THE ROLE OF COENZYME Q_{10} AND CIRCUIT RESISTANCE TRAINING ON ENERGY EXPENDITURE AT REST AND DURING SUBMAXIMAL TREADMILL WALKING IN 40-60 YEAR-OLD OVERWEIGHT WOMEN

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Abstract:

Coenzyme Q_{10} (CoQ_{10}) helps the body produce energy within cell from converting the energy in carbohydrates and fatty acids into ATP production. However, the association between CoQ_{10} and/or circuit resistance training on energy expenditure has never been clarified. The objectives were to investigate the role of CoQ_{10} and/or circuit resistance training on energy expenditure in 40-60 year-old overweight women. Forty-eight overweight women subjects at Bank of Thailand, were enrolled. Subjects were purposively assigned to one of four groups: Group 1 (CoQ_{10}) with supplemented CoQ_{10} only (n=12), group 2 (Ex) with circuit resistance training only (n=12), group 3 (Ex&CoQ_{10}) with both supplemented CoQ_{10} and circuit resistance training (n=12), and group 4 control group (n=12). CoQ10 was taken in 100 mg capsules two times daily after meals for 12 weeks. After treatment, VO_2Max was found to be significantly increased in group 1 (CoQ_{10}), group 2 (Ex) and group3 (Ex&CoQ_{10}) and there were significant differences between all experimental groups and the control group. Moreover, plasma CoQ10 levels were significantly increased within all groups. There were significant differences in plasma CoQ10 levels between group 1 (CoQ_{10}) and control group, group 1 (CoQ_{10}) and group 2 (Ex), group 3 (Ex&CoQ_{10}) and control group as well as group 3 (Ex&CoQ_{10}) and group 2 (Ex). Also, weight and BMI were significantly decreased in group 2 (Ex) and group 3 (Ex&CoQ_{10}). Fat free mass (FFM) was significantly decreased in group 3 (Ex&CoQ_{10}) but Fat mass (FM) was found to be significantly decreased in group 2 (Ex), group 3 (Ex&CoQ_{10}) and group 4 (control group). Resting energy expenditure (REE) was found to be significantly decreased in group 1 (CoQ_{10}), group 2 (Ex) and group 4 (control group).Walking energy expenditure, glucose levels, cholesterol, triglycerides, LDL and HDL did not differ significantly among groups in both before and after treatment. After treatment, no significant differences were found in energy expenditure at rest and during submaximal treadmill walking among all groups. However, maximum oxygen consumption (VO_2Max) and plasma CoQ10 levels were likely found to have positive effects in overweight subjects with supplemented CoQ10 and/or circuit resistance training. Moreover, the researcher found positive correlation between maximum oxygen consumption (VO_2Max) and plasma CoQ10 levels.

Keywords: CoQ10, Circuit resistance training, Energy expenditure, Overweight women, Thailand

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INTRODUCTION

Coenzyme Q_{10} is an essential cofactor in mitochondrial oxidative phosphorylation and necessary for ATP production. In this role, CoQ_{10} acts as a mobile electron carrier, transferring electrons from complex I (NADH coenzyme Q reductase) to complex III (cytochrome bc1 complex) or from complex II (succinate dehydrogenase) to complex III [1]. This coenzyme helps in many diseases like congestive heart failure, diabetes etc. It helps heart by increasing the flow of blood with

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oxygen to the heart and thus preventing cholesterol buildup [2]. Moreover, CoQ_{10} may increase in energy expenditure because it helps the energy production by transferring electrons from NADH and $FADH_2$ to oxygen [1].

Previous studies have found that CoQ_{10} supplementation (60–100 mg/day for 4–8 weeks) improves aerobic power, anaerobic threshold, exercise performance, and/or recovery after exercise in trained athletes and untrained individuals [3-5]. These findings suggest that provision of CoQ_{10} in a fast-melt or effervescent form may facilitate CoQ_{10} delivery and uptake to the muscle. Theoretically, this may enhance bioavailability of CoQ_{10} and promote a greater metabolic and/or ergogenic impact. However, the effects of CoQ_{10} on energy expenditure and exercise performance have never been clarified.

To cope with the problems more effectively, the objectives of this research were to study the role of CoQ_{10} and/or circuit resistance training on energy expenditure at rest and during submaximal treadmill walking in 40-60 years old overweight women.

METHODOLOGY

This study was approved by the Ethics Review Committee for Research Involving Human Research Subjects, Health Science Group, College of Public Health Sciences, Chulalongkorn University.

Forty-eight overweight women subjects based on the Western Pacific Region criteria were recruited from the Bank of Thailand (BOT). Inclusion criteria included participants answered no to all the PAR-Q questions, healthy women ages ranged 40 to 60 years old, non-smoking and non-alcohol drinking at least 6 months before the study, participants agreed to sign informed consent form, overweight determined by BMI in adult Asians; Overweight ≥ 23-27.4, the Western Pacific Region [6]. Exclusion criteria included participants answered yes to one or more in PAR-Q questions, complications or co-morbidities associated with cardiovascular disease, obesity or metabolic disease, severe arterial hypertension, dizziness or syncope after cessation of exercise, taking Warfarin and Statin group for treatment of hypercholesterolemia, and participants desired to stop.

A randomized control experimental intervention of 12 weeks duration was to perform in subjects with uncomplicated overweight women. Pilot studies with three participants were used to test logistic procedure of equipment and gather information prior to a larger study. Samples were obtained by voluntary process and purposive sampling. Research assistants were trained to standardize their performances and work under the supervision. The researcher ran the screening process combined with individual medical history such as PAR-Q, anthropometric measurements, body composition, laboratory blood tests, gas analysis and individual medical record. The instruments were verified by calibration before testing every time.

Subjects were purposively assigned into one of four groups: Group 1 (CoQ_{10}) with supplemented CoQ_{10} only (n=12), group 2 (Ex) with circuit resistance training only (n=12), group 3 (Ex&CoQ_{10}) with both supplemented CoQ_{10} and circuit resistance training (n=12), and group 4 control group (n=12). CoQ_{10} was taken as 200 mg per day (100 mg twice daily) (CoQ_{10} TruNature® - 100 mg 150 Soft gels, USP Verified, USA) after a meal for 12 weeks.

Anthropometric measurements

The anthropometric measurements were taken in the morning before breakfast then after the measurement, breakfast was provided for the participants. The body weight was measured according to the international standards [7] by using a body composition analyzer (ioi-353, Jawon Medical, Korea). The BMI was calculated by dividing the weight in kilograms by the height in square metres, as set out in the anthropometric measurement standardization methodology handbook [8].

Body composition

Body composition was evaluated using a bioelectrical impedance analyzer (ioi-353, Jawon Medical, Korea). It directly measured bioimpedance of each body part as allowing the current and voltage into the body via tetra-polar method using 8 touch electrodes. Body composition analyzer ioi-353 approved accuracy with high correlativity to DEXA.

Chemical analysis

Chemical reagents: CoQ_{10} reference standard was provided to each of the collaborating laboratories. The reference standard was obtained from Sigma-Aldrich (St. Louis, MO; P/N C9538) and the purity was determined by HPLC analysis against a USP reference standard. The method of analysis was followed by Littarru et al. [9] and Lunetta et al. [10]. Peak area analysis was performed by Millenium[32] software system.

Biochemistry

Venous blood sample was collected at baseline and at the end of intervention in the morning after a 12 h overnight fast. Blood samples, which were kept on ice or in refrigerated at 4°C, were processed identically at hourly intervals up to 8 h after collection. For those tests not carry out immediately, serum and plasma frozen at -80°C and thaw immediately prior to analysis, all within a three-month period.

Laboratory blood tests

Two tubes of blood samples (4-6 ml/tube); one was operated at Department of Clinical Chemistry, Faculty of Allied Health Sciences, Chulalongkorn University to test fasting blood glucose, total cholesterol (TC), triglyceride (TG), high density lipoprotein (HDL) and low density lipoprotein (LDL) and the other was operated at the Center for Instrument Facility (CIF), Faculty of science, Mahidol University was to test plasma CoQ_{10} levels.

Gas analysis

A portable cardiopulmonary exercise system (MetaMax 3B) operated with a volume sensor which was integrated into a mask as well as oxygen and carbon dioxide sensors (Cortex Biophysik, Germany). Gas analysis was manipulated at Sports Science Laboratory, Faculty of Sports Science, Chulalongkorn University.

The method of automated breath-by-breath analysis was presented as either l/min (litres per minute) or ml/kg/min (millilitre of oxygen per kilogram of body weight per minute).

Measuring resting energy expenditure

Resting Energy Expenditure (REE) was measured by indirect calorimetry using a portable telemetric gas analyzer (Metamax 3B, Germany), oxygen consumption and carbon dioxide production were measured and converted to energy expenditure using Weir equation [11].

$$\text{REE (kcal)} = \left[\left(VO_2 \frac{L}{min}\right)(3.941) + \left(VCO_2 \frac{L}{min}\right)(1.11)\right] \text{1440 minutes}$$

Where VO_2 and VCO_2 were expressed in L/min and 1440 was equal to the number of minutes in a day.

The acceptability criteria of recordings as obtained from data points were collected every 30 s and steady-state was defined as 10 min during which the volume of oxygen uptake, VE and RER did not vary >10%. Age, weight, height and sex were fed into the computer manually. The measurements were performed between 8.00 and 10.00 AM at approximately the same time for each individual, with empty stomach (at least 12 hours) and free from any type of strenuous physical activities for at least 24 hours.

Measuring energy expenditure during treadmill test

The subject was wearing a breathing face mask. Age, weight, height, sex and walking speed were fed into the computer manually. After a rest period of 15 min to stabilize circulation and breathing, the calorimetric measurements started with a 10-min walk at the selected speed of 5 km/h on the treadmill [12].

Gas measurements were made every 30 s. Borg's scale was used at the end of every 1-min period to rate the perceived exertion (manual recording). Talking was avoided during the walking sessions. Basic measures of exercise responses included HR, BP, respiratory rate (RR), and rate of perceived exertion (RPE). The RPE was recorded according to the method of Borg scale, using the rate of perceived exertion (RPE) scale 6–20 [13]. The energy expenditure during walking sessions was calculated according to the formula [11].

$$EE\left(\frac{\frac{kcal}{kg}}{min}\right) = 3.941 \times VO_2\left(\frac{\frac{ml}{kg}}{min}\right) + 1.106 \times VCO_2\left(\frac{\frac{ml}{kg}}{min}\right)$$

Estimating VO_2 Max

The single stage treadmill walking test was a submaximal aerobic fitness test that estimating VO_2 max. It was suitable for low risk, apparently healthy, non-athletic adults 20-59 years of age. The walking pace required throughout the test also made it appropriate for participants who experience problems such as knee pain when exercising at a jogging pace. The test was administered to moderate sized groups of participants with low to moderate fitness levels and required only a treadmill and a HR monitor [14].

Circuit resistance protocol

The circuit resistance training (CRT) program was trained by pulling the band for 3 circuits (10 muscle training positions in each circuit with 60-90 seconds rest interval between each circuit). Each muscle training position was trained with 1 set and with 8-12 repetitions a set and then was alternatively trained with the other muscle groups without any break in one circuit. They were trained 3 days a week for every other day.

Table 1 Baseline characteristics of the subjects (n=12 in each group)

Characteristics	Control (n=12)			CoQ_{10} (n=12)			Ex (n=12)			Ex&CoQ_{10} (n=12)			*P-value*
	Mean		SD	Mean		SD	Mean		SD	Mean		SD	
Age (year)	48.7	±	3.57	50.1	±	5.82	52.3	±	6.23	50.9	±	4.1	0.377
Weight (kg)	60.7	±	5.57	62.6	±	6.12	60.8	±	5.79	64	±	4.89	0.988
Height (cm)	157	±	4.2	156	±	4.72	157	±	6.59	157	±	5	0.429
BMI (kg/m^2)	24.8	±	1.48	25.6	±	1.12	24.7	±	1.28	25.9	±	1.35	0.085

CoQ_{10} = Supplemented CoQ_{10} only, Ex = Circuit resistance training only, Ex&CoQ_{10} = Supplemented CoQ_{10} with circuit resistance training and Control Group. Each parameter represents Mean ± SD. *Significant if p<0.05 among group of subjects.

Circuit Resistance Training Program	
Load	3 sets with 8-12 RM each set
Number of exercise	10 exercises
Time per set	30-60 seconds
10 exercises per session	3 sessions
Rest interval between sets	Continuous
Rest interval between circuits	60-90 seconds
Speed of execution	Slow to medium
Frequency	3 alternate days per week (Monday, Wednesday, and Friday)

Protection of human subjects

To ensure the human right protection of the subjects, the overweight women would be informed about the research objectives and procedures required for cooperation. The participants had the freedom to withdraw their participation at any time without any effects. Each subject would be coded for the identification number that matches the participant's code in the data form. The participant's identity was not mentioned or discussed with anyone. The data collected were kept strictly confidential and would be presented as group of data only.

Data analysis

Descriptive statistic including percentages, mean and standard deviation were used to analyze the demographic data. The Kolmogorov-Smirnov test was used to assess normal distribution of independent and dependent variables. One-way analysis of covariance (ANCOVA) was used to determine the difference between groups of subjects by using pretreatment evaluation as covariate and the differences in pairs of means among groups were made by Fisher's Least Significant Difference (LSD) test. Paired t-test was used to determine the difference between results of before and after treatment. Pearson's Product Moment Correlation was used to present the relationships between CoQ_{10} and VO_2Max by using Fisher & Corcora's relationship criteria (r). If the statistical probability (p-value) was less than or equal to 0.05, the differences were consider to be statistically significant. All data were analyzed by using the SPSS software (version 17).

RESULTS

Forty-eight overweight subjects participated (aged 50.5 ± 4.93 years, height 156.75 ± 5.13 cm, body weight 62.0 ± 5.6 kg, and BMI 25.25 ± 1.31 kg/m^2) in this study. Participants completed an informed consent form, medical history, dietary, and Physical Activity Readiness Questionnaire (PAR-Q) to determine acceptability. Participants were non-smoking and non-alcohol drinking at least 6 months before the study.

All subjects were purposively assigned into one of four groups: Group 1 (CoQ_{10}); supplemented CoQ_{10} only (n=12), group 2 (Ex); circuit resistance training only (n=12), group 3 (Ex&CoQ_{10}); both supplemented CoQ_{10} with circuit resistance training (n=12), group 4 (Control); control group (n=12). CoQ_{10} was taking as 100 mg capsules two times daily. The baseline characteristics of the subjects were shown in Table 1. There were no statistical significant differences among four groups in age, weight, height, and BMI (p<0.05).

The morphological, physiological and biochemical characteristics were shown in Table 2. After treatment, there was significant difference among group in maximum oxygen consumption (VO_2Max) between group 1 (CoQ_{10}) (VO_2Max $33.6^{*a\#}$ ± 2.6 ml/kg/min) and control group (VO_2Max 32.3 ± 3.4 ml/kg/min), group 2 (Ex) (VO_2Max $34.5^{*a\#}$ ± 2.4 ml/kg/min) and control group (VO_2Max 32.3 ± 3.4 ml/kg/min), and also between group 3 (Ex&CoQ_{10}) (VO_2Max $34.6^{*a\#}$ ± 1.7 ml/kg/min) and control group (VO_2Max 32.3 ± 3.4 ml/kg/min), respectively. Moreover, there was significant difference among group in plasma

Table 2 Morphological, physiological and biochemical characteristics before and after treatment in each group (n=12 in each group)

Parameters	Control (n=12)						CoQ_{10} (n=12)						Ex (n=12)						Ex & CoQ_{10} (n=12)					
	Before			After			Before			After			Before			After			Before			After		
	Mean		SD	Mean		SD	Mean		SD	Mean		SD	Mean		SD	Mean		SD	Mean		SD	Mean		SD
Weight (kg)	60.7	±	5.57	60.2	±	4.11	62.6	±	6.13	62.3	±	6.09	60.8	±	5.8	59.8$^{\#}$	±	5.8	64	±	4.9	63.3$^{\#}$	±	4.9
BMI (kg/m^2)	24.8	±	1.48	24.4	±	1.09	25.6	±	1.12	25.4	±	1.23	24.7	±	1.28	24.3$^{\#}$	±	1.44	25.9	±	1.35	25.6$^{\#}$	±	1.3
FFM (kg)	40.7	±	2.84	40.4	±	2.53	41.7	±	4	41.4	±	3.89	40.8	±	3.65	40.4	±	3.93	41.7	±	3.2	41.4$^{\#}$	±	3.13
FM (kg)	20.8	±	2.57	19.9$^{\#}$	±	1.84	20.9	±	2.24	20.7	±	2.48	20	±	3.02	19.4$^{\#}$	±	2.96	22.2	±	2.6	21.7$^{\#}$	±	2.46
REE (kcal)	1726	±	358	1370$^{\#}$	±	389	1736	±	290	1460$^{\#}$	±	264	1780	±	262	1435$^{\#}$	±	363	1426	±	403	1444	±	305
EE Walk (kcal)	70.3	±	17.9	63.1	±	25.3	66.4	±	16.1	75.1	±	9	69.6	±	22.9	75.9	±	16.4	69	±	21.1	74.5	±	14.1
VO_2Max (ml/kg/min)	33.4	±	3.2	32.3	±	3.4	30.4	±	1.8	33.6$^{*a\#}$	±	2.6	32.5$^{\mathbf{b}}$	±	2	34.5$^{*a\#}$	±	2.4	31.6	±	1.5	34.6$^{*a\#}$	±	1.7
Glucose (mg/dl)	89.4	±	6.7	90.1	±	6	90.2	±	8.5	89.2	±	9.3	90.3	±	6.7	88.8	±	6.4	92.6	±	8.5	90.4	±	6.6
TC (mg/dl)	211	±	34.7	214	±	28.3	229	±	36.6	217	±	29.1	229	±	55.5	223	±	29.9	224	±	28.7	216	±	30.4
TG (mg/dl)	88.5	±	31.8	110	±	46.8	122	±	68.6	116	±	48.7	134	±	73.5	148	±	91.9	105	±	52.9	113	±	82.5
LDL (mg/dl)	134	±	27.7	131	±	30	148	±	30	135	±	25.3	146	±	50.6	140	±	24.9	141	±	26.6	134	±	29.2
HDL (mg/dl)	59.4	±	17.9	61	±	14.7	56.5	±	12.5	58.7	±	13.7	56.6	±	14.4	53.3	±	11.5	61.7	±	19.2	59.4	±	22.5
CoQ_{10} (µmol/l)	0.24	±	0.07	0.43$^{\#}$	±	0.12	0.23	±	0.09	0.90*$^{a\#}$	±	0.44	0.25	±	0.1	0.53$^{b\#}$	±	0.19	0.3	±	0.12	0.94$^{ac*\#}$	±	0.18

Group 1 = Supplemented CoQ_{10} only (CoQ_{10}), Group 2 = Circuit resistance training only (Ex), Group 3 = Supplemented CoQ_{10} with circuit resistance training (Ex&CoQ_{10}) and Control Group. Each parameter represents mean ± SD. * Significant difference between groups of subjects by using one-way ANCOVA ($p<0.05$)**,** **a** Significant comparing with control ($p<0.05$), **b** Significant comparing with CoQ_{10} ($p<0.05$), **c** Significant comparing with Ex ($p<0.05$).

$^{\#}$ Significant difference between before and after treatment by paired t-test ($p<0.05$)

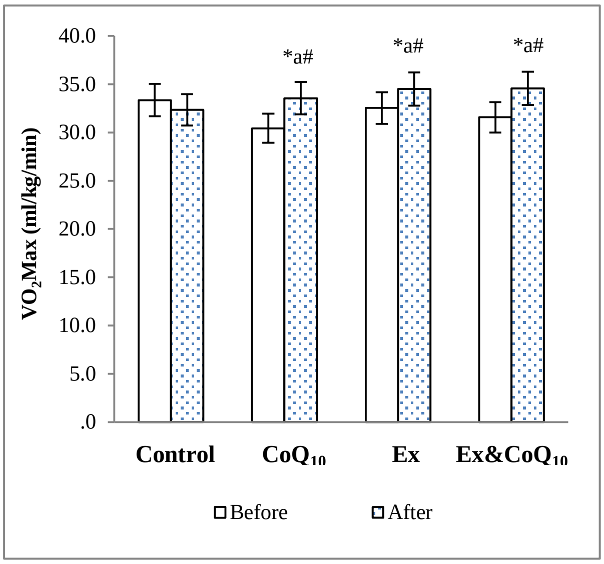

Figure 1 VO_2Max (ml/kg/min) before and after treatment.
Each parameter represents Mean ± SD.
* Significant between groups of subjects ($p<0.05$)
a Significant comparing with control ($p<0.05$)
Significant between before and after treatment ($p<0.05$)

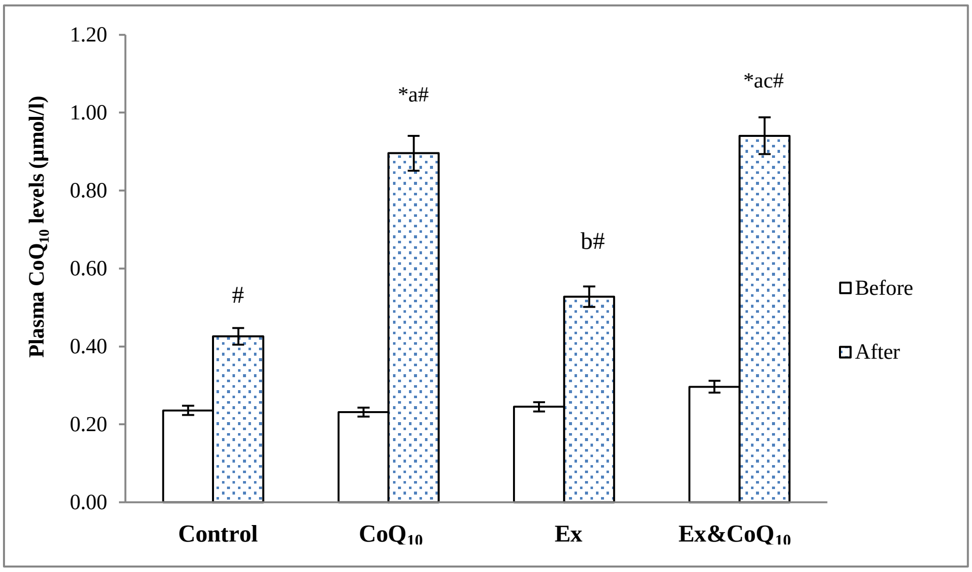

Figure 2 Plasma CoQ_{10} (µmol/l) levels before and after treatment.
Each parameter represents Mean ± SD.
* Significant between groups of subjects ($p<0.05$)
a Significant comparing with control ($p<0.05$)
b Significant comparing with CoQ_{10} ($p<0.05$)
c Significant comparing with Ex ($p<0.05$)
Significant between before and after treatment ($p<0.05$)

CoQ_{10} levels between group 1 (CoQ_{10}) (CoQ_{10} 0.90*[a] ± 0.44 µmol/l) and control group (CoQ_{10} 0.43 ± 0.12 µmol/l) as well as group 1 (CoQ_{10}) (CoQ_{10} 0.90*[a] ± 0.44 µmol/l) and group 2 (Ex) (CoQ_{10} 0.53[b#] ± 0.19 µmol/l) and also between group 3 (Ex&CoQ_{10}) (CoQ_{10} 0.94*[ac] ± 0.18 µmol/l) and control group (CoQ_{10} 0.43 ± 0.12 µmol/l) as well as group 3 (Ex&CoQ_{10}) (CoQ_{10} 0.94*[ac] ± 0.18 µmol/l) and group 2 (Ex) (CoQ_{10} 0.53[b#] ± 0.19 µmol/l), respectively. In addition, there was significant difference between before and after treatment including weight (kg) in group 2 (Ex) (60.8 ± 5.8 vs. 59.8[#] ± 5.8) and group 3 (Ex&CoQ_{10}) (64 ± 4.9 vs. 63.3[#] ± 4.9); BMI (kg/m^2) in group 2 (Ex) (24.7 ± 1.28 vs. 24.3[#] ± 1.44) and group 3 (Ex&CoQ_{10}) (25.9 ± 1.35 vs. 25.6[#] ± 1.3); FFM (kg) in group 3 (Ex&CoQ_{10}) (41.7 ± 3.2 vs. 41.4[#] ± 3.13); FM (kg) in control group, group 2 (Ex) (20 ± 3.02 vs. 19.4[#] ± 2.96) and group 3 (Ex&CoQ_{10}) (22.2 ± 2.6 vs. 21.7[#] ± 2.46); REE (kcal) in control group, group 1 (CoQ_{10}) (1736 ± 290 vs. 1460[#] ± 264) and group 2

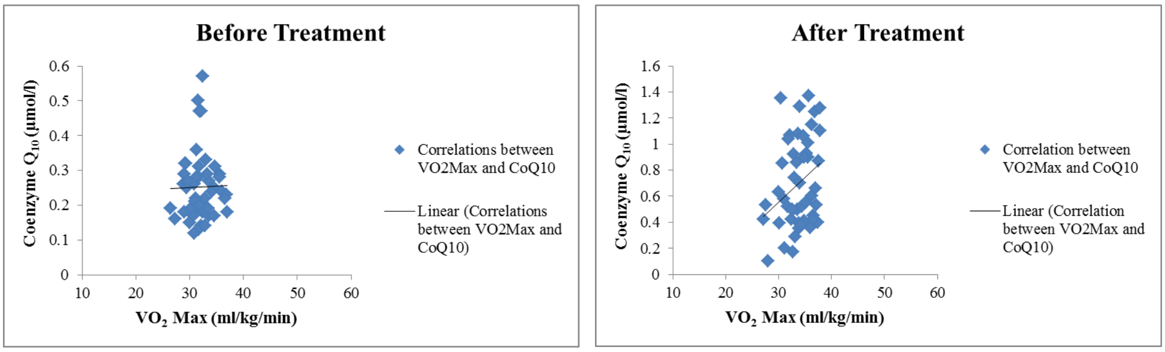

Figure 3 Correlations between VO_2Max and CoQ_{10} before and after treatment

Table 3 The Pearson correlation coefficient between VO_2Max and CoQ_{10} before and after treatment

Correlations		**Before treatment**		**After treatment**	
		VO_2Max	**CoQ_{10}**	**VO_2Max**	**CoQ_{10}**
VO_2Max	Pearson Correlation	1	.024	1	.298*
	Sig. (1-tailed)		.434		.020
	N	48	48	48	48
CoQ_{10}	Pearson Correlation	.024	1	.298*	1
	Sig. (1-tailed)	.434		.020	
	N	48	48	48	48

* Correlation is significant at the 0.05 level (1-tailed)

(Ex) (1780 ± 262 vs. $1435^{\#}$ ± 363); VO_2Max (ml/kg/min) in group 1 (CoQ_{10}) (30.4 ± 1.8 vs. $33.6^{*a\#}$ ± 2.6) and group 2 (Ex) (32.5 ± 2 vs $34.5^{*a\#}$ ± 2.4) and group 3 (Ex&CoQ_{10}) (31.6 ± 1.5 vs $34.6^{*a\#}$ ± 1.7) ; CoQ_{10} (µmol/l) in in control group (0.24 ± 0.07 vs. $0.43^{\#}$ ± 0.12), group 1 (CoQ_{10}) (0.23 ± 0.09 vs. $0.90*^{a\#}$ ± 0.44), group 2 (Ex) (0.25 ± 0.1 vs. $0.53^{b\#}$ ± 0.19) and group 3 (Ex&CoQ_{10}) (0.3 ± 0.12 vs $0.94*^{ac\#}$ ± 0.18). No significant differences were found between before and after treatment in EE Walk (kcal), Glucose (mg/dl), Cholesterol (mg/dl), Triglycerides (mg/dl), LDL (mg/dl) and HDL (mg/dl) ($p<0.05$), respectively. The results of VO_2Max before and after treatments were demonstrated in Figure 1. Plasma CoQ_{10} levels before and after treatments were demonstrated in Figure 2. After treatment, Figure 3 showed the correlation between VO_2Max and plasma CoQ_{10} levels in all four groups both before and after the experiment. Table 3 showed the significant positive low correlations between VO_2Max and plasma CoQ_{10} levels in all four groups ($r = 0.298$, $p <0.05$).

DISCUSSION

Previous studies have reported that CoQ_{10} is an essential cofactor involved in the electron transport pathway that is released from aerobic respiration within the mitochondria [1]. Recent studies have shown the provision of facilitating CoQ_{10} delivery and uptake to the muscle cell. Theoretically, this may enhance bioavailability of CoQ_{10} and promote greater energy expenditure. However, the effects of CoQ_{10} and/or exercise performance on plasma CoQ_{10} concentrations have never been clarified. Therefore, this study aimed to determine the role of CoQ_{10} and/or circuit resistance training on energy expenditure in overweight women. Body mass index (BMI) was used as a guideline to screen the overweight women to achieve a realistic target with a high probability of health benefits.

The results of this study showed that weight and BMI in this study was significantly lower after treatments in group 2 (Ex) and group 3 (Ex&CoQ_{10}). Fat mass (FM) was significantly lower after treatments in group 2 (Ex), group 3 (Ex&CoQ_{10}) and control group. Fat mass (FM) decreased in control group possibly caused by intervening variables in test-retest situations, related to the calorie restriction or fasting [15]. An unexpected result in fat free mass (FFM) in group 3 (Ex&CoQ_{10}) was significantly lower after treatments might be affected by dietary restriction induced degradation in body weight and BMI, which was based on decreasing in FM and FFM [16]. Resting energy expenditure (REE) was found to be significantly decreased in group 1 (CoQ_{10}), group 2 (Ex) and group 4 (control group). But energy expenditure during treadmill walking (EE walk) was not significant difference between before and after treatments. The negative results in REE and EE walk in this research may be caused by dietary restriction and/or insufficient recovery after training session. Moreover, some researches had suggested that the number of repetitions, sets, and intensity used for each exercise should be varied over time for progression [17]. Glucose, cholesterol, triglyceride, LDL and HDL were found to be no significant differences among all groups in both before and after treatment. The adverse effects of the previous results also supports the recent study that elastic band exercise for 12 weeks did not change in blood lipids but significantly improved body composition and overall physical fitness in the elderly [18]. This can be considered that the overweight subjects in this study had no experience of circuit resistance training enough to exert a significant beneficial effect or shorter duration of training.

In addition, the results of this study showed that maximum oxygen consumption (VO_2Max) was significantly higher after treatments in group 1 (CoQ_{10}), group 2 (Ex) and group 3 (Ex&CoQ_{10}). It was possible that the CoQ_{10} supplementation and/or circuit resistance training have shown the performance-enhancing effects after treatment [19]. Plasma CoQ_{10} levels were significantly higher after treatments in four groups. The higher levels of plasma CoQ_{10} in group 2 (Ex) and control group might be caused by nutrition replenishment that available in most foods [1]. The increased levels of plasma CoQ_{10} after treatment were up to the standard range based on the reference intervals in healthy adults of plasma CoQ_{10} levels range from 0.40 to 1.91 µmol/l [20].

In this report, the researcher found that the maximum oxygen consumption (VO_2Max) was positively correlated with plasma CoQ_{10} levels. Previous research has suggested that CoQ_{10} supplementation could be used a good reflection of physical performance [19]. Therefore, CoQ_{10} supplementation tend to increase the physical performance capacity probably as a result of CoQ_{10}-induced changes in the physical performance [21].

In contrast, the researcher found the paradoxical effects by using antioxidant supplementation combined with high intensity training between group 3 (Ex&CoQ_{10}) and group 1 (CoQ_{10}), group 2 (Ex) and control group in FFM, REE and EE walk after the experiment. This may be caused by not only aging and high intensity exercises that were related to increase in free radical formation in the skeletal muscle [22] but also antioxidant supplementation may impair performance during training by decreasing exercise-induced mitochondrial biogenesis and the antioxidant capacity in skeletal muscle [23]. Therefore, whether antioxidant supplementation or strenuous exercise would impair the skeletal muscle would be important for more clarification in the further study.

The conflicting results in this study were associated with the research limitations relate to the following issues: 1) The metabolism might be lower than usual if the subjects did not have enough sleep. Therefore, the subjects were advised to sleep at least 6-8 hours per day. 2) The subjects were given instructions about the suggested nutrition per day, but not required to control their diet. Therefore, if the subjects did not follow the instruction by eating too much or too little food, it might affect their metabolism. 3) This experiment did not control the daily activities of the subjects. Although the subjects were chosen based on their similarity of daily activities, but the result of each subject may be different due to the shift in their normal daily activities.

CONCLUSION

It was concluded in this study that after treatment no significant differences were found in energy expenditure at rest and during submaximal treadmill walking among all groups. However, maximum oxygen consumption (VO_2Max) and plasma CoQ_{10} levels were found to have positive adaptation in overweight subjects with CoQ_{10} supplement and/or circuit resistance training [21]. Therefore, supplementation of CoQ_{10} including circuit resistance training were necessary for overweight women. Moreover, the researcher found positive correlation between maximum oxygen consumption (VO_2Max) and plasma CoQ_{10} levels. In addition, the possibility that CoQ_{10} and/or circuit resistance training can increase energy expenditure in adolescent and athlete need to be further studied with more subjects and longitudinal studies so as to give more information about association between plasma CoQ_{10} levels, energy expenditure and physical performance.

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