A Case Study of an Iron-Deficient Female Olympic 1500-m Runner

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This case study examines the impact of low serum ferritin (sFe) on physiological assessment measures and performance in a young female 1500-m runner undertaking approximately 95–130 km/wk training. The study spans 4 race seasons and an Olympic Games. During this period, 25 venous blood samples were analyzed for sFe and hemoglobin (Hb); running economy, VO\textsubscript{2\text{max}}, and lactate threshold were measured on 6 occasions separated by 8–10 mo. Training was carefully monitored including 65 monitored treadmill training runs (targeting an intensity associated with the onset of blood lactate accumulation) using blood lactate and heart rate. Performances at competitive track events were recorded. All data were compared longitudinally. Mean sFe was 24.5 ± 7.6 μg/L (range 10–47), appearing to be in gradual decline with the exception of 2 data points (37 and 47 μg/L) after parenteral iron injections before championships, when the lowest values tended to occur, coinciding with peak training volumes. Each season, 1500-m performance improved, from 4:12.8 in year 1 to 4:03.5 in year 4. VO\textsubscript{2\text{max}} (69.8 ± 2.0 mL · kg\textsuperscript{-1} · min\textsuperscript{-1}) and running economy (%VO\textsubscript{2\text{max}} at a fixed speed of 16 km/h; max 87.8%, min 80.3%) were stable across time and lactate threshold improved (from 14 to 15.5 km/h). Evidence of anemia (Hb <12 g/dL) was absent. These unique data demonstrate that in 1 endurance athlete, performance can continue to improve despite an apparent iron deficiency. Raising training volume may have caused increased iron utilization; however, the effect of this on performance is unknown. Iron injections were effective in raising sFe in the short term but did not appear to affect the long-term pattern.

Keywords: endurance, athlete, ferritin, hemoglobin

Endurance training may cause an increased iron turnover due to foot-strike hemolysis, calorie restriction, and decreased absorption caused by a reduced visceral blood flow during and after exercise. Iron deficiency can cause fatigue, particularly if erythropoiesis and hemoglobin (Hb) are compromised (iron-deficient anemia). Athletes are often regularly screened for iron stores; indeed, the International Olympic Committee recommends screening to identify iron deficiency. Typically, a test of serum ferritin (sFe) is employed. The impact of low sFe on physiological determinants of performance and competitive performance is poorly understood and rarely documented; however, it could be hypothesized that iron deficiency might result in suboptimal adaptation and reduced performance. Jones\textsuperscript{3} presented a case study of the physiological adaptations occurring longitudinally in a world-record marathon runner, and Ingham et al\textsuperscript{4} recently presented a case study of a male 1500-m runner; however, few longitudinal data exist in female middle-distance runners describing a long-term physiological adaptation. This case study examined performance data over a 39-month period (spanning 4 competitive seasons including an Olympic Games) and within this, physiological test data and venous blood data over a 28-month period, in a young, female 1500-m runner.

Methods

The runner’s characteristics were age 17 to 20 years, height 167.6 cm, weight 54.7 ± 0.65 kg. Blood samples were collected from an antecubital vein after a 12-hour fast and analyzed for sFe and Hb on approximately a monthly basis (total 25 samples within the 28 mo); treadmill-based (Woodway ELG, Germany) physiological tests (total of 6 tests, separated by 8–10 mo) were performed for the assessment of lactate threshold, running economy, and VO\textsubscript{2\text{max}} using a similar protocol described elsewhere.\textsuperscript{3,4} Identical equipment was used for each testing session. In addition, a total of 65 controlled treadmill-based “threshold” training runs were monitored using blood lactate and heart rate (data not presented) to assess adaptation and prescribe training intensities.
Track performances were recorded across the study period. All data were compared longitudinally.

The athlete was undertaking approximately 95 to 130 km/wk training and had access to regular professional medical and nutrition advice. Investigations to identify excessive blood loss, malabsorption, and hematological and endocrine conditions were normal. A combined iron and vitamin C oral supplement was taken throughout the period studied with some variation in doses (Ferrous Sulfate 200–400 mg daily, 500 mg of vitamin C). The athlete was eumenorrheic and not vegetarian, and her body weight was stable. Factors affecting iron absorption, such as iron preparation, timing of intake to avoid the postexercise period, and inhibitors to absorption, were considered and optimized. In addition, intravenous iron injections were administered on 2 occasions (Venofer, American Regent Inc, New York, USA; 5-mL dose containing 100 mg elemental iron; see Figure 1).

Results

Mean sFe from all tests was toward the lower end of the normal range at 24.5 ± 7.6 μg/L (range 10–47) with increasingly lower occasional values (17, 15, 11, 10 μg/L) during the period of investigation with the exception of 2 data points at 37 μg/L and 47 μg/L (see Figure 1). These 2 points resulted from parenteral iron injections before major championships, when the lowest values tended to occur (see Figure 1). There was no evidence of anemia (Hb <12 g/dL) during the period studied. Actual Hb values were 13.6 ± 0.4 g/dL (max 14.3, min 12.9).

Personal-best performance times over 1500 m were 4:12.8 (m:s), 4:06.7, 4:05.8, and 4:03.5 in years 1 to 4, respectively (see Figure 1 for all recorded 1500-m performance times). Physiological test data revealed a stable absolute and relative VO_{2max} (69.8 ± 2.0 mL · kg⁻¹ · min⁻¹) and stable running economy (see Figure 2), expressed as a %VO_{2max} at a fixed speed of 16 km/h (max 87.8%, min 80.3%) and in terms of the relative oxygen uptake per kilometer (see Figure 2). Velocity at lactate threshold improved from 14 km/h to 15.5 km/h.

Discussion and Conclusions

This case study presents unique data demonstrating that in 1 female endurance athlete competitive performance and physiological test data can be maintained (VO_{2max}; economy) or improve (lactate threshold) despite an apparent iron deficiency (sFe <30 g/dL) as demonstrated by a standard routine blood test for sFe. Iron injections were effective in raising sFe in the short term and could have affected performance but did not appear to affect the long-term pattern of sFe. There was no evidence of anemia (Hb <12 g/dL). The lowest sFe values coincided with increases in training volume and intensity before the taper for a major championship, and we speculate that this is related to increased turnover of Hb caused by

Figure 1 — Ferritin values (open squares) and 1500-m-running time (min:s; closed diamonds) during the period studied. The 2 highest serum ferritin values (>35 g/dL) occurred after iron injections, and the lowest values (<20 g/dL) corresponded with peak training volumes, often preceding major championships. Linear trend lines of best fit are shown (upper line: r² = .92 for annual personal best; lower line: r² = .02 for sFe). x’s denote the treadmill tests (data are presented in Figure 2) and +’s represent iron injections.
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foot-strike hemolysis and/or an increased utilization of iron due to increased metabolic demands and thermoregulation (sweating). In addition, the interaction between training intensity and frequency with hepcidin activity may be implicated.5

Although we observed ongoing improvements in lactate threshold and performance, the same is not true of VO2max and running economy. Conceivably, aerobic adaptation may have been inhibited by iron deficiency, and greater improvements in performance might have been possible. Indeed, others have recently reported improved metabolic pathways and aerobic capacity in iron-deficient, anemic volleyball players when they were treated with iron-replacement therapy.6 Alternatively, it may represent a plateau in these aerobic indices of performance. Few longitudinal studies have reported physiological data in elite female distance runners, and those that have shown improved aerobic indices together with improved performance. Jones3 observed an ongoing improvement in running economy and performance; however, neither of these studies considered markers of iron status.

In conclusion, this case study demonstrates that in this athlete, endurance-running performance continued to improve despite a long-term clinically low sFe. Iron injections resulted in a short-term increase in sFe that may or may not have influenced performance. This raises questions regarding the interpretation of sFe assessment, the optimal level of sFe for endurance performance, and the relationship of sFe to whole-body iron stores.

Future research should address the following issues: the appropriateness of sFe in isolation as a marker of iron deficiency in athletes, the implications of low sFe in adaptation to endurance training, the efficacy of iron injections on exercise performance in athletes with chronic iron deficiency, and the use of additional markers such as Hb mass to assist with interpretation of results pertaining to iron status.

Acknowledgments

Thanks to the athlete and coach, who gave their permission and were positive about the publication of these data.

Figure 2 — (A) Maximal aerobic capacity (VO2max), (B) velocity at lactate threshold, (C) running economy, and (D) the percentage of VO2max at 16 km/h.
References


Erratum

On p. 696 of this article, we printed an incorrect version of Figure 1, without the ×’s and +’s referred to in the caption. Please see below for the correct version of the figure, along with the caption.

**Figure 1** — Ferritin values (open squares) and 1500-m-running time (mins:s; closed diamonds) during the period studied. The 2 highest serum ferritin values (>35 g/dL) occurred after iron injections, and the lowest values (<20 g/dL) corresponded with peak training volumes, often preceding major championships. Linear trend lines of best fit are shown (upper line: $r^2 = .92$ for annual personal best; lower line: $r^2 = .02$ for sFe). ×’s denote the treadmill tests (data are presented in Figure 2) and +’s represent iron injections.