Serum Ferritin and Anemia in Trained Female Athletes

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The aim of this study was to establish whether extremely low serum ferritin values in female athletes were associated with indications of iron deficiency anemia and whether serum ferritin values were influenced by the type of training or participants’ body size. Hematological data collected during 6 years at the Australian Institute of Sport were reviewed to quantify changes in serum ferritin concentration associated with training and to establish whether decrements in serum ferritin were associated with any change in hemoglobin concentration, mean corpuscular volume, or mean corpuscular hemoglobin concentration. Mean serum ferritin concentrations of 7.5 µg·L⁻¹ were not associated with any indication of iron-deficiency anemia. Serum ferritin declined by approximately 25% with the onset of rigorous daily training (p < .01) whether training was predominantly weight-bearing or non-weight-bearing. Rowers had significantly higher ferritin concentrations than basketball players of similar stature (p = .02). We conclude that considerable background information such as the stage of training, specific sport, and previous blood results should be sought when interpreting serum ferritin concentrations in female athletes.

Key Words: iron stores, training, mean cell volume, mean cell hemoglobin concentration, body mass index

Ferritin is a spherical protein that encapsulates intracellular iron atoms and thus protects against possible oxidative damage (4). A similar form of this protein, with no obvious biological role (12), is also found within the bloodstream. The concentration of ferritin in the blood correlates with tissue iron levels (3) and can provide a convenient and simple estimate of total body iron stores.

Female athletes, concerned that low body iron stores may impair hemoglobin production and thus athletic performance, often provide routine blood samples to monitor serum ferritin concentrations. Typically, athletes tend to have lower serum...
ferritin values than sedentary controls (20). Serum ferritin concentrations below 12 µg·L⁻¹ indicate depleted iron stores in sedentary populations (3) and are associated with indications of iron-deficiency anemia such as reduced hemoglobin concentration (Hb), mean corpuscular volume (MCV), and mean corpuscular hemoglobin concentration (MCHC) (17). However, there has been no rigorous analysis of this relationship in intensely training athletes (20), and it is not known whether similarly low ferritin concentrations in athletes are associated with indications of iron-deficiency anemia.

Although serum ferritin concentration has been shown to decline substantially following the commencement of regular physical exercise (5, 10, 14), it is unclear why this should be the case (6) or whether the mode of training influences the magnitude of this reduction. Telford et al. (19) observed that mean ferritin concentrations varied according to the particular sport, which suggests that the type of training does influence ferritin values.

The purpose of this retrospective evaluation of blood parameters was to investigate the relationship between low serum ferritin concentrations and indications of iron-deficiency anemia in female athletes. We also sought to document seasonal changes in serum ferritin in highly trained athletes and investigate whether these changes were influenced by the mode of training. A final goal was to confirm previously established differences in ferritin concentration that exist between specific sports independent of athletes' body sizes. A detailed understanding of factors that influence serum ferritin concentration in trained athletes could help practitioners interpret routine blood tests.

Methods

Subjects

Only data from female athletes participating in rowing, basketball, and netball were analyzed, since iron deficiency is seldom an important issue for males (6). All athletes were either scholarship holders or attended the Australian Institute of Sport as part of a training camp scheme and therefore belonged to national training squads. Athletes gave written consent to the methods used in this study, which were approved by the Australian Institute of Sport Ethics Committee.

Design

Hematological data were obtained from the confidential evaluation of routine blood tests conducted over a 6-year period (1990–1996), which were provided as a monitoring service to athletes and coaches. All available samples from the database, provided they met the experimental criteria for the separate aspects of the study, were included. Blood samples analyzed in a previous paper (19) were not included in this study. In all cases, blood parameters were measured from venous blood samples collected via venipuncture from athletes in a supine position.

Serum ferritin concentration was measured using an Abbott IMX Ferritin Assay (Abbott Laboratories, IL). The assay was calibrated using 6-point IMX Ferritin Calibrators (No. 2219-01) and checked with low, medium, and high IMX Ferritin Controls (No. 2219-10). Hemoglobin concentration (Hb), hematocrit (Hct), and red blood cell count (RBC) were measured using a Coulter JT Hematology
Analyzer (Coulter Electronics, Sydney), which was calibrated using Coulter SCAL Calibrator and checked using Coulter 4-C low, normal, and high FBC controls. Mean corpuscular volume (MCV = Hct/RBC) and mean corpuscular hemoglobin concentration (MCHC = Hb/Hct) were derived using standard equations based on the direct measures (1).

**Data Analyses**

**Seasonal Variation in Serum Ferritin.** One possible explanation for a decrease in serum ferritin has been linked with excessive red blood cell destruction associated with footstrike hemolysis (15). We compared a predominantly nonweight-bearing activity (rowing, the Nonweight group) with weight-bearing sports likely to involve increased hemolysis (netball and basketball, the Weight group). The initial sample (Pre) was taken at the beginning of a training season, with second (Mid) and final (End) samples assessed following 2- to 3-month intervals. Measures were included from several seasons to avoid bias associated with particular squads or training regimes. Differences between Pre, Mid, and End were analyzed with a 2 × 3 ANOVA (Activity × Time) with repeated measures over time, with Scheffé post hoc comparison (n = 46 sample sets each from Nonweight and Weight groups).

**Individual Variation in Hematological Parameters Following Changes in Serum Ferritin.** Serum ferritin concentrations below 12 µg · L⁻¹ are associated with decreases in blood parameters (MCV, MCHC, and Hb) sensitive to iron-deficiency anemia in sedentary subjects. A subset of 36 females with serum ferritin below 12 µg · L⁻¹ (designated Low), who had been tested on a separate occasion when serum ferritin was much higher (mean 41.9 ± 15.7 µg · L⁻¹, designated High), were identified (Low measures were included whether they had been taken before or after High). A control group consisted of 36 female athletes randomly selected from the database. Differences in MCV, MCHC, and Hb between paired Low and High subjects as well as control subjects were analyzed with one-way ANOVA with Scheffé post hoc comparison. Subjects designated as Low had been measured with similarly low serum ferritins on separate tests, negating the likelihood of their low values being due to measurement error.

**Variations in Serum Ferritin Between Sports Independent of Body Mass Index (BMI).** Unusual body types may be associated with particular sports due to the performance advantage this confers, which may confound comparison between sports if BMI has an impact on serum ferritin concentration. Athletes from basketball and rowing for whom both hematological and anthropometric data were available were matched as closely as possible for height, weight, and BMI, and their ferritin values were compared using Student’s unpaired t test (n = 26 unmatched sample sets). Netball players were found to differ markedly from both basketball players and rowers in stature and so were excluded from this analysis. All blood samples were taken within a day after the anthropometric data were recorded.

Data were analyzed using Statistica (StatSoft, Inc., Tulsa, OK, Version 4.5). For all analyses, significance was set at p < .05.

**Results**

Although serum ferritin concentration declined significantly during the season, no Activity × Time interaction was observed for these changes (p = .43). Mean serum
ferritin was higher in Nonweight than in Weight groups (47.2 ± 24.8 vs. 39.6 ± 24.8 μg · L⁻¹, p < .01). This difference was significant at every time point except End (p = .36). Serum ferritin was significantly lower at the Mid timepoint than at Pre for both Nonweight (p < .01) and Weight groups (p < .01), although values did not change significantly between Mid and End for either group (Figure 1).

Neither MCV (p = .19), MCHC (p = .42), nor Hb (p = .21) was different between Low, High, and control groups (Table 1). Serum ferritin values in the Low group were well below the threshold for depleted iron stores and significantly lower than for High and control groups (7.5 ± 2.7 μg · L⁻¹, p < .01), but High and control serum ferritin values were not different (41.9 ± 15.7 vs. 48.0 ± 33.3 μg · L⁻¹, p = .45).

Careful matching of pairs allowed for almost identical values of height (180 ± 3 vs. 179 ± 8 cm, p = .65), weight (74 ± 5 vs. 74 ± 9 kg, p = .99), and BMI (22.9 ± 1.2 vs. 23.1 ± 1.7 kg · m², p = .73) to be established between rowers and basketball players, respectively. Despite similar anthropometric values, basketball players had significantly lower serum ferritin concentrations than rowers (29.2 ± 15.7 vs. 39.3 ± 14.4 μg · L⁻¹, p = .02).

Discussion

This study shows that although individual serum ferritin concentrations decreased to below 12 μg · L⁻¹ in trained female athletes, there were no indications of iron-deficiency anemia based on blood parameters measured. Statistically significant and reproducible decreases of around 25% in serum ferritin occurred in female rowers, basketball players, and netball players during a training season. Rowers had significantly higher serum ferritin concentrations than basketball players of similar stature. These results suggest that considerable background information, such as

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**Figure 1** — Serum ferritin at beginning of season (Pre), after 2–3 months (Mid), and after a further 2- to 3-month interim (End) in subjects who performed non-weight-bearing activity (rowing: open circles; n = 46) and weight-bearing activities (netball, basketball; closed squares; n = 46). *Significantly different (p < .05) from Mid and End. †Significantly different (p < .05) between activities.
previous blood results, phase of training, and type of sport should be sought when interpreting serum ferritin values in trained athletes.

Many athletes and coaches rely on iron supplementation to boost low serum ferritin levels, presumably to avoid the perceived risk of impaired performance associated with iron store depletion (20). There has been considerable research involving the possible debilitating effects of low serum ferritin on athletic performance. Contemporary theory suggests that low serum ferritin, in the absence of clinical signs of anemia, is not detrimental to performance (11). Our study showed that hematological parameters sensitive to iron-deficiency anemia showed no change when athletes' serum ferritin values fell well below the threshold for iron store depletion. This was surprising, as similarly low ferritin values in sedentary subjects are associated with a reduction in these parameters (17). We conclude that some female athletes are able to tolerate very low serum ferritin values without indications of iron-deficiency anemia, and we concur with the view of Cook (6) that, as far as athletes are concerned, oral supplementation in females with low serum ferritin values is of dubious benefit unless clinical signs of anemia are present.

There was a significant decrease in serum ferritin of approximately 25% in both non-weight-bearing (rowing) and weight-bearing (netball and basketball) activities. These findings agree with previous studies involving hockey players (10), cross-country skiers (5), and participants in general physical activity (14). It is clear that physical training reduces serum ferritin concentration. However, these chronic decreases are opposite in direction to the acute increase in serum ferritin documented within hours of physical activity (8, 9, 18). Serum ferritin is known to behave as an acute phase protein and is influenced by various cytokines (2). It remains unclear, however, what chronic effect these cytokines may have on serum ferritin, and whether the relationship between serum ferritin and body iron stores can be uncoupled as a consequence of regular physical training.

Alternatively, the decrease in serum ferritin may represent a genuine negative iron balance, and several possibilities have already been explored to explain this. Nachtigall et al. (16) detected increased occult intestinal blood loss correlated with the intensity of training; however, the 10 μg·L⁻¹ fall in serum ferritin noted in our

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Table 1 Hematological Parameters in 36 Female Athletes Measured With Both Low and High Ferritin on Separate Occasions and a Control Group of 36 Females Randomly Selected From the Database

<table>
<thead>
<tr>
<th>Parameter</th>
<th>Low M</th>
<th>SD</th>
<th>High M</th>
<th>SD</th>
<th>Control M</th>
<th>SD</th>
</tr>
</thead>
<tbody>
<tr>
<td>MCV (fl)</td>
<td>88.0</td>
<td>4.0</td>
<td>89.5</td>
<td>3.3</td>
<td>89.2</td>
<td>3.6</td>
</tr>
<tr>
<td>MCHC (g·dl⁻¹)</td>
<td>33.4</td>
<td>1.3</td>
<td>33.6</td>
<td>0.9</td>
<td>33.7</td>
<td>1.2</td>
</tr>
<tr>
<td>Hb (g·dl⁻¹)</td>
<td>13.2</td>
<td>0.9</td>
<td>13.5</td>
<td>0.9</td>
<td>13.4</td>
<td>0.8</td>
</tr>
<tr>
<td>Ferritin (μg·L⁻¹)</td>
<td>7.5</td>
<td>2.7</td>
<td>41.9</td>
<td>15.7</td>
<td>48.0</td>
<td>33.3</td>
</tr>
</tbody>
</table>

Note. There were no significant differences between groups, except the ferritin value for Low, which was significantly lower (p < .05) than High and Control.
athletes would be equivalent to the iron contained in half a unit (225 ml) of blood (7). A blood loss of this magnitude would necessitate training of unrealistically high intensity to be sustained over several months, suggesting that occult blood loss may contribute only partially to the decline in serum ferritin. Magnusson et al. (15) proposed that the reduction in serum ferritin was a consequence of the physical destruction of red cells and the coincident removal of iron from the available storage pool. Subsequent research demonstrated that iron from senescent red cells was available for future red cell production (13), indicating that increased red cell turnover is an overly simplistic mechanism to explain the decline in serum ferritin. No single theory has adequately explained the magnitude of the decline in serum ferritin following physical training (6).

It is no less difficult to explain why athletes' mean serum ferritin values vary according to the sport. Telford and Cunningham (19) documented this in well-trained athletes from several sports. Our study confirms that the difference in serum ferritin remains between specific sports after body size has been adjusted for. Significant between-sport differences were evident at the beginning of the season. This could imply the existence of some chronic influence on serum ferritin in addition to the acute influence detected during the training season, or it could represent a carryover effect from previous years of training. Although most of the athletes used in this comparison were resident at the institute and thus had access to meals with similar bioavailability of iron, substantially different eating behaviors between sports, and thus dietary iron intake, may have contributed to this difference.

Despite the popularity and widespread use of serum ferritin concentration as an indication of body iron stores in female athletes, blood tests should be interpreted with caution. Our study confirms that serum ferritin concentrations will vary between specific sports. Serum ferritin values decrease substantially over the training season, and many athletes with apparent iron store depletion may have no indication of iron deficiency anemia. Such athletes would, therefore, be unlikely to receive any hematological benefit from iron supplementation.

References


*Manuscript received: September 15, 1997
Accepted for publication: February 20, 1998*