Effects of Vitamin-Mineral Supplementation on Cardiac Marker and Radical Scavenging Enzymes, and MDA Levels in Young Swimmers

Levent Cavas and Leman Tarhan

The relationship among the enzyme activities of cardiac markers, the antioxidant defense system, and erythrocyte membrane malonyldialdehyde (MDA) levels related to vitamin-mineral supplementation in swim exercise was investigated. Swimmers aged 11–13 years were divided into 2 separate groups as control and vitamin-mineral supplemented. Swimmers participated in a monthly swimming program (4 times/wk) and swam approximately 2–2.5 km/d. Cardiac markers such as creatine kinase (CK), creatine kinase-MB (CK-MB), glutamic oxaloacetic transaminase [GOT (AST)], lactate dehydrogenase (LDH), and antioxidant enzymes such as superoxide dismutase (SOD), catalase (CAT), and glutathione peroxidase (GSH-Px) activities in post-training samples were found to be significantly ($p < .05$) higher than in pre-training samples. Except for GOT (AST), the activity increases in CK, CK-MB, and LDH in female and male supplemented groups were significantly ($p < .05$) lower than those of control groups during the 1-month period of swim training. Antioxidant enzyme activity increases in the male vitamin-mineral group were significantly ($p < .05$) higher when compared with the other groups. Post-training MDA levels were significantly ($p < .001$) higher than pre-training MDA levels in the control groups, whereas no significant ($p > .05$) differences were found between the vitamin-mineral supplemented groups. Vitamin-mineral supplementation was found to attenuate cardiac and muscle damage markers while also enhancing antioxidant levels and reducing membrane LPO levels in response to 1 month of swim training.

Key Words: CK, CK-MB, LDH, GOT (AST), SOD, CAT, GSH-Px, LPO, MDA, swimming, physical exercise

Introduction

Increased activities of serum cardiac marker enzymes such as creatine kinase (CK), creatine kinase-MB (CK-MB), glutamic oxaloacetic transaminase (GOT), also known

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as aspartate aminotransferase (AST) and lactate dehydrogenase (LDH), have been used diagnostically as specific indicators of acute myocardial infarction (AMI) and muscle damage (34). CK catalyses the reversible transfer of a phosphoryl group from phosphocreatine to ADP, thereby regenerating ATP. When muscle has been damaged or diseased, CK leaks into the bloodstream, where it can be measured. Increased levels may signal muscular dystrophy, polymyotitis, dermatomyositis, and some myositis as well as a heart attack. Increased activity of the creatine kinase MB isoenzyme in serum has also been used diagnostically as a specific indicator of AMI and skeletal muscle damage. Glutamic oxaloacetic transaminase [GOT (AST)] catalyses the reaction between L-aspartate and 2-oxoglutarate from which oxaloacetate is formed. Serum GOT (AST) levels in healthy subjects are low, but the levels are significantly elevated in a number of clinical conditions, such as acute and chronic hepatitis, carcinoma of the liver, myocardial infarction, and muscular dystrophy; therefore, determination of the serum GOT (AST) level has great clinical and diagnostic significance. The increased activities of CK and CK-MB as well as of LDH during long, exhausting physical exercise are of noncardiac origin. Therefore, recent attention has been given to cardiac marker enzymes such as CK, CK-MB, LDH, and GOT (AST) in serum of variously trained athletes (6, 7, 12, 21, 40, 47, 49, 52). LDH is an oxidoreductase, which catalyses the conversion of lactate to pyruvate. It consists of four subunits, which may be of different types M and H (M, muscle; H, heart). Five different isoenzymes are therefore possible depending on the subunit composition.

Protection against exercise-induced oxidative damage by antioxidant supplementation is an important issue in sports medicine and sports nutrition. The biologically damaging effects of reactive oxygen species (ROS) are controlled in vivo by a wide spectrum of antioxidant defense mechanisms. Interest in oxygen-centered radicals has motivated investigators to question whether exercise-stimulated overconsumption of oxygen might induce an oxidative stress and pose some risk to biological systems (28). The aerobic metabolic rate may increase up to 10-fold during physical exercise (27), causing overproduction of reactive oxygen species such as superoxide radical anion (O$_2^-$), H$_2$O$_2$, and HO·. If the rise in the level of oxygen free radicals exceeds the antioxidant defense capacity of the cells, damage to DNA, proteins, enzymes, and subcellular organelles can occur, resulting in possible muscle fatigue (16). The three major antioxidant enzymes are superoxide dismutase (SOD), catalase (CAT), and glutathione peroxidase (GSH-Px). SOD enzymes remove superoxide radicals by converting two oxygen radicals and two hydrogens into hydrogen peroxide (H$_2$O$_2$). Although the conversion of oxygen radicals to H$_2$O$_2$ is a useful temporary fix, removal of H$_2$O$_2$ is critical for cell survival. CAT can facilitate the removal of H$_2$O$_2$, producing harmless water in the process (22). GSH-Px also removes H$_2$O$_2$ from the cell. As a result, glutathione is oxidized to glutathione disulphide (GSSG). Animal studies have shown that strenuous exercise promotes free radical formation and lipid peroxidation in skeletal muscle (16, 50). Post-exercise increases in plasma CK activities and indices of lipid peroxidation (LPO) have also implicated free radicals in muscle damage and soreness following exercise (5, 17, 32, 36, 48).

In the present study, the effects of vitamin-mineral supplementation on cardiac markers and antioxidant defense system enzymes and erythrocyte membrane LPO levels were examined in young swimmers.
Material and Methods

Thirty (15 female, 15 male) well-trained swimmers of İzmir Büyükbehir Belediyesi Sports Club, aged 11–13 years, who attended the national swimming competition, participated in this study. The mean age (F = 12.2 ± 1.6; M = 11.9 ± 1.7 yr), weight (F = 57.0 ± 4.7; M = 57 ± 3.3 kg), height (F = 160 ± 3; M = 158 ± 3 cm), and duration of training (2 h/d, 4 d/wk) were recorded. The swimmers were randomly divided into two groups, control and vitamin-mineral supplemented. The subjects in the vitamin-mineral supplemented group received one tablet (One a Day for Junior©, Bayer; Table 1) per day during the 1-month training program.

All swimmers had been advised to obey a standard 2500–3000 kcal daily diet (2, 25, 39), and they also were advised not to consume any other dietary supplements during the study. The training protocol is presented in Table 2.

Table 1  Vitamin and Mineral Ingredients of One a Day for Juniors©

<table>
<thead>
<tr>
<th>Vitamin</th>
<th>QPT*</th>
<th>Vitamin</th>
<th>QPT</th>
<th>Mineral</th>
<th>QPT</th>
</tr>
</thead>
<tbody>
<tr>
<td>Vitamin A</td>
<td>5000 IU</td>
<td>Vitamin B₆</td>
<td>2 mg</td>
<td>Calcium</td>
<td>100 mg</td>
</tr>
<tr>
<td>Vitamin C</td>
<td>60 mg</td>
<td>Niacin</td>
<td>20 mg</td>
<td>Iron</td>
<td>18 mg</td>
</tr>
<tr>
<td>Vitamin D</td>
<td>400 IU</td>
<td>Folic Acid</td>
<td>0.40 mg</td>
<td>Phosphor</td>
<td>100 mg</td>
</tr>
<tr>
<td>Vitamin E</td>
<td>30 IU</td>
<td>Vitamin B₁₂</td>
<td>6 mcg</td>
<td>Iodine</td>
<td>150 mcg</td>
</tr>
<tr>
<td>Vitamin B₁</td>
<td>1.5 mg</td>
<td>Biotin</td>
<td>40 mcg</td>
<td>Magnesium</td>
<td>20 mg</td>
</tr>
<tr>
<td>Pantothenic A</td>
<td>10 mg</td>
<td></td>
<td></td>
<td>Copper</td>
<td>2 mg</td>
</tr>
</tbody>
</table>

*Quantity per tablet.

Table 2  Swimming Protocol for the Swimmers Participated to Study

<table>
<thead>
<tr>
<th>Sets</th>
<th>Drills</th>
<th>Total distance</th>
</tr>
</thead>
<tbody>
<tr>
<td>Warm up</td>
<td>200 m front crawl, 200 m pull, 200 m fixed drills, all done at easy pace</td>
<td>600 m</td>
</tr>
<tr>
<td>Main set</td>
<td>4 × 200 m, 3 × 100 m, 3 × 100 m, mixed still</td>
<td>1400 m</td>
</tr>
<tr>
<td>Technique set</td>
<td>6 × 25 m catch up, trails fingers or fists, 2 × 50 m stroke counting each length, 6 × 25 m kicking 40 s</td>
<td>400 m</td>
</tr>
<tr>
<td>Cool down</td>
<td>100 m easy swimming mixed strokes</td>
<td>100 m</td>
</tr>
</tbody>
</table>
Blood samples were obtained from each swimmer in the afternoon by using trace element–free vacutainer tubes containing 14300 U/L heparin as the anticoagulant. The blood samples were centrifuged at 4000 g for 10 min at 4 °C and the plasma removed as completely as possible. The red cells were washed three times with 0.9% NaCl solution, and the packed cells were hemolyzed by adding an equal volume of cold distilled water followed by freeze-thaw. Blood collection groups were identified as Male Control Group (MCG), Female Control Group (FCG), Female Vitamin-Mineral Supplemented Group (FSG), and Male Vitamin-Mineral Supplemented Group (MSG).

**Statistical Analysis**

Means and standard deviations were calculated for all parameters investigated using the pre-training, post-training, and difference between the post- and pre-training values (delta). Statistical analysis was performed using an analysis of variance (three-way ANOVA). The .05 level was selected as the point of minimum statistical significance.

**Analytical Methods**

Determination of Enzymatic Activities. Total CK, CK-MB, total LDH, and GOT (AST) were measured using an OPERA-Chemistry System Analyzer (Bayer) and Roche Diagnostic kits.

SOD activity assay system was based on the inhibitory effect of SOD on the spontaneous auto-oxidation of 6-hydroxydopamine (6-OHDA). One IU was the amount of superoxide dismutase required to inhibit the initial rate of 6-OHDA autooxidation by 50% (15).

CAT activity was determined using a method described by Aebi that measures the decrease in the H₂O₂ at 240 nm. The reaction mixture (1 ml) contained 50 mM phosphate buffer pH 7.0 and 10 mM H₂O₂ (1).

GSH-Px activity was measured in a coupled system by measuring the decrease in NADPH at 340 nm. The reaction mixture (1 ml) contained in order of addition: 20 mM phosphate buffer pH 7.4, 0.25 µmol reduced glutathione, 0.12 µmol NADPH, 0.5 units (0.5 µmol NADPH oxidized per min) glutathione reductase, and 0.20 µmol cumene hydroperoxide (44).

Lipid peroxidation was estimated by the method of Jain (26) based on thiobarbituric acid (TBA) reactivity. Malonyldialdehyde (MDA), an end product of fatty acid peroxidation, can react with TBA to form a colored complex that has a maximum absorbance at 532 nm and 600 nm. Butylated hydroxytoluene (BHT), an antioxidant, was added to prevent MDA formation during the assay, which could result in falsely elevated TBA reactivity.

Total protein concentration was determined by the Bradford Method (13), using Bovine Serum Albumin (BSA) as the standard.

**Results**

Effects of vitamin-mineral supplementation on plasma cardiac marker enzymes, packed erythrocyte antioxidant enzymes, and membrane lipid peroxidation levels were investigated in response to a 1-month period of swim training in young female and male swimmers.
According to Figure 1, CK activities in all groups increased significantly \((p < .001)\) after the 1-month period of swim training. The CK activity values increased from 96 ± 5 to 141 ± 6 U/L in FCG, from 97 ± 5 to 121 ± 7 U/L in FSG, from 114 ± 6 to 156 ± 7 U/L in MCG, and from 110 ± 6 to 132 ± 8 U/L in MSG. When the sex difference was analyzed, there was no significant statistical \((p > .05)\) difference between delta values of FCG and MCG and of FSG and MSG. On the other hand, vitamin-mineral supplementation did affect the CK activities significantly \((p < .05)\). Significant differences \((p < .05)\) were found between delta values of FCG and FSG and of MCG and MSG.

As can be seen from Figure 2, CK-MB activities in all groups also increased significantly \((p < .001)\) after the 1-month period of swim training. CK-MB activities in the FCG, FSG, MCG, and MSG increased from 16 ± 1 to 56 ± 3 U/L, from 17 ± 1 to 47 ± 3 U/L, from 18 ± 0.9 to 70 ± 3.5 U/L, and from 14 ± 1 to 54 ± 2 U/L, respectively. A significant gender effect \((p < .05)\) for CK-MB activity was found between delta values of FCG and MCG, and of FSG and MSG. Vitamin-mineral supplementation also affected the CK-MB values; delta values of control groups were significantly \((p < .05)\) higher than those of vitamin-mineral supplemented groups.

GOT (AST) activity, which is one of the important liver function markers, has elevated significantly \((p < .001)\) in all control and vitamin-mineral supplemented groups with an approximately similar increase in value (Figure 3). The activities increased significantly from 22 ± 1 to 33 ± 2 U/L in FCG, from 25 ± 1 to 39 ± 2 U/L in FSG, from 24 ± 1 to 33 ± 2 U/L in MCG, and from 23 ± 1 to 31 ± 2 U/L in MSG. When gender differences were examined, a significant difference \((p < .05)\) was found between delta values of FCG and MCG, and of FSG and MSG. Even though a

![Figure 1](image_url)  
**Figure 1** — Effects of 1 month swim training on plasma CK activity in both control and vitamin-mineral supplemented groups. Values are means ± SD. Values were expressed as U/L. FCG: Female Control Group; FSG: Female Vitamin-Mineral Supplemented Group; MCG: Male Control Group; MSG: Male Vitamin-Mineral Supplemented Group. *Significantly different \((p < .05)\) between pre- and post-training; \(a\) significantly different \((p < .05)\) between supplement and control groups.
Figure 2 — Effects of 1 month swim training on plasma CK-MB activity in both control and vitamin-mineral supplemented groups. Values are means ± SD. Values were expressed as U/L. FCG: Female Control Group; FSG: Female Vitamin-Mineral Supplemented Group; MCG: Male Control Group; MSG: Male Vitamin-Mineral Supplemented Group. *Significantly different \((p < .05)\) between pre- and post-training; \(^{a}\) significantly different \((p < .05)\) between supplement and control groups; \(^{b}\) significantly different \((p < .05)\) between males and females.

Figure 3 — Effects of 1 month swim training on plasma GOT (AST) activity in both control and vitamin-mineral supplemented groups. Values are means ± SD. Values were expressed as U/L. FCG: Female Control Group; FSG: Female Vitamin-Mineral Supplemented Group; MCG: Male Control Group; MSG: Male Vitamin-Mineral Supplemented Group. *Significantly different \((p < .05)\) between pre- and post-training; \(^{a}\) significantly different \((p < .05)\) between supplement and control groups; \(^{b}\) significantly different \((p < .05)\) between males and females.
statistical significance \((p < .05)\) was found between delta values of FCG and MCG, there was no significant \((p > .05)\) change between MCG and MSG.

Figure 4 shows that the other cardiac marker enzyme, LDH, also increased significantly \((p < .001)\) in all groups after the 1-month period of swim training. LDH values increased from 187 ± 9 to 424 ± 16 U/L in the FCG, from 178 ± 9 to 287 ± 12 U/L in the FSG, and from 232 ± 12 to 289 ± 13 U/L in the MSG, and the highest increase was observed in the MCG from 214 ± 11 to 498 ± 24 U/L. According to statistical analysis, there was a significant difference \((p < .001)\) between delta values of control and vitamin-mineral supplemented groups. When the gender effect was examined, delta values in MCG were significantly \((p < .05)\) higher than those of FCG.

In order to observe any relationship among cardiac markers, the antioxidant defense system, and erythrocyte membrane LPO levels, SOD, CAT, GSH-Px, and MDA levels were examined.

As can be seen in Figure 5, while SOD activities in FCG, FSG, and MSG increased significantly \((p < .05)\) from 3.39 ± 0.2 to 3.54 ± 0.2 IU/mg, from 3.42 ± 0.2 to 4.01 ± 0.2 IU/mg, and from 3.62 ± 0.2 IU/mg to 4.47 ± 0.2 IU/mg, respectively, SOD activity in MCG did not significantly \((p > .05)\) change after the 1-month period of swim training (from 3.56 ± 0.2 to 3.49 ± 0.2 IU/mg). A significant effect of gender was found for SOD enzyme activity between the control and vitamin-mineral supplement groups. The delta value for FCG was significantly greater \((p < .05)\) when compared with the MCG. However, the delta value for FSG was significantly \((p < .05)\) lower than that of MSG. Delta values in vitamin-mineral supplemented groups were significantly \((p < .05)\) higher than the control groups.

Figure 4 — Effects of 1 month swim training on plasma LDH activity in both control and vitamin-mineral supplemented groups. Values are means ± SD. Values were expressed as U/L. FCG: Female Control Group; FSG: Female Vitamin-Mineral Supplemented Group; MCG: Male Control Group; MSG: Male Vitamin-Mineral Supplemented Group. *Significantly different \((p < .05)\) between pre- and post-training; a significantly different \((p < .05)\) between supplement and control groups; b significantly different \((p < .05)\) between males and females.
According to Figure 6, while CAT activities in FCG, FSG, and MSG increased significantly \((p < .05)\) from 280 ± 14 to 299 ± 16 IU/mg, from 285 ± 14 to 506 ± 25 IU/mg, and from 305 ± 15 to 572 ± 29 IU/mg, respectively, CAT value in MCG did not significantly \((p > .05)\) change after the 1-month period of swim training (from 310 ± 15.5 to 322 ± 17.8 IU/mg). Delta values in vitamin-mineral supplemented groups were significantly \((p < .001)\) higher than those for the control groups. Furthermore, delta values in FCG and MSG were significantly \((p < .05)\) higher than those of MCG and FSG, respectively.

GSH-Px activities in both control and vitamin-mineral supplemented groups are presented in Figure 7. GSH-Px activity increased significantly \((p < .001)\) after the 1-month period of swim training from 6001 ± 300 to 7202 ± 360 U/L in FCG, from 6101 ± 305 to 8302 ± 415 U/L in FSG, from 6201 ± 310 to 7317 ± 354 U/L in MCG, and from 6256 ± 312 to 9256 ± 462 U/L in MSG. A significant difference \((p < .001)\) was observed between the vitamin-mineral supplemented groups and control groups. Delta values of vitamin-mineral groups were significantly \((p < .05)\) higher than those of control groups. When gender was controlled, delta values in FCG and MSG were significantly \((p < .05)\) higher than those of MCG and FSG, respectively.

The erythrocyte membrane LPO levels in both the control and the vitamin-mineral supplemented groups are given in Figure 8. MDA concentration in the vitamin groups did not significantly \((p > .05)\) change, whereas statistical significant differences \((p < .001)\) were observed in the control groups between pre-training and
Figure 6 — Effects of 1 month swim training on packed erythrocyte CAT activity in both control and vitamin-mineral supplemented groups. Values are means ± SD. Values were expressed as IU/mg. FCG: Female Control Group; FSG: Female Vitamin-Mineral Supplemented Group; MCG: Male Control Group; MSG: Male Vitamin-Mineral Supplemented Group. *Significantly different (p < .05) between pre- and post-training; a significantly different (p < .05) between supplement and control groups; b significantly different (p < .05) between males and females.

Figure 7 — Effects of 1 month swim training on packed erythrocyte GSH-Px activity in both control and vitamin-mineral supplemented groups. Values are means ± SD. Values were expressed as U/L. FCG: Female Control Group; FSG: Female Vitamin-Mineral Supplemented Group; MCG: Male Control Group; MSG: Male Vitamin-Mineral Supplemented Group. *Significantly different (p < .05) between pre- and post-training; a significantly different (p < .05) between supplement and control groups; b significantly different (p < .05) between males and females.
post-training values. MDA values increased from 4.4 ± 0.2 to 7.1 ± 0.4 nmol MDA / gHb in FCG and from 4.7 ± 0.2 to 8.2 ± 0.4 nmol MDA / gHb in MCG. When gender was examined, delta values in FSG and MCG were significantly (p < .05) higher than those of MSG and FCG, respectively. Vitamin-mineral supplementation was found to have a significant effect on MDA values. There was a significant difference (p < .001) between delta values of FCG and FSG, and of MCG and MSG.

Discussion

The present study reported on the effects of a multiple nutrient mixture on plasma enzyme markers, erythrocyte antioxidant enzymes and erythrocyte membrane lipid peroxidation levels in young swimmers in response to a 1-month program of swim training. Regular exercise and exercise training are important in both the primary and secondary prevention of diseases such as atherosclerosis, muscular dystrophy, and various heart diseases (24, 29, 30, 53). One of the most important cardiac marker enzymes, Serum CK, has for years been measured and evaluated in exercise science as an essential parameter for the determination of muscular stress and various heart diseases (34, 41). In the present study, post-exercise CK activities of male groups were higher than female groups, and they reached to 141 ± 7 U/L in the FCG, 156 ± 8 U/L in the MCG, 121 ± 6 U/L in the FSG, and 132 ± 7 U/L in the MSG. Early studies concerning CK activities in some experimental animals support our study; female rats had lower rates of CK release from exercising muscles than males (3, 4,
In our study, similar increases were seen in the CK-MB activities. The increases in CK-MB activities of the control groups were significantly ($p < .05$) higher than those of the vitamin-mineral supplemented groups (Figure 1). On the other hand, the increases in CK-MB activities of male groups were higher than in female groups. This gender related difference in CK and CK-MB activities have been reported in various papers (37, 51). One possible explanation for the lower CK and CK-MB values observed in women is the fact that men have a greater muscle mass and therefore may have a greater CK content in skeletal muscles resulting from muscle damage (3, 37).

LDH and GOT (AST) enzyme activities, as well as the activities of CK and CK-MB, increased significantly ($p < .05$) in all groups after a 1-month period of swim training. Our results support previous findings in this area (16, 19, 42). Cardiac marker enzymes such as CK, CK-MB, and LDH revealed a similar trend during the 1-month period of swim training. The delta values of these enzymes were significantly ($p < .05$) lower in the vitamin-mineral supplement group than in the control groups. However, the delta value for GOT (AST) activity was significantly ($p < .05$) higher for FSG than FCG. There was no significant difference ($p > .05$) between MCG and MSG. With the exception of GOT (AST) activity, our results indicate that vitamin-mineral supplementation in young swimmers might provide a resistance to some exercise-based disorders.

During physical exercise, a large amount of oxygen is inhaled into the body. Earlier studies have shown that when the body is subjected to oxidative stress, ROS are overproduced by metabolism (27). These ROS are scavenged by SOD, CAT, GSH-Px, and the antioxidant vitamins such as vitamins A, C, and E (10, 18, 45).

The increases, by percentage, in SOD and CAT activities of FSG and MSG were 17%, 23%, 77%, and 87%, respectively. These increases in the vitamin-mineral supplemented groups might be explained by the trace elements copper (Cu) and iron (Fe), which are components of the vitamin-mineral mixture. Since Cu is a cofactor of Cu,Zn-SOD and Fe is an important part of the heme group of CAT, these elements can be stimulating agents for the SOD and CAT activities during swim exercise in the vitamin-mineral supplemented groups (Figures 5 and 6). Various studies have proved that there is a direct correlation between trace elements and some antioxidant enzymes (11, 14, 23, 33, 35, 43, 54). In addition, GSH-Px activities were elevated significantly in all groups. In the vitamin-mineral supplemented groups, increased superoxide radicals may have been dismutated into hydrogen peroxide by the increasing in SOD activity. The toxicity of $H_2O_2$ may have been decreased by both CAT and GSH-Px activities; therefore, these data can be evidence in support of the unchanged LPO in the vitamin-mineral supplemented groups after 1 month of a swim training program.

Our data indicate that increased antioxidant enzyme activity and antioxidant vitamins such as vitamins A, C, and E might prevent ROS-based oxidation of polyunsaturated fatty acids of membrane lipids in vitamin-mineral supplemented swimmers. These results also support the previous findings in this area (8, 20, 31, 38). Greater cardiac marker enzyme activities observed in male control groups may cause higher LPO levels when compared with female control groups. On the other hand, cardiac markers such as CK and GOT, and antioxidant enzymes such as SOD, CAT, and GSH-Px did not demonstrate a significant change between female and male control groups. However, the remarkably different activities observed in CK-MB and LDH of these groups may explain the increase in LPO levels, which reached
to $7.1 \pm 0.4$ in FCG and $8.2 \pm 0.4$ nmol MDA/gHb in MCG. Accordingly, increased CK-MB and LDH activities may damage membrane lipids. Our data also showed that the increases of cardiac marker enzymes in vitamin-mineral supplemented groups were lower than those of the control groups. On the contrary, the observation of higher antioxidant enzyme activities in vitamin-mineral supplemented groups may be due to the removal of membrane damage caused by ROS during swim exercise. Accordingly, it can be said that the suppressed activity of cardiac marker enzymes due to both the increased antioxidant enzyme activities and vitamin-mineral supplementation may cause less muscle damage.

In conclusion, vitamin-mineral supplementation was found to attenuate cardiac and muscle damage markers, enhance antioxidant levels, and reduce membrane LPO levels in response to 1 month of swim training.

References


