

## Coenzyme Q10 distribution in blood is altered in patients with Fibromyalgia

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### Abstract

**Objective:** Coenzyme Q10 (CoQ<sub>10</sub>) is an essential electron carrier in the mitochondrial respiratory chain and a strong antioxidant. Signs and symptoms associated with muscular alteration and mitochondrial dysfunction, including oxidative stress, have been observed in patients with fibromyalgia (FM). The aim was to study CoQ<sub>10</sub> levels in plasma and mononuclear cells, and oxidative stress in FM patients.

**Methods:** We studied CoQ<sub>10</sub> level by HPLC in plasma and peripheral mononuclear cells obtained from patients with FM and healthy control subjects. Oxidative stress markers were analyzed in both plasma and mononuclear cells from FM patients.

**Results:** Higher level of oxidative stress markers in plasma was observed respect to control subjects. CoQ<sub>10</sub> level in plasma samples from FM patients was doubled compared to healthy controls and in blood mononuclear cells isolated from 37 FM patients was found to be about 40% lower. Higher levels of ROS production was observed in mononuclear cells from FM patients compared to control, and a significant decrease was induced by the presence of CoQ<sub>10</sub>.

**Conclusion:** The distribution of CoQ<sub>10</sub> in blood components was altered in FM patients. Also, our results confirm the oxidative stress background of this disease probably due to a defect on the distribution and metabolism of CoQ<sub>10</sub> in cells and tissues. The protection caused in mononuclear cells by CoQ<sub>10</sub> would indicate the benefit of its supplementation in FM patients.

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**Keywords:** Coenzyme Q<sub>10</sub>; Fibromyalgia; Mononuclear cells; Oxidative stress

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Fibromyalgia (FM) is a common chronic pain syndrome accompanied by other symptoms such as fatigue, headache, sleep disturbances, and depression. It affects predominantly females, but its pathogenesis is still unknown. FM is diagnosed according to the classification criteria established by the American College of Rheumatology (ACR) [1] and routine laboratory investigations usually yield normal results [2],

therefore new diagnostic markers for FM are needed. Characteristics of muscle in FM patients are muscle pain, fatigue and weakness, which could correspond to the abnormalities observed such as disorganization of Z bands and an altered number and shape of mitochondria. These muscles also show abnormalities of ATP and phosphocreatine levels [3]. Coenzyme Q<sub>10</sub> (CoQ<sub>10</sub>) is often reduced in patients with myopathy, either as a primary or secondary event [4], and also there is a positive correlation of the content of CoQ<sub>10</sub> in plasma and mononuclear cells in rats supplemented with this compound [5], and there is a positive correlation between mononuclear cells and skeletal muscle [6]. We hypothesize that an altered homeostasis of CoQ<sub>10</sub> would lead to an increased oxidative

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stress in plasma and a dysfunction in muscle and mononuclear cells. We have found that plasma CoQ<sub>10</sub> levels were higher in FM patients than control but blood mononuclear cells showed a decrease of CoQ<sub>10</sub> indicating a dysfunction of CoQ<sub>10</sub> distribution in the blood of these patients.

## Patients and methods

### Patients and controls

The study was performed with the informed consent of all participants and the approval of the local ethical committee. We have studied 40 patients (males/4, females/36) recruited from the database of the Sevillian Fibromyalgia Association (AFIBROSE) and 30 healthy controls with no pain declared (males/7, females/23). The diagnosis of FM was established by an experienced rheumatologist according to ACR criteria [1]. All patients had not taken any drug during a 15 days period before the collection of the blood samples. All patients reported following a standard balanced diet.

Heparinized and coagulated bloods were collected from each patient, centrifuged at 3800 g for 5 min, and plasma and serum were stored at  $-80^{\circ}\text{C}$  until testing. Serum biochemical parameters were assayed by routine analytical methods.

### Blood mononuclear cells preparation and cultures

Peripheral blood mononuclear cells were purified from heparinized blood by isopycnic centrifugation using Histopaque-1119 and Histopaque-1077 (Sigma Chemical Co., St. Louis, MO, USA).

### Measurement of CoQ<sub>10</sub> levels

Both plasma and cellular CoQ<sub>10</sub> contents were analyzed by HPLC (Beckmann 166-126 HPLC) with ultraviolet detection (275 nm) according to the method of Montero et al. [7].

### Malondialdehyde levels

TBARS levels were determined by a method based on the reaction with thiobarbituric acid (TBA) at  $90\text{--}100^{\circ}\text{C}$  [8]. Shortly, the reaction was performed at  $90^{\circ}\text{C}$  for 15 min pH 2–3. The sample was mixed with two volumes of cold 10% (w/v) trichloroacetic acid to precipitate protein. This precipitate was pelleted by centrifugation and an aliquot of the supernatant was reacted with an equal volume of 0.67% (w/v) TBA in a boiling water bath for 10 min. After cooling, the absorbance was read at 532 nm. Results were expressed as nmol/mL.

### Protein carbonyl content

Plasma protein carbonyl content was quantified by spectrophotometric measurement of 2, 4-dinitrophenylhydrazine derivatives of protein carbonyls. Samples were precipitated with trichloroacetic acid at a final concentration of 20%, centrifuged at 16400 g for 10 min and protein pellets allowed to

react with 2,4-dinitrophenylhydrazine. Pellets were then dissolved in sodium hydroxide and the concentration of protein carbonyls measured spectrophotometrically at 360 nm, according to the method of Harma et al. [9]. Results are expressed as nmol/mL.

### Intracellular ROS production

Reactive oxygen species (ROS) production were measured according to Quinzii et al. [4].

### Statistical analysis

All results are expressed as means $\pm$ SD unless stated otherwise. The unpaired Student's *t* test was used to evaluate the significance of differences between groups, accepting  $P < 0.05$  as level of significance.

## Results

Mean age was  $47.5 \pm 11$  for the FM group and  $44.2 \pm 13$  years for the control group.

Routine laboratory test yield normal results for glucose  $93.15 \pm 18.06$  mg/dL (normal values 76–110), urea  $35.97 \pm 10.39$  mg/dL (n.v. 10–45), uric acid  $4.65 \pm 1.51$  mg/dL (n.v. 2.5–7.5), total protein  $7.64 \pm 0.40$  g/dL (n.v. 6.6–8.7), creatinine  $0.77 \pm 0.11$  mg/dL (n.v. 0.5–1.1), aspartate aminotransferase  $22.94 \pm 7.94$  mU/mL (n.v. 10–40), alanine aminotransferase  $21.21 \pm 12.33$  mU/mL (n.v. 10–40), cholesterol  $227 \pm 46.07$  mg/dL (n.v. >220), and triglycerides  $109.92 \pm 65.5$  mg/dL (n.v. 150–200).

On average FM patients showed higher level of oxidative stress markers in plasma respect to control subjects (malondialdehyde: FM  $14.2 \pm 3.7$  nmol/mL; controls:  $8 \pm 1.2$  nmol/mL,  $P < 0.005$ ), protein carbonyls: FM  $40.6 \pm 7.6$  nmol/mL and control  $18.3 \pm 2.2$ ,  $P < 0.001$ ). However, antioxidant CoQ<sub>10</sub> level average in plasma samples from FM patients was doubled compared to healthy controls (Fig. 1). The ratio of CoQ<sub>10</sub> to

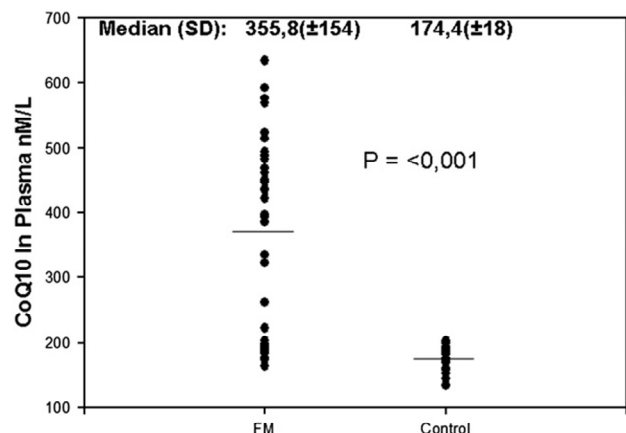


Fig. 1. Coenzyme Q10 levels in plasma from fibromyalgia patients and healthy control subjects. The analysis of CoQ<sub>10</sub> content in FM patients shows a significant increase of the concentration relative to control samples.

cholesterol in plasma were of 1.56 in FM patients and 0.76 in control.

Interestingly, CoQ<sub>10</sub> concentration determined in blood mononuclear cells isolated from 37 FM patients was found to be about 40% lower than in control cells ranging from 138.4 ± 48.5 pmol CoQ<sub>10</sub>/mg protein in FM samples to 225.1 ± 12.1 pmol CoQ<sub>10</sub>/mg protein in controls ( $P < 0.01$ ).

To confirm this deficiency detected, blood mononuclear cells from six representative FM patients were incubated with 10 μmol/L CoQ<sub>10</sub> and the analysis of ROS production was determined in both treated and non treated cells. Mononuclear cells isolated from FM patients showed higher levels of ROS production compared to control cells (FM: 16.8 ± 3 a.u.; control: 10.4 ± 0.1 a.u.,  $P = 0.025$ ), and a significant decrease was induced by the presence of CoQ<sub>10</sub> (FM plus CoQ<sub>10</sub>: 11.9 ± 0.9 a.u.,  $P \leq 0.03$ ). CoQ<sub>10</sub> concentration in mononuclear cells from FM patients was increased by 35% (189.2 ± 36 pmol CoQ<sub>10</sub>/mg protein) and by 10% in control (246 ± 14 pmol CoQ<sub>10</sub>/mg protein).

## Discussion

CoQ<sub>10</sub> plays a crucial role in cellular metabolism acting as the electron carrier between complexes I and II and the complex III of the mitochondrial respiratory chain; and regulates uncoupling proteins, the transition pore, β-oxidation of fatty acids, and nucleotide pathway [5].

CoQ<sub>10</sub> deficiency has been associated to a variety of human disorders, some of them caused by a direct defect of CoQ<sub>10</sub> biosynthesis genes or as a secondary event [4]. Interestingly, patients with CoQ<sub>10</sub> deficiency display improvement of symptoms, sometimes dramatic, after oral CoQ<sub>10</sub> supplementation [10].

Despite being a common disorder, FM affects at least 5 million individuals in the United States [1], its pathogenic mechanism remains elusive. Recently oxidative stress markers have been proposed as a relevant event in the pathogenesis of this disorder [11].

Major antioxidant factors in plasma are α-tocopherol and CoQ<sub>10</sub>, and cooperate to prevent oxidative damage. In the present study we have confirmed the significant increase of serum markers associated with oxidative stress in FM patients, and provide for the first time direct evidence of increased ROS production at the cellular level. In fact we have found a lower content of CoQ<sub>10</sub> in blood mononuclear cells of these patients correlating with increased ROS production in these cells, which could be corrected by CoQ<sub>10</sub> supplementation in the culture medium. This situation is not contradictory because CoQ<sub>10</sub> shows both pro-oxidant and antioxidant activities depending on its concentration and membrane environment [5]. Furthermore, fibroblasts of some patients with CoQ<sub>10</sub> deficiency syndrome show a higher production of ROS in mitochondria [4].

It should be noted that in general there is a poor correlation between plasma and tissues levels of CoQ<sub>10</sub>, and even patients with genetically proven CoQ<sub>10</sub> deficiency may have plasma CoQ<sub>10</sub> levels in the normal range [7]. It is also important to

consider that both endogenous biosynthesis and diet contribute to the final content of CoQ<sub>10</sub> in blood. Both patients and control did not show significant differences in their diets in this work. However, there is a positive correlation between the content of CoQ<sub>10</sub> in skeletal muscle and mononuclear cells [6], and it has been demonstrated that human supplementation with CoQ<sub>10</sub> induced an increase in both plasma and mononuclear cells, but not in polinuclear cells [5]. Furthermore, mononuclear cells were successfully used to determine CoQ<sub>10</sub> deficiency [6]. The protective effect of CoQ<sub>10</sub> supplementation on mononuclear cells could explain the previous pilot study that has reported beneficial effects of CoQ<sub>10</sub> administration to FM patients, although this could be also due to the presence of Gingko [12]. In these patients the increased plasma levels does not imply the accumulation in mononuclear cells indicating that cell uptake and/or metabolism of CoQ<sub>10</sub> is altered showing a new marker for this disorder. If this defect is affecting to other tissues would contribute to understand the pleiotropic aspect of the disease.

Because FM is diagnosed only on the basis of clinical criteria it is necessary to find novel diagnostic markers. According to our results, the dysfunction of the CoQ<sub>10</sub> distribution between plasma and mononuclear cells, and the correlation between these cells and muscle [6], would represent a good marker for the diagnosis of FM. In conclusion, our results confirm the oxidative stress background of this disease probably due to a defect on the distribution and metabolism of CoQ<sub>10</sub> in cells and tissues. We propose the analysis of CoQ<sub>10</sub> levels as a biochemical marker for FM, which could represent a defect of antioxidant homeostasis in this disease.

## Disclosure

The authors report no conflicts of interest.

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