentary status after eating (T3, 2 hours postprandial) we obtained a better postprandial oxidant status, as we did in previous trained and CoQ10 supplemented groups. Antioxidant supplementation

brought OS status in high-calorie diets to similar values as those seen in standard diets. Antioxidant capacity decreased by consumption compared to T1, less in trained and CoQ10 groups and more in high calories diets. Postprandial oxidative stress has been adressed in few studies, most of them on Mediterranean diet in elderly, where small doses of CoQ10 supplementation came to amplify the OS reduction [35, 36], with higher increase in capillary flow and in nitric oxide levels, lower lipid peroxidation and postprandial glutathione peroxidase activity reduction. Our study was similar to these studies, involving three types of diets, and also concluding the benefits of antioxidant (CoQ10) supplementation in postprandial antioxidant activity. Even in an occasionally postprandial sedentary time, as T3 for the trained groups, the antioxidant capacity maintains better values than in sedentary groups.

Tissue concentrations of OS parameters were similar to the serum findings. We obtained lower liver MDA values in CoQ10 groups and slightly higher values in trained rats, hence concluding that antioxidant supplementation can change the tissue concentrations of OS, but exercise cannot. This also shows a better role of chronic exercise in serum oxidant-antioxidant balance. SH were lower in trained and CoQ10 groups, as the antioxidant levels dropped, as a result of chronic intracellular consumption. Highest OS parameters were found in high-calorie diets, but the correlation between them was lower, showing that other parameters are involved in the tissue antioxidant response. High fat meals increased liver MDA in previous studies [37], but no correlation was found to this point in oxidant/antioxidant capacity. The high OS levels found in the liver of the high-calorie fed rats suggest higher local lipid peroxidation. Liver steatosis, found in MetS, is a source for this peroxidation, and its products can have harmful effects on the hepatic cells. The oxygen reactive species produced will interfere with the mitochondrial respiratory chain and consequently with supplementary OS production, additional liver disorders, aggravation of metabolic syndrome features or even apoptosis or necrosis of the cell with final fibrosis [38]. The same conclusion was drawn from our study: as the caloric intake rises, so does the MDA and SH levels in the liver. CoQ10 supplementation managed to reduce this increase, but not the exercise itself.

In this study, MetS was obtained through sedentarism and high-calorie diets. Antioxidant supplementation managed to reduce the effects of MetS, and along with chronic exercise, the OS status to values similar to the ones found in standard diets. This study shows the importance of CoQ10 supplementation in different lifestyles, especially in the ones that can lead to obesity and metabolic changes.

Considering that there is an exact amount of each nutrient needed for a healthy life, this study demonstrates that high amounts of antioxidants are required to interfere with the metabolic changes in MetS and its leading lifestyles. As no such high dosage is available for human use, it would be necessary to involve more antioxidants rather than just one. This could be possible by combining different antioxidants with potential additive effects.

Limits of the study

This study evaluated only one type of standard exercise, as anaerobic exercise is more efficient in weight loss. Swimming can be considered anaerobic only for the first days, when the animals are not yet adapted to daily exercise [39]. Some authors considered the amount of time to induce diet related cardiovascular risk up to six weeks [40]. Our study was conducted during 28 days, enough to induce weight gain and metabolic disorders, as the first components of MetS. Also we determined two OS markers (one out of the TBARS and one from antioxidant capacity), and the results were interpreted accordingly, with high significance level.

Conclusions

CoQ10 supplementation and chronic exercise improved diet-related and exercise-induced OS. The higher the daily calorie intake, the more significant the antioxidant effect of CoQ10, as the most desired effect is found in high fat diet. Chronic exercise along with CoQ10 supplementation ameliorates the OS balance in sedentary postprandial case. CoQ10 supplementation reduced liver MDA and SH, with the highest significance in high-calorie diets, while chronic exercise did not induce significant changes.

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Conflict of interest
The authors declare that there are no conflicts of interest.

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