Original research article

The effect of different doses of zinc supplementation on serum element and lactate levels in elite volleyball athletes

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ABSTRACT

The present study aims to examine the effect of different doses of zinc administration on serum element metabolism and fatigue. The study registered 20 female elite athletes. The subjects were divided into two groups in equal numbers. Group supplemented with 220 mg/day zinc sulfate. Group supplemented with 440 mg/day zinc sulfate. Athletes who were already engaged in their daily training routines were put to a 20-m shuttle run test to create fatigue before and after supplementation. Blood samples were collected from the subjects for a total of 7 times, before and after zinc supplementation and during rest and after exercise within one-week intervals over the course of the 4-week supplementation. The blood samples collected as such were analyzed to determine serum magnesium, phosphorus and calcium, zinc, iron, copper, and selenium, and plasma lactate. Both exercise and zinc supplementations significantly elevated magnesium, calcium, and iron levels for 4 weeks. Pre-supplementation exercise elevated plasma lactate levels, while zinc supplementation led to a fall in plasma lactate. The results of the present study indicate that zinc-supplementation for 4 weeks may have a positive impact on athletic performance by delaying fatigue.

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Introduction

Involved in the structure of more than 300 enzymes in the living organism and essential for a variety of metabolic reactions, zinc is an important trace element (Vallee and Falchuk, 1993). As a number of immune and endocrine functions depend on zinc, its deficiency is associated with problems in some physiological activities including cell proliferation, wound recovery, bone metabolism, growth and development, brain functions, regulation of nutrition, etc. (Baltaci et al., 2004; Prasad, 2009a, 2009b, 2013). Zinc, which is essential for carbohydrate, protein, and fat metabolisms, is integrally related to exercise (Bicer et al., 2012; Vallee and Falchuk, 1993). Its effects on tissue repair and protein synthesis, in particular, indicates the importance of zinc in post-exercise recuperation (Kilic, 2007; Prasad, 1985). In addition to the effects of zinc on exercise and performance, exercise has critical effects on zinc metabolism. Previous studies showed that not only low-intensity exercise produced short-term effects on zinc metabolism, but also high-intensity exercise performed for a prolonged period could do so (Cordova and Alvarez-Mon, 1995). These studies demonstrated a decrease in zinc levels after exercise (Couzy et al., 1990; Haralambie, 1981; Khaled et al., 1999). Low zinc levels may lead to a fall in muscle zinc concentrations. As zinc is required for the activity of a number of enzymes in the energy metabolism, reduced muscle zinc levels may bring about a decrease in endurance capacity (Cordova and Navas, 1995). It may be that the zinc deficiency observed in athletes performing endurance training is a factor triggering various functional changes in different systems and tissues that may be associated with the pathogenesis of fatigue (Cordova and Navas, 1998).McDonald and Keen (1988) have reported that it is important known of relationship between interaction diet zinc and other elements for sportsperson health and performance. It has been postulated that zinc has significant effects on element distribution in body (Eskici et al., 2016); especially has on positive affects on calcium-phosphor metabolism özellikle kalsiyum-fosfor metabolizması (Baltaci et al., 2014) and zinc supplementation has
regulatory effects on magnesium, phosphor, calcium, iron, copper and selenium levels (Sivrikaya et al., 2012). All of them mentioned references show possible affects of zinc elements metabolism in sportsperson. The objective of the present study is to examine the effect of different doses of zinc supplementation on serum element metabolism and fatigue.

Materials and methods

Participants

The research included 20 female athletes who were on the volleyball team of Gazi University Sports Club and whose mean age, weight, and height were 15.1 ± 1.07 years (14–17), 59.9 ± 6.4 kg (50.4–72.2), and 175.3 ± 6.5 cm, respectively. The subjects (and/or their parents) who were verbally informed also signed copies of the Helsinki Declaration explaining who is conducting the study and why. The study protocol was approved by the Ethics Committee of Selcuk University School of Physical Education and Sports.

We have conducted the present research, each group of athlete’s in resting and exhausting period lactate and serum element levels were determined; thereafter we postulated pre-measured periods as control levels. We have not used different control group.

The athletes in the study were divided into two groups:

Group 1 was supplemented with 220 mg/day zinc sulphate (Each 220 mg zinc sulphate has included 50 mg elemental zinc) and Group 2 was supplemented with 440 mg/day zinc sulphate (Each 440 mg zinc sulphate has included 100 mg elemental zinc). (Zinc sulfate capsules were supplied by Berko Drug and Chemicals Industry Inc. in the form of capsules each containing 220 mg zinc sulphate.) Mentioned doses were used previous search (Duchateau et al., 1981).

Procedures

The athletes who continued their routine daily training (6 days a week) were put to a 20m shuttle run test before and after supplementation to induce fatigue (Gunay et al., 2006). 20 m shuttle run test, one of the aerobic power field test was performed in order to create just fatigue. Blood samples were collected from the subjects for 7 times before and after zinc supplementation and during rest and after exercise in one-week intervals over the course of 4 weeks. Blood samples (10 ml) were taken by specialist medical staff (nurse) from the forearm vein. Since the athletes were all females, the analyses were interrupted in the week they had their menstruation. The samples were stored at −80 °C until the time of analysis. The study was conducted during the 8- to 10-week general preparation period (consisting of 70–80% strength and 20–30% technical/tactical training) of the athlete group.

Serum zinc, magnesium, phosphorus, calcium, iron, copper, and selenium analyses

Blood samples put into Eppendorf tubes were centrifuged at 3000 rpm for 10 min to separate serum. Serum samples obtained as such were analyzed for magnesium, phosphorus, calcium (mg/dl), zinc, iron, copper, and selenium (μg/dl) levels in an atomic emission device (ICP-MS).

Plasma lactate analyses

Blood samples of 2 ml were put into tubes containing fluoride-oxalate anticoagulant. The tubes were kept in ice blocks for 15 min and then centrifuged at 3000 rpm at 4 °C for 5 min to separate plasma. Plasma lactate levels were determined in Rocher Cobas Mira Plus brand device (Lot number: W253088) (read at 556 nm wavelength) as mmol/l.

Statistical evaluations

Mann Whitney U test was employed to determine the differences between groups. The comparison of measurements at different times within the group tested with two-way repeated measures analysis of variance, which arise from timing differences to determine whether the Bonferroni test was used. Level of significance was taken to be p < 0.05.

Results

Pre-supplementation serum element levels of the groups (at rest and after exercise)

Serum Mg, Ca, Fe, Cu, Se, P, and Zn levels measured before supplementation (at rest and post-exercise) were not different between groups 1 and 2 (Table 1). Likewise, there was no significant difference between serum Mg, Ca, Fe, Cu, Se, P, and Zn levels measured at rest in weeks 1, 2, 3, and 4 after supplementation in groups 1 and 2 (Table 1).

Post-supplementation serum element levels of the groups after exercise

Serum Mg, Ca, Fe, Cu, Se, and Zn levels measured after exercise in the post-supplementation period in groups 1 and 2 were not different, whereas p level in group 1 was significantly higher than that in group 2 (p < 0.05, Table 1).

Comparison between pre- and post-zinc supplementation and pre- and post-exercise serum element levels

Exercises both before and after zinc supplementation increased magnesium, calcium, iron, copper, selenium, phosphorus, and zinc levels in both groups 1 and 2, in comparison to the levels measured in pre-exercise periods (p < 0.05, Tables 2 and 3).

Comparison between the weekly changes caused by zinc supplementation in serum element levels in groups 1 and 2

Zinc supplementation significantly elevated magnesium, calcium, iron, and zinc levels over the course of 4 weeks (p < 0.05, Tables 2 and 3).

On the other hand, zinc supplementation significantly reduced copper and selenium levels in one-week periods over the course of 4 weeks (p < 0.05), while it did not cause any change in phosphorus levels (Tables 2 and 3).

Comparison between plasma lactate values

Pre-supplementation exercise increased plasma lactate levels (p < 0.05, Table 4), while exercise after zinc supplementation decreased plasma lactate (p < 0.05, Table 4).

Discussion

Discussion of magnesium, calcium, and iron levels in the study groups

Both exercise and zinc supplementation significantly elevated magnesium, calcium, and iron levels for 4 weeks. Despite the presence of contradicting results (Lukaski, 2000), magnesium (mg), nerve transmission, muscle contraction, and in particular involved in the energy production of ATP is a mineral
There is significant difference between means of the same parameter with a different superscripted letter the same line ($P < 0.05$).

<table>
<thead>
<tr>
<th>Elements</th>
<th>Before supplementation pre-exercise</th>
<th>Before supplementation post-exercise</th>
<th>Weeks 1 after supplementation</th>
<th>Weeks 2 after supplementation</th>
<th>Weeks 3 after supplementation</th>
<th>Weeks 4 after supplementation before-exercise</th>
<th>Weeks 4 after supplementation post-exercise</th>
</tr>
</thead>
<tbody>
<tr>
<td>Mg (mg/dl)</td>
<td>1.66 ± 0.19 d</td>
<td>1.75 ± 0.18 cd</td>
<td>1.61 ± 0.21 d</td>
<td>1.83 ± 0.21 c</td>
<td>1.98 ± 0.19 c</td>
<td>2.12 ± 0.15 b</td>
<td>2.37 ± 0.25 a</td>
</tr>
<tr>
<td>Ca (mg/dl)</td>
<td>9.64 ± 0.60 cd</td>
<td>9.91 ± 0.54 cd</td>
<td>9.26 ± 0.33 cd</td>
<td>9.64 ± 0.31 cd</td>
<td>10.30 ± 0.55 b</td>
<td>10.54 ± 0.40 b</td>
<td>11.62 ± 0.60 a</td>
</tr>
<tr>
<td>Fe (mg/dl)</td>
<td>71.35 ± 21.95 c</td>
<td>82.57 ± 25.19 c</td>
<td>110.46 ± 11.66 b</td>
<td>119.11 ± 15.79 b</td>
<td>131.35 ± 16.71 a</td>
<td>142.59 ± 16.77 a</td>
<td>158.94 ± 27.50 a</td>
</tr>
<tr>
<td>Cu (mg/dl)</td>
<td>114.71 ± 17.33 a</td>
<td>121.85 ± 19.92 a</td>
<td>82.50 ± 11.84 b</td>
<td>82.40 ± 5.21 b</td>
<td>86.43 ± 16.15 b</td>
<td>79.78 ± 12.35 b</td>
<td>83.58 ± 10.64 b</td>
</tr>
<tr>
<td>Se (mg/dl)</td>
<td>10.15 ± 0.90 b</td>
<td>11.11 ± 1.00 a</td>
<td>4.35 ± 2.23 c</td>
<td>4.31 ± 1.30 c</td>
<td>4.82 ± 1.95 c</td>
<td>4.61 ± 1.66 c</td>
<td>5.79 ± 2.04 c</td>
</tr>
<tr>
<td>P (mg/dl)</td>
<td>4.21 ± 0.43 b</td>
<td>4.71 ± 0.45 ab</td>
<td>4.33 ± 0.40 b</td>
<td>4.44 ± 0.34 ab</td>
<td>4.58 ± 0.37 a</td>
<td>4.66 ± 0.38 a</td>
<td>5.08 ± 0.16 a</td>
</tr>
<tr>
<td>Zn (mg/dl)</td>
<td>74.68 ± 10.04 e</td>
<td>80.58 ± 9.20 e</td>
<td>89.84 ± 7.56 d</td>
<td>107.66 ± 10.88 c</td>
<td>137.08 ± 12.27 b</td>
<td>156.90 ± 16.85 a</td>
<td>165.83 ± 21.96 a</td>
</tr>
</tbody>
</table>

a, b, c, d, e: There is significant difference between means of the same parameter with a different superscripted letter the same line ($P < 0.05$).
study, both doses of zinc supplementation restored the calcium levels which dropped in Week 1 to resting values in Week 2. Calcium levels in Weeks 3 and 4 were found significant in comparison to resting values. Zinc has critical effects on calcium metabolism, and consequently, on the structure and development of bone tissue (Ma and Yamaguchi, 2001). The results of the researchers cited above are in agreement with increased calcium levels we found after zinc supplementation.

It was reported that serum iron levels significantly increased after the run in marathon runners (Buchman et al., 1998), and similarly, that plasma iron showed a remarkable increase after high-intensity endurance training in bicyclists (Dressendorfer et al., 2002). In the same vein, serum iron was shown to increase after 60-min running exercise in trained medium-level athletes (Peeling et al., 2009) and plasma iron was found to rise in female swimmers following swimming exercise (Łukasaki et al., 1990). These reports lend significant support to the elevated serum iron values observed after exercise in the present study. The results of the study demonstrate that, when compared to resting values, zinc supplementation brought about significant increases in serum iron in one-week periods over the course of 4 weeks. It was noted that knowledge of the interaction between dietary zinc and other elements was important for athlete health and performance, as excess iron intake could lead to zinc deficiency (McDonald and Keen, 1988). Supplementation of 22 mg oral zinc to male football players for 12 weeks significantly reduced plasma iron (Oliveira et al., 2009). This result is in contradiction to the elevated serum iron levels we found with zinc supplementation. However, in the concerned study, zinc supplementation to the athlete group was continued for 12 weeks. The contradiction may be attributed to the differences in duration and/or dose of supplementation. As Cordova et al. (1993) stated, 200 ppm oral zinc support elevated serum iron in rats. This report is consistent with the increased serum iron levels we found after zinc supplementation in the present study.

Discussion of copper, selenium, and phosphorus levels in the study groups

Exercise before and after zinc supplementation resulted in increased copper, selenium, and phosphorus levels. Zinc supplementation significantly reduced copper and selenium, but did not change phosphorus in one-week periods over the course of 4 weeks.

It was shown that plasma copper values increased after physical activity in female swimmers (Łukasaki et al., 1990), and also that high-intensity endurance training brought about a marked increase in plasma copper in male bicyclists (Dressendorfer et al., 2002). Anderson et al. (1995) reported that acute exercise significantly elevated serum copper in both athletes and sedentary individuals. Consequently, the results of the studies about the relation between exercise and copper demonstrate increases in serum copper levels after exercise and this is consistent with the elevated serum copper levels we found after exercise in the present study. Zinc supplementation in both group 1 and group 2 significantly reduced copper levels in one-week periods over 4 weeks, in comparison to the resting values. It was already suggested that there was a negative correlation between body zinc and copper levels (Kilic, 2007). Oral zinc supplementation was reported be able to affect copper absorption in a period of 24 h, while chronic zinc support at a dose of 50 mg/day was shown to be capable of causing copper deficiency (Fischer et al., 1984). Similarly, 22 mg/day zinc gluconate support to bicyclists for 22 days caused a significant drop in plasma copper levels (Marques et al., 2011). Reduced serum copper found after zinc supplementation in this study is parallel to the reports of the cited researchers.

Selenium is known to be necessary for a variety of metabolic processes including thyroid hormone metabolism, protection against oxidative stress, and immunity functions (Akil et al., 2011). Physical exercise causes re-distribution of elements between body reserves, blood and tissues (Bordin et al., 1993).

Table 3

<table>
<thead>
<tr>
<th>Elements</th>
<th>Before supplementation pre-exercise</th>
<th>Before supplementation post-exercise</th>
<th>Weeks 1 after supplementation</th>
<th>Weeks 2 after supplementation</th>
<th>Weeks 3 after supplementation</th>
<th>Weeks 4 after supplementation before-exercise</th>
<th>Weeks 4 after supplementation post-exercise</th>
</tr>
</thead>
<tbody>
<tr>
<td>Mg (mg/dl)</td>
<td>1.65 ± 0.21 c 1.70 ± 0.23 bc</td>
<td>1.60 ± 0.25 c 1.82 ± 0.21 b</td>
<td>2.00 ± 0.16 ab 2.15 ± 0.33 ab</td>
<td>2.29 ± 0.39 a</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Ca (mg/dl)</td>
<td>9.56 ± 0.84 bc 9.91 ± 0.53 bc</td>
<td>9.14 ± 0.69 c 9.39 ± 0.44 bc</td>
<td>10.24 ± 0.73 b 10.90 ± 0.66 a</td>
<td>11.48 ± 1.03 a</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Fe (µg/dl)</td>
<td>74.44 ± 18.26 d 85.10 ± 22.25 d</td>
<td>114.87 ± 12.28 c 126.83 ± 12.44 b</td>
<td>135.04 ± 14.44 b 150.16 ± 21.70 ab</td>
<td>165.05 ± 22.67 a</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Cu (µg/dl)</td>
<td>115.33 ± 25.80 ab 128.55 ± 23.42 a</td>
<td>83.62 ± 10.23 bc 82.11 ± 5.99 c</td>
<td>80.42 ± 20.03 c 80.37 ± 22.59 c</td>
<td>86.45 ± 28.86 bc</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Se (µg/dl)</td>
<td>8.77 ± 2.82 a 10.75 ± 1.47 a</td>
<td>4.04 ± 1.73 b 4.62 ± 1.44 b</td>
<td>3.90 ± 1.14 b 4.20 ± 2.17 b</td>
<td>4.84 ± 1.76 b</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>P (mg/dl)</td>
<td>4.10 ± 0.76 c 4.71 ± 0.56 a</td>
<td>4.23 ± 0.42 bc 4.38 ± 0.37 b</td>
<td>4.47 ± 0.42 ab 4.58 ± 0.45 ab</td>
<td>4.80 ± 0.46 a</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Zn (µg/dl)</td>
<td>72.90 ± 15.38 d</td>
<td>79.27 ± 15.94 d</td>
<td>88.78 ± 18.32 d</td>
<td>106.16 ± 19.35 c</td>
<td>128.09 ± 25.32 b</td>
<td>150.80 ± 22.66 a</td>
<td>148.63 ± 28.22 a</td>
</tr>
</tbody>
</table>

a, b, c: There is significant difference between means of the same parameter with a different superscripted letter the same line (P < 0.05).

Table 4

<table>
<thead>
<tr>
<th>Parameter</th>
<th>Groups (n = 10)</th>
<th>before supplementation pre-exercise</th>
<th>before supplementation post-exercise</th>
<th>weeks 4 after supplementation before-exercise</th>
<th>weeks 4 after supplementation post-exercise</th>
</tr>
</thead>
<tbody>
<tr>
<td>Plasma lactate (mmol/L)</td>
<td>1</td>
<td>1.78 ± 0.64 b</td>
<td>8.26 ± 1.86 a</td>
<td>0.95 ± 0.18 c</td>
<td>6.95 ± 1.27 a</td>
</tr>
<tr>
<td></td>
<td>2</td>
<td>1.98 ± 0.93 c</td>
<td>9.79 ± 2.13 a</td>
<td>1.13 ± 0.41 c</td>
<td>6.78 ± 1.59 b</td>
</tr>
</tbody>
</table>

a, b, c: There is significant difference between means of the same parameter with a different superscripted letter the same line (P < 0.05).
Thus, exhaustion exercise is expected to alter element levels. The report that acute swimming exercise significantly elevated serum selenium levels in rats (Bicer et al., 2011) lends important support to the increases identified in selenium levels after exercise. In the present study, zinc supplementation markedly lowered selenium levels in one week periods over 4 weeks, relative to resting selenium values. There are a limited number of studies exploring the relation between zinc and selenium. Bicer et al. (2011) reported that the increases caused by acute swimming exercise in serum selenium levels were prevented by 4-week zinc supplementation. The results of the concerned study support, though indirectly, the reduced selenium levels established after zinc supplementation.

Exercise before and after zinc supplementation increased serum phosphorus values in this study. This result is consistent with the study which showed that acute swimming exercise significantly increased plasma phosphorus (Baltaci et al., 2009). The results of this study also revealed that 4-week zinc support did not affect serum phosphorus levels. In fact, it was reported that 6 mg/kg/day intraperitoneal zinc supplementation to rats for 4 weeks did not bring about a remarkable change in serum phosphorus levels, in comparison to control values (Bicer et al., 2011). The results of the cited study are parallel to the results of this study.

Discussion of zinc values in the study groups

Exercise before and after 220 mg/day zinc supplementation was found to significantly elevate serum zinc levels, while exercise following 440 mg/day zinc supplementation caused a decrease in zinc levels. Short-term high-intensity exercise (Ohno et al., 1985) and marathon run (Marrella et al., 1993) were both shown to increase plasma zinc. Increased plasma zinc levels caused by exercise were reported by other researchers as well (Cordova and Navas, 1998; Mundie and Hare, 2001). Serum zinc increase found after exercise in the present study is parallel to the results of the researchers cited above. Interestingly, exercise after 440 mg/day zinc supplementation reduced serum zinc levels. This can probably be explained by increased excretion of zinc from the digestive system. It is known that the activities of zinc transporters (ZnT) ZnT1, ZnT4, and ZnT5 which enable zinc absorption in the digestive system increase in lower zinc levels to increase zinc absorption in the small intestines and conversely that these transporters are suppressed in higher zinc levels to increase zinc absorption. The results of this study also had higher plasma lactate levels and developed hypoglycemia (Khaled et al., 1997). This interesting piece of information may stimulate further research into the effects of zinc, which is an important trace element, on physiological performance. An overall assessment of the data presented above suggests that zinc has critical effects on muscle functions and therefore, it can delay muscle tiredness. It was reported in a study by Baltaci et al. (2003) that plasma lactate levels which were elevated in zinc deficiency in rats subjected to an acute swimming exercise were reduced by zinc supplementation. This is a significant result for research into zinc and tiredness relationship and is consistent with reduced lactate levels obtained with zinc supplementation.

The results of present study show that 4 weeks zinc supplementation delay tiredness exhaustion by regulate elements metabolism. Zinc supplementation may have useful on sportive performance.

Acknowledgements

Zinc sulfate capsules were supplied by Berko Drug and Chemicals Industry Inc.

References


