Altered Antioxidant and Trace-Element Status in Adolescent Female Gymnasts

Eyad Alshammari, Shahida Shafi, Jaana Nurmi-Lawton, Andrew Taylor, Susan Lanham-New, and Gordon Ferns

Physical activity is associated with the generation of reactive oxygen species and may lead to decreased levels of plasma antioxidants and increased oxidant stress. Some studies have reported that antioxidant supplements can reduce the consequences of oxidative stress during exercise. In this study the authors aimed to assess the chronic effects of exercise on endogenous serum antioxidant enzyme concentrations. Glutathione peroxidase (GPx) and superoxide dismutase (SOD) activity were measured in adolescent girls who were either competitive gymnasts or sedentary controls. The relationship between age, body-mass index, dietary intake, trace-element status, and serum GPx and SOD was determined. The participants in the study were part of a 3-yr longitudinal investigation of exercise and peak bone-mass development in 38 competitive gymnasts and 40 healthy sedentary adolescent females 8–17 yr of age. Serum GPx and SOD were measured using colorimetric assays, and trace elements were measured using inductively coupled plasma mass spectrometry. The mean serum GPx concentrations were significantly higher in the gymnasts than in the sedentary females (157 ± 11.1 vs. 126 ± 8.8 U/ml, p < .05). In contrast, serum SOD concentrations were significantly lower in the gymnasts than in the sedentary group (7.24 ± 2.6 vs. 8.57 ± 2.3 U/ml, p < .05). Serum selenium, zinc, and copper were higher in the physically active group than in the inactive group (0.89 ± 0.03, 10.86 ± 0.39, 14.50 ± 0.50 vs. 0.81 ± 0.03, 10.32 ± 0.28, and 14.38 ± 0.42 μmol/L, respectively), although only serum selenium reached statistical significance (p < .05). The findings show that young female gymnasts have an altered antioxidant enzyme profile compared with their less physically active peers.

Keywords: physical activity, dietary intake, ROS, GPx, SOD

Reactive oxygen species (ROS) are generated during exercise from several sources including leakage from the electron transport chain. These ROS may cause cellular damage that could subsequently lead to lipid oxidation, protein denaturation, and DNA damage (Droge, 2003). Glutathione peroxidase (GPx) and superoxide dismutase (SOD) are important plasma antioxidant enzymes that may prevent the potentially deleterious effects of ROS. Intracellular concentrations of glutathione may be used as an indicator of redox status of the cell (Fang, Yang & Wu, 2002).

Exercise is reported to enhance the endogenous antioxidant defenses (Rousseau, Margaritis, Arnaud, Faure, & Roussel, 2006). Repeated episodes of aerobic exercise have been reported to induce the expression of antioxidant enzymes (Ji, 2002). It is unknown whether these adaptive mechanisms differ with age. In animal models, reduced glutathione appears to be an important nonenzymatic antioxidant that plays a critical role in protection against oxidative stress induced by exercise (Greathouse, Samuels, DiMarco, & Criswell, 2005). Exercise may be associated with increased levels of serum GPx activity; this was particularly so when coupled with dietary restriction in an animal model (Aydin et al., 2007) and energy restriction in athletes (Rankin, Shute, Heffron, & Saker, 2006).

Several studies have shown a relationship between extent of physical activity and plasma antioxidant concentrations including GPx and SOD (Criswell et al., 1993; Dekany et al., 2006; Marsh, Laursen, & Coombes, 2006). Dekany et al. investigated the effects of duration and intensity of prolonged physical exercise on markers of oxidative stress and reported that exercise can increase the production of ROS. The relative effects of low- versus high-intensity resistance exercise on lipid peroxidation were investigated by Hoffman et al. (2007), who reported that the increase in plasma malondialdehyde was independent of exercise intensity. Pialoux et al. (2006), however, reported that the intensity of exercise and exposure to hypoxia may have a cumulative effect on oxidative stress.

A major problem with these previous studies was the possibility of interference from confounding factors resulting from differences in dietary intake including that of trace elements. This may be important because the
trace elements selenium (Se), copper (Cu), and zinc (Zn) form part of the active sites of the antioxidant enzymes GPx and SOD (Fang et al., 2002). The principal objective of the current study was to determine whether chronic exercise alters antioxidant status by comparing adolescent female gymnasts engaged in high-intensity physical activity with sedentary girls matched for chronological and pubertal age. The specific objectives were to assess their serum levels of the antioxidant enzymes GPx and SOD activity and to determine the association with trace-element status, age, body size, and dietary intakes of trace elements.

### Materials and Methods

#### Participants

Participants were recruited as part of a 3-year longitudinal investigation of the effects of exercise on peak bone-mass development, as previously reported (Nurmi-Lawton et al., 2004). Thirty-eight female gymnasts 8–17 years of age were originally recruited from five competitive gymnastic clubs in the South of England within a 70-mile radius—namely, Dynamo, Southampton; Leatherhead and Dorking, Surrey; Pinewood, Berkshire; Heathrow, Middlex; and Woking, Surrey. The gymnasts were eligible to join the study if they trained >10 hr/week and regularly took part in competitions (at club regional level). A total of 40 female healthy normally active controls were randomly recruited through the database of local general practices in Guildford, Surrey, England. Potential participants were selected at random from the general practices list and invited to come to the University of Surrey. The response rate to the letter was ~20%. Controls were involved in normal activities (including walking to school and physical education classes) for on average 5.6 ± 2.6 hr/week (determined by questionnaire) but not in sports requiring year-round training at the competitive level. In addition, anthropometric variables, physical activity, and dietary intake were estimated as previously described (Nurmi-Lawton et al., 2004). Anthropometric data were collected by a nutritionist. None of the participants had evidence of acute infection or inflammation at the time of recruitment or at the time of blood-sample collection. Each gymnast was matched to a nonactive control, initially by age and then subsequently by pubertal age once Tanner staging had been completed and analyzed. The baseline data were collected between the months of October and December of the same year for both gymnasts and controls. Because of the competitive-gymnastics cycle, it was not possible to collect data during the off-peak season, but participants were asked to refrain from collecting their dietary data in the week leading up to a competition and data were collected within the week and weekend before competition. Controls were asked to refrain from collecting their dietary data outside the holiday period.

#### Dietary Analysis

The dietary intake of gymnasts and controls was recorded for 7 days at baseline using estimated food diaries, which have been shown to have an acceptable relative validity (Bingham et al., 1994). Instructions, including how to estimate portion size, were given both verbally and in writing to each participant or her parent by a registered dietician (J.N.-L.). Gymnasts were asked to complete the diary on a noncompetition week during the athletic training season, and controls, on a nonholiday week, without changing their usual dietary habits. Participants (or their parents) were asked to describe the portion sizes and write these in the diary. The diaries were analyzed using the Diet5 for Windows computer package (Robert Gordon University, Aberdeen, UK), which is based on McCance and Widdowson’s food-composition tables (Roe, Finglas, & Church, 2002). This allowed an estimate of dietary macronutrients (protein, carbohydrate, and fat) and micronutrients (including Se, Zn, and vitamins A, E, and C).

#### Physical Activity Assessment

The hours of training, changes in training regimen of each gymnast, and type and amount of exercise undertaken by controls were assessed using a questionnaire. The Blair score was calculated as described previously (Blair et al., 1985), which gives an indication of the individual’s level of physical activity: <33 = very inactive, 33 to <37 = inactive, 37 to <40 = moderately active, and ≥40 = active.

#### Blood Collection

Nonfasted blood samples were collected from both the controls and the gymnasts. Because of the recruitment procedure required for the gymnasts, that is, via gymnastic clubs that only met late afternoon or early evening, blood samples after a 12-hr fast were not possible. Control participants predominantly came to the University of Surrey Clinical Investigation Unit in the afternoon and early evening. Collections of samples for the gymnast group were carried out before training in a noncompetition week. Samples from the controls were collected during the school holiday. In all cases, they were collected around the time that the dietary estimates were obtained. Blood samples were centrifuged at 3,000 g at room temperature to obtain serum for analysis of antioxidants and trace elements. Serum samples were frozen at −80 °C until they were assayed.

### Determination of Serum Antioxidant Enzyme Activities

#### GPx and SOD

Serum GPx activity was measured using a commercial assay kit (Cayman GPx kit; IDS Ltd., UK). Briefly, serum (20 μl/well) was added to a 96-well microtiter plate followed by 50 μl of cosubstrate mixture (NADPH, glutathione, and glutathione reductase), and the assay was performed according to the manufacturer’s
instructions. As a positive control, bovine erythrocyte GPx was used. The enzymatic reaction was initiated by the addition of cumene hydroperoxide (20 μl), and the decrease in absorbance at 340 nm was read over 3 min. GPx activity was determined from the linear portion of the curve. One unit of GPx activity was defined as the amount of enzyme required to cause the oxidation of 1 nmol/min of NADPH at 25 °C.

Serum total SOD activity was measured using a colorimetric commercial kit (Cayman SOD kit; IDS Ltd.) in which superoxide radicals were generated by xanthine oxidase and hypoxanthine and detected using a tetrazolium salt at 450 nm. One unit of SOD was defined as the amount of enzyme needed to produce 50% dismutation of the superoxide radical. SOD activity was expressed as U/ml. All assays were performed in duplicate.

The intra-assay CVs for the serum GPx and SOD assays were 5.7% and 3.2%, respectively, and the between-assays CVs were 7.2% and 3.7%.

**Serum Trace-Element Analysis.** Serum concentrations of Se, Cu, and Zn were measured by inductively coupled plasma mass spectrometry as previously described (Taylor, Longerich, & Greenough, 2003). Germanium (1.5 ppb final concentration) was used as an internal standard. Se (0.5–4 μmol/L), Cu (5–40 μmol/L), and Zn (5–40 μmol/L) standards were used to calculate the concentration of serum trace elements as μmol/L. The intra-assay CVs for serum Se, Cu, and Zn were 3.9%, 1.5%, and 1.4%, respectively, and between-assays CVs were 7.1%, 2.4%, and 3.5%. The standards used were in a serum matrix.

**Statistical Analysis**

Statistical analysis was performed using SPSS (Statistical Program for the Social Sciences; version 15, 2007, SPSS Inc., Chicago, IL). Data are expressed as M ± SEM unless otherwise stated. Normality of the distribution of variables was confirmed using the Kolmogorov–Smirnov test, and parametric or nonparametric tests were applied accordingly. Anthropometric and other data at baseline were compared between gymnasts and controls using independent t test or Mann–Whitney tests. A p ≤0.05 was considered statistically significant. We initially used a univariate model to investigate the association between antioxidants and physical activity. Stepwise multiple-regression models were used to assess which of the confounding variables could influence antioxidant enzyme concentrations. GPx activity and concomitantly enzyme concentrations. GPx activity and concomitantly SOD were entered into the regression equation, with the following variables included as potential determinants: physical activity (min/week); Se, Zn, and Cu status; age; weight; and height, as well daily intakes of the trace elements (Se, Cu, and Zn).

**Results**

**Participants’ Anthropometric Characteristics**

Study participants’ physical activity and anthropometric data (height, body-mass index [BMI], weight, and midarm circumference) are shown in Table 1. As may have been expected the gymnasts showed fourfold higher physical activity compared with controls. Compared with healthy adolescent females, the gymnasts were also shorter, with a lower BMI, mean weight, and percent body fat, as previously reported (Filaire, Lac, & Pequignot, 2003; Laing et al., 2002). These differences were statistically significant (p < .01).

**Dietary and Energy Intakes**

Energy and dietary intake of fat and trace elements determined by food diary at baseline are shown in Tables 2 and 3. For Table 3, the RNI (reference nutrient intake) and LRNI (lower reference nutrient intake) values for the United Kingdom are provided. The gymnasts consumed significantly less total fat, particularly saturated fat and cholesterol, than the controls based on average daily intake baseline record (p < .05). They also had significantly lower intake of Se (p < .05). There were no significant differences in energy or dietary antioxidant intake between the two groups. The mean dietary intakes of both gymnasts and controls were higher in energy, fat, monounsaturated fats (MUFAs), polyunsaturated fats (PUFAs), and vitamin C than reported in the National Dietary Nutritional Survey (Gregory et al., 2000). Furthermore, mean dietary saturated fatty acids, cholesterol, and Zn were higher in the gymnasts and lower in the control group compared with data from the National Dietary Nutritional Survey (Gregory et al., 2000). Overall, 22.1% of our participants were below the LRNI for Se intake and 28.7% for Zn intake. This rose to 81.4% of the study population.

**Table 1** Comparison of Anthropometric Characteristics of the Study Participants, M ± SEM

<table>
<thead>
<tr>
<th>Characteristic</th>
<th>Control, n = 40</th>
<th>Gymnast, n = 38</th>
</tr>
</thead>
<tbody>
<tr>
<td>Age (years)</td>
<td>11.31 ± 0.26</td>
<td>11.30 ± 0.34</td>
</tr>
<tr>
<td>Physical activity (min/week)</td>
<td>338.65 ± 21.87</td>
<td>1,256.82 ± 40.81**</td>
</tr>
<tr>
<td>Height (m)</td>
<td>1.48 ± 0.02</td>
<td>1.36 ± 0.02**</td>
</tr>
<tr>
<td>Body-mass index (kg/m^2)</td>
<td>18.48 ± 0.40</td>
<td>16.76 ± 0.29**</td>
</tr>
<tr>
<td>Weight (kg)</td>
<td>40.97 ± 1.54</td>
<td>31.72 ± 1.26**</td>
</tr>
</tbody>
</table>

**p < .01 compared with the gymnasts.
of all participants below the RNI for Se intake and all participants being below the RNI for Zn intake.

### Serum Antioxidant Enzymes and Trace-Element Concentrations

As shown in Table 4, serum GPx concentrations were significantly higher in the gymnast group than in the controls (156.92 ± 11.07 vs. 125.14 ± 8.79 U/ml; p < .05). Serum Se concentrations were also significantly higher in the gymnasts (0.89 ± 0.03 vs. 0.81 ± 0.03 μmol/L; p < .05) despite their having a significantly lower dietary intake of the nutrient. In contrast, serum SOD concentrations were lower in the gymnast group (7.23 ± 0.41 vs. 8.57 ± 0.385 U/ml; p = .05). There was no significant difference in serum Zn or Cu between the two groups.

### Univariate Analysis

The associations between anthropometric measurements, dietary intakes with serum antioxidant enzymes (GPx and SOD), and trace elements (Se and Zn) were assessed using Pearson’s product–moment correlation coefficients (Table 5). The results showed a significant, strong, positive association between levels of physical activity and serum Zn concentration in gymnasts and the control participants (.05 < p < .01). No other associations were observed between anthropometric measurements and antioxidant enzymes or any other trace element measured either in gymnasts or in the control participants (Table 5), except for age, which also showed a significant positive association with serum Zn concentration for the gymnasts alone.
Table 5  Pearson’s Product–Moment Correlation Coefficients Between Demographic and Dietary Intake With Measures of Serum Antioxidant and Trace-Element Status

<table>
<thead>
<tr>
<th>Variable</th>
<th>Gymnasts (Serum)</th>
<th></th>
<th>Controls (Serum)</th>
<th></th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>GPx</td>
<td>SOD</td>
<td>Se</td>
<td>Zn</td>
</tr>
<tr>
<td>Height (m)</td>
<td>–.008</td>
<td>–.027</td>
<td>.274</td>
<td>.376*</td>
</tr>
<tr>
<td>Weight (kg)</td>
<td>–.061</td>
<td>.003</td>
<td>.265</td>
<td>.287</td>
</tr>
<tr>
<td>Body-mass index (kg/m²)</td>
<td>–.119</td>
<td>.055</td>
<td>.157</td>
<td>.155</td>
</tr>
<tr>
<td>Physical activity (min/week)</td>
<td>.263</td>
<td>–.103</td>
<td>.016</td>
<td>.328*</td>
</tr>
<tr>
<td>Age (years)</td>
<td>.054</td>
<td>.010</td>
<td>.182</td>
<td>.346*</td>
</tr>
<tr>
<td>Dietary factors</td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>total energy intake</td>
<td>.091</td>
<td>.246</td>
<td>.289</td>
<td>.098</td>
</tr>
<tr>
<td>fat</td>
<td>.085</td>
<td>.310</td>
<td>.222</td>
<td>.084</td>
</tr>
<tr>
<td>saturated fatty acid</td>
<td>.072</td>
<td>.194</td>
<td>.125</td>
<td>.112</td>
</tr>
<tr>
<td>monounsaturated fatty acid</td>
<td>.101</td>
<td>.358*</td>
<td>.242</td>
<td>.082</td>
</tr>
<tr>
<td>polyunsaturated fatty acid</td>
<td>.071</td>
<td>.350*</td>
<td>.276</td>
<td>.007</td>
</tr>
<tr>
<td>cholesterol</td>
<td>.046</td>
<td>.096</td>
<td>.277</td>
<td>.109</td>
</tr>
<tr>
<td>Dietary micronutrients</td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Zn</td>
<td>.108</td>
<td>.096</td>
<td>.103</td>
<td>.031</td>
</tr>
<tr>
<td>Se</td>
<td>–.030</td>
<td>.114</td>
<td>.330</td>
<td>.104</td>
</tr>
<tr>
<td>vitamin C</td>
<td>–.260</td>
<td>.084</td>
<td>.330</td>
<td>.104</td>
</tr>
<tr>
<td>vitamin A</td>
<td>–.118</td>
<td>.258</td>
<td>–.092</td>
<td>–.011</td>
</tr>
<tr>
<td>vitamin E</td>
<td>–.187</td>
<td>.034</td>
<td>–.191</td>
<td>–.291</td>
</tr>
</tbody>
</table>

Note. GPx = glutathione peroxidase; SOD = superoxide dismutase; Se = selenium; Zn = zinc.

*p < .05, **p < .01 compared with controls.
In controls, there were significant negative correlations between serum Se concentrations and dietary total energy intake and carbohydrates (.05 < p < .01). In the gymnasts (Table 5) significant positive correlations were observed between serum SOD and dietary MUFAs and PUFAs (p < .05). Cholesterol intake correlated negatively with serum Cu concentration.

However, no significant correlations between dietary micronutrients (Zn, Se, and vitamins A, C, and E) and antioxidant enzymes or the trace-element concentrations measured in the healthy controls or adolescent gymnasts were observed (Table 5).

**Multiple-Regression Analysis**

To account for potentially confounding variables, we used stepwise regression analysis, in which GPx was entered into the regression equation as the dependent variable, and weight; height; physical activity; Se, Cu, and Zn status; and dietary intake of trace elements were entered as independent variables. The results revealed that physical activity was the strongest predictor of GPx activity, contributing approximately 7% of the variation in GPx activity: GPx activity = 107.6 + 0.04 × physical activity (min/week), with an adjusted \( R^2 = .01 \). Physical activity also explained 7.4% of the variation in SOD activity: SOD activity = 9 + (0.001) × physical activity (min/week), with an adjusted \( R^2 = .07 \). Table 6 shows the partial correlation coefficients between GPx activity and physical activity (\( p < .033 \)) and the inverse relationship between SOD activity and physical activity (\( p < .01 \)). After adjustments for weight, height, and BMI, these confounding variables remained significant.

**Discussion**

Although physical activity is associated with increased oxygen consumption and oxidative stress and is accompanied by the acute release of free radicals and consumption of antioxidants, studies have demonstrated that chronic physical activity may be associated with a compensatory induction of the antioxidant defense that includes the antioxidant enzymes GPx and SOD (Abernethy, Thayer, & Taylor, 1990). Most previous studies have not taken into account the possibility of confounding factors that include anthropometric differences and dietary intake, which are also likely to vary between active and less active participants. In the current study we have attempted to take these factors into account.

**Associations Between Trace-Element Status, Anthropometric Measures, and Serum Antioxidant Enzyme Concentrations**

Serum GPx was higher in the gymnasts than in the control group. While this may in part be explained by an induction of this enzyme as a compensatory mechanism in response to the chronic exposure to increased levels of radicals, our findings for serum SOD are not entirely consistent with this hypothesis, so there may be other explanations for this. We have previously reported in a large, mixed-gender sample that serum concentrations of several trace elements may be affected by dietary intake, physical activity, and anthropometric factors including adiposity (Ghayour-Mobarhan, Taylor, New, Lamb, & Ferns, 2005). It has been reported that dietary deficiency of Cu and Zn may be associated with decreased tissue levels of SOD, possible peroxidative cell damage, and increased ROS generation (Hammermueller, Bray, & Bettger, 1987). Although gross dietary deficiency is an unlikely finding in these healthy groups of girls, previous studies have reported that female athletes in their desire to lose weight may have an insufficient dietary intake (Hinton, Sanford, Davidson, Yakushko, & Beck, 2004). Of particular interest were the low levels of Zn, which was consistent in the gymnast and control groups. The standard reference range in our laboratories for Zn status is 11–24 μmol/L, and results indicated that 46.3% were below 10 μmol/L. This is of interest and certainly warrants further investigation.

**Associations Between Serum Antioxidant Enzymes and Extent of Physical Activity**

The duration of habitual physical activity was clearly different between the gymnasts and controls (\( p < .001 \)), and it is likely that the intensity of activity was also greater for the gymnasts. Physical activity was a significant determinant of serum GPx concentrations even after correction for several anthropometric variables. There were also significant positive associations between physical activity levels and serum Zn in both the gymnasts (\( r = .328, p < .05 \)) and controls (\( r = .390, p < .01 \)). These data are consistent with previous reports in which Zn and Cu intakes did not affect the biochemical indices measured. Athletes engaging in long-distance or high-impact aerobic modalities have been reported to have higher indices of antioxidant protection (erythrocyte Zn, SOD activity, and metallothionein) than those undertak-

<table>
<thead>
<tr>
<th>Enzyme</th>
<th>( \beta ) coefficient</th>
<th>( p )</th>
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<tbody>
<tr>
<td>Superoxide dismutase</td>
<td>( r = -.248 )</td>
<td>.033</td>
</tr>
<tr>
<td>Glutathione peroxidase</td>
<td>( r = .295 )</td>
<td>.010</td>
</tr>
</tbody>
</table>

*Note. The \( \beta \) coefficient was derived from univariate analysis.*
ing short-distance, low-impact activities, suggesting that there is adaptation of antioxidant capacity in response to the specific training (Koury et al., 2004). However, some studies have shown findings similar to ours. Zembron-Lacny, Ostapiuk, Slowinska-Lisowska, Witkowski, and Szyszka (2008) showed significant reductions in serum SOD activity and elevations in other antioxidant enzymes including GPx and catalase in response to muscle damage associated with exercise. Our results indicate that serum antioxidant enzyme concentrations may depend on the amount and intensity of physical activity undertaken. These findings are in agreement with those of Covas et al. (2002), who also showed that serum antioxidant enzymatic activity was directly related to physical activity in females. Although we have focused on the chronic effects of physical activity, there are also acute effects of exercise. Erythrocyte glutathione levels have been reported to increase during extreme exercise, whereas serum SOD activity decreased (Machefer et al., 2007). In elite ironman triathletes, significantly lower levels of serum malondialdehyde, a marker of oxidative stress, have been reported; this was associated with higher serum concentrations of GPx and catalase. However, serum GPx concentrations were found to be higher in half of a group of ironman triathletes, who were also found to have higher serum malondialdehyde concentrations and significantly lower concentrations of serum GPx, SOD, and catalase activity. Therefore the relationship between physical activity and plasma and erythrocyte antioxidant levels is complex, depending on the intensity, duration, and chronicity of the exercise.

The interesting link between depressed antioxidant capacity and reduced physical performance was not examined in this data set because we did not collect information on fatigue or other markers of reduced performance. Injury and illness data have been collected but have not yet been analyzed; they would be worthy of further investigation.

In the current study, we found a significant relationship between serum antioxidant enzymes, serum trace elements, and dietary factors that included MUFAs, PUFAs, and cholesterol. It has previously been proposed that cholesterol, MUFAs, and PUFAs may be affected by levels of physical activity (Gordon et al., 2008; Squali Houssaini et al., 2001). In our study we found that the gymnasts had a higher reported dietary intake of MUFAs and PUFAs, and in this group this intake was strongly related to serum SOD activity; however, it is not possible to infer a causative effect.

Study Limitations

There are several limitations of our study. The blood samples were not fasted. The collection of a fasted blood sample was our preferred option, but because the recruitment of participants was through gymnastic groups who only met as a group in the afternoon or evening, it was not possible to collect the samples in this way. Furthermore, we were not able to collect information on the timing of the menstrual cycle in postpubertal participants. Estrogen and progesterone may affect Cu and Zn concentrations in plasma, although there is limited information on this in the literature. We were not able to calculate the dietary Cu intakes of the participants because the version of the computer package we used did not have an accurate measure of Cu values of food groups and items. This information would have been helpful and is certainly an area for further research.

Concluding Remarks

We found that young female gymnasts have a different serum antioxidant enzyme profile than their less physically active peers (25% higher GPx and 16% lower SOD). This appears to be partly related to degree of physical activity and does not appear to be related to their dietary antioxidant intake, but it may be affected by dietary macronutrient intake, including dietary fiber and MUFAs and PUFAs. The changes in antioxidant status may be a compensatory response to chronic exposure to increased levels of free radicals released during exercise, and it is unclear to what extent they may affect performance. The type, intensity, and duration of exercise, and perhaps the activity of the xanthine dehydrogenase–xanthine oxidase system, may also affect serum GPx and SOD concentrations (Vina et al., 2000).

Acknowledgments

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References


