Orijinal Araştırma

JAMER
Journal of Anatolian Medical Research

EKSOJEN KOENZİM Q_{10} VE ÇİNKO İLAVESİNİN GENÇ AMATÖR BOKSÖRLERDE PERFORMANS VE KAS HASARI ÜZERİNE ETKİLERİ

Effects Of Exogenous Coenzyme Q_{10} And Zinc Supplementation On Performance And Muscular İnjury İn Young Amateur Boxers

Çiğdem Karakükcü[1] Yahya Polat[2] Yasemin Altuner Torun Polat[3] Adile İrfan Ortaköylüoğlu[4] Yavuz Katırcılar[4]

[1] Department of Biochemistry, Kayseri City Hospital, Kayseri
[2] School of Physical Education and Sports, Erciyes University Kayseri
[3] Department of Pediatry, Kayseri City Hospital, Kayseri
[4] Department of Internal Medicine, Kayseri City Hospital, Kayseri

ABSTRACT

Aim: In this study we aimed to demonstrate the effects of zinc and/or CoQ_{10} supplementation on physical performance and muscular injury parameters in young boxers which use both aerobic and anaerobic energy pathways.

Material and Method: The study included 64 healthy male amateur competitive boxers aged between 12- 14 years, who were randomly allocated into four groups after the baseline exercise session. Boys were supplemented with zinc or CoQ_{10} or both or with placebo (Zn-SUP, CoQ_{10}-SUP, Zn- CoQ_{10} SUP and control groups respectively) for eight weeks. Physical fitness parameters such as endurance, velocity, VO2max, anaerobic power capacity and muscular injury parameters such as CK, CK-MB, LDH and ALP were measured.

Results: Serum CK, CK-MB and LDH activities increased in all groups after fatigue according to resting, however increases were significant for CK and CK-MB in control and Q_{10}-Zn-SUP groups ($p < 0.001$). Zinc and CoQ_{10} both improved different physical fitness parameters. ALP levels significantly increased only in control group ($p <0.01$).

Conclusions: These results show that both CoQ_{10} and zinc supplementation reduces muscular injury when used separately.

Keywords: coenzyme Q10, zinc supplementation, muscular injury, boxer

ÖZ

Amaç: Bu çalışmada, aerobik ve anaerobik enerji yolaklarının her ikisini birden kullanan genç boksörlerde çinko ve/veya CoQ10 ilavesinin fiziksel performans ve kas hasarı üzerindeki etkilerini göstermeyi amaçladık.

Gereç ve Yöntem: Çalışmaya, temel egzersiz seansından sonra rastgele dört gruba ayrılan 12-14 yaşları arasında 64 sağlıklı erkek amatör boksör dahil edildi. 4 gruba ayrılan sporculara (Zn-SUP, CoQ10-SUP, Zn-CoQ10 SUP ve kontrol grupları) sekiz hafta boyunca sırasıyla çinko, CoQ10, veya her ikisi birlikte destek amaçlı verildi. Dayanıklılık, hız, VO2max, anaerobik güç kapasitesi gibi fiziksel güç parametreleri ve CK, CK-MB, LDH ve ALP gibi kas hasarını gösteren parametreler çalışıldı.

Bulgular: Serum CK, CK-MB ve LDH aktiviteleri egzersiz sonrası, istirahat durumuna göre tüm gruplarda artmasına rağmen, kontrol ve Q10-Zn-SUP gruplarında CK ve CK-MB için artış istatistiksel olarak da anlamlı bulundu ($p <0.001$). Zinc ve CoQ10'un her ikisi de farklı fiziksel güç parametrelerinde artış sağladı. ALP düzeyleri sadece kontrol grubunda anlamlı olarak arttı ($p <0.01$).

Sonuç: Bu sonuçlar hem CoQ10 ve hem çinko desteğinin ayrı ayrı kullanıldıklarında da kas hasarını azalttıklarını göstermektedir.

Anahtar kelimeler: Koenzim Q 10, çinko ilavesi, kas hasarı, boksör

Geliş tarihi/Received: 03.11.2019
Kabul tarihi/Accepted: 25.11.2019

Yazışma adresi/Address for Correspondence:
Şerife Çetin
Kayseri Üniversitesi Tıbbi Hizmetler ve Teknikler Bölümü Kayseri, Türkiye
e-posta: srfcngz@gmail.com

INTRODUCTION

Young athletes dealing with a sport may be denied the benefits of varied activity while facing additional physical, physiologic, and psychological demands from intense training and competition (1). Excessive stress or overload can lead to tissue breakdown and injury especially in the the rapid growth period during puberty by creating extra tightness and tension in muscles and tendons, making teens more prone to injury (2).

As there appear to be increasing numbers of children who specialize in a sport before and during puberty, there has been a growing interest in research about the relation between exercise, tissue injury and minerals and elements at this age.

Both CoQ_{10} and zinc are thought to improve physical performance and some elite athletes use both. Nevertheless, the data is not confident and satisfactory. Zinc and coenzyme Q_{10} (CoQ_{10}) are compounds appear to have a close connection to antioxidant activity. However, there is scarce information about their effects in energy metabolism, on performance. Zinc is an essential micronutrient and is found in almost every cell supports a healthy immune system, aids wound healing, is required in DNA synthesis, is required for growth and development during pregnancy, childhood, and adolescence, and maintains the senses of taste and smell (3,4). Some zinc-containing enzymes, such as carbonic anhydrase and LDH, are involved in intermediary metabolism during exercise. Another zinc-containing enzyme, superoxide dismutase, protects against free radical damage (5,6).

CoQ_{10} plays several crucial roles in the body; acts as a redox electron carrier in mitochondria, acts as an essential antioxidant and influences the stability of membranes (7-9). It is found in all cell membranes, but most of it is located in mitochondria, the energy producing part of every cell, especially in the heart, brain, kidneys and liver. CoQ_{10} is essential in producing ATP or fuel on which the body functions. It is also a fat-soluble anti-oxidant and therefore helps boost the body's immune system by destroying free radicals (10). For these reasons, most sportsmen and women have found CoQ_{10} to be a natural manner in which to improve performance.

In this study, we aimed to demonstrate the changes in different physical performance and muscular injury parameters with the use of either zinc or CoQ_{10} in young boxers, those use both aerobic and anaerobic energy pathways. Indeed, we aimed to show the changes in these parameters by using zinc and CoQ_{10} together for the first time in our knowledge.

MATERIAL and METHODS

Subjects

The study included 64 healthy, voluntary male amateur competitive boxers, aged between 12-14 years. They were all sedentary and all had no training background before. Boys participated into the study after a full explanation of the objectives and their parent's informed written consent. This study was conducted according to the guidelines laid down in the Declaration of Helsinki and the ethics committee of Erciyes University approved all procedures.

Experimental Design

The experimental approach was designed to evaluate the improvement in physical performance and muscular injury parameters before and after taking zinc and/or CoQ_{10} in young amateur boxers.

The study was a 8 week single-blinded, intervention trial, composed of 8 week periods of regular boxing exercise and supplementation with pills containing either 60 mg/dL oral CoQ_{10} (GNC) or 50 mg/dL oral zinc sulphate or both CoQ_{10} and zinc together or placebo (glucose). After the baseline exercise session the first sampling and anthropometric measurements were done for all subjects and then the participants were randomly allocated to 4 groups according to the supplementation that they take: Zn supplementation group (Zn-SUP), CoQ_{10} supplementation group (CoQ_{10}-SUP), both CoQ_{10} and Zn supplementation group (Zn-CoQ_{10}-SUP) and placebo (control) group. All volunteers (including control group) had boxing training 3 days in a week for 8 weeks with a period of 90-120 min while keeping their habitual feeding and nutrition. During exercises, pulses were controlled between 140-160 pulse/min for all boxers with a pulse counter.

Exercise protocol

At the beginning of all trainings, a 10 min warming up was applied to boxers with a target heart rate (THR) 90-130 pulse/min. During the main technical boxing trainings, force, speed, endurance and coordination exercises were done (THRR=120-140 pulse/min).

JAMER 2019;4(2):37-46
Orijinal Araştırma

Reaction time, first acceleration, fast force and coordination exercises of extremities with their own body weight and half, quarter and lower weighs. Short, mean and long time anaerobic exercises were also done with their own body weights.

After main training, a 20 min cooling down and extremity relaxing exercises were applied.

Anthropometric Measurements

The anthropometric measurements were made according to the protocols recommended by different investigators (11-15).

1- The height and weight of the subjects in shorts and no shoes were measured. Height was measured using the Holtain Stadiometer having 0.1 cm sensitivity, and weight was measured using a bascule (Angel) having 0.02 kg sensitivity.

2- Body Mass Index (BMI) was determined using the formula: weight (kg) / height (m)^2.

3- Body fat % was determined using Skinfold Method. Measurements were taken by a specialized person using Skinfold Calliper (Holtain Ltd, England) having 0.2 mm sensitivity. Triceps, subscapular, abdominal and supraliac skinfold measurements were obtained. Each skinfold was measured three times and the median value was used for calculation. To determine the fat percentage of the subjects, Durning and Womersley formula was applied.

Fat % (Triceps+Subscapular+Abdominal+Supraliac) = logX= (4.95/D-4.5)*100

D=1.1620-0.0630*X

Physical fitness

Physical fitness was determined using the following tests: a) isometric strength: handgrip, knee extension and elbow flexion, b) velocity: shuttle-run, c) back and hamstring flexibility: sit-and-reach test of Wells and Dillon, d) lower limb power: vertical jump, and e) 20 m run/walk test to estimate VO2max (16).

Isometric grip strength, strength of knee extension and elbow flexion were obtained by using the ‘Takei Physical Fitness Test’ dynamometer. After specific stretching and warm-up, three maximal attempts were performed, with an interval of 60 seconds between attempts, and the best result was used for analysis.

The velocity of the subjects was determined using the 30m run test. Measurements were made using a photocell chronometer. With 5 min resting intervals, the test was repeated three times. The lowest time was recorded.

Back and hamstring flexibility was evaluated by the sit-and-reach test. The maximum distance reached (cm), with one hand parallel to the other and the knees extended, was used as an indicator of back and hamstring flexibility.

Lower limb power was measured by the vertical jump test, with assistance of the upper limbs and trunk movement by using the ‘Takei Physical Fitness Test’ dynamometer. The difference between the highest point reached after jumping and total height was used as an indicator of lower limb power.

For all physical fitness tests, the subjects made three attempts and the best result obtained in the tests was used for analysis.

Aerobic Capacity (Max V02)

Max V02 measurement was made using the Multistage Fitness Test. This test involved continuous running between two lines 20 m apart in time to recorded beeps. The time between recorded beeps decrease each minute (level).

Anaerobic Power

Anaerobic power was tested using the Sargent vertical jump test and calculated using the Lewis formula (Fox. & Matthews, 1974).

Anaerobic Power=√4.9 * (Body Weight) * √ D

D=Vertical Jump Height (m)

Laboratory assays

After a 12 h overnight fasting venous blood samples were collected from all participants before any supplementation during resting and after exhaustion exercise. Blood sampling protocol was repeated 8 weeks later after supplementations. Serum creatinine, creatine kinase (CK) and lactate dehydrogenase (LDH) levels were measured by an enzymatic method and creatine kinase MB (CK-MB) levels were measured by immunoinhibition method on an autoanalyser (ARCHITECT c16000, Abbott Diagnostics, Canada, USA). Serum zinc analyses were conducted in a Shimatsu ASC-600 Atomic Absorption Spectrophotometer. Measurements were carried out twice with light at 213 nm wavelength using flame atomization technique and levels are presented as µg/dL.

Statistical analysis

The effect of supplementation on variables within each group was evaluated by comparing results after treatment with those at baseline, using paired *t*-test.

Data are expressed as mean ± standard deviation (SD). For comparison among the groups, one-way analysis of variance (ANOVA) was used. Scheffe' post hoc test was performed to evaluate a significant F-value. To avoid a mutual association with the other variables, partial correlationcoefficient test was used in order to assess the relationships between selected variables. Statistical significance was accepted for $p < 0.05$. Statistical analysis of the data was performed using the Statistics Package for Social Science (SPSS version 13.0, SPSS Inc., Chicago, IL, USA).

RESULTS

The mean initial weight of the 64 boxers was 45.3 ± 6.2 kg, and height was 145.4 ± 4.8 cm. Anthropometric and physiologic variables for the randomly selected four groups are outlined in Table 1.

Physical fitness parameters of all groups those administered an eight-week boxing training program were compared before and after supplementation. BMI increased in control and Zinc-SUP groups despite decreasing in Q_{10}-SUP and Q_{10}-Zn-SUP groups, although the difference was not significant in Q_{10}-Zn-SUP group. In all groups anaerobic power capacity increased after exercises but the maximum increases were in Zn-SUP and Q_{10}-Zn-SUP groups (Table 2).

Decrease in body fat % was significant in control, Q_{10}-SUP and Q_{10}-Zn-SUP groups. Max VO2 increased in Q_{10}-SUP and Q_{10}-Zn-SUP groups. Also increase in vertical jumping was significant in Zinc-SUP and Q_{10}-Zn-SUP groups (Table 2).

There was no difference between groups for other physical fitness parameters (isometric strength, velocity, back and hamstring flexibility and lower limb power).

Table 1. Baseline physical characteristics of supplementation and control groups. Data are mean ± SD.

	Control (n=16)	Zn-Sup (n=16)	CoQ_{10}-Sup (n=16)	Zn-CoQ_{10} Sup (n=16)	p
Age (years)	12.9±0.6	12.8±0.9	13.1±0.6	12.8±0.7	<0.05
Height (cm)	145.9±4.9	145.5±5.2	145.4±4.2	144.9±5.7	<0.05
Weight (kg)	46.4±5.2	44.3±7.6	45.5±5.7	45.1±7.0	<0.05
BMI (kg/m^2)	21.8±2.0	21.0±4.2	21.6±2.8	21.5±3.6	<0.05
Body fat %	14.6±3.9	16.4±2.4	14.5±3.6	16.1±2.6	<0.05

Table 2: Comparison of physical fitness parameters of groups. Data are mean± SD.

	Groups							
	Control (n=16)		Zn-Sup (n=16)		CoQ_{10}-Sup (n=16)		Zn-CoQ_{10} Sup (n=16)	
	Baseline	Post-Exercise	Baseline	Post-Exercise	Baseline	Post-Exercise	Baseline	Post-Exercise
BMI (kg/m^2)	21.8 ± 2.0	22.7 ± 1.9**	21.0 ± 4.2	21.4 ± 4.2**	21.6 ± 2.8	21.0 ± 2.8**	21.5 ± 3.6	21.2 ± 3.1^{NS}
Anaerobic performance	83.9 ± 4.2	85.5 ± 5.2*	81.8 ± 9.3	86.3 ± 9.3**	83.8 ± 4.0	86.8 ± 4.3**	82.8 ± 8.4	87.7 ± 7.5**
Body fat %	14.6 ± 3.9	13.5 ± 3.7**	16.4 ± 2.4	14.2 ±2.4^{NS}	14.5 ± 3.6	11.1 ± 2.7**	15.2 ± 2.6	13.0 ± 2.5**
Vertical jumping (cm)	31.1 ± 2.0	31.0 ± 2.6^{NS}	31.0 ± 2.5	33.8 ± 2.3**	31.8 ± 2.2	34.8 ± 2.2^{NS}	31.1 ± 2.2	35.4 ± 2.1**
VO_{2max} (ml/kg/min)	39.6 ± 4.1	40.3 ±4.8^{NS}	37.1 ± 2.7	39.1 ± 2.7^{NS}	39.6±3.9	41.4 ± 4.0**	38.0 ± 2.8	41.8 ± 2.5**

* $p < 0.05$, ** $p < 0.001$ and NS=not significant

Serum zinc levels at baseline were in normal range values in all groups (70-120 µg/dL). After eight-week supplementation and exercise period there was significant increase in serum zinc in Zn-SUP and Q_{10}-Zn-SUP groups ($p < 0.01$), however a decrease in Q_{10}-SUP ($p < 0.05$) and control ($p < 0.001$) (Figure 1). The increase in Q_{10}-Zn-SUP was higher than Zn-SUP group, even though the difference was not significant. Serum CK, CK-MB and LDH activities increased in all groups after fatigue according to resting, however increases were significant for CK and CK-MB in control and Q_{10}-Zn-SUP groups. ALP levels significantly increased only in control group (Table 3).

DISCUSSION

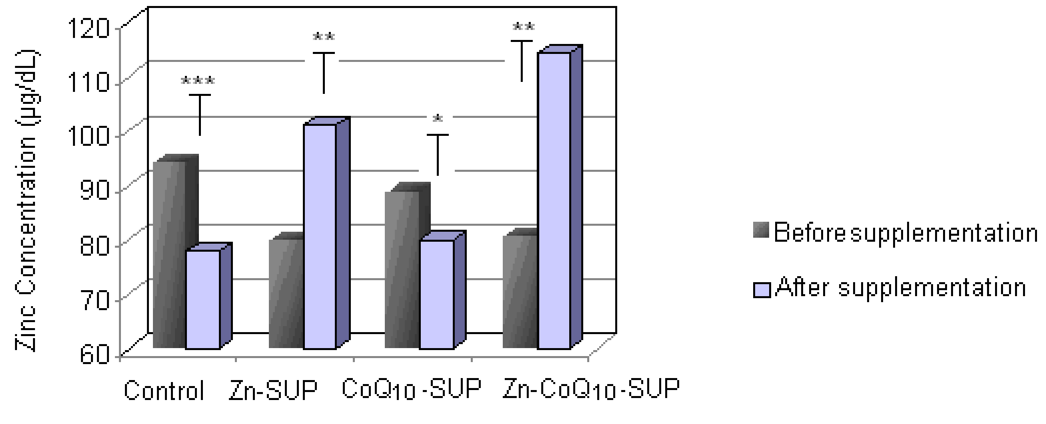
The effect of supplementations on physical fitness and performance parameters

In this study, VO2max values of the boxers after 8-week Q_{10} or Zinc- Q_{10} supplementation were higher than those before supplementation; however the difference was not statistically significant in control and Zn-SUP groups (Table 2). In Co Q_{10}-SUP group anaerobic power was also significantly increased according to baseline. These results indicate that Co Q_{10} is effective in increasing both anaerobic power and maximal oxygen uptake, which indicates aerobic power in strenuous exercise.

Table 3: Comparison of enzymatic activities or concentrations of some muscular injury markers

Biochemical Parameters	Groups							
	Control (n=16)		Zn-Sup (n=16)		CoQ10-Sup (n=16)		Zn-CoQ10 Sup (n=16)	
	Resting	Post-Exercise	Resting	Post-Exercise	Resting	Post-Exercise	Resting	Post-Exercise
CK(U/L)	144.8 ± 32.3	269.1 ± 131.2*	184.4 ± 61.5	238.1 ± 125.6	149.9 ± 65.6	210.5 ± 84.0	147.0 ± 33.7	209.4 ± 89.4*
CK-MB (U/L)	24.6 ± 4.6	38.9 ± 9.3**	23.6 ± 9.3	29.5 ± 22.0	30.3 ± 7.1	32.0 ± 8.2	20.3 ± 4.8	31.5 ± 8.6**
LDH (U/L)	244.6 ± 39.3	253.5 ± 38.9	246.9± 36.6	239.9 ± 37.2	236.3 ± 35.2	241.4 ± 24.0	237.8 ± 20.5	241.6 ± 32.3
ALP (U/L)	309.4 ± 96.4	323.1 ± 87,1**	296.8 ± 71.5	318.1 ± 71.1	340.4± 126.3	317.0± 126.8	270.3 ± 91.4	272.1 ± 85.5

* p < 0.05 and ** p < 0.01 compared with resting.



Different symbols represent the difference within groups before and after supplementation (* p‹ 0.05, ** p‹ 0.01, *** p‹ 0.001).

Figure 1: Serum resting zinc concentrations of groups at baseline and after supplementation at the end of eight-week strenuous exercise.

The results from CoQ_{10} studies on exercise performance have mostly focused on aerobic capacity and exercise induced muscle injury. A study on top-level Finnish cross-country skiers using 90 mg of CoQ_{10} showed a significant improvement in VO2max and both aerobic and anaerobic performance. In addition, 94% of the treatment group felt they had better recovery (17). Recently Gokbel et al. showed CoQ_{10} supplementation increased performance, especially anaerobic capacity during repeated bouts of supramaximal exercises in sedentary men (18). In another study, it was shown that CoQ_{10} could improve work capacity, reduce fatigue during extended cycling tests (19) and tended to increase time to exhaustion (20). Our results are in line with these studies.

There are also some previous studies, which have failed to demonstrate performance-enhancing effects in trained athletes and/or untrained individuals following CoQ_{10} supplementation (21-23). Recently, Zhou and colleagues investigated the effects of a 4 week CoQ_{10} supplementation on aerobic power, ventilatory threshold and exercise economy of healthy males. Results showed no significant changes in aerobic performance (VO2max) or exercise economy in response to supplementation. Although CoQ_{10} concentration was elevated in plasma, no significant increases were observed within muscle. Thus, the authors concluded that the lack of ergogenic benefit was likely due to an inability of supplementation protocol to increase CoQ_{10} concentration within the muscle (23). In our study, anaerobic power capacity also increased after physical activity in all groups, but the maximum increases were in Zn-SUP and Q_{10}-Zn-SUP groups (Table 2). In addition, increase in vertical jumping was significant in Zinc-SUP and Q_{10}-Zn-SUP groups. The findings about zinc supplementation was also in concordance with literature (24,25). Krotkiewski et al evaluated muscle strength and endurance in women supplemented with 135 mg Zn/d for 14 day (25). Subjects supplemented with zinc, compared with placebo, had significantly higher dynamic isokinetic strength at angular velocity and isometric endurance.

In the current study, our results showed in all groups there was an increase in muscle endurance parameters determined by isometric strength, velocity, back and hamstring flexibility, lower limb power tests, even though both CoQ_{10} and Zn supplementation did not statistically differ this increase rate. Also the lack of difference with the placebo group for these parameters may be caused from the selection of group consisted of amateur boxers; those started a heavy physical activity not done regularly before. Physical activity applied in a disciplined order is generally considered to increase physical power like maximum oxygen consumption (VO2max), anaerobic power (26-28), strength of various muscle groups (26,27,29,30), lower limb muscle power and running velocity, back and hamstring flexibility, and to reduce body adiposity (26,30).

The decrease in body fat % takes a great deal of oxygen by converting stored body fat into energy, hence promotes increase in performance (31). In this study BMI increased in control and Zinc-SUP groups (may be caused by appetite and taste increasing effects of zinc) (5,6) in eight-week time despite decreasing in Q_{10}-SUP and Q_{10}-Zn-SUP groups. However, the difference was not significant in Q_{10}-Zn-SUP group. Our study groups were aged between 12-14, which contributes to the puberty age with a rapid increase in height and weight. We believe that the change in BMI seen in control group reflects the rapid changes that can occur during puberty. For that reason to evaluate the changes in BMI in pubescent subjects is a potential confounding factor for this study.

The effect of supplementations on muscle injury

The relation between muscle tiredness and zinc is a topic that also merits attention. Zinc plays a role in building and repairing of muscle as well as energy production. Some zinc-containing enzymes, such as carbonic anhydrase and LDH, are involved in intermediary metabolism during exercise and superoxide dismutase, protects against free radical damage (3,4). Exercise is a stressor that can decrease zinc levels, and thus athletes are at risk for being deficient (32). Boxers doing strenuous exercise are much more sensitive to conditions that would not affect sedentary people, due to the increased demand on their circulatory system. The boxers in this study all had serum zinc levels in normal range at baseline. After eight-week exercise and supplementation period while a decrease in serum zinc concentration was seen in control and CoQ_{10}-SUP groups, there was increase in Zn-SUP and CoQ_{10}-Zn-SUP groups. The lack of muscle injury indicators in Zn-SUP group suggests the protective effect of zinc on muscle function and tiredness. Because zinc is necessary for the activity of some enzymes in energy metabolism and because exercise decreases muscle zinc levels, muscle injury and tiredness may be decreased by zinc intake.

The existing data about the effect of CoQ_{10} supplementation on exercise induced muscle damage and oxidative stress are sparse and inconsistent (33). In an in vitro system, tissue slices from animals fed CoQ_{10} were more resistant to tertbutyl hydroperoxide-induced lipid peroxidation than were those from control animals fed normal diets (34). In addition, Okamoto *et al*. have showed that CoQ_{10} protected cultured skeletal muscle. Furthermore, exogenous administration of CoQ_{10} suppressed hepatic oxidative damage after reperfusion following ischemia (35). Supplementation with CoQ_{10} decreased initial release of CK and LDH in rats running downhill (36), but had no effect on CK release in human subjects exercised to exhaustion on a cycle ergometer (37). Kon et al. investigated the effect of CoQ_{10} supplementation on exercise-induced muscular injury of rats and found that exhaustive exercise significantly decreased total CoQ_{10} concentration in plasma (10). They also showed that 300 mg of CoQ_{10} may be protective of muscle injury during extended training sessions in Kendo practitioners who trained 5½ hours per day (38). Exhaustive exercise increases energy demand and oxidative stress in tissues, and induces tissue damage. Therefore, CoQ_{10} in plasma may be distributed to various tissues during exhaustive exercise and there may be a lack of muscle CoQ10 concentration. From these findings, it can be proposed that CoQ_{10} supplementation has the potential to reduce strenuous exercise-induced tissue injury and oxidative stress. CoQ_{10} has a structural stabilizing effect on cell membrane phospholipids (39,40). Indeed in its reduced form it acts as an antioxidant (41,42). Therefore, it is quite likely that CoQ_{10} supplementation increases CoQ_{10} concentration in muscle cell membranes and reduces strenuous exercise-induced muscular injury by enhancing cell membrane stabilization. And also it might be expected to exert a protective effect against oxidative damage to membranes

Many researchers have indicated that exercise increases plasma CK and CK-MB activities, which are the most commonly used marker of skeletal muscle damage induced by exercise (43,44). Even though both CoQ_{10} and Zinc usage in strenuous exercise are studied and suggested to increase performance and decrease muscle damage and fatigue, their supplementation together has not yet been studied in human in our knowledge. In order, both seem to reduce muscular damage and improve performance cause of their antioxidant and membrane stabilizing properties. In the present research, plasma CK and CK-MB activities were higher after exhausting exercise according to resting in all groups, however the increase in CK and CK-MB activities were highest and statistically different in control and CoQ_{10}-Zn-SUP groups (Table 3).This result indicated that muscle damage was induced by exhaustive exercise. However, there was no difference between post-exercise and resting serum CK, CK-MB activities in Zn-SUP and CoQ_{10}-SUP groups. Besides, the increase in ALP was highest in control according to supplemented groups in this study. ALP is found in many tissues and its levels can become elevated 7-14 days after tissue damage or infarction due to ALP produced by fibroblasts and endothelial cells proliferating in new granulation tissue (45). Thus, both lonely zinc and CoQ_{10} supplementation provided protection against strenuous exercise-induced muscular injury in this study.

We suggest that in Q_{10}-Zn-SUP group despite an increase in both aerobic and anaerobic power, higher CK and CK-MB activities after exercise may be came out from the interaction between CoQ_{10} and zinc in respect to their physical properties. Zinc absorption is poor and it easily complexes to amino acids, peptides, proteins and nucleotides. Small molecular weight ligands such as amino acids, improve absorption, whereas large molecular weight ligands such as phytic acid reduce absorption, thus decrease its bioavailability (46,47). CoQ_{10} is a high molecular weight and lipophilic substance which makes it poorly water soluble and consequently leads to low systemic availability (48-50). Therefore, CoQ_{10} and zinc may form complexes and decrease bioavailability of each other. The higher serum zinc concentration in Q_{10}-Zn-SUP group, even though the given doses of zinc were the same to Zn-SUP and Q_{10}-Zn-SUP groups, supports this hypothesis; which can show poor distribution of zinc into tissues (Fig 1). Further researches are needed about bioavailability of CoQ_{10} and zinc supplementation together.

In conclusion, we investigated the effect of CoQ_{10} and/or Zinc supplementation on physical performance and exhaustive exercise-induced injury in young amateur boxers.

The study revealed that both zinc and CoQ_{10} supplementation increased performance parameters and reduced

The study revealed that both zinc and CoQ_{10} supplementation increased performance parameters and reduced exhaustive exercise-induced muscular injury at this age. On the other hand, CoQ_{10} and zinc supplementation together was not able to reduce muscular injury as revealed by higher levels of CK and CK-MB. This may be resulted from the high molecular weight of CoQ_{10}, which is predisposed to make complex with zinc that leads to decreased bioavailability for each one. As a result, supplementation with either zinc or CoQ_{10} reduces exhaustive exercise-induced muscular injury and improves performance, but they should not be used together as they decrease bioavailability of each other.

ACKNOWLEDGEMENTS

We would like to thank the subjects who participated in this study and Erciyes University Foundation who provided grant funding (TSY-11-3454) for this project.

REFERENCES

1. Klentrou N. Puberty and Athletic Sports in Female Adolescents. Ann Nestlé. 2006;64:85–94.
2. Committee on Sports Medicine and Fitness, AAP. Intensive Training and Sports Specialization in Young Athletes. Pediatrics. 2000;106:154-7.
3. de Oliveira Kde J, Donangelo CM, de Oliveira AV Jr, da Silveira CL, Koury JC. Effect of zinc supplementation on the antioxidant, copper, and iron status of physically active adolescents. Cell Biochem Funct. 2009;27:162-6.
4. Vallee BL, Falchuk KH. The biochemical basis of zinc physiology. Physiol Rev. 1993;73:79-118.
5. Prasad AS. Zinc: An overview. Nutrition 1995;11:93-9.
6. Heyneman CA. Zinc deficiency and taste disorders. Ann Pharmacother. 1996;30:186-7.
7. Crane FL. Biochemical functions of coenzyme Q10. J Am Coll Nutr 2001;20: 591-8.
8. Jones K, Hughes K, Mischley L, McKenna DJ. Coenzyme Q-10: efficacy, safety, and use. Altern Ther Health Med. 2002; 8:42-55.
9. Niki, E. Mechanisms and dynamics of antioxidant action of ubiquinol. Mol Aspects Med. 1997;18: 63-70.
10. Kon M, Kimura F, Akimoto T, Tanabe K, Murase Y, Ikemune S, Kono I. Effect of Coenzyme Q10 supplementation on exercise-induced muscular injury of rats. Exerc Immunol Rev. 2007;13:76-88.
11. Eston R, Reilly T, eds. Kinanthropometry and Exercise Physiology Laboratory Manual: Tests, Procedures and Data. Volume 1: Anthropometry. 2nd ed., New York: Routledge, Taylor & Francis Group, 2001.
12. Jelliffe EEP, Jelliffe DB. The arm circumference as a public health index of protein-calorie malnutrition of early childhood. J Trop Pediatr. 1969;15:179-192.
13. Lohman TG. The use of skinfold to estimate body fatness on children and youth. JPERD. 1987;58:98-102.
14. Carter JEL. The Heath-Carter Anthropometric Somatotype – Instruction Manual. San Diego, CA, 2002. Available at: http://www.somatotype.org/Heath-
15. le Gall F, Carling C, Williams M, Reilly T. Anthropometric and fitness characteristics of international, professional and amateur male graduate soccer players from an elite youth academy. J Sci Med Sport. 2010;13:90-5.
16. Canhadas IL, Silva RLP, Chaves CR, Portes LA. Anthropometric and physical fitness characteristics of young male soccer players. Rev Bras Cineantropom Desempenho Hum. 2010,12:239-45.
17. Ylikoski T, Pirainen J, Hanninen O, Penttinen J. The effect of coenzyme Q10 on the exercise performance of cross-country skiers. Mol Aspects Med. 1997;18:283-90.
18. Gokbel H, Gergerlioglu HS, Okudan N, Gul I, Buyukbas S, Belviranli M. Effects of coenzyme Q10 supplementation on plasma adiponectin, interleukin-6, and tumor necrosis factor-alpha levels in men. J Med Food. 2010;13:216-8.
19. Mizuno K, Tanaka M, Nozaki S, Mizuma H, Ataka S, Tahara T, Sugino T, Shirai T, Kajimoto Y, Kuratsune H, Kajimoto O, Watanabe Y. Antifatigue effects of coenzyme Q10 during physical fatigue. Nutrition. 2008;24:293-9.
20. Cooke M, Iosia M, Buford T, Shelmadine B, Hudson G, Kerksick C, Rasmussen C, Greenwood M, Leutholtz B, Willoughby D, Kreider R. Effects of acute and 14-day coenzyme Q10 supplementation on exercise performance in both trained and untrained individuals. J Int Soc Sports Nutr. 2008;4:5-8.
21. Braun B, Clarkson PM, Freedson PS, Kohl RL. Effects of coenzyme Q10 supplementation on exercise performance, VO2max, and lipid peroxidation in trained cyclists. Int J Sport Nutr. 1991;1(4):353-65.
22. Weston SB, Zhou S, Weatherby RP, Robson SJ: Does exogenous coenzyme Q10 affect aerobic capacity in endurance athletes? Int J Sport Nutr. 1997;7:197-206.

23. Zhou S, Zhang, Y, Davie, A, Marshall-Gradisnik, S, Hu, H,Wang, J, and Brushett, D. Muscle and plasma coenzyme Q10 concentration, aerobic power and exercise economy of healthy men in response to four weeks of supplementation. J Sports Med Phys Fitness 2005;45: 337–46.

24. Cordova A, Alvarez-Mon M. Behaviour of zinc in physical exercise: a special reference to immunity and fatigue. Neurosci Biobehav Rev 1995;19:439-45.

25. Krotkiewski M, Gudmundsson M, Backstrom P, Mandroukas K. Zinc and muscle strength and endurance. Acta Physiol Scand 1982; 116:309–11.

26. Malina RM. Anthropometry, strength and motor fitness. In: Ulijaszek SJ, Mascie-Taylor CGN, editors. Anthropometry: The Individual and the Population. Cambridge, UK: Cambridge University Press, 1994, p. 160-177.

27. Naughton G, Farpour-Lambert NJ, Carlson J, Bradney M, Van Praagh E. Physiological issues surrounding the performance of adolescent athletes. Sports Med 2000;30:309-25.

28. Stabelini Neto A, Mascarenhas LP, Bozza R, Ulbrich AZ, Vasconcelos IQ, Campos W. Antropemetric and physical fitness characteristics of young male soccers. Rev Bras Cineantropom Desempenho Hum 2007;9:159-64.

29. Hansen L, Bangsbo J, Twisk J, Klausen K. Development of muscle strength in relation to training level and testosterone in young male soccer players. J Appl Physiol. 1999;87:1141-7.

30. Vicente-Rodriguez G, Jimenez-Ramirez J, Ara I, Serrano-Sanchez JA, Dorado C, Calbet JA. Enhanced bone mass and physical fitness in prepubescent footballers. Bone 2003;33:853-9.

31. Lukaski HC. Vitamin and mineral status: effects on physical performance. Nutrition 2004;20:632-44.

32. Mohr CR, Volpe SL. Effect of Zinc Supplementation on Plasma Zinc Status and Resting Metabolic Rate in Physically Active Individuals. Medicine & Science in Sports & Exercise 2002;345:387.

33. Witt EH, Reznick AZ, Viguie CA, Starke-Reed P, Packer L. Exercise, oxidative damage and effects of antioxidant manipulation. J Nutr 1992;122:766-73.

34. Leibovitz B, Hu ML, Tappel AL. Dietary sup plements of vitamin E, beta-carotene, coenzyme QIO and selenium protect tissues against lipid peroxidation in rat tissue slices. J Nutr 1990;120:97-104.

35. Okamoto T, Kubota N, Takahata K, Takahashi T, Goshima K, Kishi T. Protective effect of coenzyme Q10 on cultured skeletal muscle cell injury induced by continuous electric field stimulation. Biochem Biophys Res Commun 1995;216:1006-12.

36. Shimomura Y, Suzuki M, Sugiyama S, Hanaki Y, .Ozawa T. Protective effect of coenzyme Q10 on exercise-induced muscular injury. Biochem Biophys Res Commun 1991;176: 349-55.

37. Zuliani U, Bonetti A, Campana M, Cerioli G, Solito F, Novarini A. The influence of ubiquinone (Co Q10) on the metabolic response to work. J Sports Med Physical Fitness 1989;29: 57-62.

38. Nagai S, Miyazaki Y, Ogawa K, Satake T, Sugiyama S, Ozawa T. The effect of Coenzyme Q10 on reperfusion injury in canine myocardium. J Mol Cell Cardiol 1985;17: 873-84.

39. Kambara N, Takagi K, Satake T, Sugiyama S, Ozawa T. Mechanism responsible for endotoxin-induced lung microsomal dysfunction in rats. Lung 1983;161:361-8.

40. Kon M, Tanabe K, Akimoto T, Kimura F, Tanimura Y, Shimizu K, Okamoto T, Kono I. Reducing exercise-induced muscular injury in kendo athletes with supplementation of coenzyme Q10. Br J Nutr 2008;100:903-9.

41. Frei B, Kim MC, Ames BN. Ubiquinol-10 is an effective lipid-soluble antioxidant at physiological concentrations. Proc Nati Aca Sci 1990;87: 4879-83.

42. Kagan V, Serbinova E, Packer L. Antioxidant ef fects of ubiquinones in microsomes and mitochondria are mediated by tocopherol recycling. Biochem Biophys Res Com 1990:169:851-7.

43. Koutedakis Y, Raafat A, Sharp NC, Rosmarin MN, Beard MJ, Robbins SW. Serum enzyme activities in individuals with different levels of physical fitness. J Sports Med Phys Fitness 1993;33: 252-7.

44. Olerud JE, Homer LD, Carroll HW. Incidence of acute exertional rhabdomyolysis. Serum myoglobin and enzyme levels as indicators of muscle injury. Arch Intern Med 1976;136: 692-7.

45. Ravel R. Clinical Laboratory Medicine: Clinical Application of Laboratory Data. ed 4; pp 564-5

46. Rimbach G, Brandt K, Most E, Pallauf J. Supplemental phytic acid and microbial phytase change zinc bioavailability and cadmium accumulation in growing rats. J Trace Elem Med Biol 1995;9:117-22.

47. Zhou JR, Fordyce EJ, Raboy V, Dickinson DB, Wong MS, Burns RA, Erdman JW Jr. Reduction of phytic acid in soybean products improves zinc bioavailability in rats. J Nutr 1992;122:2466-73.
48. Johns Cupp M, Tracy TS. Coenzyme Q10 (Ubiquinone, Ubidecarenone). In: Johns Cupp M, Tracy TS, eds. Dietary Supplements, Toxicology and Clinical Pharmacology. Totowa, NJ: Humana; 2002, p. 74.
49. Miles M, Horn P, Miles L, et al. Bioequivalence of coenzyme Q10 from over-the-counter supplements. Nutr Res 2002;22: 919-29.
50. Tomono Y, Hasegawa J, Seki T, et al. Pharmacokinetic study of deuterium-labelled coenzyme Q10 in man. Int J Clin Pharmacol Ther Toxicol. 1986;24:536-41.