Training for cross-country skiing and iron status

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ABSTRACT

HAYMES, E. M., J. L. PUHL, and T. E. TEMPLES. Training for cross-country skiing and iron status. *Med. Sci. Sports Exerc.*, Vol. 18, No. 2, pp. 162–167, 1986. Effects of iron supplements and training for cross-country skiing on hematological and iron status were studied in nine men and ten women from the U. S. Nordic ski team. Four men and five women received a multiple vitamin, multiple mineral supplement containing 18 mg iron for 8 months while five men and five women received a placebo. Fasting blood samples were taken from all skiers prior to supplementation (May) and in August, November, and January. Hemoglobin, hematocrit, plasma iron, total iron binding capacity (TIBC), percentage of transferrin saturation, serum ferritin, free erythrocyte porphyrin, and haptoglobin were measured on each sample. Hemoglobin, hematocrit, and TIBC were higher in November when both men and women skiers trained at altitude than in August. In January TIBC was further increased, haptoglobin was increased, hemoglobin for the men fell below May levels, and hematocrit returned to May levels. Skiers receiving iron had lower TIBC levels in November and January than the placebo group. Six women and two men had ferritin levels below 28 ng·ml⁻¹, which suggests prelatent iron deficiency. Free erythrocyte porphyrin levels above 100 μg·dl⁻¹ RBC were found in all skiers at some point during training. The results suggest that multivitamin, multimineral supplements containing iron have little effect on the iron status of cross-country skiers.

AEROBIC TRAINING, CROSS-COUNTRY SKIING, DIETARY SUPPLEMENTATION, HEMOGLOBIN, IRON STATUS, PRELATENT IRON DEFICIENCY

Iron deficiency with and without anemia is relatively common among female endurance athletes (2, 21, 26). Several recent studies also report low iron levels for male endurance athletes as well (2, 10, 17). There is evidence that endurance training may reduce the amount of iron stored in the body (10, 34). During training iron is taken up by the skeletal muscles to form myoglobin and other iron-containing enzymes and coenzymes (35). Increased rates of red blood cell destruction have been reported during early phases of training which could lead to a negative iron balance if the hemoglobin iron is excreted rather than recycled

(14, 27, 35). Most of the studies which reported low iron levels or increased red blood cell destruction examined distance runners. Since red blood cells can be mechanically destroyed by running on hard surfaces, runners may have a greater need for iron than endurance athletes in other sports, e.g., swimming, rowing, and cycling (7, 9). Little is known about the iron status of cross-country skiers. Because the endurance requirements are similar for cross-country skiing and distance running and dryland training includes distance runs, cross-country skiers may become iron deficient during training.

Several investigators have suggested that the use of iron supplements while training may prevent iron deficiency from occurring (3, 34). Studies of iron supplementation during training have produced mixed results. Cooter and Mowbray (6) and Pate et al. (23) reported little difference in hemoglobin, serum iron, and total iron binding capacity (TIBC) content of women athletes taking iron supplements for several weeks compared to control groups not taking the supplement. On the other hand, iron supplements were beneficial in raising hemoglobin and serum ferritin levels of distance runners who were iron deficient (17, 21, 26). Most of these studies were of relatively short duration and failed to report the iron content of their athletes' diets. If the dietary iron intake was adequate to meet the needs of the athlete, then iron supplements should have little effect on iron status. Since only 10 to 20% of the ingested iron is absorbed, it will take several months for a small iron supplement (18 mg Fe) to significantly increase the iron stores.

Because little information is available on iron status of cross-country skiers and because of the similarity in training of skiers and distance runners, cross-country skiers on the U. S. ski team were studied over an 8-month period. The purposes of this study were 1) to determine if iron status changes during different stages

of training and 2) to determine if an iron supplement has an effect on iron status during training.

METHODS

Nine men and ten women members of the U. S. Nordic ski team volunteered to serve as subjects. Subjects were informed of their rights and signed a written consent form prior to participation in the study. Nine subjects (four men and five women) received a multiple vitamin, multiple mineral supplement containing 18 mg iron (ferrous fumarate) daily throughout the study. Vitamins and minerals contained in the supplement were the following: vitamin A, 5000 IU; vitamin D, 400 IU; vitamin E, 30 IU; vitamin C, 90 mg; folic acid, 0.4 mg; thiamine, 2.1 mg; riboflavin, 2.4 mg; niacin, 20 mg; vitamin B_6, 2 mg; vitamin B_{12}, 9 μg; biotin, 0.3 mg; pantothenic acid, 10 mg; calcium, 600 mg; phosphorous, 450 mg; iodine, 150 μg; iron, 18 mg; magnesium, 200 mg; copper, 2 mg; and zinc, 15 mg. The remaining ten subjects received the same multiple vitamin, multiple mineral supplement containing no iron which was especially prepared for the study by the Shaklee Corporation. The study was conducted double blind with neither the investigators nor the subjects being aware of which subjects were receiving iron or the placebo. Physical characteristics and food iron intake of the skiers prior to iron supplementation are presented in Table 1. Subjects kept a 3-d food intake diary after receiving detailed instructions from a nutritionist. Iron intake was analyzed using the National Heart, Lung, and Blood Institute dietary data base (11).

Blood samples were taken four times during the year beginning in May at a dryland training camp (altitude 3600 ft) before supplementation began. The second sample (August) was taken after 3 months of supplementation and dryland training at the skier's residence. Eight skiers, six men and two women, resided at altitudes of 6000 ft and above at the time of the August sample. The third sample (November) was taken after 6 months of supplementation during an on-snow training camp at an altitude of 6667 ft with skiing at ap-

TABLE 1. Characteristics of the skiers.

Group	Age (yr)	Weight (kg)	Food Iron (mg·d⁻¹)
Women			
Iron	20.0	56.36	19.8
	±3.5	±2.60	±3.0
Placebo	21.4	58.26	21.4
	±5.9	±5.37	±8.6
Men			
Iron	24.2	77.02	25.8
	±3.3	±0.67	±3.4
Placebo	21.6	68.82	28.8
	±3.9	±8.92	±6.5

Values are mean ± SD.

proximately 8500 ft. Final samples (January) were taken after 8 months of supplementation and 2 months of competition during trials for the World Championships at an altitude of approximately 1000 ft. Blood samples were obtained between 6 and 9 a.m. following an overnight fast.

Hemoglobin and hematocrit were measured immediately using the cyanmethemoglobin and microhematocrit techniques, respectively. Three 20-μl whole blood samples were obtained for the free erythrocyte porphyrin measurements. The remainder of the blood was centrifuged, and the plasma was frozen for later analysis. Plasma iron and TIBC were measured using the methods of Ramsay (28, 29), serum ferritin was measured using a radioimmuno assay (New England Nuclear), free erythrocyte porphyrin was measured using the method of Piomelli et al. (25), and serum haptoglobin was measured using the radial immunodiffusion method (12).

A three-way analysis of variance with repeated measures was used to test for main effects differences between the iron and placebo groups, men and women, and training ($2 \times 2 \times 4$ design). The Newman-Keuls follow-up procedure was used to test for significant differences when a significant F for training occurred. The 0.05 level of probability was accepted as significant.

RESULTS

Food iron intake for these skiers has previously been reported in another study (11). There was no significant difference in food iron intake prior to iron supplementation between the iron supplementation and placebo men or women; however, the men skiers had higher food iron intakes than the women (Table 1).

Hemoglobin and hematocrit levels for four groups (men iron, men placebo, women iron, women placebo) are presented in Figure 1. Significant main effects for sex and training were found for both hemoglobin and hematocrit. Men had significantly higher hemoglobin and hematocrit levels than women before and throughout training. Mean hematocrit for all skiers combined was significantly higher in November ($\overline{X} = 46.7\%$) than in May ($\overline{X} = 44.5\%$), August ($\overline{X} = 44.6\%$), and January ($\overline{X} = 44.7\%$). There was a significant interaction between sex and training for hemoglobin content. Mean hemoglobin concentration for men skiers was highest in November ($\overline{X} = 17.5$ g·dl⁻¹) and significantly lower in January ($\overline{X} = 15.7$ g·dl⁻¹) than in May ($\overline{X} = 16.3$ g·dl⁻¹) and August ($\overline{X} = 16.1$ g·dl⁻¹). Women skiers had significantly higher hemoglobin levels in May ($\overline{X} = 14.3$ g·dl⁻¹) and November ($\overline{X} = 14.2$ g·dl⁻¹) than in August ($\overline{X} = 13.7$ g·dl⁻¹). No significant differences in hemoglobin content or hematocrit were found between the iron and placebo groups throughout the study.
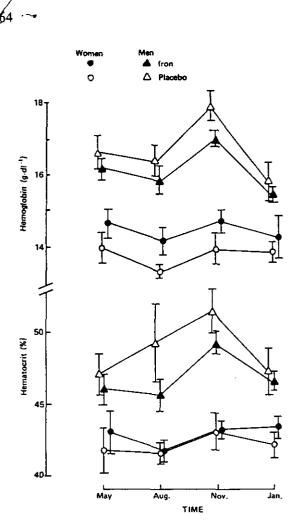
Women   Men
●   ▲ Iron
○   △ Placebo

Figure 1—Mean hemoglobin and hematocrit levels of men and women skiers receiving an 18-mg iron supplement daily and men and women skiers who received a placebo. Bars, SE.

Plasma iron and percent transferrin saturation are presented in Figure 2. Men (iron and placebo groups) had significantly higher plasma iron and percentage of transferrin saturation than women (iron and placebo groups) throughout training. There were no significant effects of iron supplementation or training on either plasma iron content or percentage of transferrin saturation. Although there appeared to be some differences between iron and placebo groups at some stages of training, there were no significant interactions between treatment and training for plasma iron or percentage of transferrin saturation.

There was a significant main effect for training on TIBC (Fig. 2). Mean TIBC for all skiers was significantly higher in November ($\overline{X} = 331.5$ μg·dl^{-1}) and January ($\overline{X} = 339.8$ μg·dl^{-1}) than in May ($\overline{X} = 303.1$ μg·dl^{-1}) or August ($\overline{X} = 276.2$ μg·dl^{-1}). There was also a significant interaction between treatment, sex, and training for TIBC. Men and women skiers in the placebo group had significantly higher TIBC's in November and January than men and women skiers who received iron. In August men in the placebo group had significantly higher TIBC levels than men in the iron group, while

women in the iron group had higher TIBC's than women in the placebo group. At the beginning of the study, men had significantly higher TIBC levels than women.

Ferritin levels for the four separate groups are presented in Figure 3. Women (iron and placebo groups combined) had significantly less ferritin (X = 32.8 ng· ml^{-1}) than combined iron and placebo groups of men ($\overline{X}$ = 56.1 ng·ml^{-1}) throughout training. There were no significant differences in ferritin levels between the iron and placebo groups, although there was a trend for the iron group to have higher levels after iron supplementation began. Changes in ferritin levels during different stages of training were not significant. Ferritin levels increased from May to January 38 and 43%, respectively, for the women and men receiving iron, increased 17% for the men receiving the placebo, and decreased 23% for the women in the placebo group.

Free erythrocyte porphyrin (FEP) in μg·dl^{-1} RBC and haptoglobin are presented in Figure 3. Only the May, November, and January FEP samples were in-
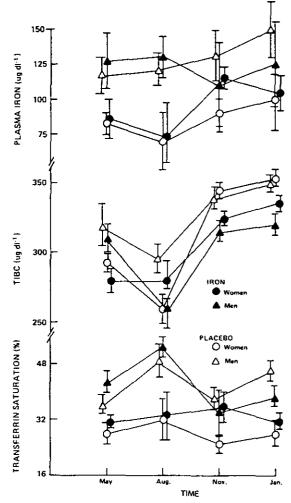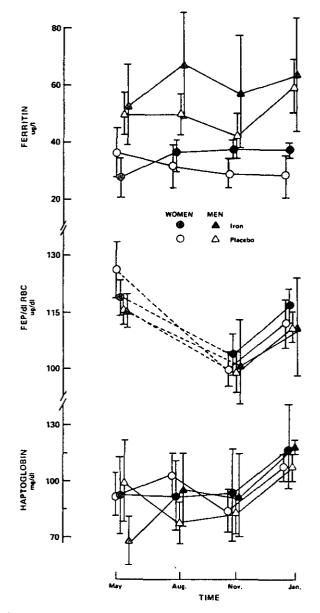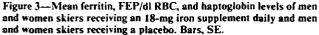

Figure 2—Mean plasma iron, TIBC, and percentage of iron saturation of men and women skiers receiving an 18-mg iron supplement daily and men and women skiers receiving a placebo. Bars, SE.

Figure 3—Mean ferritin, FEP/dl RBC, and haptoglobin levels of men and women skiers receiving an 18-mg iron supplement daily and men and women skiers receiving a placebo. Bars, SE.

cluded in the statistical analysis because of technical problems with the August samples. FEP's were significantly lower for the total group in November than in May or January. There were no significant differences in FEP's and haptoglobin between treatment groups or between men and women. Haptoglobin concentration for the total group was significantly higher in January ($\overline{X}$ = 111.9 mg·dl^{-1}) than in May ($\overline{X}$ = 86.2 mg·dl^{-1}), August ($\overline{X}$ = 92.4 mg·dl^{-1}), and November ($\overline{X}$ = 87.3 mg·dl^{-1}).

None of the skiers was anemic (Hb < 12 g·dl^{-1}) at any time during the study. Low ferritin levels (<28 ng·ml^{-1}) were observed in eight skiers, six women and two men, at various times during the study, and those skiers were classified as prelatent iron deficient (16). Two of

the women in the iron supplement group were low in ferritin at the beginning of the study, and one, a resident of moderate altitude, was still low after 3 months of iron supplementation. The other four women were in the placebo group and were classified as prelatent iron deficient as training progressed. Two of these same four women had ferritin levels below 12 ng·ml^{-1}, FEP levels of 100 μg·dl^{-1} RBC or above, and/or transferrin saturations of 16% or below at some point during training and were classified as iron deficient (1, 4). Both of the men with low ferritin levels were residents of moderate altitude (>7000 ft). One of these men was in the iron supplement group and did not have a ferritin level above 28 ng·ml^{-1} until January. FEP levels above 100 μg·dl^{-1} RBC were observed in all of the men and women at one or more of the sampling periods during the study.

DISCUSSION

Significant changes in hemoglobin, hematocrit, TIBC, FEP, and haptoglobin were observed during the course of the study. Hemoglobin for the men and hematocrit for both men and women reached peak levels in November during on-snow training at altitude. Increases in hemoglobin and hematocrit between August and November may have been due to a decrease in plasma volume which occurs shortly after arrival at altitude (8, 15, 30). Seven of skiers, five women and two men, had been at altitude for less than 3 weeks when the November sample was taken. TIBC was also elevated in November. However, in January hemoglobin concentration was 4% lower for the men skiers and 2% lower for the women skiers than at the beginning of the study, but TIBC was 6% greater for the men and 20% greater for the women. Expansion of the plasma volume may be a reason for the decrease in hemoglobin concentration in the men, since six of the nine men skiers resided at moderate altitudes during the summer and fall.

Increased TIBC in November and January suggests an increased need for iron. As the iron stores become depleted, the TIBC increases (1). Under most circumstances the serum ferritin levels would be expected to decrease simultaneously. Although the changes were not significant, ferritin levels decreased when the skiers trained at altitude in November, but they were higher when the skiers were competing at sea level in January. An increased rate of iron turnover occurs shortly after arrival at altitude, suggesting an increased rate of erythropoiesis (30). The significant increase in TIBC and trend toward lower ferritin levels suggest that iron was being removed from storage for hemoglobin formation. Erythropoiesis is depressed after returning to sea level; therefore, more iron can be stored, and the serum ferritin levels should increase.

pends on endurance and the maximal ability to use oxygen (19), use of iron supplements, especially by the women skiers who are more prone to iron deficiency, could be beneficial.

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Elevated FEP is an indicator of iron deficient erythropoiesis (1). Although FEP levels were lower in November than January, increases and decreases in FEP lag behind changes in iron status (18). FEP levels for the skiers were elevated throughout training compared to the normal range for adult males and females (4) and considerably higher than those reported for female distance runners and control subjects (14). The skiers' elevated FEP levels also suggest a lack of adequate iron stores in the bone marrow.

Runners have significantly higher TIBC and lower serum ferritin levels than swimmers (7). Results for our male skiers suggest that they have even lower serum ferritin levels ($\overline{X} = 56.1$ ng·ml^{-1}) than the runners studied by Dickson et al. (7) ($\overline{X} = 118.6$ ng·ml^{-1}) but more than the male runners studied by Clement and Asmundson (2) ($\overline{X} = 41.1$ ng·ml^{-1}). Ehn et al. (10) observed an increased loss of iron in male runners during training which was approximately twice that normally found in sedentary men. The reason for the accelerated iron loss is unknown at present, but two sources are suspected: increased hemolysis during running (9) and iron loss through sweating (24). When red blood cells are destroyed in the blood stream, hemoglobin is released into the plasma. Haptoglobin binds with the hemoglobin and is removed by the liver. Depressed haptoglobin levels suggest that increased intravascular hemolysis is occurring. Increased red blood cell fragility (27) and reduced haptoglobin levels (9) have been found in runners during training. The skiers' haptoglobin levels were significantly higher in January after they had been training on snow for 3 months. Most of the skiers had discontinued dry land training less than 3 weeks before the November sample. The results suggest that intravascular hemolysis was occurring during dryland training which included distance running and could have contributed to a negative iron balance.
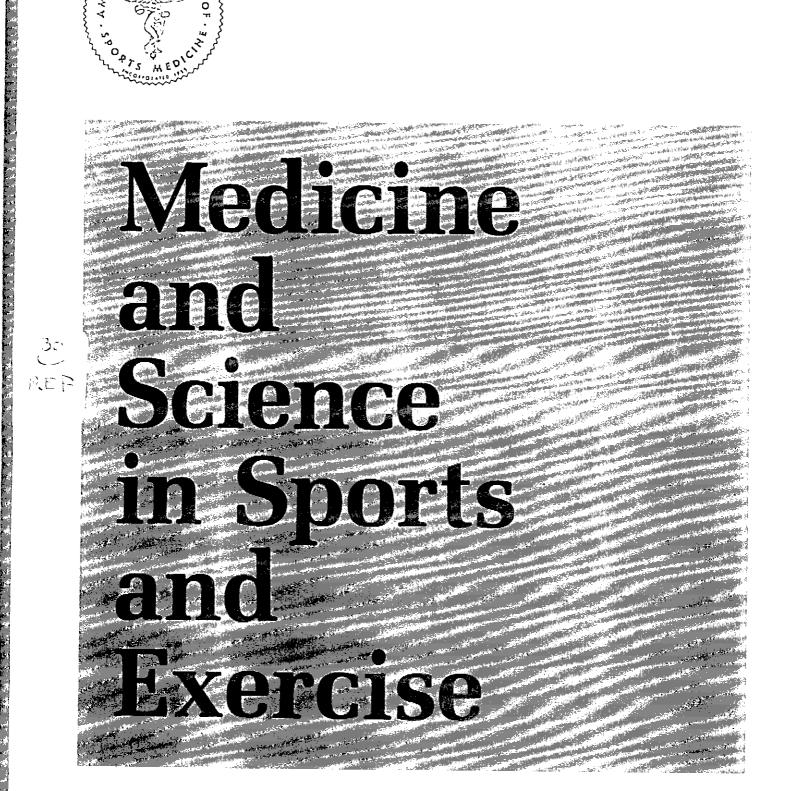
Serum ferritin levels for the women skiers ($\overline{X} = 32.8$ ng·ml^{-1}) were similar to those reported for Canadian women runners ($\overline{X} = 27.9$ ng·ml^{-1}) (2) and adult women living in the U. S. ($\overline{X} = 34$ ng·ml^{-1}) (5). Clement and Asmundson (2) reported that 82% of their women runners had serum ferritin levels below 25 ng·ml^{-1}. We chose to use the criteria of Heinrich et al. (16) for defining prelatent iron deficiency as a serum ferritin level below 28 ng·ml^{-1}. Six women (60%) were classified as prelatent iron deficient at one or more sampling periods. One possible reason for the slightly higher proportion of runners with low serum ferritin could be the dietary iron intake. Low serum ferritin levels in women are thought to be due to inadequate dietary iron intake. The Recommended Dietary Allowance (RDA) for iron is 18 mg per day for women and 10 mg per day for men. Iron intake for the Canadian women runners was 12.5 mg·d^{-1} (2). The women skiers' dietary iron intake prior to supplementation in May was 20.6 mg·d^{-1}. Six of the ten skiers had dietary iron intakes

which exceeded the RDA for women in May; however, seven were below the RDA in August (11).

Lower TIBC levels in the subjects receiving 18 mg iron daily suggest that iron supplements were beneficial during training for both male and female skiers. Several previous studies failed to find any significant changes in hematological and iron status with iron supplementation of athletes during training (6, 23). The present investigation followed the subjects for 8 months, twice as long as the two previous studies. Significantly lower TIBC levels in the female skiers receiving iron did not occur until November, 6 months after iron supplementation was begun.

While not statistically significant, the trend was for serum ferritin to be higher among those subjects receiving iron. Among the women, the trend was for serum ferritin in the iron group to remain fairly constant, while the ferritin levels of the placebo group decreased during training. Two women in the supplement group who were classified as prelatent iron deficient at the start of the study incresed their ferritin levels, while two women in the placebo group became iron deficient during training. Ferritin levels for the men tended to fluctuate more with changes in altitude but were higher for the men receiving iron. The small amount of iron (18 mg) in the supplement may be responsible for the failure to produce significant differences in ferritin levels. Two studies of women athletes which reported significant increases in serum ferritin used iron supplements containing 60 mg or more of iron (21, 31). Pregnant women receiving iron supplements for 12 wk significantly increased their serum ferritin levels when the supplement contained 120 or 240 mg FeSO$_4$ but not with 60 mg FeSO$_4$ (33). The presence of calcium and phosphorus in the multivitamin, multimineral supplement may have reduced the iron absorbed from the diet in both the iron and placebo groups (20).

There appeared to be little effect of iron supplements on hemoglobin levels of the skiers in this study. Four recent studies have reported beneficial effects of iron supplements on hemoglobin concentration of athletes (17, 21, 26, 31). In all four studies larger iron supplements, 60 mg Fe and above, were used. The mean hemoglobin levels were also lower in these athletes prior to supplementation compared to the skiers in the present study. Iron supplementation is more effective in increasing hemoglobin levels in individuals who are iron deficient. It has previously been shown that low hemoglobin levels limit the amount of oxygen transported to the muscles during maximal work (32). Several recent studies have shown reduced endurance performance and increased blood lactate in subjects with low serum iron but normal hemoglobin levels (13, 22). Iron supplements have been shown to be beneficial in lowering heart rate (22) and blood lactate (31) during exercise in non-anemic subjects with low iron levels. Since performance in cross-country skiing events de-

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