

Applied nutritional investigation

Antifatigue effects of coenzyme Q10 during physical fatigue

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Manuscript received August 31, 2007; accepted December 11, 2007.

Abstract

Objective: This study examined the effects of coenzyme Q10 administration on physical fatigue.

Methods: In a double-blinded, placebo-controlled, three crossover design, 17 healthy volunteers were randomized to oral coenzyme Q10 (100 or 300 mg/d) or placebo administration for 8 d. As a fatigue-inducing physical task, subjects performed workload trials on a bicycle ergometer at fixed workloads twice for 2 h and then rested for 4 h. During the physical tasks, subjects performed non-workload trials with maximum velocity for 10 s at 30 min (30-min trial) after the start of physical tasks and 30 min before the end of the tasks (210-min trial).

Results: The change in maximum velocity from the 30- to the 210-min trial in the 300-mg coenzyme Q10-administered group was higher than that in the placebo group. In addition, subjective fatigue sensation measured on a visual analog scale in the 300-mg coenzyme Q10-administered group after the fatigue-inducing physical task and recovery period was alleviated when compared with that in the placebo group.

Conclusion: Oral administration of coenzyme Q10 improved subjective fatigue sensation and physical performance during fatigue-inducing workload trials and might prevent unfavorable conditions as a result of physical fatigue. © 2008 Elsevier Inc. All rights reserved.

Keywords:

Fatigue; Exercise; Coenzyme Q10; Antifatigue; Physical performance; Bicycle ergometer

Introduction

Fatigue is a common symptom in sickness but is also seen in healthy individuals [1–3]. Interest has recently increased in the use of over-the-counter supplements and naturally occurring nutraceuticals for the attenuation of fatigue. However, there are no established treatment recom-

mendations for fatigue. One of the factors making it difficult to establish treatment recommendations for fatigue was that no adequate fatigue-inducing tasks have been developed. Another was that no proper evaluation methods of fatigue have been found.

Fatigue is best defined as difficulty in initiating or sustaining voluntary activity [4] and can be classified into mental and physical fatigue. We recently succeeded in establishing physical-inducing tests (Nozaki et al., unpublished observations) and in finding evaluation methods for physical fatigue. Therefore, in this study, we attempted to test the effects of candidate antifatigue substances on physical fatigue.

There are numerous reports on the biochemical mechanisms of peripheral fatigue: depletion of glycogen and phos-

This work was supported in part by Special Coordination Funds for Promoting Science and Technology, and the 21st Century COE Program “Base to Overcome Fatigue”, from the Ministry of Education, Culture, Sports, Science and Technology, the Japanese Government.

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phocreatine, which are physical energy sources; decrease in resting membrane potential or dysfunction of the calcium pump in the sarcoplasmic reticulum in skeletal muscles; and failure of neuromuscular transmission [5]. Thus, exogenous dietary substances involved in energy production are also candidate antifatigue substances for physical fatigue. Muscular exercise promotes the production of radicals and other reactive oxygen species in the working muscle [6]. Growing evidence indicates that reactive oxygen species are responsible for exercise-induced protein oxidation and contribute to physical fatigue. To protect against exercise-induced oxidative injury, muscle cells contain complex endogenous cellular defense mechanisms to eliminate reactive oxygen species. Furthermore, exogenous dietary antioxidants interact with endogenous antioxidants to form a cooperative network of cellular antioxidants. Recently, we reported that oral administration of Applephenon (Asahi Breweries, Ltd., Tokyo, Japan), an antioxidant, for 1 wk improved physical performance during fatigue-inducing workload trials on a bicycle ergometer [7]. Accordingly, exogenous dietary antioxidants are candidate antifatigue substances for physical fatigue.

Coenzyme Q10 (2,3 dimethoxy-5 methyl-6-decaprenyl benzoquinone) is a fat-soluble, vitamin-like quinone commonly known as ubiquinone or CoQ [8,9]. Coenzyme Q10 was first isolated in 1957 in beef mitochondria and is found in the highest concentrations in tissues with high-energy turnover, such as the heart, brain, liver, and kidney [9]. Coenzyme Q10 is a ubiquitous compound vital to energy metabolism. In addition, it is an indispensable compound in the respiratory chain of the inner mitochondrial membrane and acts as an essential antioxidant, assisting in the regeneration of other antioxidants [10–12]. Therefore, researchers have investigated the effects of coenzyme Q10 as an antifatigue substance during physical load in healthy volunteers [13–16]. These studies revealed that oral coenzyme Q10 administration (70–100 mg/d for several weeks or months) had no antifatigue effects based on evaluation of exercise performance, oxygen uptake, and lipid peroxidation as compared with placebo administration. However, it is possible that the dose of coenzyme Q10 was inadequate to induce antifatigue effects.

The aim of this study was to test the antifatigue effects of oral administration of 100 and 300 mg/d of coenzyme Q10 using recently established physical fatigue-inducing and evaluation methods (Nozaki et al., unpublished observations).

Materials and methods

Subjects

Seventeen healthy volunteers (37.5 ± 9.9 y of age; nine women and eight men; height 163.0 ± 8.1 cm; body weight 58.3 ± 11.3 kg; body mass index 21.9 ± 4.0 kg/m [mean \pm

SD]) were enrolled in three double-blinded, randomized, placebo-controlled, crossover trials. Participants were recruited by advertisements. Current smokers, subjects with a history of medical illness, taking chronic medication or supplemental vitamins, with a body weight <40 kg, having donated blood within 1 mo before the study, or with blood hemoglobin levels <12.0 g/dL were excluded from the experiments. Good health was also assessed by physical examination, electrocardiogram, chest X-ray, blood chemistry panel (glucose, hemoglobin A1c, creatinine, uremic nitrogen, sodium, potassium, chloride, uric acid, aspartate aminotransferase, alanine aminotransferase, γ -glutamyl transpeptidase, and creatine phosphokinase), lipid profile (total cholesterol and triacylglycerol), complete blood cell count, and urinalysis. The protocol was approved by the ethics committees of Soiken Incorporation and Soiken Clinic and was carried out in accordance with the Declaration of Helsinki. All subjects gave written informed consent for participation in the study.

Experimental design

After admission into the study, subjects were randomized in a double-blinded manner to receive three capsules of placebo (410 mg of medium-chain triacylglycerol, Sunsho Pharmaceutical Co., Ltd., Shizuoka, Japan; 40 mg of glycerin fatty acid ester, Sunsho Pharmaceutical Co., Ltd., Shizuoka, Japan) or three capsules of coenzyme Q10 (16.7 or 50 mg of coenzyme Q10, Kaneka Corporation, Osaka, Japan, and Nisshin Pharma Inc., Tokyo, Japan; 410 mg of medium-chain triacylglycerol, Sunsho Pharmaceutical Co., Ltd.; 40 mg of glycerin fatty acid ester, Sunsho Pharmaceutical Co., Ltd.) twice a day for 1 wk before the experimental day. The same subjects participated in each of the three (placebo, coenzyme Q10 100 mg, and coenzyme Q10 300 mg) experiments. No side effects were observed by oral administration of coenzyme Q10 in any subject. The day before each experiment, subjects finished dinner by 2000 h and then fasted overnight. The subjects were prohibited from bathing. At 0715 h the next day, subjects were asked to rate their subjective sensations of fatigue level on a visual analog scale from 0 (no fatigue) to 100 (total exhaustion), blood pressure and heart rate were measured, and blood samples were collected. Thereafter, the subjects had breakfast (glucose solution; TRELAN-G 75, Shimizu Pharma, Shizuoka, Japan). It has been shown that adequate plasma levels of coenzyme Q10 are essential to cause antifatigue effects [13–16]. To elevate the plasma coenzyme Q10 level, just before the start of the physical task, three capsules of placebo or coenzyme Q10 were administered in each experiment, as in our previous study [7]. As a fatigue-inducing physical task, subjects performed workload trials on a bicycle ergometer (Aerobike 75XL2 ME, Combi Wellness Co., Tokyo, Japan) at fixed workloads to reach 80% of heart rate at anaerobic threshold, as described previously (Nozaki et al., unpublished observations) for 2 h. The physical

fatigue-inducing task was successively repeated two times (total 4 h) in each (placebo or coenzyme Q10 administered) experimental day.

Physical tasks began at 0810 h. During the physical tasks, blood pressure was measured every 30 min. After the end of the final task session, subjects were asked to rate their subjective sensations of fatigue level, blood pressure and heart rate were measured, and blood samples were collected. Thereafter, subjects had lunch at 1330 h. After lunch, subjects consumed three capsules of placebo or coenzyme Q10 in each experiment and then read books or magazines, listened to music, or conversed for fatigue recovery until 1630 h. At the end of the recovery period, subjects were asked to rate their subjective sensations of fatigue, blood pressure and heart rate were measured, and blood samples were collected.

Subjects were allowed to take water only during the experiment. The contents of the dinner before the experimental day and those of lunch on the experimental day were the same among experiments. Studies were conducted in a quiet, temperature-, and humidity-controlled environment. Before each visit, subjects refrained from strenuous physical activity and had normal diets, drinks, and sleeping hours for 1 wk. The interval between each test was set at 4 wk to take into account the female subjects' menstrual cycles.

Physical performance test

During the physical tasks, subjects were asked to perform non-workload trials with maximum velocity for 10 s at 30 min (30-min trial) after the start of physical tasks and 30 min before the end of the tasks (210-min trial). If the physical performance test was performed just after the fatigue-inducing physical tasks, it was difficult to discuss whether the changes of various parameters were due to the physical performance test or physical fatigue-inducing tasks. Therefore, we performed the second physical performance test before the end of the physical tasks, as in our previous study [7]. The torque of the bicycle ergometer in each subject was calculated as 8.5% of body weight for male subjects and 7.5% of body weight for female subjects.

Blood sample analyses

Blood samples were collected from the brachial vein. Blood samples for analysis of plasma coenzyme Q10 were collected in heparin-containing tubes and centrifuged at $1700 \times g$ for 10 min at 4°C. Plasma samples (50 μL) were mixed vigorously with 250 μL of methanol and 500 μL of hexane in a 1.5-mL polypropylene tube and centrifuged at $10\,000 \times g$ for 3 min at 4°C, after which 5 μL of the hexane layer corresponding to 0.5 μL of plasma was stored at -80°C until high-performance liquid chromatographic analysis. Assays for plasma coenzyme Q10 were performed at Nikken Seil Co., Ltd. (Shizuoka, Japan) [17]. Blood samples for analysis of serum creatine phosphokinase (CPK), aspartate aminotrans-

ferase (AST), lactate dehydrogenase (LDH), free fatty acid, and cortisol were centrifuged at $1700 \times g$ for 10 min at 4°C. Blood samples for analysis of serum ascorbic acid was collected in oxalic acid-containing tubes and kept on ice until being centrifuged at $1700 \times g$ for 10 min at 4°C. Blood samples for analysis of serum tocopherol were collected in fluorescent tubes and kept on ice until being centrifuged at $1700 \times g$ for 10 min at 4°C. Blood samples for analysis of plasma glucose were collected in fluorosodium-containing tubes and centrifuged at $1700 \times g$ for 10 min at 4°C. Blood samples for analysis of plasma amino acids (valine, leucine, isoleucine and alanine) were collected in heparin-containing tubes and kept on ice until being centrifuged at $1700 \times g$ for 10 min at 4°C. Plasma samples were deproteinized with 5% trichloroacetic acid for 30 min on ice and centrifuged at $13\,600 \times g$ for 10 min at 4°C. Blood samples for analysis of plasma adrenocorticotrophic hormone (ACTH) were collected in tubes containing ethylenediamine- N,N,N',N' -tetraacetic acid and disodium salt and kept on ice until being centrifuged at $1700 \times g$ for 10 min at 4°C. Blood samples for analysis of blood lactate were collected in 0.8 N perchloric acid-containing tubes and kept on ice until being centrifuged at $1700 \times g$ for 5 min at 4°C. All supernatants were stored at -80°C until analyzed. Assays for plasma amino acids were performed at Osaka City University; assays for serum cortisol, tocopherol, and plasma ACTH were performed at Special Reference Laboratories (Tokyo, Japan); and assays for serum CPK, AST, LDH, free fatty acid, ascorbic acid, plasma glucose, and blood lactate were performed at Sakai Bio-clinical Laboratory, Inc. (Osaka, Japan).

Statistical analyses

Values are presented as means \pm SD. Two-way analysis of variance for repeated measures was used to test for comparisons between the placebo and coenzyme Q10-administered groups, followed by paired *t* test with Bonferroni's correction. All *P* values were two-tailed and those <0.05 were considered statistically significant. Analyses were performed with SPSS 11.0 (SPSS Inc., Chicago, IL, USA).

Results

The baseline scores on the visual analog scale for fatigue in the study group are shown in Figure 1, and other baseline characteristics of the study group are presented in Table 1. In the coenzyme Q10-administered groups, scores on the visual analog scale for fatigue, mean systolic blood pressure, diastolic blood pressure, heart rate, serum CPK, AST, LDH, free fatty acid, cortisol, plasma glucose, ACTH, branched-chain amino acids (BCAAs), alanine, ascorbic acid, tocopherol, and blood lactate levels did not differ from those in the placebo group. In the coenzyme Q10-

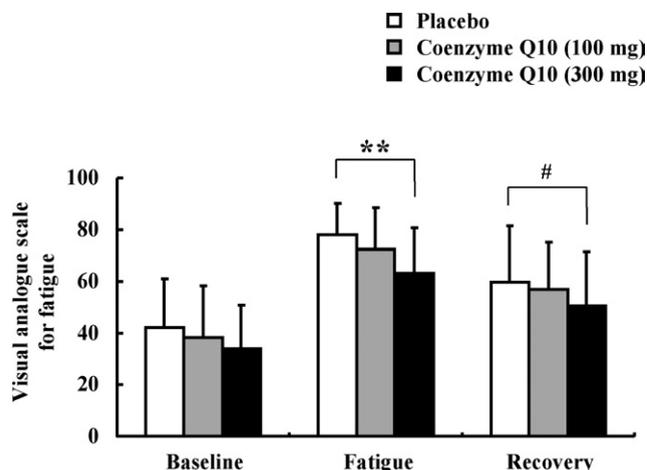


Fig. 1. Study subjects' subjective fatigue sensation before (baseline) and after (fatigue) the fatigue-inducing physical tasks and after the recovery period (recovery) from the fatigue-inducing physical tasks. Subjects were randomized to receive double-blinded placebo, 100 mg of coenzyme Q10, and 300 mg of coenzyme Q10. Subjects were asked to rate their subjective sensation of fatigue level on a visual analog scale from 0 (no fatigue) to 100 (total exhaustion). Data are presented as mean \pm SD. ** $P < 0.01$, significantly different (two-way analysis of variance for repeated measures, followed by paired t test with Bonferroni's correction). # $P < 0.1$, different (two-way analysis of variance for repeated measures, followed by paired t test with Bonferroni's correction).

administered groups, plasma coenzyme Q10 levels were dose-dependently higher than those in the placebo group.

The performance of the study group during physical tasks is presented in Figure 2 and Table 2. Mean systolic blood pressure, diastolic blood pressure, and heart rate in the coenzyme Q10-administered groups did not differ from those in the placebo group. With regard to physical performance tests, the change in maximum velocity from the 30- to the 210-min trial in the 300-mg coenzyme Q10-administered group was higher than that in the placebo group. This indicates that the decreased physical performance due to physical fatigue in the 300-mg coenzyme Q10-administered group was inhibited when compared with that in the placebo group.

The result of visual analog scale for fatigue after the fatigue-inducing physical tasks is shown in Figure 1. After the fatigue-inducing physical tasks, scores on the visual analog scale for fatigue in the 300-mg coenzyme Q10-administered group were lower than those in the placebo group. Other results for the measured parameters in the study group after the fatigue-inducing physical tasks are presented in Table 3. Mean systolic blood pressure, diastolic blood pressure, heart rate, serum CPK, AST, LDH, free fatty acid, cortisol, plasma glucose, ACTH, BCAA, alanine, ascorbic acid, tocopherol, and blood lactate levels did not differ from those of the placebo group in the coenzyme Q10-administered groups. In the coenzyme Q10-administered groups, plasma coenzyme Q10 levels remained higher than those in the placebo group.

The result of the visual analog scale for fatigue after the recovery period is shown in Figure 1. After the recovery period, scores on the visual analog scale for fatigue in the

300-mg coenzyme Q10-administered group tended to be lower than those in the placebo group. Other results for the measured parameters in the study group after the recovery period are presented in Table 4. Mean systolic blood pressure, diastolic blood pressure, heart rate, serum CPK, AST, LDH, free fatty acid, cortisol, plasma glucose, ACTH, BCAA, alanine, ascorbic acid, tocopherol, and blood lactate levels after the recovery period in the coenzyme Q10-administered groups did not differ from those in the placebo group. In the coenzyme Q10-administered groups, plasma coenzyme Q10 levels after the recovery period remained higher than those in the placebo group.

Discussion

We found that oral administration of 300 mg of coenzyme Q10 for 1 wk improved physical performance during fatigue-inducing workload trials on a bicycle ergometer. In

Table 1
Baseline characteristics of various parameters in study subjects*

	Placebo	Coenzyme Q10	
		100 mg	300 mg
SBP (mmHg)	111.8 \pm 11.4	110.6 \pm 9.1	112.6 \pm 10.9
DBP (mmHg)	66.8 \pm 8.8	65.4 \pm 6.8	67.4 \pm 9.3
HR (beats/min)	68.1 \pm 8.8	67.6 \pm 9.9	70.3 \pm 8.9
CPK (IU/L)	85.4 \pm 38.3	99.2 \pm 64.6	90.3 \pm 36.2
AST (IU/L)	15.6 \pm 3.5	15.6 \pm 3.3	18.9 \pm 12.9
LDH (IU/L)	144.0 \pm 27.5	138.9 \pm 25.4	146.2 \pm 26.4
Glucose (mmol/L)	5.5 \pm 0.3	5.5 \pm 0.4	5.5 \pm 0.4
Lactate (mmol/L)	0.79 \pm 0.41	0.72 \pm 0.25	0.94 \pm 0.67
Free fatty acid (mEq/L)	0.26 \pm 0.11	0.26 \pm 0.11	0.28 \pm 0.14
Cortisol (nmol/L)	506.8 \pm 182.3	496.2 \pm 210.1	508.9 \pm 170.1
ACTH (pmol/L)	65.7 \pm 28.1	65.3 \pm 23.6	60.7 \pm 23.2
BCAAs (μ mol/L)	405.5 \pm 56.6	393.8 \pm 59.6	406.3 \pm 65.6
Valine	224.2 \pm 29.0	215.4 \pm 30.1	224.4 \pm 36.1
Leucine	120.7 \pm 19.4	120.1 \pm 20.9	121.8 \pm 21.4
Isoleucine	60.7 \pm 9.9	58.2 \pm 10.2	60.2 \pm 10.7
Alanine (μ mol/L)	368.4 \pm 92.9	392.5 \pm 95.9	380.0 \pm 103.1
Ascorbic acid (μ mol/L)	62.1 \pm 17.4	65.6 \pm 25.5	56.6 \pm 16.0
Tocopherol (μ mol/L)	28.7 \pm 5.4	29.2 \pm 5.9	29.5 \pm 5.9
Coenzyme Q10H (μ g/mL)	0.53 \pm 0.17	1.94 \pm 0.77 [†]	3.29 \pm 1.09 [†]
Coenzyme Q10 (μ g/mL)	0.01 \pm 0.01	0.02 \pm 0.01 [†]	0.04 \pm 0.02 [†]
Total Q10 (μ g/mL)	0.54 \pm 0.18	1.96 \pm 0.79 [†]	3.33 \pm 1.10 [†]
Q10H/total (%)	98.9 \pm 0.8	98.8 \pm 0.4	98.7 \pm 0.3

ACTH, adrenocorticotropic hormone; AST, aspartate aminotransferase; BCAA, branched-chain amino acid; CPK, creatine phosphokinase; DBP, diastolic blood pressure; HR, heart rate; LDH, lactate dehydrogenase; SBP, systolic blood pressure; coenzyme Q10H, reduced form of coenzyme Q10

* Data are presented as mean \pm SD.

[†] $P < 0.01$, significantly different from corresponding values of the placebo group (two-way analysis of variance for repeated measures, followed by paired t test with Bonferroni's correction).

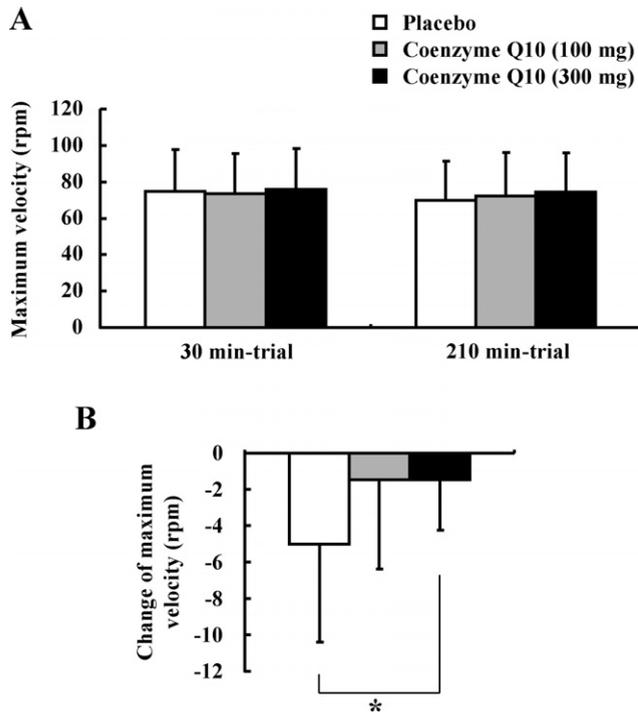


Fig. 2. Study subjects' performance during physical testing: (A) maximum velocities at the 30- and 210-min trials and (B) change of maximum velocity from the 30- to the 210-min trial. Subjects were randomized to receive double-blinded placebo, 100 mg of coenzyme Q10, and 300 mg of coenzyme Q10. During the physical performance test, subjects were asked to perform non-workload trials with a maximum velocity for 10 s at 30 min (30-min trial) after the start of physical testing and 30 min before the end of the test (210-min trial). Data are presented as mean \pm SD. * $P < 0.05$, significantly different (two-way analysis of variance for repeated measures, followed by paired t test with Bonferroni's correction).

addition, subjective fatigue sensation measured using visual analog scales in the 300-mg coenzyme Q10-administered group after the fatigue-inducing physical task and recovery period was lower when compared with that in the placebo group.

To evaluate physical performance with the ergometer, cycling performance, aerobic threshold, anaerobic threshold, and maximum oxygen uptake with workloads have generally been used [13,15,18]. These evaluation methods are performed until exhaustion. In contrast, we developed an evaluation method based on minimal fatigue load. In this

Table 2
Performance of study subjects during physical tasks*

	Placebo	Coenzyme Q10	
		100 mg	300 mg
SBP (mmHg)	123.1 \pm 10.5	123.5 \pm 10.8	122.9 \pm 10.0
DBP (mmHg)	69.0 \pm 6.3	69.2 \pm 6.9	69.8 \pm 6.2
HR (beats/min)	105.5 \pm 10.5	105.2 \pm 12.3	106.5 \pm 12.0

DBP, diastolic blood pressure; HR, heart rate; SBP, systolic blood pressure

* Data are presented as mean \pm SD.

Table 3
Effects of coenzyme Q10 on various parameters after physical tasks*

	Placebo	Coenzyme Q10	
		100 mg	300 mg
SBP (mmHg)	110.3 \pm 10.2	109.7 \pm 10.3	112.5 \pm 10.0
DBP (mmHg)	64.1 \pm 9.2	62.2 \pm 7.1	61.8 \pm 10.3
HR (beats/min)	83.5 \pm 11.1	80.6 \pm 9.3	83.8 \pm 11.4
CPK (IU/L)	100.6 \pm 47.1	127.2 \pm 104.4	105.1 \pm 38.3
AST (IU/L)	16.1 \pm 2.9	17.1 \pm 3.6	19.1 \pm 11.6
LDH (IU/L)	155.2 \pm 24.1	156.1 \pm 25.5	155.1 \pm 23.1
Glucose (mmol/L)	5.0 \pm 0.3	4.9 \pm 0.3	4.9 \pm 0.3
Lactate (mmol/L)	0.82 \pm 0.30	0.84 \pm 0.26	0.88 \pm 0.25
Free fatty acid (mEq/L)	1.22 \pm 0.36	1.21 \pm 0.3	1.21 \pm 0.25
Cortisol (nmol/L)	424.3 \pm 189.8	398.9 \pm 154.8	429.4 \pm 176.3
ACTH (pmol/L)	60.4 \pm 27.6	60.1 \pm 30.0	70.9 \pm 44.2
BCAAs (μ mol/L)	364.9 \pm 55.7	347.0 \pm 43.8	356.1 \pm 60.1
Valine	195.2 \pm 31.3	185.3 \pm 22.6	191.4 \pm 33.1
Leucine	113.2 \pm 17.8	108.8 \pm 15.6	110.2 \pm 20.2
Isoleucine	56.4 \pm 8.3	52.9 \pm 7.5	54.6 \pm 9.0
Alanine (μ mol/L)	277.2 \pm 55.8	255.3 \pm 41.5	254.3 \pm 45.0
Ascorbic acid (μ mol/L)	67.0 \pm 17.7	68.9 \pm 25.9	60.7 \pm 17.3
Tocopherol (μ mol/L)	29.4 \pm 5.2	29.2 \pm 6.5	29.7 \pm 5.8
Coenzyme Q10H (μ g/mL)	0.54 \pm 0.17	2.05 \pm 0.79 [†]	3.07 \pm 1.09 [†]
Coenzyme Q10 (μ g/mL)	0.01 \pm 0.01	0.03 \pm 0.02 [†]	0.04 \pm 0.01 [†]
Total Q10 (μ g/mL)	0.55 \pm 0.18	2.08 \pm 0.80 [†]	3.11 \pm 1.10 [†]
Q10H/total (%)	98.3 \pm 1.0	98.7 \pm 0.6	98.7 \pm 0.4

ACTH, adrenocorticotropic hormone; AST, aspartate aminotransferase; BCAA, branched-chain amino acid; CPK, creatine phosphokinase; DBP, diastolic blood pressure; HR, heart rate; LDH, lactate dehydrogenase; SBP, systolic blood pressure; coenzyme Q10H, reduced form of coenzyme Q10

* Data are presented as mean \pm SD.

[†] $P < 0.01$, significantly different from corresponding values of the placebo group (two-way analysis of variance for repeated measures, followed by paired t test with Bonferroni's correction).

study, during the fatigue-inducing physical tasks, subjects performed non-workload trials with maximum velocity for 10 s. Using this method, we were able to assess physical performance with minimal additional effect on physical fatigue.

As mentioned in the INTRODUCTION, exercise-induced reductions in energy substrates, reactive oxygen species, and protein oxidation are thought to be associated with physical fatigue. Coenzyme Q10 is a vitamin-like, lipid-soluble compound existing in all cells [10]. It is an indispensable compound in the respiratory chain of the inner mitochondrial membrane and acts as an essential antioxidant assisting in the regeneration of other antioxidants [10–12]. It has been shown that coenzyme Q10 has a protective effect against an excessive reduction in mitochondrial membrane phospholipids during prolonged exercise [19], and treatment with coenzyme Q10 improves muscle phosphocreatine recovery from exercise [20]. Therefore, administration of coenzyme

Table 4
Effects of coenzyme Q10 on various parameters after recovery period*

	Placebo	Coenzyme Q10	
		100 mg	300 mg
SBP (mmHg)	110.1 ± 10.1	111.8 ± 11.3	113.2 ± 10.0
DBP (mmHg)	60.5 ± 8.4	63.1 ± 7.7	64.4 ± 10.8
HR (beats/min)	83.5 ± 11.1	80.6 ± 9.3	83.8 ± 11.4
CPK (IU/L)	102.3 ± 44.0	131.6 ± 118.0	111.9 ± 41.3
AST (IU/L)	14.6 ± 2.6	15.8 ± 3.8	17.7 ± 10.6
LDH (IU/L)	150.6 ± 25.1	151.8 ± 6.3	148.3 ± 33.1
Glucose (mmol/L)	6.4 ± 0.7	6.4 ± 0.9	6.2 ± 0.7
Lactate (mmol/L)	1.02 ± 0.46	0.92 ± 0.29	0.87 ± 0.26
Free fatty acid (mEq/L)	0.06 ± 0.13	0.08 ± 0.19	0.03 ± 0.02
Cortisol (nmol/L)	355.9 ± 219.8	371.8 ± 189.5	315.0 ± 122.4
ACTH (pmol/L)	46.2 ± 40.1	115.9 ± 322.7	40.6 ± 30.6
BCAAs (μmol/L)	292.1 ± 43.5	286.4 ± 41.3	289.9 ± 49.4
Valine	173.8 ± 24.5	169.4 ± 22.1	172.5 ± 28.1
Leucine	78.3 ± 14.3	78.2 ± 14.3	77.7 ± 16.1
Isoleucine	40.1 ± 7.7	38.8 ± 8.1	39.7 ± 6.1
Alanine (μmol/L)	289.3 ± 9.6	298.5 ± 51.5	300.1 ± 41.8
Ascorbic acid (μmol/L)	61.2 ± 17.1	64.2 ± 23.8	56.3 ± 18.3
Tocopherol (μmol/L)	26.0 ± 4.7	25.8 ± 5.5	25.9 ± 4.9
Coenzyme Q10H (μg/mL)	0.55 ± 0.18	2.04 ± 1.00 [†]	3.06 ± 1.15 [†]
Coenzyme Q10 (μg/mL)	0.01 ± 0.01	0.02 ± 0.01 [†]	0.03 ± 0.01 [†]
Total Q10 (μg/mL)	0.55 ± 0.18	2.06 ± 1.01 [†]	3.09 ± 1.15 [†]
Q10H/total (%)	98.9 ± 1.0	98.8 ± 0.6	98.9 ± 0.3

ACTH, adrenocorticotropic hormone; AST, aspartate aminotransferase; BCAA, branched-chain amino acid; CPK, creatine phosphokinase; DBP, diastolic blood pressure; HR, heart rate; LDH, lactate dehydrogenase; SBP, systolic blood pressure; coenzyme Q10H, reduced form of coenzyme Q10

* Data are presented as mean ± SD.

[†] $P < 0.01$, significantly different from corresponding values of the placebo group (two-way analysis of variance for repeated measures, followed by paired t test with Bonferroni's correction).

Q10 may attenuate physical fatigue through its functions as an antioxidant or in assisting oxidative phosphorylation.

We found that oral administration of 300 mg of coenzyme Q10 for 1 wk improved physical performance during fatigue-inducing workload trials on a bicycle ergometer. However, this positive result was not seen in the group administered 100 mg of coenzyme Q10. In previous studies, groups administered coenzyme Q10 (70–100 mg for several weeks or months) have shown no antifatigue effects compared with placebo groups. Consistent with the present study, the levels of plasma coenzyme Q10 in these groups administered coenzyme Q10 (70–100 mg) were $<2 \mu\text{g/mL}$. In contrast, Ylikoski et al. [21] reported that, although the dose of coenzyme Q10 (90 mg) for 6 wk was not rich, levels of plasma coenzyme Q10 in the coenzyme Q10-administered group increased from 0.8 to 2.8 $\mu\text{g/mL}$ and physical performance was improved compared with the placebo group. These results suggest that adequate plasma levels of coenzyme Q10 may be important in inducing antifatigue effects.

Subjective fatigue sensation measured using a visual analog scale in the 300-mg coenzyme Q10-administered group after the fatigue-inducing physical task and recovery period was improved. Porter et al. [22] reported that subjects administered coenzyme Q10 (150 mg for 2 mo) showed an increase in perception of vigor in the resting condition using a visual analog scale. Moreover, Ylikoski et al. [21] found that 70% of coenzyme Q10-administered subjects reported positive effects of supplementation during exercise and after recovery from fatigue. These results indicate that the effects of supplementation with coenzyme Q10 are not only an improvement of exercise performance but also a decrease in the extent of subjective fatigue sensation. However, the role of coenzyme Q10 in central fatigue is still unclear. Therefore, additional investigations need to be undertaken to better elucidate the role of coenzyme Q10 in central fatigue.

We conducted this study with a limited number of subjects, administration dose, and administration time schedule. To generalize our results, studies involving larger numbers of subjects and a variety of administration doses and time schedules are essential.

Conclusion

We demonstrated that oral administration of coenzyme Q10 improved subjective fatigue sensation and physical performance during fatigue-inducing workload trials. The present data suggest that administration of coenzyme Q10 might prevent unfavorable conditions as a result of physical fatigue.

Acknowledgments

The authors thank Dr. Tim Jones for editorial help with the manuscript.

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