Iron Status of Highly Active Adolescents: Evidence of Depleted Iron Stores in Gymnasts

Naama W Constantini, Alon Eliakim, Levana Zigel, Michal Yaaron, and Bareket Falk

Much attention has focused on the nutrition and hematological profile of female athletes, especially gymnasts. The few studies on iron status of male adolescent athletes found a low incidence of iron deficiency. The present study investigated the iron status of male and female gymnasts (G) and compared it with athletes of other sports. Subjects were 68 elite athletes (43 M, 25 F) ages 12–18, of four sports: gymnasts (11 M, 12 F), swimmers (11 M, 6 F), tennis players (10 M, 4 F), and table tennis players (11 M, 3 F). All lived in the national center for gifted athletes, trained over 25 hr a week, ate in the same dining room, and shared a similar lifestyle. Mean levels of hemoglobin (Hb), red blood cell indexes, serum ferritin, serum iron, and transferrin were measured in venous blood. There was no difference in mean Rb among gymnasts (G) and nongymnasts (NG). However, Hb was less than 14 g/dL in 45% of M G vs. only 25% in NG, and less than 13 g/dL in 25% of premenarcheal FG vs. 15% in NG. Low transferrin saturation (<20%) was detected in 18% of M G and 25% of FG vs. 6% and 8% in male and female NG, respectively (p < .05). The percentage of males suffering from low ferritin level (<20 ng/ml) was twice as high in G (36%) vs. NG (19%), and about 30% in all females. In summary, iron stores were consistently lower in M G vs. NG. Adolescent athletes of both genders, G in particular, are prone to nonanemic iron deficiency, which might compromise their health and athletic performance.

Key Words: anemia, athletes, exercise, ferritin, children, training

During rapid growth, and particularly during the years of sexual maturation, iron requirements are largely influenced by increases in body mass, blood volume, hemoglobin (Hb), and myoglobin concentration and iron-containing cellular proteins (5). Exercise further accentuates the need for adequate iron stores because training can induce the same changes as growth and maturation (15, 30). In addition, training can result in iron loss through hemolysis, as well as loss in stool, urine, and sweat (15, 18, 22, 25).

Iron deficiency can interfere with normal growth and maturation, as well as with psychomotor, cognitive, immunologic, and gastrointestinal functions, and
may impair performance in the physically active child (2, 6, 25, 34). True anemia is rare in athletes. However, iron deficiency, which may lead to overt anemia, is highly prevalent among adult athletes, particularly women (see Ref. 15 for review). Few studies have examined iron status in adolescent athletes, but it seems that these athletes are also prone to nonanemic iron deficiency (1, 17, 19, 26–28).

Most studies of adolescent athletes have focused on endurance athletes, in whom the iron deficiency is partly explained by exercise-induced iron loss (15, 25). Low ferritin levels were found in 11–47% of female high school runners, depending on the cutoff point for hypoferritinemia and the stage of the running season during which the girls were examined (1, 17–19, 26, 27, 29).

Very few studies have examined young athletes other than runners. Rowland and Kelleher (28) found serum ferritin levels below 12 μg/L in 7 of 15 high school female swimmers (47%) and in none of the 15 male swimmers. Willows et al. (35) examined the hematological profiles of 107 male and female physically active young people 9–18 years of age who were involved in swimming, gymnastics, dancing, or running, and found a high prevalence of ferritin levels below 20 μg/L. However, they grouped the athletes according to pubertal stage, not by sport. And the percentage of hypoferritinemia in each sport group was not provided. This is important, since in gymnasts, for example, iron loss through hemolysis, stool, urine, or sweat does not theoretically present a problem. However, gymnasts are often characterized by poor nutrition, which can lead to iron deficiency (3, 13, 14, 24).

The purpose of this study was to investigate the hematological and iron profiles of highly trained young athletes of various sport disciplines. In particular, we aimed to compare the iron status of gymnasts with that of young athletes in sports not necessarily characterized by poor nutrition and which do not demand weight control.

**Methods**

Subjects were 68 elite young athletes, ages 12–18 years, who were living and training in a national center for children gifted in sport. The athletes were selected to this boarding school based on their skill and athletic achievements. There were 43 males (M) and 25 females (F), divided into two groups: gymnasts (G) and nongymnasts (NG)—swimmers, tennis players, and table tennis players. Table 1 shows the number of subjects in each group and their age. All athletes trained 25–30 hr a week and shared a similar lifestyle including common meals in the dining room of the training institute. They underwent a yearly assessment, including a physical examination and blood test. Although ages were not statistically different, all female Gs were premenarche, whereas half of the NGs were already menstruating. None of the athletes took any food supplement or drugs (e.g., nonsteroidal antiinflammatory drugs) on a regular basis.

Venous blood samples were drawn in the morning, after an overnight fast and at least 12 hr following the last workout. In menstruating girls, blood was drawn during the early follicular phase, due to variations in iron status parameters during different menstrual phases (12). All athletes were assessed about 1 month prior to the competition season. Hemoglobin (Hb), hematocrit (Het), red blood cell (RBC), mean corpuscular volume (MCV), and mean corpuscular hemoglobin (MCH) were analyzed by technican autoanalyzer (H.). Serum iron (SI) was determined by atomic absorption (IL Video-II) and transferrin (TR) by nephelometric technique (Beckman, Array-360). Transferrin saturation (TS) was calculated as the percent of SI divided
Table 1  Number and Age of Subjects According to Groups

<table>
<thead>
<tr>
<th></th>
<th>Males</th>
<th></th>
<th>Females</th>
<th></th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>n</td>
<td>Age (yrs)</td>
<td>n</td>
<td>Age (yrs)</td>
</tr>
<tr>
<td>Total</td>
<td>43</td>
<td>15.3 ± 1.6</td>
<td>25</td>
<td>13.5 ± 1.6</td>
</tr>
<tr>
<td>Gymnasts</td>
<td>11</td>
<td>15.6 ± 1.8</td>
<td>12</td>
<td>13.0 ± 1.8</td>
</tr>
<tr>
<td>Nongymnasts</td>
<td>32</td>
<td>15.2 ± 1.6</td>
<td>13</td>
<td>13.9 ± 1.4*</td>
</tr>
<tr>
<td>Swimmers</td>
<td>11</td>
<td>15.9 ± 1.1</td>
<td>6</td>
<td>14.4 ± 1.4</td>
</tr>
<tr>
<td>Tennis</td>
<td>10</td>
<td>15.5 ± 1.3</td>
<td>4</td>
<td>13.8 ± 1.0</td>
</tr>
<tr>
<td>T-tennis</td>
<td>11</td>
<td>14.2 ± 1.2</td>
<td>3</td>
<td>13.0 ± 1.3</td>
</tr>
</tbody>
</table>

Note: *54% of nongymnasts were postmenarche. All gymnasts were premenarche.

Table 2  Hematological and Iron Parameters in 68 Young Athletes

<table>
<thead>
<tr>
<th></th>
<th>Males</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>(n = 11)</td>
</tr>
<tr>
<td>Hemoglobin (g/dL)</td>
<td>14.2 ± 0.9</td>
</tr>
<tr>
<td>Hematocrit (%)</td>
<td>45.7 ± 2.4</td>
</tr>
<tr>
<td>RBC count × 10^6/mm³</td>
<td>5.4 ± 0.3</td>
</tr>
<tr>
<td>MCV (fL)</td>
<td>84 ± 2*</td>
</tr>
<tr>
<td>MCH (pg)</td>
<td>26.5 ± 1.4</td>
</tr>
<tr>
<td>Serum iron (µg/dl)</td>
<td>96 ± 26*</td>
</tr>
<tr>
<td>TS (%)</td>
<td>30 ± 8*</td>
</tr>
<tr>
<td>Ferritin (ng/ml)</td>
<td>28 ± 18</td>
</tr>
</tbody>
</table>

<table>
<thead>
<tr>
<th></th>
<th>Females</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>(n = 12)</td>
</tr>
<tr>
<td>Hemoglobin (g/dL)</td>
<td>13.5 ± 0.9</td>
</tr>
<tr>
<td>Hematocrit (%)</td>
<td>44.1 ± 1.6</td>
</tr>
<tr>
<td>RBC count × 10^6/mm³</td>
<td>5.3 ± 0.3</td>
</tr>
<tr>
<td>MCV (fL)</td>
<td>84 ± 4b</td>
</tr>
<tr>
<td>MCH (pg)</td>
<td>25.6 ± 1.5</td>
</tr>
<tr>
<td>Serum iron (µg/dl)</td>
<td>82 ± 29b</td>
</tr>
<tr>
<td>TS (%)</td>
<td>25 ± 8b</td>
</tr>
<tr>
<td>Ferritin (ng/ml)</td>
<td>25 ± 10</td>
</tr>
</tbody>
</table>

*Significant difference between male G and NG; 'signif. diff. between female G and NG. TS = transferin saturation.

by TR. Ferritin was analyzed by matrix electrostatic interaction assay (MEIA) (Abbott, IMX).

A two-way ANOVA (sport [G/NG] and gender [M/F]) was performed to assess differences between groups. Significance level was set at alpha < .05. Data are reported as mean ± standard deviation.

Results

Table 2 describes the hematological and iron profile of the male and female G and NG. The Hb level was similar in both G and NG. None of the male athletes had an Hb level <13.0 g/dL, and only one female G was anemic (Hb < 12.0 g/dL). No differ-
ences in Hct and RBC were observed between groups. Gymnasts, regardless of gender, had lower MCV than nongymnasts \( (p < .01) \).

Mean values of SI and TS were statistically lower in G than in NG in both genders \( (p < .01) \); the percentage of athletes with SI < 70 \( \mu \)g/ml (Figure 1) and TS < 20\% (Figure 2) was over three times higher among G of both genders than among NG. Thirty-six percent of male G, as well as 33\% of female G and NG, had ferritin levels below 20 \( \mu \)g/ml (Figure 3). There were no differences in iron stores between menstruating and nonmenstruating female athletes.

![Figure 1](image1.png)

**Figure 1** — Percentage of athletes with serum iron levels below 70 \( \mu \)g/ml. It was over three times higher among gymnasts (both genders) versus nongymnasts, \( p < .05 \).

![Figure 2](image2.png)

**Figure 2** — Percentage of athletes with transferrin saturation below 20\%. It was over three times higher among gymnasts (both genders) versus nongymnasts, \( p < .05 \).
Discussion

This study shows that (a) poor iron status is found among "nonendurance" athletes such as gymnasts and table tennis players; (b) male G are particularly prone to nonanemic iron deficiency, and the prevalence of hypoferritinemia is similar to that of female athletes; and (c) both male and female G tend to have poor iron status compared with NG.

Blood ferritin concentrations correlate well with bone marrow iron, and thus serve as a sensitive indicator of body iron stores (15). The ferritin concentration is also the first indicator of iron depletion, since low transferrin saturation and anemia appear only at later stages of iron deficiency (6). Plasma ferritin levels can have a day-to-day variation of up to 40% and may be increased by chronic or acute inflammation (33). We have no indication that any of the subjects suffered from such an inflammation on the day of testing, as all athletes were closely supervised by a medical staff on campus. Although we did not control for day-to-day variation, our finding that 36% of male G and 32% of all female athletes had ferritin levels below 20 ng/ml is worrisome since it means that a third of these highly active, maturing youngsters have latent iron deficiency and are at risk for developing overt anemia. It should be noted, however, that the small sample size, especially of the female athletes, results in a low statistical power. Additionally, in a previous unpublished study of adolescents who live in the same area as the population of the present study, 33% of the girls and 21% of the boys were found to have low iron stores. Thus, the finding of low ferritin level in 36% of male G is particularly important for medical staff who work with young male G, since this group has not traditionally been considered at risk.

Iron deficiency in athletes can result from either excessive iron loss or from inadequate dietary intake. Menses are a major cause of iron loss in female athletes.
Women, on average, lose about $\geq 0.6 \text{ mg}$ or more of iron per day when menstruating. None of the gymnasts were menstruating, half of the nongymnasts were, yet one third of both groups had low ferritin levels. Thus the comparison of various indicators of iron status between pre- and postmenarcheal athletes did not reveal a clear effect of maturation. However, in view of the small number of subjects, no clear conclusion can be drawn.

Other mechanisms for iron loss can be the result of intravascular hemolysis, gastrointestinal bleeding, and/or sweating. Exercise-induced intravascular hemolysis, often called “foot-strike hemolysis,” has been extensively examined in adults, especially runners (15), but rarely in adolescent athletes. Nickerson et al. (18) and Rowland and Kelleher (28) were not able to demonstrate this phenomenon in male and female high school runners and swimmers, respectively. Gastrointestinal bleeding has been described in young female runners (18), but no study has examined this phenomenon in adolescent athletes of other sports. Iron can also be lost through perspiration (15), but in children this is negligible (7). These mechanisms were not evaluated in the present study.

The recommended daily allowance (RDA) for iron in adolescents is 18 mg (6). In order to achieve this amount in an average mixed diet, which contains 6 mg iron per 1,000 kcal, one must consume about 3,000 kcal per day. Since many female athletes do not reach this daily caloric intake, it is not surprising that the prevalence of low ferritin levels in this population is high (15, 23, 29). This problem is more pronounced in female gymnasts due to their small size and characteristic dietary restrictions (3, 13, 14, 24). In a study of a similar population of athletes at the national center for children gifted in sport (32), using 3-day dietary recall, we found a mean intake of $1,214 \pm 304$ calories per day ($\text{kcal} \cdot \text{d}^{-1}$) in female G vs. $2,090 \pm 544$ kcal $\cdot$ d$^{-1}$ in female NG, both well below the 3,000 kcal $\cdot$ d$^{-1}$ needed to receive the adequate amount of iron. In the same study we found that male G also had lower caloric intake ($2,366 \pm 472$ kcal $\cdot$ d$^{-1}$) compared with male NG ($2,868 \pm 921$ kcal $\cdot$ d$^{-1}$).

One limitation may be the known underreporting of dietary intake, especially among gymnasts. The finding in male G, which has not yet been described, can partly explain the poor iron status we found. The significant differences in caloric intake between male and female gymnasts do not confirm that iron intakes were different. Indeed, factors such as food selection and iron bioavailability may have influenced iron intake. Nevertheless, there was no difference in iron status between groups. This indicates that other mechanisms besides poor nutrition are responsible for the low iron stores in male gymnasts.

Iron deficiency anemia is associated with fatigue, reduced physical work capacity, and lower maximal oxygen uptake. This has been repeatedly documented in both animal and human studies (15, 25). However, whether nonanemic iron deficiency impairs performance in humans, as it does in rats (8, 9), is not yet clear. Several studies have shown improvements in peak performance (27) and lowered blood lactate levels at maximal exercise following iron supplementation (31), but others failed to demonstrate any influence (4, 16). For recent reviews, the reader is referred to Haymes (11) and Tobin and Beard (33).

This issue may be particularly important in growing children because data from animal studies suggest that age may influence the effects of iron deficiency on intracellular aerobic metabolism (10). That is, a decrease of 20–50% in myoglobin concentration was observed in iron-deficient rats during the growth period, whereas
in adult rats, even under severe iron depletion, no decrease in myoglobin was apparent. Indeed, Rowland et al. (27) reported that nonanemic female high school runners who had low ferritin levels and were treated with iron for a month demonstrated an improvement in treadmill endurance time compared with the group treated with placebo.

Only one study has examined the effect of iron deficiency without anemia on anaerobic ability (16). Forty recreational women runners, ages 18 to 40 years, with ferritin levels below 20 ng/ml, performed the Wingate anaerobic cycle test and the anaerobic speed treadmill test before and after 8 weeks of iron supplementation. Treatment did not significantly enhance their performance. It is unknown what the effect of iron supplementation on anaerobic capacity may be in adolescents suffering from low ferritin.

A low ferritin level is the first indicator of iron depletion, followed by low transferrin saturation and low hemoglobin. Reduced ferritin levels with normal hemoglobin concentrations do not generally influence functional outcome (33). Nevertheless, low ferritin levels have been shown to adversely affect performance in adolescent nonanemic female runners (27), although the decrease in performance is not consistent in all studies (16). Also, the effect of nonanemic iron deficiency on athletic performance might not be due solely to its effects on intracellular aerobic metabolism. It may also be due to possible effects on mood, cognitive function, intellectual ability, motivation, and attention span (2, 6, 20, 21, 25), which are extremely important in gymnastics and other sports as well. In view of the fact that nonanemic low ferritin levels can have an adverse effect on performance and can develop into overt anemia, this condition should be prevented.

We conclude that nonanemic iron deficiency is prevalent not only in adult runners but also in young athletes (especially females) engaged in other sports. Moreover, nonanemic iron deficiency is present in male adolescent gymnasts as well. To our knowledge, there are no studies that have identified nonanemic iron deficiency in young male gymnasts. More research is needed to reveal the incidence of nonanemic iron deficiency among young male gymnasts and the effect that such a deficiency may have on their performance.

We recommend that the nutritional and iron status of highly active young athletes should be carefully monitored—regardless of their sport or gender—particularly those engaged in sports characterized by a limited food intake. Athletes should especially be educated regarding an iron-rich diet.

References


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