

Effects of Iron Intake Through Food or Supplement on Iron Status and Performance of Healthy Adolescent Swimmers During a Training Season

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Abstract

Maintenance of a normal iron status is important for swimming performance during training and competition. The purpose of this study was to investigate whether 1) the iron status of healthy adolescent swimmers changes during a training season of six months, and 2) increasing daily iron intake affects iron status or performance. Forty-two (21 male and 21 female) swimmers, aged 12–17, without anemia or iron deficiency were divided into three equal groups. Group A received an iron supplement of 47 mg per day, group B followed a dietary plan rich in iron (providing, on average, 26 mg per day), and group C had a regular diet. Blood samples were taken before the beginning of the study and at the end of each of three training phases (moderate intensity training, high intensity training, and tapering) for the deter-

mination of hematological and iron status parameters. To evaluate performance, swimming tests at different distances were conducted along with blood sampling. The results showed significant fluctuations of iron status during the training season, including an increase in erythrocyte parameters during moderate intensity training. No significant differences in iron status or performance were found among the three groups. In conclusion, iron status and performance of healthy adolescent swimmers were affected by training irrespective of iron intake ranging from one to over five times the RDA over a period of six months.

Key words

Erythrocyte count · packed cell volume · hemoglobin · transferrin saturation · total iron-binding capacity · ferritin

Introduction

Competitive swimming places considerable demands on the respiratory, cardiovascular, and energy producing systems of the body. These demands are met primarily by proper training and adequate nutrition, including increased energy and, possibly, micronutrient intake. Therefore, nutritional as well as hematological status of the swimmer are important factors for successful training and competition [14,16].

The age of most competitive swimmers ranges from twelve to eighteen years. Besides their age-group championships, they participate in men's and women's championships, as well as in national and international competitions, thus being subjected to high physical and mental straining. This, combined with the

increased requirements for certain nutrients (such as protein, calcium, phosphorus, and iron) during puberty, makes competitive swimming an appropriate environment to study how rigorous sport participation affects the nutritional, hematological and biochemical status of adolescents.

In our experience, coaches and parents of adolescent swimmers often associate a failure to meet the training and competition goals with low iron status. Given this, coaches and parents frequently administer iron supplements to young athletes without signs of decreased iron status. However, there is no sufficient evidence in the literature that iron status decreases during a swimming season. The relevant studies have reported divergent results including no significant changes [20,33], improvement [16], deterioration [3], or mixed outcomes [13,18]. These discrep-

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ancies may be explained by the lack of control for extraneous variables, most notably, nutrition. Moreover, it is not clear if an improvement in iron status (e.g., an increase in hemoglobin and/or ferritin levels) through nutritional intervention has any effect on performance of adolescent non-anemic, non-iron-deficient swimmers. Additionally, it has been reported that increasing the iron intake through the diet rather than supplementation is more beneficial to the iron status [15]. Therefore, the purpose of this study was to examine whether 1) iron status changes during a training season, and 2) increasing daily iron intake through supplementation or the diet affects iron status or performance of adolescent swimmers.

Material and Methods

Subjects

Participants were 42 age-group swimmers (21 male and 21 female), aged 12–17, who did not suffer from any acute or chronic illness. They belonged to a Greek swimming club, had participated in swimming training for at least four years, attended daily training sessions, and participated in regional as well as national competitions regularly. One of the authors (GT) trained and monitored the athletes during all phases of the study. All athletes were non-anemic (hemoglobin > 12 g/dl) and non-iron-deficient (ferritin > 7 ng/ml according to [29]). The swimmers and their parents were informed about the design and probable risks of the research, and consented to participate. The study was designed and carried out according to the guidelines of the University of Thessaloniki Ethics Committee.

Study design

The duration of the study was six months, i.e., from the beginning of the training season (mid-September) to the winter championship (mid-March). Subjects provided an initial blood sample for the determination of erythrocyte count, packed cell volume (PCV), hemoglobin, serum iron, total iron-binding capacity (TIBC), transferrin saturation, and ferritin (as described below). Based on the results of the hemoglobin and ferritin determinations, as well as their performance records, the swimmers were equally divided into three groups (7 males and 7 females in each) of similar age, performance level, and iron status. The groups were then randomly assigned the following dietary treatments for the entire study period:

A. Subjects followed their regular diet and received one capsule of pharmaceutical ferrous sulfate containing 47 mg of iron over an empty stomach daily.

B. Subjects were given a six-day balanced dietary plan rich in iron, covering Monday through Saturday, whereas their diet was free on Sundays. The dietary plan met their energy requirements, which were calculated from estimated resting energy expenditure [34] and energy cost of physical activities [1,2]. The plan was repeated each week, but subjects were allowed to change the sequence of days.

C. Subjects followed their regular diet.

The participants were instructed not to consume any vitamin or mineral supplement (other than the experimental supplement) during the entire study period.

Training protocol

All swimmers followed the same training program. The training period was divided into three phases, i.e., moderate intensity (endurance) training lasting three months, high intensity (power) training lasting two months, and tapering lasting one month. The average distance that they swam daily was 6 km during the first phase, 5 km during the second phase (of which approximately 15% was anaerobic training), and 3 km during tapering. Additionally, the swimmers performed dryland training (consisting of low intensity stretching and submaximal resistance exercises), three times per week, 45 min per session, during the first phase.

Anthropometric measurements

Body mass and height were measured before the beginning of the study and at the end of each training phase. At the same time, body fat was estimated by bioelectrical impedance through the use of a Bodystat 1500 apparatus (Douglas, United Kingdom). Because bioelectrical impedance is influenced by the amount of body water, the participants were asked to abstain from any food or drinks for at least 4 h, physical exercise for at least 12 h, and caffeine containing beverages as well as sauna for at least 24 h before each measurement. Skeletal maturity was assessed in the middle of the study period through radiographs of the left hand of each swimmer according to the RUS method [27].

Hematological and biochemical measurements

Morning fasting blood samples were taken from an antecubital vein in sitting position two days after the last training session on four occasions: before the beginning of the study and two days after the end of each training phase. An aliquot of each sample was mixed with EDTA solution to prevent clotting, and erythrocyte count, PCV, as well as hemoglobin concentration were measured in a Sysmex K-1000 (Kobe, Japan) hematological auto-analyzer. Serum was prepared from the remaining blood by centrifugation after clotting and was stored at -20°C for the determination of iron, TIBC, transferrin saturation, and ferritin. Iron was assayed spectrophotometrically through a reagent kit from Böhringer (Mannheim, Germany). TIBC was determined likewise after saturation of transferrin and precipitation of the excess of iron with a kit from Elitech (Sees, France). Transferrin saturation was calculated as the ratio of iron concentration to $\text{TIBC} \times 100$. Ferritin was determined by enzyme immunoassay with a kit from DRG (Marburg, Germany). All serum samples were analyzed concurrently at the completion of the study to eliminate variation in assay conditions. The intra-assay coefficients of variation were 1.4% for iron, 1.6% for TIBC, and 6.3% for ferritin.

Swimming tests

Participants performed two identical tests, one at the beginning and one at the end of each training phase, for the assessment of performance. All swimming tests were performed in the morning and athletes abstained from any strenuous physical activity for two days before the tests. The tests flanking the first phase were at 2000 m, those flanking the second phase were at 800 m, and those flanking the third phase were at 200 m. These distan-

ces were selected in order to evaluate the accomplishment of the goals of each training phase. Additionally, the swimmers performed a 25-m sprint in water at the beginning of the study and at the end of each training phase for the determination of their maximal swimming velocity. Finally, at the beginning of each training phase, they performed a so-called two-speed test [32] consisting of two 200-m swims with a 20-min interval for the assessment of the velocity corresponding to a blood lactate concentration of 4 mmol/l (V4). The first swim was at a velocity just below V4 and the second at a velocity just above V4. These velocities had been determined in previous routine tests. For lactate determination, capillary blood samples were taken from an earlobe one minute after the first bout and one as well as three minutes after the second bout. Blood was immediately mixed with an excess of 0.6 mol/l perchloric acid, and lactate was measured spectrophotometrically in the supernatant after centrifugation, using a kit from Böhlinger. V4 was calculated linearly from the value after the first bout and the highest of the two values after the second bout.

Dietary records

All participants recorded their food intake daily during the entire study. Dietary records were analyzed for energy, carbohydrate, fat, protein, iron, calcium, folate, vitamin C, and fiber intake in Microsoft® Access through the use of a food database created in our laboratory on the basis of published data [12]. Athletes of group A were asked to return the vial containing the experimental capsules that they had been given at the beginning of the study so that their compliance could be determined.

Menstruation

Female participants recorded the number of sanitary napkins they used during their menses, as a semi-quantitative index of blood loss. Of the 84 blood samples collected from females, only three were collected during menstruation.

Statistical analysis

Results are reported as the mean \pm SD, except in the figures where SE are reported for clarity. A Student's paired *t*-test was used to compare chronological and skeletal age. Comparisons among groups A, B, and C with respect to age, dietary intakes, and sanitary napkins were performed by simple ANOVA. Significant differences were followed-up with a Scheffé test. Comparisons with respect to physical characteristics, hematological parameters, biochemical parameters, and performance were initially carried out by three-way (sex \times dietary intervention \times time) ANOVA with repeated measures on time. Since no significant interaction of the three factors was found, data of both sexes were pooled to increase the power of analysis, and two-way (dietary intervention \times time) ANOVA was performed instead. Significant differences were followed-up with simple contrasts. Correlations between variables were examined by Pearson's correlation analysis. The level of statistical significance was set at $\alpha = 0.05$. Data were analyzed in SPSS 10.0 (SPSS, Chicago, IL).

Results

Chronological and skeletal age data of the participants are shown in Table 1. No statistically significant differences were found among groups. Skeletal age was significantly higher than chronological age (by an average of 0.6 years, $p < 0.001$).

Physical characteristics of the swimmers at the onset and the end of the study are presented in Table 2 (data from the second and third measurements are omitted for clarity). The three groups did not differ significantly with respect to body mass, height, body mass index (BMI), and percentage body fat. Body mass and height increased significantly ($p < 0.001$) during the study, but no significant changes were found in BMI or percentage body fat. The menstrual status of the female participants was similar among groups (Table 3).

The results of dietary analysis are summarized in Table 4. ANOVA showed significant differences in daily energy, carbohydrate, fat, protein, iron, calcium, folate, vitamin C, and fiber intake among groups ($p \leq 0.001$). These differences were located in group B, which had significantly higher values than groups A or C with regard to all of the above parameters except iron, where, as a result of the study design, differences were significant between any two of the three groups. Daily iron intake was 60 ± 3 mg for the boys and 57 ± 3 mg for the girls of group A, 26 ± 1 mg for the boys and 25 ± 1 mg for the girls of group B, as well as 14 ± 3 mg for the boys and 9 ± 3 mg for the girls of group C. Most partici-

Table 1 Chronological and skeletal age of participants at the middle of the study period ($n = 14$ in each group)

Group	A	B	C
Chronological age (year)	14.6 \pm 1.3	14.5 \pm 1.3	14.7 \pm 1.4
Skeletal age (year)	15.3 \pm 1.1	14.9 \pm 1.4	15.3 \pm 1.3

A: group supplemented with iron, B: group following dietary plan, C: control group.

Table 2 Physical characteristics of participants at the onset and the end of the study (six-month difference)

Group	A		B		C	
	Onset	End	Onset	End	Onset	End
Body mass (kg)	52.6 \pm 7.5	54.2 \pm 7.8*	57.2 \pm 11.5	58.9 \pm 11.9*	51.8 \pm 6.1	53.6 \pm 6.7*
Height (m)	1.61 \pm 0.08	1.63 \pm 0.09*	1.67 \pm 0.08	1.69 \pm 0.08*	1.63 \pm 0.07	1.65 \pm 0.07*
BMI (kg m ⁻²)	20.3 \pm 1.7	20.4 \pm 1.9	20.4 \pm 2.4	20.4 \pm 2.6	19.4 \pm 1.5	19.7 \pm 1.9
Body fat (%)	15.3 \pm 6.0	15.9 \pm 5.7	14.0 \pm 5.7	14.7 \pm 4.8	13.6 \pm 5.6	14.0 \pm 6.1

A, B, C: see footnote of Table 1.

*Significantly higher than onset ($p < 0.001$).

Table 3 Menstrual status of female participants (n=7 in each group)

Group	A	B	C
Sanitary napkins used during the study	256 ± 25	250 ± 32	253 ± 31
Eumenorrheic*	6	3	5
Oligomenorrheic	1	2	1
Amenorrheic	0	2	1

A, B, C: see footnote of Table 1.
*Menstrual cycle of 21–35 days.

Table 4 Daily energy and nutrient intake throughout the study period

Group	A	B	C
Energy (kcal)	2087 ± 560	3223 ± 363*	2171 ± 692
Energy (kcal/kg)	39 ± 10	57 ± 8*	42 ± 13
Carbohydrate (g)	236 ± 68	383 ± 35*	233 ± 78
Carbohydrate (% energy)	45 ± 5	48 ± 2	43 ± 4
Fat (g)	90 ± 27	130 ± 19*	98 ± 34
Fat (% energy)	39 ± 5	36 ± 1	40 ± 5
Protein (g)	83 ± 22	128 ± 17*	88 ± 25
Protein (% energy)	16 ± 2	16 ± 1	17 ± 3
Iron (mg)	58 ± 3†	26 ± 1†	12 ± 4†
Calcium (mg)	1213 ± 290	1984 ± 250*	1236 ± 300
Folate (µg)	192 ± 77	856 ± 61*	235 ± 79
Vitamin C (mg)	120 ± 74	453 ± 34*	136 ± 52
Fiber (g)	18 ± 6	42 ± 4*	18 ± 7

A, B, C: see footnote of Table 1.

* Significantly higher than groups A or C ($p < 0.05$).

† Significantly different from the other groups ($p < 0.001$).

pants of group A received all capsules regularly, but a few omitted some. Compliance was $96 \pm 3\%$. No side effects were reported by any of the participants.

Neither the interaction between dietary intervention and time nor the main effect of dietary intervention was found to be significant with regard to any hematological, biochemical or performance parameter (presented in Figs. 1–4). For this reason and for the sake of simplicity, descriptive statistics are given below for the three groups combined ($n = 42$), although each group is represented separately in the figures.

Hematological parameters are presented in Fig. 1. The main effect of time was significant on all three parameters. Significant increases were observed during the first phase of the study (moderate intensity training) in erythrocyte count (from 4.8 ± 0.4 to 5.0 ± 0.5 M/ μ L), PCV (from 41.0 ± 2.6 to $45.6 \pm 2.5\%$), and hemoglobin concentration (from 14.0 ± 0.9 to 14.6 ± 0.9 g/dL, $p < 0.001$ for all three parameters). These values decreased significantly to 4.9 ± 0.5 M/ μ L, $42.4 \pm 2.9\%$, and 14.4 ± 0.9 g/dL ($p \leq 0.05$) during the second phase (high intensity training), and did not change during the third phase (tapering). The values at the end of the study (4.9 ± 0.4 M/ μ L, $42.4 \pm 2.8\%$, and 14.4 ± 1.0) were significantly higher as compared to the beginning ($p < 0.001$).

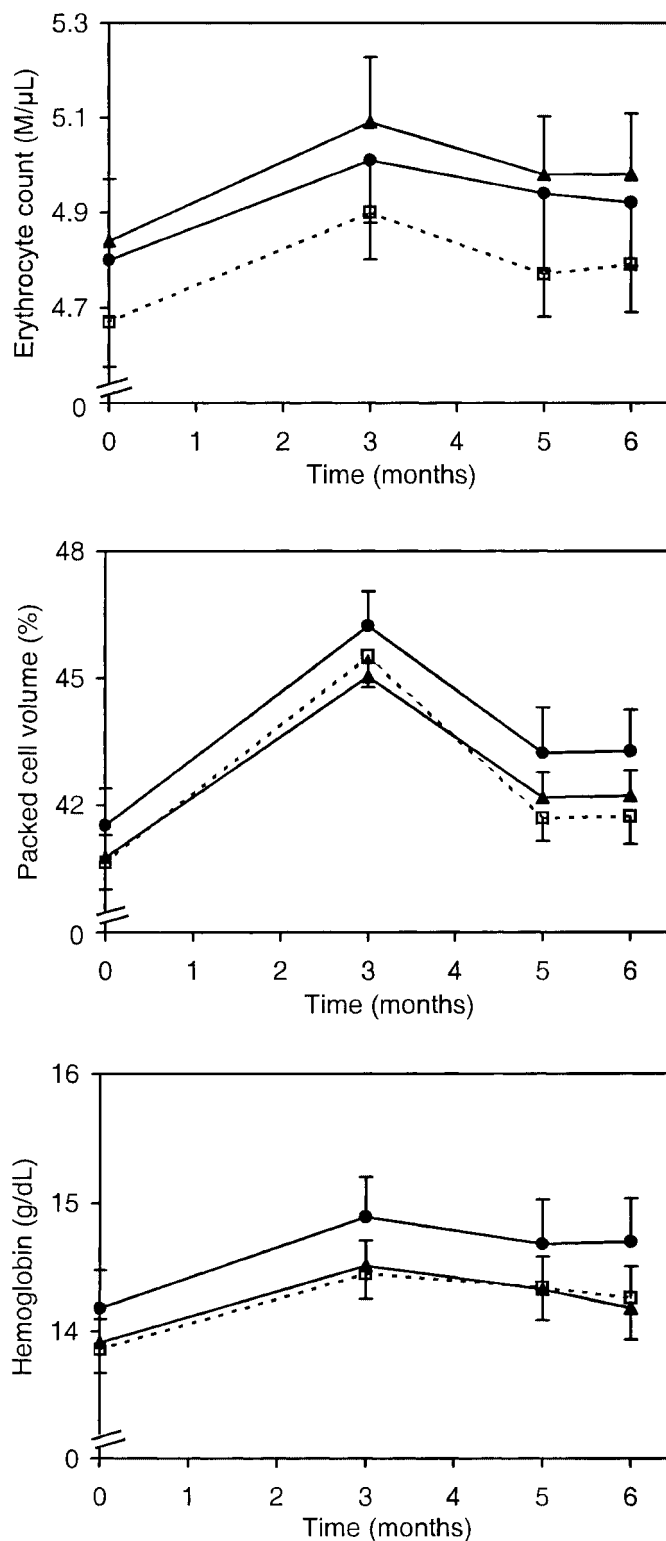


Fig. 1 Changes in hematological parameters of groups A (▲), B (●), and C (□) during the study. Differences among groups were not significant. Differences between any two time points for the three groups combined were significant ($p \leq 0.05$) except between the third and fourth measurements. Error bars indicate SE.

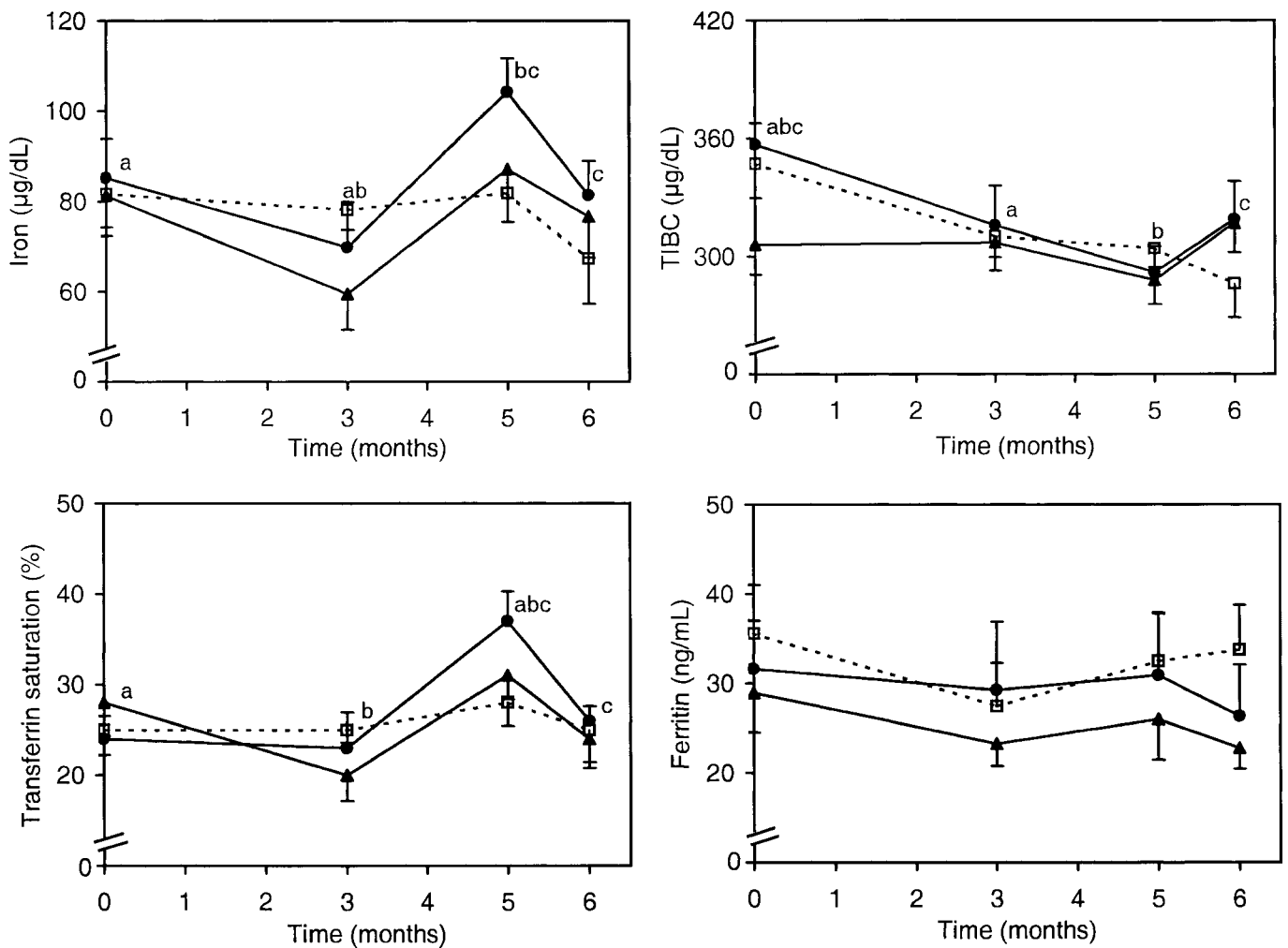


Fig. 2 Changes in biochemical parameters of groups A (▲), B (●), and C (□) during the study. Differences among groups were not significant. Differences among time points for the three groups combined were significant with regard to iron, TIBC, and transferrin saturation

($p < 0.01$). Identical letters denote time points differing significantly from each other ($p < 0.05$). Error bars indicate SE.

With regard to the biochemical parameters (Fig. 2), a significant main effect of time was found on iron concentration, TIBC, and transferrin saturation ($p < 0.01$). Iron exhibited a significant decrease during the first phase (from 83 ± 30 to 69 ± 30 µg/dl, $p < 0.05$) followed by a significant increase to 91 ± 27 µg/dl ($p = 0.001$) during the second phase, and a significant decrease to 75 ± 33 µg/dl ($p < 0.01$) during the third phase. The final values did not differ significantly from baseline. TIBC decreased during the study and was significantly lower than the initial values (337 ± 58 µg/dl) at all subsequent time points (311 ± 56 , 295 ± 44 , and 307 ± 64 µg/dl in sequence, $p \leq 0.01$). Transferrin saturation showed similar fluctuations to iron concentration (culminating at $31.8 \pm 11.1\%$ after the second phase), with the exception that the change during the first phase was not significant. Finally, ferritin concentration did not change significantly during the study, decreasing from 32.1 ± 18.9 to 27.6 ± 17.4 ng/ml.

Results of the swimming tests are presented in Figs. 3 and 4. Performance at 2000, 800, and 200 m increased significantly with time ($p < 0.01$, Fig. 3). Performance at 25 m increased significantly during the first and third phase, as well as overall ($p < 0.01$, Fig. 4). Finally, V4 increased significantly from baseline to the second and third measurement ($p < 0.001$).

No significant correlations were found between iron intake and any hematological, biochemical or performance parameter for the sum of the participants. Of the other nutrients, whose intake could affect iron status (i.e., calcium, folate, vitamin C, and fiber), only vitamin C intake was positively correlated with serum iron at the third measurement ($r = 0.33$, $p = 0.038$). Additionally, some significant correlations were observed between biochemical parameters at the second measurement, namely, iron and ferritin ($r = 0.36$, $p = 0.021$), transferrin saturation and ferritin ($r = 0.51$, $p = 0.001$), as well as TIBC and ferritin ($r = -0.38$, $p = 0.014$).

Discussion

In the present study we monitored the diet, iron status, and performance of 42 adolescent swimmers during a six-month training season including endurance training, power training, and tapering, under three dietary conditions: iron supplementation, dietary plans rich in iron, and no intervention. To our knowledge, this is the first study to monitor the effect of different training regimens and iron intake on iron status of adolescent athletes for such a prolonged period. Furthermore, we focused on healthy

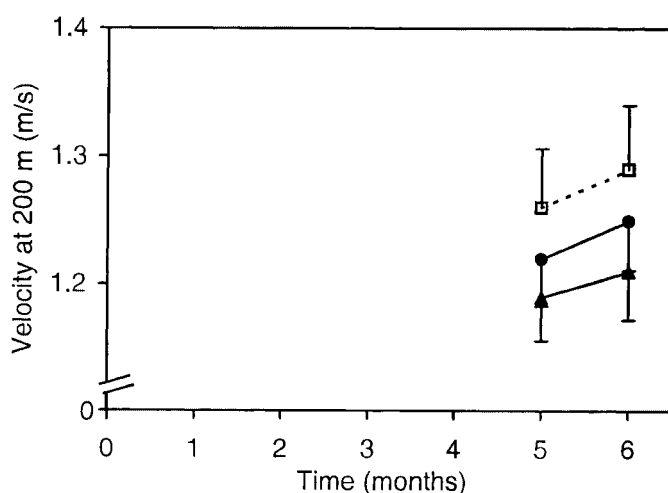
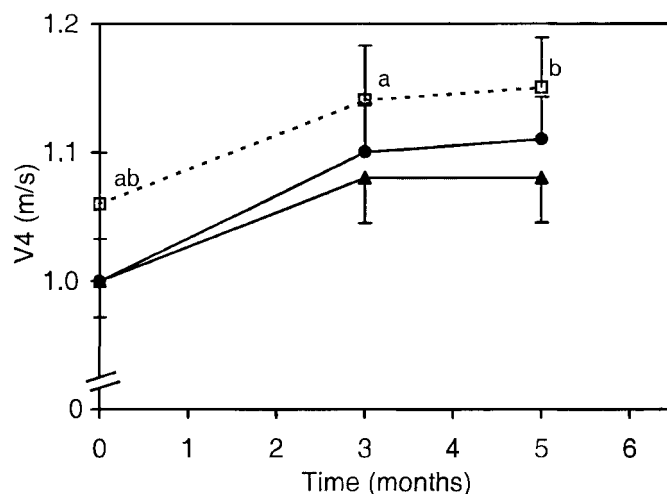
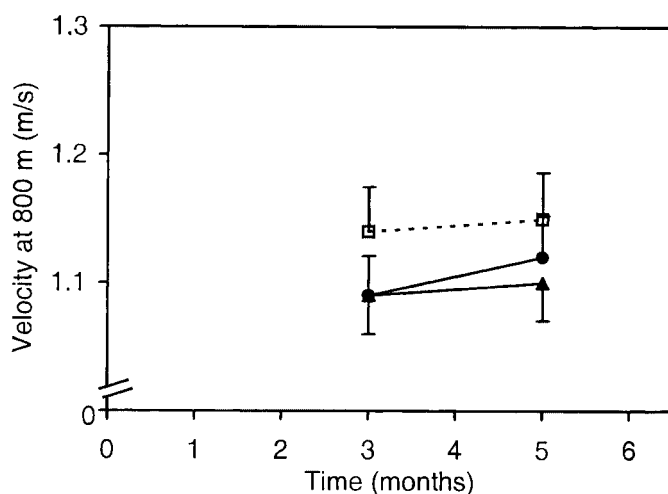
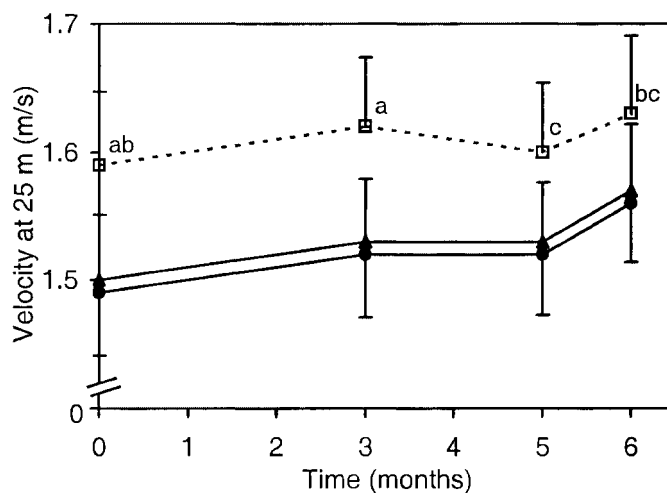
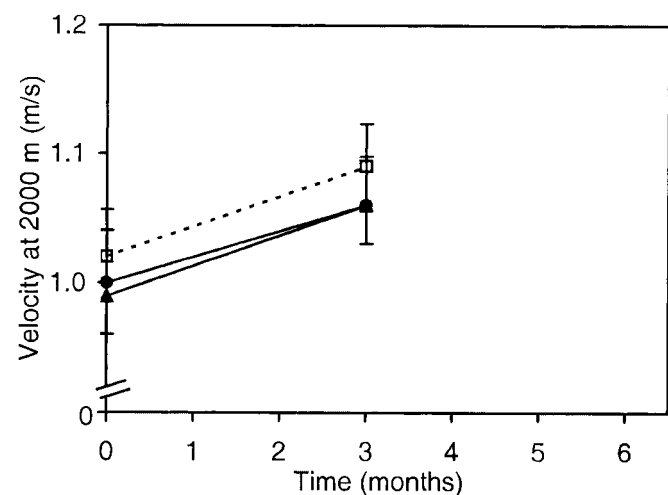


Fig. 3 Changes in swimming velocity at 2000, 800, and 200 m of groups A (▲), B (●), and C (□) during the study. Differences among groups were not significant, but differences between time points for the three groups combined were ($p < 0.01$). Error bars indicate SE.

athletes in contrast to many of the longitudinal studies on iron supplementation, which have used iron depleted and/or anemic athletes [3,6,7,11]. Our choice was dictated by the fact that, as already mentioned, iron supplementation of athletes (particularly adolescent ones) without any symptom of iron deficiency is very

Fig. 4 Changes in swimming velocity at 25 m, and swimming velocity corresponding to a blood lactate concentration of 4 mmol/l (V4) of groups A (▲), B (●), and C (□) during the study. Differences among groups were not significant but differences among time points for the three groups combined were ($p < 0.05$). Identical letters denote time points differing significantly from each other ($p < 0.05$). Error bars indicate SE.

common. The mean values of body mass and height for the participating athletes (Table 2) were similar to the corresponding values of European adolescents of the same age [5].

Dietary analysis showed significantly higher energy, macronutrient and micronutrient intakes for group B (on dietary plan) as compared to groups A and C (Table 4). This finding is inconsistent with the fact that the three groups had almost identical changes in body mass and height, as well as the same physical activity. We hypothesize that the observed differences are due to underreporting of dietary intake by the athletes of groups A and C as a result of omissions and underestimation of food quantities. Athletes of group B, on the other hand, had only to abide by a given dietary plan consisting of foods, most of which were prepared by a parent who also supervised compliance. Underreporting is also supported by the fact that the daily energy intake (in kcal/kg body mass) reported by the athletes of groups A and C (Table 4) was lower than even the daily energy requirement for adolescent non-athletes of the same age (49 kcal/kg for boys and 41 kcal/kg

for girls, [5]). Based on the comparison of daily energy intake (in kcal/kg) between groups A and C, on the one hand, and B, on the other, an average underreporting of 29% arises, which is within the margins reported in review articles of the relevant literature, especially for adolescents [10,22]. In fact, an even higher (43%) underreporting by young female swimmers during a high-volume training period has been reported [30].

Daily iron intake through the regular, uncontrolled diet was very similar between group A excluding supplementation and group C (see Results), averaging 13 mg for the male and 10 mg for the female participants of these groups. If these values are corrected for underreporting, they increase to 19 and 14 mg, respectively, identical to those reported for Swedish adolescent boys and girls [21]. The male value is well above the recently proposed RDAs for iron [25], i. e., 7.9 mg for ages 9–13, and 10.8 mg for ages 14–18 (in fact, the male value was above the RDAs even before correcting for underreporting). The female value is above or close to the corresponding RDAs [25], i. e., 8.3 mg for ages 9–13, and 14.8 mg for ages 14–18. Given, additionally, the fact that all participants had normal iron status, it seems that iron intake through the regular diet was adequate. Interestingly, iron intake through the regular diet (group A excluding supplementation and group C) was 5.4 mg per 1000 kcal, which is close to the value reported in the literature (6 mg/1000 kcal) as the iron content of the typical Western diet [9,17], whereas iron intake through the dietary plans (group B) was 1.5 times as much (8.0 mg/1000 kcal). Participants of group B received, on average, 2.4 times their RDA for iron, whereas participants of group A received, on average, 4.0 times their RDA for iron as supplement (on top of their dietary intake).

Daily intake of folate (considered important for erythropoiesis) exceeded the recently proposed RDA of 400 µg [24] only for group B. Intake of vitamin C (which facilitates absorption of non-heme iron) was well above the recently proposed RDAs (45–75 mg, [23]), while intake of calcium, which has been negatively correlated with the iron status [8,31], was approximately 1700 mg/day for groups A and C after correcting for underreporting, and 2000 mg/day for group B. These values are above the recently proposed adequate intake of 1300 mg for adolescents [26]. Finally, intake of dietary fiber (which impairs iron absorption) through the regular diet (approximately 25 g/day for groups A and C after correcting for underreporting) was within the recommended intake of 20–35 g/day [4], whereas intake through the dietary plans (42 g/day) exceeded the recommendation. Taken together, and along with the dearth of significant correlations between the intakes of the above nutrients and the iron status in the present study, our findings suggest that these intakes were within margins that do not affect the iron status.

As far as we know, few studies have monitored the iron status of competitive athletes through a training season extending up to six months, and these are confined to the adult population. Studies on swimmers have employed 5–26 weeks of observation and have mostly shown no significant effects of training on hematological and biochemical indices, such as PCV, hemoglobin, iron, and ferritin [13,18,20,33]. One study reported a decrease in hemoglobin and ferritin concentration of mostly iron-depleted female swimmers during a competitive season [3], while another

found decreased hemoglobin (but no other erythrocyte indices) in male swimmers after 8–9 weeks of training [18]. On the other hand, hemoglobin [16], and ferritin [13] were reported to increase significantly during training. Differences in sex, age, performance level, iron status, training mode, observation period, and nutrition among these studies are apparently responsible for these discrepancies.

Improvements in all performance tests demonstrate that the training regimen employed in this study was adequate to induce beneficial physiological adaptations. Hematological parameters (erythrocyte count, PCV, and hemoglobin) changed significantly during the different phases of the training season (Fig. 1). All three parameters increased significantly by the third month of training, probably as a result of adaptations to the aerobic program. The same parameters decreased significantly within the next two months of intensive training. The significantly higher values of all three erythrocyte variables at the end as compared to the beginning of the study are apparently the result of adaptations to the training program, biological maturation, and/or seasonal variation. At any rate, these increases were relatively small (by 2.0 to 4.3%) and of questionable physiological relevance. Regarding the significant fluctuations of iron, TIBC, and transferrin saturation, these are probably adaptations to the different demands of each training phase, since, generally, they moved in a similar manner through time in all three groups.

Ferritin did not show significant changes during the study, although it tended to decrease overall. Additionally, it did not correlate with the iron intake, which is in agreement with published data [21,28]. The failure of high iron intake through either supplementation (group A) or a diet rich in iron (group B) to affect iron status may be attributed to homeostatic mechanisms that maintain hemoglobin and iron stores within certain ranges. These mechanisms include mainly regulation of iron absorption [9]. Pertinent to the present study, Roughead and Hunt [19] reported reduced nonheme-iron absorption in response to an iron supplementation similar to ours (50 mg/day as ferrous sulfate).

In accordance with the lack of significant effects of dietary manipulation on iron status and the lack of significant correlations between iron intake and iron status, we found no significant differences among the three groups in performance parameters or significant correlations between iron intake and performance. These findings agree with the majority of relevant studies (reviewed in [17]), which show that iron supplementation does not improve performance of healthy adult athletes.

In conclusion, the major erythrocyte variables of healthy age-group swimmers changed significantly during a six-month training period depending on the training phase, the most notable change being an increase during the initial trimester of endurance training. However, neither iron status nor swimming performance was affected by high iron intake through supplement (47 mg/day) or a diet rich in iron (providing, on average, 26 mg/day). Our findings imply that the regular diet of most adolescent swimmers meets their iron requirements and that parents or coaches concerned with a decreased performance are not justified to associate it with decreased (albeit, within the normal ranges) iron status and try to counter it with iron supplementation.

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