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Effect of an iron supplement on body iron status and aerobic capacity of young training women

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Summary. Serum iron deficiency has a high incidence in female athletes. We investigated the effects of a daily oral iron supplement, (160 mg) administered during an intensive 7-week physical training programme, on body iron status, and the maximal aerobic capacity ($\dot{V}O_{2max}$) of 13 women (group A) compared to 15 who took a placebo (group B). The subjects were 19 years old. Blood samples were obtained before training began and on days 1, 7, 21 and 42 of training. They were analysed for packed cell volume (PVC) and for haemoglobin (Hb), 2,3-diphosphoglycerate (2,3-DPG), haptoglobin, iron and ferritin concentrations. The $\dot{V}O_{2max}$ was measured on days 0, 21 and 42 of training. Following 21 days of training Hb, PCV and ferritin were significantly higher ($P \leq 0.01$) in group A compared to group B. Over the training period Hb rose by 9.3% and 2.4% in groups A and B, respectively. At the end of training 66% of group B exhibited ferritin concentrations below 10 $ng \cdot ml^{-1}$, while none of group A had such low values. Mean $\dot{V}O_{2max}$ of group A had increased by 7.5% following 21 days of training ($P \leq 0.01$) and by 15.3% after 42 days. No appreciable increase in $\dot{V}O_{2max}$ had occurred in group B by day 21 (significantly lower than $\dot{V}O_{2max}$ of group A; $P \leq 0.05$), however by day 42 it had increased by 14.3% ($P \leq 0.05$). In both groups 2,3-DPG $\cdot$ g Hb^{-1} had increased significantly ($P \leq 0.005$) by day 7 (22%) and remained at that level for an additional 35 days. We concluded that a daily oral iron supplement given to young women during intensive training improved several haematological variables and their body iron status. This improvement was associated with an increased $\dot{V}O_{2max}$ only during the early stages of their training (day 21) compared with the placebo group.

Key words: Ferritin - Haptoglobin - Maximal aerobic power - 2,3-Diphosphoglycerate

Introduction

Physical exercise may be associated with changes in hormonal, physiological, haematological, metabolic and biochemical constituents in the human body. The magnitude of these alterations is related to the intensity, rate and the duration of the exercise. During exercise, respiration, heart rate, oxygen uptake, cardiac-output and blood flow to the muscles increase, while blood flow to the skin and splanchic vessels decreases during dynamic muscle exercise (MacArdle 1986). Athletes, especially women undergoing long term strenuous training, may develop body iron depletion (Clement and Asmundson 1982; Plowman and McSwegin 1981). Iron is a vital constituent of haemoglobin (Hb), myoglobin and of key mitochondrial enzymes; therefore, body iron deficiency is associated with reduced muscular mitochondrial oxidative capacity resulting in reduced aerobic and endurance abilities (Clement and Sawchuk 1984; Davies et al. 1984; Kanstrup and Ekblom 1984). In a recent study we reported virtually no improvement in the aerobic capacity of iron deficient, vigorously training, women (Magazanik et al. 1988).

In spite of numerous investigations, there is still no consensus as to the effect of exercise on body iron status and the incidence of depletion and its severity in athletes undergoing training (Simon 1988). Furthermore, little and inconsistent information is available on the effects of a combination of an iron supplement and physical training on the aerobic capacity of iron deficient female athletes (Banister and Hamilton 1985; Hegenauer et al. 1983; Magnusson et al. 1984). We undertook the present investigation to study the effects of an oral iron supplement on body iron status and on the aerobic capacity of young women undergoing 7-weeks intensive physical training.

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Methods

Subjects. The participants, 28 women (mean age 19 years, SEM 1; mean body mass 58.6 kg, SEM 5.7; mean height 163.5 cm, SEM 5.3) signed written informed consent form, in accordance with the Helsinki convention, after being familiarized with the purposes and methods of the study. All the subjects were nonsmokers and were menstruating regularly. The subjects were randomly divided into two groups; group A ($n=13$) was given a daily supplement of ferrous sulfate [(160 mg) as Slow Fe^R, Ciba Laboratories, Horsham, England] and group B ($n=15$) was given placebo tablets, daily. All subjects took their tablets at the same hour over the entire training period without missing a day, in a double-blind design. The participants' daily diet was well balanced and included 15 mg iron (estimated from standard food charts).

Training. The 7-week training regime was based on the overload principle, which emphasizes a gradual increase in conditioning intensity throughout the training period. The training consisted each day of 5–6 h of intensive physical activity, 6 days a week, and included field running (4–5 km a day), jumping, weightlifting and cliff climbing. The training employed, therefore, both arm and leg exercise which were anaerobic as well as aerobic in nature.

Data acquisition. The percentage body fat was calculated from three skin-fold measurements (Brozek and Keys 1951). The maximal aerobic capacity ($\dot{V}O_{2max}$) of the subjects was measured directly using a modified Balke (Balke and Ware 1959) protocol which included walking on a treadmill at a constant speed ($6.5 km \cdot h^{-1}$) with a gradient increased by 2% every minute. Gas exchange and heart rate data were collected using a computerized data analysis system which included Applied Electrochemistry S-3A O_2 analyser (Sunnyvale, CA, USA), Beckman LB-2 CO_2 analyser (Fullerton, CA, USA) and Hewlett Packard Fleisch type pneumotachometer (Waltham, MA, USA). The gas analysers were calibrated with precision gas mixtures and the pneumotachometer with a precision vacumed calibration syringe. The $\dot{V}O_{2max}$ was measured at the onset (day 0), and on days 21 and 42 of the training period.

Venous blood samples were collected at 6.00 a.m. on days 0, 1, 7, 21, and 42 of the training period, into Becton and Dickinson-vacutainers (Becton Dickinson, Rutherford, New Jersey, USA), prior to the daily physical activity routine of the subjects and following overnight rest and fasting, with water ad libitum. Blood sampling coincided with the days of $\dot{V}O_{2max}$ measurements (except for day 7). The haemoglobin (Hb) concentration, red blood cell count (RBC) and packed cell volume (PCV) ratios were measured with a Coulter Counter Model S (Coulter Electronics, Luton, England). Haptoglobin concentration was determined with immunodiffusion plates (Kallestad, Austin, Texas, USA). Serum iron concentrations were analysed by Atomic Absorption Spectrophotometer (I.L-Video-11, Instrumentation Laboratory, Andover, MA, USA). Total iron binding capacity (TIBC) was assessed using the ferrozine method and serum ferritin concentration was measured with a TANDEM-R radio-immonoassay (RIA) kit (Hybritech, Liege, Belgium). Serum 2,3-diphosphoglycerate (2,3-DPG) concentration was measured with a Sigma 35-UV kit (SIGMA Chemicals Co., St. Louise, MO, USA).

Statistics. Repeated measures ANOVAS, in which treatment (iron tablets vs placebo tablets) constituted the independent variable, were applied to all dependent variables with the baseline (day 0) values as a covariance. This was followed by either postpriori contrast or ANCOVA procedures to compare the two groups at each period. A difference at the $P \leq 0.05$ level was considered statistically significant.

Table 1. Mean body mass, percentage body fat and lean body mass (LBM) in the iron supplemented (A, $n=13$) and the placebo (B, $n=15$) groups during 42 days training

Days		Body mass (kg)		Body fat (%)		LBM (kg)	
		A	B	A	B	A	B
0	mean	58.5	58.1	16.4	16.8	48.8	48.1
	SEM	1.5	2.0	0.8	0.9	1.1	1.3
21	mean	60.1#	59.1#	15.0#	15.3#	50.9#	49.9#
	SEM	1.5	2.1	0.7	0.9	1.0	1.5
42	mean	60.5#	58.7	13.7*#	14.2#	52.1*#	50.3#
	SEM	1.6	2.0	0.8	0.9	1.2	1.5

is significant (within groups) differences at the $P \leq 0.03$ level compared to day 0; * is significant difference compared with day 21 ($P \leq 0.05$). LBM = body mass minus fat mass

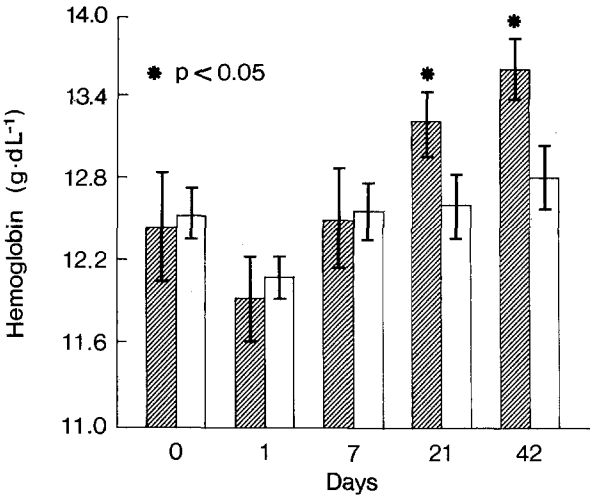

Fig. 1. Hemoglobin concentration of the placebo and the iron supplemented groups during 42-day training. Results are presented as mean and SEM. * $P \leq 0.05$ between groups. Within group variations are described in the text. Iron supplement (▨) and placebo (□)

Results

Anthropometric measurements presented in Table 1 illustrated no significant difference between the two experimental groups throughout the training period. Repeated measures ANOVA indicated a significant decrease in percentage body fat [$F(2.48)=22.101$; $P \leq 0.0001$] and increased body mass and lean body mass [$F(2.48)=14.177$; $P \leq 0.0001$ and $F(2.48)=34.861$; $P \leq 0.0001$, respectively] in all subjects over the training period.

The variations in Hb concentration during training in both groups are presented in Fig. 1. Repeated measures ANOVA revealed that the two groups differed in their mean Hb concentrations on days 21 and 42 of the training [$F(1.25)=5.046$; $P \leq 0.03$]. Mean Hb concentrations had decreased after the 1st day of physical training in both groups ($P \leq 0.05$) and returned to their initial values after 7 days. A significant increase in mean

Table 2. Packed cell volume (PCV) ed blood cell count (RBC) and haptoglobin concentration in the iron supplemented (A, $n=13$) and the placebo (B, $n=15$) groups during 42 days training

Days		PCV (%)		RBC (mm^3)		Hpt ($mg \cdot dl^{-1}$)	
		A	B	A	B	A	B
0	mean	38.86	39.01	4.34	4.32	121.9	98.3
	SEM	1.01	0.66	0.10	0.06	12.9	7.1
1	mean	37.72*	38.05*	4.23*	4.23*	115.6	96.7
	SEM	0.82	0.55	0.08	0.06	15.8	7.5
7	mean	38.94	38.91	4.32	4.29	93.7**	79.5*
	SEM	0.88	0.67	0.08	0.06	8.6	4.2
21	mean	40.18**	38.53^{A}	4.43	4.36	91.9**	86.0
	SEM	0.58	0.66	0.07	0.05	11.2	7.5
42	mean	43.01***	40.91^{A,**}	4.82***	4.76***	98.9*	107.7*
	SEM	0.57	0.60	0.07	0.05	8.9	10.0

*, ** and *** are significant (within groups) differences at the $P \leq 0.05$, $P \leq 0.01$ and $P \leq 0.001$ levels compared to day 0, respectively; ^{A} is for $P \leq 0.05$ between groups

Hb concentration was observed in group A following 21 days (to 13.22 $g \cdot dl^{-1}$, SEM 0.25) and 42 days (to 13.59 $g \cdot dl^{-1}$, SEM 0.21) of training ($P \leq 0.01$ and $P \leq 0.005$, respectively), compared with day 0 (12.44 $g \cdot dl^{-1}$, SEM 0.38). In contrast, the mean Hb concentration of group B did not change significantly over the same period. The PCV values in both groups (Table 2) followed a trend similar to the Hb changes.

The mean RBC in both groups decreased significantly after 1 day of training ($P \leq 0.05$), returning to baseline values after 7 days. On day 42, significantly elevated RBC was recorded in both groups compared with day 0 ($P \leq 0.001$). Serum haptoglobin concentration of both groups had decreased significantly ($P \leq 0{,}025$) after 7 days of exercise (Table 2). As training continued haptoglobin concentration of all participants increased gradually, and in group B it had surpassed the initial values at the end of the training ($P \leq 0.05$).

Serum iron concentrations of both groups (Table 3) did not change significantly over the training period; however, the mean iron concentration of group A was higher than the value measured in group B ($P \leq 0.05$) only on day 21. The TIBC of group A was significantly lower ($P \leq 0.025$) than that of group B on days 21 and 42 of training (Table 3). At the end of training TIBC of group A was significantly lower than its initial value ($P \leq 0.05$) while no such difference was observed in group B.

Mean serum ferritin concentrations are illustrated in Fig. 2. Repeated measures ANCOVA (with serum ferritin concentration of day 0 as a covariate) revealed that the two groups differed in their serum ferritin concentrations [$F(1.25) = 8.441$; $P \leq 0.008$] on days 21 and 42. However, the treatment by training interaction was found to be insignificant. Posthoc contrasts revealed that the ferritin concentration of group A was significantly higher than that of group B only on day 21 (23.6 $ng \cdot ml^{-1}$, SEM 3.2 vs 13.3 $ng \cdot ml^{-1}$ SEM 4.1; $P \leq 0.003$). Serum ferritin concentrations in group B decreased after 7 days, reaching their lowest value following 21 days ($P \leq 0.05$), while those of group A remained

Table 3. Serum iron and total iron binding capacity (TIBC) in the iron supplemented (A, $n=13$) and the placebo (B, $n=15$) groups during 42 days training

Days		Iron ($\mu mol \cdot l^{-1}$)		TIBC ($\mu mol \cdot l^{-1}$)	
		A	B	A	B
0	mean	16.29	13.01	71.40	71.37
	SEM	2.51	1.54	3.27	2.74
7	mean	14.28	11.54	69.60	72.17
	SEM	2.05	1.29	3.76	2.62
21	mean	17.07	11.65^{A}	71.83	78.60^{A}
	SEM	2.28	1.24	3.80	2.47
42	mean	14.95	15.50	63.86*	70.67^{A}
	SEM	1.56	1.60	3.73	2.21

* is for significant difference at $P \leq 0.05$, compared to day 0, within groups; ^{A} is for $P \leq 0.05$ between groups

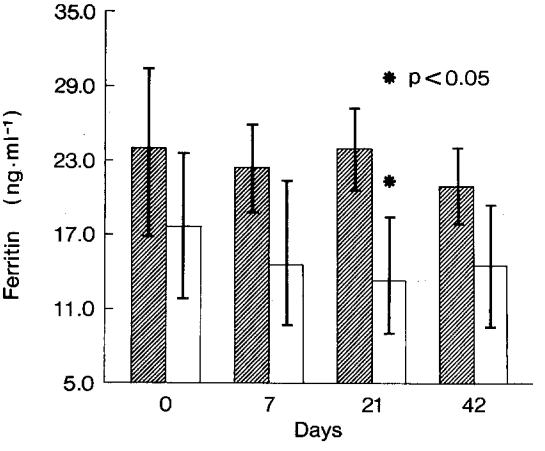

Fig. 2. Serum ferritin concentrations of the placebo and the iron supplemented groups during 42-day training. Results are presented as mean and SEM. * $P \leq 0.05$ between groups. Within group variations are described in the text. Iron supplement (▨) and placebo (□)

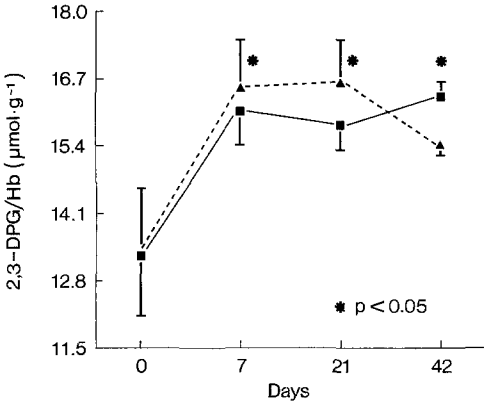

Fig.3. Changes in haemoglobin (*Hb*) specific 2,3-diphosphoglycerate (*2,3-DPG*) concentration (*2,3-DPG/Hb*) of the placebo and the iron supplemented groups during 42-days training. Results are presented as mean and SEM. * $P \leq 0.05$ compared with day 0 for both groups together. Iron supplement (▲) and placebo (■)

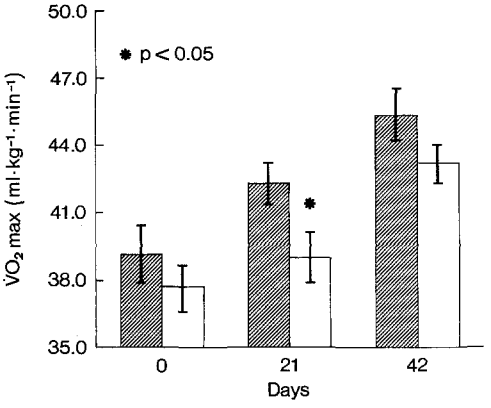

Fig. 4. Mean maximal aerobic capacity ($\dot{V}O_{2\,max}$) variations of the placebo and the iron supplemented groups during 42-day training. Results are presented as mean and SEM. * $P \leq 0.05$ between groups. Within group variations are described in the text. Iron supplement (▨) and placebo (□)

unchanged at baseline levels throughout the training period.

Following 7 days of training 2,3-DPG·g Hb^{-1} of both groups increased significantly (by 21%) compared with baseline values [$F(3.78) = 16.675$; $P \leq 0.0001$]. The 2,3-DPG·g Hb^{-1} remained at this elevated level throughout training (Fig. 3).

The repeated measures ANCOVA revealed that the two groups differed significantly in their mean $\dot{V}O_{2\,max}$ values on days 21 and 42, combined, [$F(1.25) = 4.879$; $P \leq 0.03$, Fig. 4]. Posthoc analysis showed that mean $\dot{V}O_{2\,max}$ of group A was significantly higher than that of group B only on day 21 ($P \leq 0.025$). On that day mean $\dot{V}O_{2\,max}$ of group A was 7.5% higher compared to baseline values ($P \leq 0.01$) and reached its highest value (increased by 15.8%) on day 42 ($P \leq 0.001$). Mean $\dot{V}O_{2\,max}$ of group B had not changed significantly on day 21 but on day 42 it was 14.3% higher than its baseline value ($P \leq 0.0001$). On day 42 the $\dot{V}O_{2\,max}$ difference between the groups was not statistically significant.

Discussion

A tendency to develop iron deficiency has been noted in both athletes and nonathletes participating in long term physical training, especially in women, who are more susceptible to the development of anaemia (Banister and Hamilton 1985; Clement and Sawchuk 1984; Magazanik et al. 1988). Decreased body iron content, independent of anaemia, leads to impairment of muscular mitochondrial oxidative ability, decreased work capacity and decreased $\dot{V}O_{2\,max}$ (Clement and Sawchuk 1984; Davies et al. 1984; Kanstrup and Ekblom 1984; Woodson 1984). We have recently reported that women undergoing a 7-week strenuous physical training programme developed iron deficiency and anaemia concomitant with the absence of an increase in $\dot{V}O_{2\,max}$. This was partly related to exceptionally intensive training during the first 3 weeks and to the development of latent iron deficiency (Magazanik et al. 1988).

The contribution of iron supplements during training on physiological and biochemical factors is open to debate. Some investigators have reported an increase in Hb concentration and $\dot{V}O_{2\,max}$ in athletes treated with ferrous sulfate (Hunding et al. 1981; Gardner et al. 1975; Plowman and McSwegin 1981) while others have noticed that iron therapy had no effects on body iron status or on Hb values (Cooter and Mowbray 1978; Pate et al. 1979; Hegenauer et al. 1983; Banister and Hamilton 1985; McDonald and Keen 1988).

The present study demonstrated that blood Hb concentration and PCV increased significantly in the group receiving iron supplements after 21 days of training, while no such changes were observed in the placebo group. The decreased values of several haematological parameters on the 1st day of training, in both groups, was related to an acute transient plasma-water-shift associated with the onset of abrupt strenuous muscular work (Convertino et al. 1980; Green et al. 1984; Magazanik et al. 1988; Schmidt et al. 1988). Our finding that Hb concentrations, PCV and RBC returned to their baseline levels after 7 days contrasts with several reports in the literature (Convertino et al. 1980; McDonald and Keen 1989; Newhouse and Clement 1988) showing that plasma volume remained elevated (decreased Hb concentration) at that time. The apparent disparity between our results and these studies may be related to the differing intensities and durations of the exercise. Furthermore, in the present study, the return of the haematological values to their baseline values, following 7 days of training, may be related to the attainment of new body water balance (Convertino et al. 1980; Newhouse and Clement 1988).

At the onset of training each group had 3 anaemic ($Hb < 12$ g·dl^{-1}) subjects, but at the conclusion of the training anaemic subjects (3) were only found in the placebo group. This observation agreed with the reported improved haematological profile of women in training receiving iron supplements (Sawaka et al. 1987; Brien and Simon 1987). Improved Hb concentrations and PCV resulted in enhanced O_2 transport capacity which led to a higher level of athletic perform-

ance (Sawaka et al. 1987; Brien and Simon 1987). This was vividly demonstrated by one of the females (NC) in group A who commenced training with Hb concentration of 9.3 $g \cdot dl^{-1}$ and $\dot{V}O_{2max}$ of 35.1 $ml \cdot min^{-1} \cdot kg^{-1}$ and concluded training with values of 13.6 $g \cdot dl^{-1}$ and $\dot{V}O_{2max}$ of 47.8 $ml \cdot min^{-1} \cdot kg^{-1}$.

Under situations, of chronic stress such as anaemia or during strenuous exercise there is an increased rate of 2,3-DPG synthesis through a glycolytic pathway. This leads to a right shift in the Hb-O_2 dissociation curve favouring the unloading of O_2 at the tissue level (Smalley et al. 1981; Cade et al. 1984; Hespel et al. 1988). The 2,3-DPG $\cdot$ g Hb^{-1} increased by 21% in both groups following the first 7 days of training. This may reflect the exercise-augmented synthesis of RBC (day 42, Table 2) leading to an increase in the relative fraction of young erythrocytes which contain large amounts of 2,3-DPG (Loria et al. 1967; Cade et al. 1984; Hespel et al. 1988; Schmidt et al. 1988). Postnight-sleep 2,3-DPG $\cdot$ g Hb^{-1} of all subjects (21%) were among the highest values ever recorded, which may reflect the high training intensity of our subjects (Cade et al. 1984; Hespel et al. 1988; Lijnen et al. 1988).

Army recruits undergoing basic training and strenuously exercising athletes have exhibited markedly decreased serum haptoglobin levels (Lindemann et al. 1978; Hunding et al. 1981). A period of 7-day training resulted in marked decreased haptoglobin concentration in both our groups. Decreased serum haptoglobin concentrations, indicated increased RBC haemolysis and free Hb release which is complexed with the haptoglobin (Carlson and Mawdsley 1986; MacDonald and Keen 1988; Schmidt et al. 1988; Yoshimura et al. 1980). The subsequent significant increases of serum haptoglobin concentrations and RBC counts, after 42 days, indicated a lower rate of RBC haemolysis representing an adaptation to exercise stress (Schmidt et al. 1988).

The iron supplement given to the women in group A was associated with maintenance of their serum iron and body iron stores (ferritin) at baseline concentrations throughout the training period. In contrast, ferritin concentrations of group B had decreased significantly after 21 days and remained low until the cessation of training. Low ferritin concentrations imply depleted bone marrow iron and body iron stores (Banister and Hamilton 1985). Indeed, at the cessation of training, 10 out of 15 women in group B exhibited low ferritin concentration (< 10 $ng \cdot ml^{-1}$). The absence of a decrease in serum iron concentration in group B during training may be for the following reasons. Lowering of body iron stores in exercising humans and animals is induced by mobilizing non-essential tissue iron stores. However, this process maintains serum iron at concentrations appropriate for the increased O_2 demand of the exercising muscles during enhanced physical activity (McDonald and Keen 1988). Moreover, in the present study, the application of consistent graded physical exercise throughout training was associated with prevention of serum iron depletion. Thus, two studies carried out under similar training conditions, within a period of 2 years (the present study and Magazanik et al. 1988), have yielded different results regarding changes in blood iron concentrations.

It is well established that blood Hb concentration increases as early as 15 days following daily iron therapy (Swan et al. 1959). Furthermore, the subject's well-being and physical performance were affected earlier and may have influenced the $\dot{V}O_{2max}$ (Coltman 1969). A significant increase (7.5%) in $\dot{V}O_{2max}$ of group A had occurred after 21 days training, while no appreciable increase was found in group B at that time. We suggest that the faster $\dot{V}O_{2max}$ increase of group A was associated with enhanced O_2 transport by the blood, secondary to improved PCV and Hb concentrations and to unchanged body iron status (Banister and Hamilton 1985; Cade et al. 1984; Hespel et al. 1988; Clement and Sawchuk 1984). The lack of a significant increase in $\dot{V}O_{2max}$ and the finding of depleted body iron stores in group B after 21 days was consistent with our previous findings (Magazanik et al. 1988). Furthermore, Celsing et al. (1986) concluded that 4 weeks depletion of body iron stores was too short a period to produce any changes in endurance or muscle enzymes activities.

The delayed 14.3% elevation in $\dot{V}O_{2max}$ of group B after 42 days was related to beneficial training effects such as an increase in the number of mitochondria, improved blood perfusion to the muscles and enhanced intracellular O_2 utilization and to increased lean body (muscle) mass [(Table 1) MacArdle 1986; Schmidt et al. 1988; Newhouse and Clement 1988]. It should be noted that changes in physical work capacity can occur prior to meaningful changes in Hb concentrations (Gardner et al. 1977). In addition, supplementary iron was reported to improve physical work capacity before a significant increase in Hb concentration was observed (Newhouse and Clement 1988). As both groups in the present study underwent identical training programmes the relative increase in their mean $\dot{V}O_{2max}$ following training was similar. While the difference in $\dot{V}O_{2max}$ between the groups on day 42 was not significant, there was a trend demonstrating a dissimilarity between them ($P \leq 0.067$). Thus, the rapid increase of group A $\dot{V}O_{2max}$ on day 21 was markedly associated with their superior body-iron status, as a result of iron supplements. On day 42 the reduced differences between the $\dot{V}O_{2max}$ in the two groups suggested that the effects of supplementary iron on aerobic performance of women engaged in intensive training may be most effective only during the early stages of training.

Finally, we attempted to find out whether the two groups differed in the relationship between their $\dot{V}O_{2max}$ and Hb concentrations. While $\dot{V}O_{2max}$ variations were poorly correlated with Hb concentration in group B ($r = 0.045$; NS), they were highly correlated in group A ($r = 0.609$; $P < 0.01$) (Fig. 5). It is established that iron supplements improve work capacity in iron-deficient anaemic subjects, however, it is not clear whether work capacity can improve during the prelatent iron deficient state (Newhouse and Clement 1988). We demonstrated that iron therapy to iron-reserve-depleted women improved their Hb and ferritin concentrations and PCV and $\dot{V}O_{2max}$ after 21 days of training.

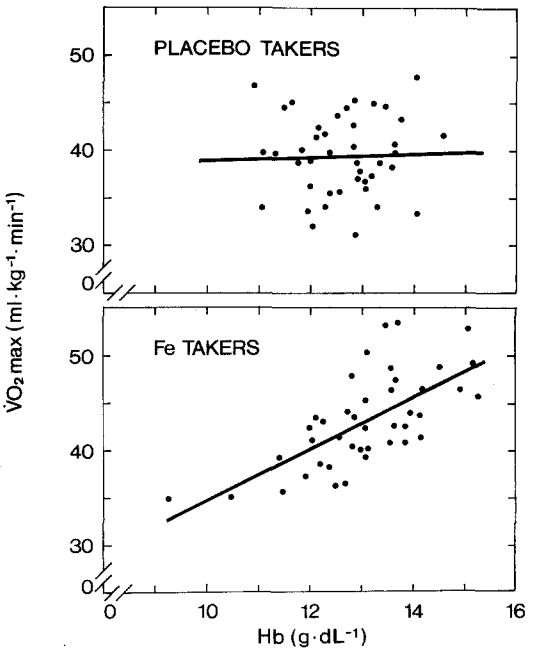

Fig.5. Individual maximal aerobic capacity ($\dot{V}O_{2max}$) changes vs haemoglobin (*Hb*) concentrations of the placebo group (*top*) and the iron (*Fe*) supplemented group (*bottom*) throughout the 42-days training. Regression analysis by the least mean square method

It is, therefore, suggested [in agreement with Kanstrup and Ekblom (1984)] that the significantly higher $\dot{V}O_{2max}$ values observed in group A, during the first 21 days of training were related to the improvement of their body iron status, PCV and Hb concentrations.

We concluded that daily iron supplements to women engaged in intensive training was associated with maintenance of body iron status and improvement of several haematological variables and $\dot{V}O_{2max}$, especially in the early stages of training (21 days). $\dot{V}O_{2max}$ variations were highly correlated to Hb concentration changes in group A and poorly correlated to Hb changes in group B. It is recommended that the body iron status of women participating in intensive physical training should be monitored regularly and that iron supplements should be prescribed as a preventive measure.

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