Quality in Sport. 2026;51:68932. eISSN 2450-3118.

https://doi.org/10.12775/QS.2026.51.68932

Quality in Sport. eISSN 2450-3118

Journal Home Page
https://apcz.umk.pl/QS/index

SZADA-BORZYSZKOWSKI, Kacper and OWCZARENKO, Konstancja. Overview of Coenzyme Q10 and its role in enhancing sport performance. Quality in Sport. 2026;51:68932. eISSN 2450-3118. https://doi.org/10.12775/QS.2026.51.68932

The journal has been awarded 20 points in the parametric evaluation by the Ministry of Higher Education and Science of Poland. This is according to the Annex to the announcement of the Minister of Higher Education and Science dated 05.01.2024, No. 32553. The journal has a Unique Identifier: 201398. Scientific disciplines assigned: Economics and Finance (Field of Social Sciences); Management and Quality Sciences (Field of Social Sciences).
Punkty Ministerialne z 2019 - aktualny rok 20 punktów. Załącznik do komunikatu Ministra Szkolnictwa Wyższego i Nauki z dnia 05.01.2024 Lp. 32553. Posiada Unikatowy Identyfikator Czasopisma: 201398. Przypisane dyscypliny naukowe: Ekonomia i finanse (Dziedzina nauk społecznych); Nauki o zarządzaniu i jakości (Dziedzina nauk społecznych). **© The Authors 2026.**
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The authors declare that there is no conflict of interest regarding the publication of this paper.
Received: 12.02.2026. Revised: 15.02.2026. Accepted: 17.02.2026. Published: 28.02.2026.

Overview of Coenzyme Q10 and its role in enhancing sport performance

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Abstract

Background

Among the many antioxidative substances tested as supplements in various sports, coenzyme Q10 appears to be one of the most promising in terms of improving physical endurance. As a part of mitochondrial respiratory chain, as well as a membrane antioxidant, its supplementation has a sound theoretical basis, as it may enhance energy production in muscles and protect them from oxidative stress, potentially leading to improved sports performance.

Aim

The aim of this study is to summarize the current knowledge regarding the impact of coenzyme Q10 supplementation on sport performance.

Materials and methods

A systematic literature review was conducted using PubMed and Google Scholar. The following search terms were used: “coenzyme Q10”, “exercise”, “sports”, and “mind sports”. Only English-language publications were analysed for possible inclusion in this review, with double-blind and single-blind, placebo-controlled studies being prioritised.

Conclusions

The studies included in this review showed contradictory results. Some demonstrated significant improvements in subjects’ physical fitness, while others showed no differences between the groups. Larger studies and meta-analyses on this topic should be conducted to more precisely evaluate the potential benefits of coenzyme Q10 supplementation.

Keywords: Coenzyme Q10, physical activity, sports, oxidative stress, supplementation, antioxidants

Introduction

Coenzyme Q10 (2,3-dimethoxy-5-methyl-6-decaprenyl benzoquinone) is a fat-soluble, vitamin-like quinone, commonly known as ubiquinone, CoQ, or vitamin Q10. First identified in 1957 through its extraction from bovine mitochondria, CoQ is predominantly found in tissues with high metabolic activity, such as the heart, brain, liver, and kidneys [1]. The name CoQ derives from its molecular structure, which features a benzoquinone ring attached to a ten-unit isoprenoid side chain. CoQ exists in three redox forms: the fully reduced form (ubiquinol, $CoQ10H_2$), the semiquinone radical intermediate ($CoQ10H\cdot$), and the fully oxidized form (ubiquinone, CoQ10). Although its structure resembles certain vitamins, such as vitamin K, CoQ is not classified as a vitamin because it can be synthesized within the human body rather than being acquired through the diet [2].

CoQ is known to promote cellular energy production by supporting ATP synthesis in the mitochondrial electron transport chain, thereby enhancing endurance, and alleviating fatigue. It contributes to muscle health by accelerating recovery, decreasing soreness, and limiting muscle damage, as indicated by markers such as creatine kinase (CK) and myoglobin (Mb). Acting as a powerful antioxidant, CoQ protects muscle cells from oxidative stress and exercise-induced injury. It also helps regulate inflammation, further supporting recovery and reducing discomfort. Additionally, CoQ benefits cardiovascular function by improving vascular performance and circulation while mitigating oxidative damage. By enhancing oxygen utilization and muscle strength, it may provide advantages for both endurance and strength of athletes [3].

The aim of this review is to present, whether CoQ could enhance sports performance. To obtain the most comprehensive perspective possible, various sports disciplines, and thus different forms of physical exertion, were analysed. In addition, mind sports were also analysed to assess the possible application of CoQ.

Metabolism and functions of Coenzyme Q10

CoQ is a fat-soluble substance that can be divided into two functional parts. The first one is its lipophilic isoprenoid side chain, the length of which depends on the repetition of isoprenoid monomers. Moreover, it varies among species, e.g. Saccharomyces cerevisiae and Escherichia coli produce CoQ6 and CoQ8, while humans use CoQ10. Due to the hydrophobic properties of this chain, CoQ is mostly found in cell membranes, predominantly in the mitochondrial inner membrane [4]. The second part of this molecule is a benzoquinone ring, which is the functional component. It can act either as a donor, or as an acceptor of electrons, therefore making it a key mitochondrial electron carrier and lipid-soluble antioxidant [5], [6]. The most important function of CoQ is its role as an electron carrier in the mitochondrial respiratory chain. CoQ10 serves as a crucial mobile electron shuttle in the electron transport chain (ETC), mediating electron transfer from NADH-derived electrons at complex I and $FADH_2$-derived electrons at complex II to complex III. This electron transfer is coupled to proton pumping across the inner mitochondrial membrane, generating the proton-motive force necessary for adenosine triphosphate (ATP) production by ATP synthase [7]. Moreover, CoQ is one of the most important antioxidant molecules in the human body. Due to the aerobic nature of energy production, reactive oxygen (sometimes nitrogen) species are created. Because of their unstable properties and high reactivity, they pose a great danger to the cells, reacting with membrane lipids, proteins, and DNA, which in turn change their chemical properties, causing damage, disrupting biological processes, and consequently leading to cell death [8], [9]. Moreover, it is the only antioxidant agent with lipophilic properties, that can be synthesized de novo in human cells and return to its original reduced form [10]. Firstly, CoQ prevents the process of oxidation of cell membrane fatty acids by reduction of carbon-centred fatty acids radicals. Secondly, it regenerates vitamin E from the α-tocopheroxyl radical, which is generated by scavenging lipid peroxyl radicals. Moreover, CoQ is regarded as a more potent antioxidant molecule, than vitamin E, thereby preserving mitochondrial and cell membrane stability [11], [12]. Additionally, in some cases, CoQ deficiency in cells was found to cause an increase in reactive oxygen species and to cause prominent damage to cells. Moreover, sufficient CoQ10 levels support mitochondrial membrane stability, reducing cytochrome c release and limiting downstream activation of caspase-mediated apoptotic pathways in muscle tissue exposed to intense mechanical and metabolic stress [11], [13]. Beyond its antioxidant function, CoQ10 may modulate intracellular signalling pathways associated with inflammation and programmed cell death. Elevated oxidative stress activates nuclear factor kappa B (NF-κB), promoting transcription of pro-inflammatory cytokines that negatively affect muscle repair and adaptation. By reducing ROS-dependent NF-κB activation, CoQ10 may attenuate inflammatory responses and protect contractile protein integrity [14].

Coenzyme Q10 bioavailability

CoQ is a substance that is extremely insoluble in water due to its hydrophobic side chain; consequently, it has poor bioavailability via oral intake. It is absorbed in the small intestine, and its absorption follows zero-order kinetics, with some authors suggesting both passive and active mechanisms of absorption [15]. Moreover, some animal studies showed that only 2-4% of ingested CoQ can be recovered from the intestine [16]. An active component of the transport of CoQ in the intestine has been also suggested. Some studies on patients showed that the absorption of CoQ may be limited in some individuals, with dosages exceeding absorption capacities unnecessarily increasing cost without resulting in higher absorption. Instead of one large dose, several lower doses administered throughout the day have been proposed [10], [15]. Because of the lipophilic nature of CoQ, it is recommended to supplement it together with meals rich in fats, or to encapsulate it in a nanoliposomal form [17]. This may improve absorption due to bile release; however, an optimal formula should be researched to improve the bioavailability of CoQ. Interestingly, CoQ absorption has been found to be inhibited by vitamin E [10].

After the absorption, CoQ has been found to fit a 3-compartment pharmacokinetic model. It is initially transported to the liver via chylomicrons, where it is integrated into lipoproteins- VLDL and LDL, which contain 16% and 58% respectively of total CoQ in serum, and subsequently distribute CoQ to the tissues [15]. Additionally, CoQ levels show a secondary plasma peak due to enterohepatic recirculation, due to its release into the bile and reabsorption in the small intestine [18]. The direct organ uptake depends on the tissue structure, location, and energy requirement. When ingested by the cell, CoQ has been found to have diverse effects. Taking only the skeletal muscle cell into consideration, Linnane et al. showed that increased levels of CoQ changed the expression of genes, thus changing muscle fibre composition resembling the fibre type of much younger subjects. A hypothesis has been proposed that CoQ modulates the membrane compartmentalized redox poise, consequently having an impact on gene expression by the second messengers, such as superoxide anions and H_2O_2 [19].

Impact of Coenzyme Q10 supplementation on selected sports

a) Soccer/ football

Ubiquinol, the active reduced form of coenzyme Q10 (CoQ10), plays an essential role in energy metabolism and antioxidant defence. Professional soccer players experience intense physical demands during competition, which substantially increase the risk of oxidative stress, muscle injury, and dysfunction, leading to delayed onset of muscle soreness, oedema and swelling, thus impairing performance indicators (speed, strength, power). Moreover, a football season often forces players to have less than 48 hours of convalescence between matches, therefore putting increasing strain on their muscles. For this reason, antioxidant supplementation, including CoQ10, has been commonly studied among athletes [20], [21].

An observational study examining plasma CoQ10–related parameters in professional players from the Spanish First Division team Athletic Club de Bilbao across two consecutive seasons was conducted by Sanchez-Cuesta et al., aiming to evaluate their association with physiological stress, muscle damage, and athletic performance during competition. Measurements were taken at three stages of the season: pre-season, early competition, and mid-season. Biomarkers of stress (testosterone/cortisol ratio) and muscle damage (creatine kinase) were assessed. Match physical performance during the 2015/16 season was analysed in players who completed 28 full matches. During the mid-season phase, plasma CoQ10 levels were significantly higher compared with the previous season (906.8 ± 307.9 vs. 584.3 ± 196.3 pmol/mL, p = 0.0006). Elevated CoQ10 concentrations during the most demanding phase of competition were associated with lower creatine kinase levels, indicating reduced muscle damage (p = 0.00168). Higher plasma ubiquinol levels were also linked to improved renal function, as reflected by lower uric acid concentrations (r = −0.287, p = 0.0443). Additionally, increased CoQ10 levels were associated with enhanced muscular performance during matches [20]. In another study two groups were enrolled (one receiving 300 mg of CoQ, the other placebo), a significant improvement in VO_2 max and the Hoff performance test was observed in the supplemented group. Maximum heart rate and fatigue index were found not to show significant differences between the placebo group, and the supplemented group. No blood tests were analysed in this study [22]. Rahimi et al. conducted a study on soccer players, focusing on the short-term impact of CoQ supplementation on cardiac stress markers, as well as on general performance. A significant reduction in post-exercise cardiac stress markers such as NT-proBNP, hs-TnT and GDF-15 (p=0,001 for each) was noted. Moreover, time to fatigue (TTF) improved significantly after supplementation. Nevertheless, this study did not examine long-term effects of supplementation on soccer players, as well as the study sample was relatively small (16 participants divided into two equal groups) [23]. Another interesting study found that supplementation of an "antioxidant cocktail" (containing CoQ, as well as e.g., zinc, selenium, folic acid, and most vitamins) did not affect the increased lymphocyte production of reactive oxygen species (ROS) after a match. Moreover, catalase and glutathione reductase activity did not differ between the supplement and placebo group after three months of training [24]. Conversely, a study by Tauler et al. came to the conclusion that supplementation with the same "antioxidant cocktail" prevented oxidative plasma molecular damage, while the activity of the neutrophils remained the same. Nevertheless, no significant difference in heart rate, or time spent in metabolic zones was found between the groups [25]. All in all, the impact of CoQ supplementation in soccer players should be investigated more thoroughly, as the previous studies mostly included small groups, short observational periods, as well as a limited number of variables.

b) Running

Running induces a significant amount of stress on the whole body, requiring a high endurance and stress resistance. Both short-distance and long-distance running can induce a substantial amount of oxidative stress in runners; thus, CoQ supplementation emerges as a potential supplement to prevent this stress in runners. Suzuki et al. conducted a double-blind, placebo controlled study including male runners who received 300 mg of CoQ daily. During this study, the participants took part in a training program, that included a 25 km run on day 7, and a 45 km run on day 9. In blood tests, a significant reduction in serum CK, ALT and LDH was noted in the supplemented group on day 6, with no significant reduction in the placebo group. Moreover, in the supplemented group, a subjective exhaustion caused by long-distance running was significantly reduced [26]. Another study that examined the short-term impact on middle-distance runners was performed by Armanfar et al. The observation period lasted 14 days, with the first and last 3000 meter running protocols conducted on days 1 and 14. The dosage of CoQ was adjusted for weight (5 mg/kg/d) and blood tests were undertaken. No significant decrease in CRP, TNF-α, IL-6, or CK was noted in the supplement group, as well as no significant differences were observed between the groups [27]. Another interesting study included healthy male runners between 50 and 64 years old, who were also divided into CoQ-receiving and non-receiving groups. A new formulation (CoQ phytosome) was administered, which improved significantly CoQ concentration in blood and in muscle tissue samples. Moreover, after one-month exercise period, malondialdehyde (which was measured as a marker of oxidative damage) was significantly lower in the study group, at both pre- and post-exercise time periods. In addition, levels of pro-inflammatory markers like IL-6 and IL-10 were also significantly lower after intervention [28].

c) Cycling, triathlon

Bonetti et al. conducted an experiment on 28 healthy, middle-aged male leisure-time cyclists. The first group received 100 mg daily of CoQ, while the other received placebo, and underwent a steady 8-week training program. After 8 weeks of supplementation, the CoQ group achieved a significantly higher improvement in maximal workload at the anaerobic threshold, while the control group did not. Conversely, no difference between serum lactate, hypoxanthine, or xanthine was recorded between the groups, moreover both had significantly increased levels of lactate and hypoxanthine after the 8 weeks of training [29]. Another study that included cyclists had similar design to the previous one, with two groups, the same dose and 8 weeks of training. The only difference was that this study included professional and trained cyclists. Maximal oxygen consumption values increased in both groups after the 8-week period, with no statistical difference between the groups. No significant difference between the levels of malondialdehyde, heart rate, or the total work performed on the exercise test was noted between the groups. In summary, no measurable difference was observed between the groups in this study, that would result from the supplementation [30]. Interestingly, another study that observed seventeen well-trained subjects, did not show any difference in CoQ levels in both skeletal muscle and skeletal mitochondria. Only plasma CoQ levels were significantly elevated after supplementation. Furthermore, no statistical difference in plasma levels of malondialdehyde, uric acid, and hypoxanthine were noted [31]. What is more interesting, another study by the same authors showed statistically worse results during an anaerobic cycling test, and a lower increase in total work performed compared to the placebo group [32].

Another study involving cyclists and triathletes observed whether CoQ could improve aerobic capacity, which is important in high endurance sports. The study group was supplemented with 1 mg/ kg/ d of CoQ. The only two differences between the groups were noted in the plasma CoQ levels and in the 6th minute of measured oxygen uptake for the CoQ group. Nonetheless, no statistical differences in oxygen uptake, exercise time to exhaustion, exercise time, or maximal oxygen consumption were noted [33]. Similar results were obtained in another study, where the researchers added 600 mg of ascorbic acid and 270 mg of α-tocopherol to the 100 mg of CoQ daily. After 6 weeks, maximal oxygen uptake was no different in the supplemented group than in the placebo group. Moreover, a nuclear magnetic resonance spectroscopy was conducted during plantar flexion to measure muscle pH, phosphocreatine reduction at the end of exercise, as well as half-time to recovery of the aforementioned phosphocreatine. It showed no statistical differences in the measured parameters between the groups, consequently demonstrating no effect of CoQ supplementation [34].

d) Swimming

Intense physical exercise combined with hyperthermia can paradoxically trigger oxidative stress and negatively affect heart function. Another study aimed to examine the impact of 14-day coenzyme Q10 (CoQ10) supplementation and pre-cooling on serum markers of cardiac injury and oxidative stress, including CK-MB, cTnI, myoglobin (Mb), LDH, total antioxidant capacity (TAC), lipid peroxidation (LPO), and CoQ10 levels in elite swimmers. A total of 36 healthy male athletes were randomly assigned to four groups: CoQ10 supplementation, CoQ10 supplementation with pre-cooling, pre-cooling alone, and a control group. Participants completed an 18-session training program, comprising morning and evening swimming sessions of 5 km each. Blood samples were collected before (two stages) and after (two stages) the interventions. No significant differences were observed among groups for CK-MB, cTnI, Mb, LD, TAC, LPO, or CoQ10 at baseline (stages 1 and 2). However, in the post-intervention measurements (stages 1 and 2), the pre-cooling and control groups exhibited significant increases in CK-MB, cTnI, Mb, LD, and LPO compared with the groups receiving CoQ10 supplementation, either alone or combined with pre-cooling ($P < 0.05$). No significant changes were observed for TAC or CoQ10 levels. These findings suggest that CoQ10 supplementation can mitigate myocardial damage and oxidative stress during competitive swimming, whereas pre-cooling alone does not appear to influence cardiac injury markers, oxidative stress, or CoQ10 concentrations [35]. Coenzyme Q10 supplementation may have a positive effect not only on cardiac damage markers (by reducing their levels) but also on skeletal muscle performance. The purpose of the next study was to examine the effects of 14 days of CoQ10 supplementation and a pre-cooling strategy on serum levels of superoxide dismutase (SOD), catalase (CAT), and glutathione peroxidase (GPX) in elite swimmers during periods of regular and intensive training, as well as during freestyle performance testing at the competition stage. A repeated-measures design was employed, with participants randomly allocated to one of four groups: CoQ10 supplementation (300 mg/day), pre-cooling (water immersion at 18 ± 0.5 °C), combined CoQ10 supplementation with pre-cooling, and a control group. The findings of the cited study demonstrated that CoQ10 supplementation reduced levels of endogenous antioxidant enzymes during periods of heavy training and competition in elite swimmers. As a potent antioxidant and a regulator of cell signalling and body temperature, CoQ10 enhances the activity of antioxidant enzymes such as GPX, SOD, and CAT. Moreover, CoQ10 supplementation appears to mitigate the negative effects associated with pre-cooling. In contrast, the use of a pre-cooling strategy in swimming alone neither prevented the reduction in serum antioxidant enzyme levels nor improved the activity of GPX, SOD, and CAT individually [36]. Another study, in which participants ingested 300 mg of CoQ daily, also showed promising results. After the supplementation period, lower levels of malondialdehyde and protein hydroperoxide were noted, with higher erythrocyte glutathione levels, higher total antioxidant capacity and CoQ levels, all of which were statistically significant. Time to exhaustion and swimming time over 100 meters also substantially improved, whereas swimming time over 800 meters did not [37].

e) Trained individuals

The study by Alf et al. included 100 young athletes, including many who competed in the 2012 Summer Olympics, who either received 60 mg of CoQ daily or placebo. Their individual fitness was measured in Watts per kilogram of body weight at three time points during the experiment: at the beginning, after 3 weeks and after 6 weeks. Even though both groups had a statistically significant improvement due to the training, the group that supplemented CoQ showed better results than the control group [38]. In another double-blind placebo-controlled study, 21 young athletes were assigned to either in a group receiving 200 mg of CoQ daily or placebo for 6 weeks. After that time, the CoQ group showed significant improvements in the systolic and diastolic blood pressure, BMI and body fat percent. Moreover, aerobic capacity, measured as VO_2max, was significantly better in the CoQ group. No differences were found in muscular strength, endurance, or power [39]. Another study examined whether CoQ could potentially improve the glycaemic profile and antioxidant status in athletes. 31 participants were given either 300 mg of CoQ daily or placebo during the 12- week trial. After this time, the plasma CoQ level and the ratio of CoQ to total cholesterol improved significantly in the study group. Moreover, erythrocyte malondialdehyde levels significantly decreased. Nevertheless, no differences in fasting glucose, HbA1c, plasma malondialdehyde or antioxidant capacity (as measured by total antioxidant capacity in serum and erythrocytes) levels were noted [40]. Another research included 100 well-trained firefighters, who either received a daily dose of 200 mg of CoQ or placebo. The first blood sample was taken on day 1, before the supplementation, then after 2 weeks. On the last day of supplementation, they performed the first exercise (after that the third sample was taken), and after 24 hours of rest (with a fourth blood sample) they did a second exercise (with a fifth blood sample). Interestingly, while there was no statistical difference in blood lactate levels, a steady decrease in blood nitric oxide levels was observed in the placebo group during the exercises, while the CoQ group showed elevated levels. The elevated levels of NO could improve endothelial function and muscle recovery. Moreover, a significant reduction in isporostanes and 8-hydroxy-2'-deoxyguanosine in urine was noted as parameters of decreased oxidative stress. In addition, statistically lower levels of plasma lipid peroxides and oxidised LDL were noted 24 hours after the first exercise in the study group, indicating an improvement in antioxidant processes in plasma. No such differences were noted in membrane lipid peroxides or carbonyls [41]. Orlando et al. conducted an even more complicated study, in which 21 young male athletes were divided into two groups. They either received 200 mg/d of CoQ or placebo for 1 month, then a washout period was introduced (where they received no supplementation). After that, the groups were switched, with the placebo receiving CoQ, and former study group receiving placebo. Blood tests were taken before and after intense exercise (40 min of running at 85% of maximal heart rate) between the periods. Nevertheless, no statistically significant difference in either improved physical performance, or reduced levels of creatine kinase, myoglobin, creatinine, glucose, or urea was noted. Conversely, only plasma levels of CoQ were significantly elevated after the supplementation period, potentially balancing the exercise-induced depletion [42].

f) Untrained individuals

The first study including untrained individuals consisted of 15 sedentary participants. It was a double-blind crossover trial, in which the control and study groups interchanged in the second phase of the study. Each participant received a daily dose of 100 mg of CoQ daily, or placebo for 8 weeks, then underwent exercise. After a 4-week wash-out period, the groups switched, with the study group receiving placebo and vice versa for the next 8 weeks. During the exercises, 5 Wingate tests were performed, with peak power measured in each. Interestingly, compared to the baseline exercise, peak power dropped significantly in the first and second measurement in the CoQ group. Moreover, the placebo group showed only one such decrease, at the second measurement. Furthermore, mean power seemed to steadily decrease in the CoQ group, with many significant differences between the tests. Nevertheless, mean power compared to the baseline exercise increased from 285,6 ± 47,7 W to 331,5 ± 84,3 W ($p<0,05$), suggesting improvement in the CoQ group. Conversely, fatigue index levels were lowered in both groups in comparison to baseline. Nevertheless, no measurable effects were achieved by supplementing CoQ in this study [43]. Similarly, in a study where a group of 21 sedentary men received either placebo, or 200 mg of CoQ, no differences were found between the plasma CK activity, myoglobin, malondialdehyde, or superoxide dismutase levels [44]. Another study included 15 middle-aged, sedentary men. Interestingly, the participants with the lowest initial levels of plasma CoQ were chosen for the supplementation, which consisted of five 30 mg capsules of CoQ daily. The rest received placebo. After 2 months, the levels of CoQ and subjective perception of vigor increased significantly in the study group. Nevertheless, no significant differences were found in maximal VO_2, maximal heart rate, or maximal workload (measured in Watts). Moreover, during hand dynamometry, forearm oxygen uptake, blood flow, and lactate release were no different between the groups [45].

Cooke et al. carried out a study, in which 22 trained and 19 untrained males and females were included, and assigned to two groups, receiving 200 mg of CoQ daily or placebo. The supplementation period lasted 14 days, with exercises performed on day 1 and 14 and blood samples taken after those exercises, in addition to muscle biopsies. After the trial, no body composition, muscle endurance, anaerobic, or aerobic capacity differences were found. Interestingly, muscle CoQ levels did not improve significantly over the period of supplementation. Moreover, only a moderate positive correlation was found between the plasma CoQ levels and oxygen consumption, or time to exhaustion [46].

g) Trivia

Kendo is a traditional Japanese martial art that involves two participants duelling while wearing protective armour and using a bamboo sword-like staff. Matches can last up to five minutes, with points earned by striking the opponent’s head, torso, forearms, or throat. The first study aimed to investigate whether CoQ could reduce muscle injury and oxidative stress during exercise training in this sport. Eighteen male elite Japanese kendo athletes were randomly assigned in a double-blind manner. Participants in the CoQ10 group took 300 mg of CoQ10 daily for 20 days, while the other group received placebo. Blood samples were collected two weeks before training, during training (days 1, 3, and 5), and one week after training. Both groups showed significant increases in serum creatine kinase activity and myoglobin levels on days 3 and 5. However, the CoQ10 group had lower CK (day 3), Mb (day 3), and lipid peroxide levels (days 3 and 5) compared with the placebo group. In addition, leukocyte counts rose significantly in the placebo group on day 3, while neutrophil counts increased in both groups on days 3 and 5. No changes were observed in serum superoxide scavenging activity in either group [47]. Additionally, another study including kendo sportsmen also showed significantly increased myoglobin and creatine kinase levels in both groups, with no differences between placebo and CoQ groups [48].

A crossover study conducted by Ylikoski et al. included 25 top-level cross-country skiers who received 90 mg of CoQ daily or placebo. A significant improvement in both aerobic and anaerobic thresholds was noted in the supplemented group, similarly to maximal VO_2. During subjective evaluation, CoQ had a statistically more positive effect than the placebo. On the contrary, lactic acid clearance did not differ between the groups [49].

Another interesting study evaluated, whether CoQ supplementation could benefit physical activity in patients with chronic kidney disease, who receive haemodialysis. 23 patients were assigned to the 200 mg of CoQ daily or placebo for 12 weeks, followed by 4 weeks of washout and 12 weeks of supplementation with the groups switched. A 6 minute walk test was performed to measure their physical capacity, as well as to measure their oxidative strain. Both the walking distance in the 6-minute walk test, and the maximal VO_2 did not show any statistical difference between the CoQ group and the placebo group. Moreover, neither malondialdehyde, nor ox-LDL levels showed any difference between the groups. Malondialdehyde levels significantly increased after exercise in both groups, with a significant reduction after 30 minutes in both. In summary, no benefits were shown for CoQ supplementation in the haemodialyzed patients [50].

h) Mind sports

The role of CoQ10 in enhancing sport performance should not only pertain to purely physical sports but also to intellectual ones (so-called mind sports). Mind sports are competitive games that challenge the intellect rather than the body. Examples include chess, draughts, Go, bridge, Sudoku, and memory contests. They develop critical thinking, memory, concentration, and strategic planning.

Playing mind sports improves cognitive abilities, patience, and emotional control, while also promoting social interaction and teamwork. They are inclusive, allowing people of all ages and abilities to compete fairly, and may even help maintain brain health in older adults.

Unfortunately, to date, there is a lack of robust evidence supporting a positive effect of coenzyme Q10 supplementation on the performance of people (professionally) engaged in mind sports. Existing research has primarily examined the relationship between coenzyme Q10 levels and cognitive function in older adults as with more older adults living in Western countries, cognitive decline is emerging as a major concern or in patients with primary coenzyme Q10 deficiency [51], [52]. It appears advisable to conduct appropriate studies in the near future to investigate the impact of coenzyme Q10 levels on the performance of people practicing the aforementioned sports disciplines, in order to obtain a comprehensive understanding of the correlation between coenzyme Q10 and improvements in their performance.

Conclusion

In conclusion, CoQ supplementation in sports has been extensively studied, with multiple publications published. Nevertheless, there is a lack of studies that include larger cohorts, or longer observation periods. Despite some mechanistic advantages, findings regarding CoQ10 supplementation and athletic performance remain inconsistent. Differences in dosage, formulation, absorption efficiency, training status, and baseline endogenous CoQ10 levels likely account for variability in study outcomes. The only common finding in most of these studies is that CoQ supplementation elevates the serum levels of CoQ, while other findings are subject to debate. Overall, the broader body of evidence suggests little to no benefit of supplementation.

Disclosure

Author's contribution

Conceptualization - Kacper Szada-Borzyszkowski

Methodology - Kacper Szada-Borzyszkowski

Software - Kacper Szada-Borzyszkowski

Check - Konstancja Owczarenko

Formal analysis - Konstancja Owczarenko

Investigation - Konstancja Owczarenko

Resources - Konstancja Owczarenko

Data curation - Kacper Szada-Borzyszkowski, Konstancja Owczarenko

Writing - rough preparation - Kacper Szada-Borzyszkowski, Konstancja Owczarenko

Writing - review and editing - Konstancja Owczarenko, Kacper Szada-Borzyszkowski

Visualization - Konstancja Owczarenko

Supervision - Kacper Szada-Borzyszkowski

All authors have read and agreed with the published version of the manuscript

Funding statement

No funding was received for this study by the authors

Institutional Review and Board statement

Not applicable.

Informed Consent Statement

Not applicable.

Data Availability Statement

Not applicable.

Conflict of Interest Statement

Authors declare no conflict of interest.

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